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Performance Under Stress

Edited by

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Preface

P.A. Hancock and J.L. Szalma (Editors)

The world is a dangerous place. Unfortunately, recent events have served to render it even less safe and there are many arenas of conflict and even combat across the world. Such situations are the quintessential expression of stress. You stand in imminent danger and live with the knowledge that you may be attacked, injured or even killed at any moment. How do people react, and continue to perform effectively under these conditions? How do they keep a heightened level of vigilance when nothing may happen in their immediate location for weeks or even months on end? What happens when the bullets actually do start flying? How do soldiers distinguish friend from foe, and either of these from innocent bystanders when their lives are in immediate peril? Can we design technology to help people make good decisions in these hazardous situations? To what degree does membership in a team act to dissipate these effects? Can we generate sufficiently stressful field exercises to simulate these conditions and can we train and/or select those most able to withstand such adverse conditions? How will the next generation of servicemen deal with these inherent problems? How does the knowledge and understanding garnered from these life-threatening situations transfer to other realms of human behavior where people are forced to operate in non-optimal conditions? These are among the questions examined here.

The text is derived largely from a multiple-year, Multiple University Research Initiative (MURI) project on stress and soldier performance on the modern, electronic battlefield. It involved leading researchers from several Institutions who have each brought their own individual expertise to bear on these crucial, contemporary concerns. United by a common research framework, these respective groups attacked the issue from different methodological and conceptual approaches ranging from traditional laboratory modeling and experimentation to realistic simulations, from involved field exercises to personal experiences of actual combat conditions. The insights that they have generated have here been distilled and presented in order to benchmark the present state of understanding and to provide future directions for research in this arena. Although this work focuses on soldier stress and soldier performance, the principles that are derived extended well beyond this single application realm. For example, one of the major forms of stress facing the modern soldier is information overload. However, this is a ubiquitous form of stress and is one that is faced by people in the business world, in research, in academe, in commercial enterprises and in most sectors of modern technological economies. Understanding distilled from the performance of soldiers, who stand in the greatest level of extremis can certainly be applied to those who face similar, if less life-threatening demand. One obvious question is how you design human-machine interfaces for people faced with these mounting cognitive demands? Can the supporting computer system perform in an adaptive manner? Can it now be considered a team member? These are not questions just for the present and future soldier; these are questions that impact everyone who works with technology. Consequently, this text is not just an account for those who wish to learn something more of the problems facing armed forces. This text is for everyone who faces stress at work as well as for those who study these processes. If that does not include you, you hold an enviable position. However, we suspect that in your under-stressed existence you are one of a small and dwindling group of individuals. Life in the modern technological world throws up many challenges. Some, we have evolved to cope with to some degree. Others are more modern in origin and emergent in nature. We now have to find effective ways to cope with these emerging demands.
if we are to improve the human condition and, perhaps, ensure the survival of our species. The present text is designed to help with that search.

Acknowledgments

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P.A. Hancock and J.L. Szalma
Orlando, FL, April 2007
Foreword

MG(R). R.H. Scales

In 1969 I was a battery commander on Firebase Bertesgaden during the Battle of Dong Ap Bia, better known to movie goers as “Hamburger Hill.” We were good soldiers but most of us were amateurs hoping to stay alive during what could only be described as a hellacious period in history. One soldier wasn’t an amateur. His name was Captain Harold Erikson, his call sign was “Viking” and he commanded B Company, 1st Battalion, 506th Airborne Infantry. He was from Mississippi, played quarterback for Georgia Tech and did a brief stint in the NFL before commissioning.

As his handle suggests he was a big, blond, blue eyed soldier. He rarely spoke and never spoke above a whisper. He wasn’t a leader in the Pattonesque tradition. He didn’t swear and avoided the limelight as much as possible. Yet when the bullets began to fly, when close combat became very close and killing became intimate, Viking came alive. When he was in charge, many enemy died and very few of his soldiers suffered a similar fate. I watched him in action one night as we were attacked by a very large force of North Vietnamese regulars. He crouched in a fox hole that doubled as his command post. Occasionally, he’d say something on the radio or whisper a command to one of his runners. Outside things just happened. The artillery came in close and deadly. The machine guns seemed to open up at just the right time and place. Troops always found a crease in the enemy’s flank and scattered them with a few tightly disciplined volleys. Remarkably Viking’s company really never fired that much. But when they fired bad guys died in huge profusion. The troops would talk about Viking in hushed tones as if he was a God. They knew an assignment to B Company probably meant a return home ticket because Viking had the right stuff and would keep them alive.

I met Peter Hancock two years ago and was immediately intrigued by the direction of his research, an inquiry that was the catalyst for this book. I asked him if Vikings could be made. Until my contact with Peter I assumed that the ability to thrive and make proper decisions in the heat of combat was a God given gift. That would explain why Vikings were so few. My epiphany was that Peter and his colleagues were beginning to discover that there was science in the making of future Vikings. That perhaps the human sciences could be mobilized to make soldiers better at the dirty and frightful business of close combat and in extremis decision making.

My only question was why it took so long for a work like this to appear. We know a great deal about astronauts. Books shelves groan under the strain of psychological and physiological studies of combat pilots. But the shelves are bare of books that seek to apply the scientific method to making soldiers better in combat. This fact is all the more incongruous given the fact that, since the end of the Second World War, over 90 per cent of those who died at the hands of the enemy have been close combat soldiers and Marines. If we support the troops, then why haven’t we done all we could do to harness science to keep them alive in combat?

Today’s wars in Iraq and Afghanistan only serve to remind us that war is inherently a human not a technological endeavor. The fight there is close and tactical. Success is less dependent on applying the latest technology and more dependent on the ability to win the human, cultural and cognitive battle, to beat the enemy at his own game. Today’s battles in Iraq and Afghanistan are in fact a portent of the future where soldier skills will be more important than his equipment; where empathy and cultural awareness will be a soldier’s most important asset; where the ability to make decisions in the heat of battle when soldiers are hot, tired, confused and afraid will be the surest
guarantee of coming out of the engagement alive. Future wars will be won not by capturing and holding terrain but by influencing and shaping perceptions and gaining the trust of alien peoples, all human skills that demand a human approach to war.

Peter Hancock and his colleagues are the first to apply in a disciplined and rigorous way human science to the problems of fighting the long war. Their effort is long overdue. And I trust that this work will be the spark that ignites a serious effort within the defense intellectual community to focus its enormous capital on the task of making better soldiers. Perhaps, thanks to the efforts of Peter and his colleagues, some day we will be able to produce a legion of Vikings, soldiers and leaders superbly conditioned cognitively and psychologically, to be better at the task of close combat than any of our enemies. Cognitive dominance not technological dominance holds the secret of future victories.

We spend trillions today to gain a few additional knots of speed, meters of precision or bits of bandwidth. Hancock’s work suggests that only a small proportion of this enormous treasure could be better spent studying the complexities humans when engaged in the horrific business of modern combat. This work is a superb first step. But if we are to be true to the needs of our soldiers fighting in distant places this work must begin a greater and more expansive investigation into the human and cognitive dimensions of war. Let’s hope for our soldier’s sake that someone in authority will read it and act soon.
1 Introduction

Stress is one of the most crucial of all areas of human understanding. Once we comprehend how individuals react under the extremes of stress, many of the more subtle forms of unstressed behavior will become immediately comprehensible. Stress is a ubiquitous fact of life but contrary to the popular conception of the notion, stress is not always a bad thing. Indeed, the capacity to adapt and respond to the various circumstances of existence may be a definition of life itself (and see Schrodinger, 1946). This chapter presents an introduction to stress through an examination of the various theories that have been proposed to understand its nature and thus account for its effects. We evaluate these conceptions and theories, pointing out their differences and commonalities as well as their respective strengths and weaknesses. In these perilous times for our world, how people react in unusual and even unprecedented situations goes well beyond just an academic exercise or yet another text book. Understanding these effects may well be the key to our collective survival. If you do not believe this assertion simply ask the people, of Baghdad, Kabul, New York, London, Madrid, Washington, and Beirut. Their response will quickly disabuse you of any misapprehension. What follows then is certainly an academic endeavor but its importance will, we hope, be felt well beyond the “ivory towers” of Universities and like institutions.

2 Structure of the Chapter

This first chapter is divided into four sections. The first of these sections considers the physiological and behavioral history of stress research. Particularly, we frame this historical survey by structuring our discussion around the ubiquitous formulation of Yerkes and Dodson (1908). Our critique of this “inverted-U” explanation is used as a unifying theme for discussion. Due to its general penetration into the wider teachings of undergraduate psychology, as well as the consciousness of the informed lay public, the inverted-U is a useful organizing principle even if we consider it to be a fundamentally flawed proposition (and see Hancock and Ganey, 2003). We should note at the outset that we do not decry Yerkes and Dodson (1908) themselves, since their work on discrimination effects in animal learning was directly relevant to the research of the day and represented a valuable contribution. Rather, what we deplore is the uncritical acceptance of the general and often misleading inverted-U description of stress effects that has found a way to attach itself to this original work. It is fairly certain that Yerkes and Dodson themselves never interpreted their findings in respect of a general stress effect but reference to their work has been employed by many subsequent commentators for their own purposes. Strangely, the way in which their original work has been abused and mis-cited over the ensuing decades provides an important insight into the development of stress theories in the twentieth and now into the twenty-first century.

We use this sequence of historical developments and critique as a basis for our second section in which we present a brief overview of the present state-of-the-art. Although we naturally favor
one particular theoretical approach (see Hancock and Warm, 1989), we look for opportunities for synthesis and integration to provide superior predictions of how individuals perform in specific, stressful conditions. Thus, the insightful work of Hockey (1997); Hendy, Farrell and East (2001), and Matthews (2001) provide important contributions to a modern, integrative theory of stress effects. These respective developments over the immediate past decades represent the backdrop to our next step in which the third section poses the challenges facing stress theory development in the immediate years to come. Especially, we have chosen to focus on the specific problems associated with the interactions of real-world sources of stress. Interaction effects represent a critical barrier that we have to overcome in order to tame the challenge of unbound combinatorial explosion of factors that comes with the step from the Laboratory to real-world prediction. We do not present any final solution to this issue but we do believe we have identified a number of potentially fruitful paths for progress. Our fourth and concluding section examines the issue of context. The general tenor of the whole of the present text is focused on military applications and much of the work that is reported is derived from testing in military settings. However, the issue of the degree of cross-contextual transfer is the one which dominates our final deliberations in this, the opening chapter. This latter discussion serves to emphasize the importance of context and the challenge of deriving contextual descriptions of behavior under stress, or more properly, descriptions of behavior which integrate the details of each different impinging context. We seek to resolve this latter challenge for a specific purpose, since this would render principles derived primarily from the context of conflict, applicable to all who try to understand the effects of stress on human performance capacities. As we indicated initially, many of the most crucial decisions that humans ever take are made under conditions which are certainly non-optimal and often very averse indeed. Beyond the ubiquitous presence of time stress and the contemporary problems associated with extremes of cognitive workload, the presence of noxious environmental influences also serves to detract from any individual’s ability to respond in an efficient and effective manner. The outcome of many of these decisions made under such conditions can mean life or death. As scientists and researchers, it is our professional and our moral responsibility to ensure that such circumstances are as well understood as is humanly possible, so that correct and effective decisions can be reliably made and executed. What follows represents our introduction to such efforts.

2 A Brief History of Stress

2.1 Stress and Evolution

Although the history of formalized stress research is not much more than a century and a half old, all species on our planet are the long-term and on-going product of stress. When it is expressed as a profile of characteristics which compose the surrounding environment, stress decides which species survive and prosper and which suffer extinction. Behavioral adaptation to these varying environmental circumstances, or the “survival of the fittest” represents the central tenet of Darwin’s fundamental theory of evolution. On average, these basic environmental stress effects cause a relatively rational sequence of development. However, there are always those unfortunate species who suffer catastrophic extinction, for whom the world seems to have reserved a quixotic and tragic doom. This circumstance has been most trenchantly captured in the title of Raup’s (1992) text, “Bad genes or bad luck.” It seems that a species can take great (if unconscious) precautions in adapting to its particular environment, only to see that environment change rapidly as a result of an apparently vengeful and arbitrary act of fate. In some ways, the most outstanding of all human characteristics as a species is our meta-adaptive abilities. That is, we have taken behavioral flexibility (and its extension through manufactured technologies) to greater heights than any
form of life has ever previously exhibited. Paradoxically, then, it will take a catastrophe of global proportions to generate a human extinction event. That such a catastrophe might well be self-generated is one of the darker cosmic jokes. In all this, the degree of stress, both physiological and psychological, that an individual and a collective group or species can tolerate, has a central role in who survives and what form that survival takes.

Stress effects and subsequent stress research is then very much set in the Darwinian tradition. Whether we talk of the survival and adaptation of species over aeons of time or the much more local ability of one individual to change their behavior in the face of momentarily changing circumstances, it is only the spatial and temporal constants involved which determines the degree of difference. As a general principle then, it is most parsimonious to first define stress as a physical property of the ambient environment. Expressed as specific values of the physical metrics which compose any environment, stress from this perspective is deterministically specified but functionally sterile. In this form, it is merely a list or a litany of descriptive numbers which is a necessary but not sufficient condition for understanding. The crucial next step is to identify the nature, the character, and the capacities of whatever entity or organism it is that we expose to such conditions. For, it is only through the consideration of this vital interaction that the dynamics of stress begin to be revealed since, in its fundamental nature, stress is primarily an interactive property. Later in this chapter we talk more of this interactive perspective on stress, especially as it relates to the “appraisal” proposition of Richard Lazarus and his colleagues (e.g., Lazarus and Folkman, 1984) and more recently elaborated by Matthews (2001).

Of course, reactions to stress depend upon the nature of that stress and what capacities that the exposed entity or organism can bring to answer the challenges which the stress poses. In the case of physical, non-living entities, for example the steel girders in the Twin Towers of the World Trade Center, they can employ only their physical constitution to combat whatever demand is placed upon them. In this tragic case it was supposedly the melting point of steel that defeated resistance. With living organisms, the response is much more complex since it involves both reactive and anticipative behavior, where the latter can sometimes circumvent the stress exposure altogether. This interactive vision possesses three distinct facets. First, there is the internal response of the exposed organism. For the sake of convenience we shall refer exclusively to human beings throughout the rest of our chapter but in principle many, if not all, of the following observations pertain to all living systems. In respect of internal response, we can ask for example, is the stress sufficient to induce a physiological response? Does the psychological evaluation of the situation appraise the circumstances as stressful in any meaningful way? How do psychological dimensions of stress-related change match to physiological responses and vice versa? The answers to these sorts of question dictate what goes on within the body of the individual under stress. However, these internal effects may well be totally hidden from public view. If the individual does not explicitly tell us how they feel and we do not have sophisticated physiological measurement systems to hand, we cannot tell the degree to which any specific environment is placing a demand on a particular individual. For example, in mental workload response to task demands, much depends upon whether the person cares about the task or not (Hancock and Caird, 1993; Hockey, 1997). If they choose to give up and essentially refuse to engage in the required task, the mental workload can simply go away. Of course, there are many situations in which we cannot simply “give up” without serious and sometimes terminal consequences. One stressful characteristic of aviation is that the plane will come down eventually and someone has to be concerned about the manner of this return to earth. Pilots cannot simply “give up” without severe consequences and this obligatory workload they share with many other professions, for example surgeons.

In contrast with these hidden or private reactions, there are the publicly-observable responses of the exposed individual expressed as direct behavior. Such behavior can range from subtle
changes in an on-going performance sequence to the incipient incapacitation of the severely damaged individual (see, for example Harris, Hancock, and Harris, 2005). The third facet of this spectrum of response is the change in the environment that is effected by the exposed individual. We have already seen that the individual may give up or run away; the classic “flight” response. However, individuals can also engage in the “fight” response which itself can act to change the surrounding conditions. Frequently, this latter response entails combat with the other individuals in the immediate locale since the major source of human stress is most often other human beings. In addition to this classic two-sided fight-flight strategy, there is also a further “freeze” response in which the individual apparently becomes incapacitated and fail to respond at all. It might be that this latter absence of response is itself also adaptive. “Freezing” means that precipitate and potentially incorrect actions are avoided if one does not rush headlong into a knee-jerk type response. Prolonging such a suspension of response however, is clearly mal-adaptive.

This behavioral litany of possible response strategies leads us to the third facet of stress which was primarily identified by Hancock and Warm (1989). They noted that, since the task at hand is often the proximal source of stress, then the behavior in response to that task is itself directly reflective of the stress level experienced. This “output” view of stress is a highly pragmatic one because, in most real-world situations, what is of interest is whether stressed individuals can perform their jobs adequately. While the allied changes in operator status are important, especially for the scientist to understand how stress affects performance, we have to acknowledge that for many commanders, employers, and supervisors in the real-world, their primary, if not their only concern is mission success. From this perspective, stress is an issue because it interferes with success and not because the stress response is an intrinsically interesting process.

2.2 From Physiology to Behavior

If much of the stress concept is founded in the Darwinian revolution of thinking, then subsequent developments are also associated with famous names in physiology. The crucial insights of Claude Bernard, formalized as the concept of homeostasis by Cannon (1932) provided critical impetus, especially to the physiological understanding of stress. Perhaps the name most associated with stress research is that of Selye (1976) and he is rightfully acknowledged as a seminal figure for his classic text “The Stress of Life.” The Yerkes-Dodson formulation, so beloved of introductory psychology texts, was re-invigorated in the early 1950s by the pivotal insights of Hebb (1955) whose influential paper served to engender a whole new spectrum of research on arousal, drive, activation and associated concepts in the early 1960s. Stress has also been a perennial, if somewhat diffuse concern to the medical community. It has also been of considerable interest to those in the industrial and organizational sciences, where stress has been seen largely as a barrier to productivity. The widespread interest in stress has resulted in numerous parallel scientific research tracks studying the same central issue but very infrequently interacting or drawing on the conceptual developments and data from the other disciplines. One of the next great challenges in stress research in general will be steps toward unification in both theoretical and practical matters. There is some evidence that these efforts are under way in stress research and indeed in science altogether (Wilson, 1998).

3 Current Stress Theory

As in many other areas of behavioral science the inherent complexity and multi-dimensionality of the stress concept has led to multiple theories and models. And, as noted, different domains have each generated their own individual ideas. Most often these serve to explain a bounded domain of
activity or to account for particular set of empirical observations in for example discrete areas such as health/clinical psychology (e.g., Selye, 1976; Lazarus and Folkman, 1984) or human performance (Sanders, 1983; Hancock and Warm, 1989; Hockey, 1997). More recently, the cognitive zeitgeist has resulted in the emergence of information processing models of stress (e.g., Hendy et al., 2001) and emotion in general (e.g., Ellsworth and Scherer, 2003; Sander and Grandjean, 2005). Here we briefly review these various theories of stress which are most relevant to human performance. Our primary emphasis is on the maximal adaptability model (Hancock and Warm, 1989) and the compensatory control model (Hockey, 1997), although as we have noted there are many alternatives to be derived from several other related realms of research.

3.1 Common Themes in Stress Theory

In recent work, we (Hancock and Szalma, 2006) noted that two general themes characterize modern stress theory. First, most theories include or implicitly assume an appraisal mechanism through which individuals evaluate events in terms of their meaningfulness to their psychological or physical well-being. Although the appraisal notion was implied in psychological theory of emotion as far back as James (1890), (see also Ellsworth, 1994), it has been most frequently associated with the work of Richard Lazarus and his colleagues (see Lazarus and Folkman, 1984; Lazarus, 1991, 1999). Indeed, for Lazarus, appraisal processes are integral to the very definition of stress itself. Thus, Lazarus and Folkman (1984) defined stress as “a particular relationship between the person and the environment that is appraised by the persona as taxing or exceeding his or her resources and endangering his or her well-being.” (p. 19). Stress in this view therefore occurs when an individual appraises an event as a threat for which they lack adequate coping resources. From this perspective the proper unit of analysis in stress research is not the person themselves or the precipitating environmental event, but the transaction between them. Further, these transactions occur at multiple levels of adaptation, ranging from the genetic to molar and even social behavior (Hancock and Warm, 1989; Teasdale, 1999; Matthews, 2001). The outcomes of these processes are patterns of appraisal that Lazarus (1991) referred to as “core relational themes.” For instance, the core relational theme for anxiety is uncertainty and existential threat, while that for happiness is evident progress toward goal achievement. Therefore, when individuals appraise events relative to their desired outcomes (goals), these can produce negative, “goal incongruent” emotions and stress if such events are appraised as hindering progress. Conversely, promotion of well-being and pleasure occur when events are appraised as facilitating progress toward a goal (i.e., “goal congruent” emotions). The second general theme in stress theory is that individuals regulate their internal states and engage these mechanisms to compensate for perturbations induced by external events, including task demands. The compensatory control model (Hockey, 1997) emphasizes this regulation of effort at two levels: A lower level that requires minimal effort and a higher level that allocates cognitive resources to meet increases in demand (and see also Broadbent, 1971).

3.2 Maximal Adaptability Model

A theoretical framework developed specifically for the prediction of stress effects as they relate to performance is the maximal adaptability model generated by Hancock and Warm (1989). They distinguished three facets of stress that were considered initially in our introduction for this chapter. They labeled these facets, the “trinity of stress,” and these are shown in Figure 1.1. “Input” refers to deterministic composition of the environment which includes its naturalistic information as well as the traditional physical inputs such as temperature, noise, vibration, etc (for example Pilcher, Nadler and Busch, 2002; Conway, Szalma, and Hancock, 2007; Hancock, Ross, and Szalma, 2007). As
actual real-world environments consist of multiple forms of these various inputs it is best expressed as a stress “signature.” That is, it can be described completely but still represents an essentially unique assemblage (technically, if we include time in this definition no environment ever precisely repeats itself). In principle, this physical assemblage can be represented as a vector sum of the various scalar values which compose it, a useful property that is explored below. The second facet of the trinity is adaptation, which encompasses the psychological appraisal mechanisms as well as physiological responses we have discussed earlier. These are compensatory processes that are possessed by virtually all individuals. Such compensatory processes work in general in the same way for each individual and they are therefore nomothetic in nature. However, since all individuals do not possess all these forms of compensation and because all individuals do not react in the same way, adaptation is not deterministic in nature (cf. Scherer, 1999). The third and final component of the trinity of stress is the output which indicates how each specific organism behaves in respect to their individually set goals. This facet of response clearly depends on the explicit goals and cognitive state of each individual and is thus considered idiographic in nature. In this sense, we all react differently to each input circumstance that we face, even though we might all use essentially the same compensatory processes to do so. A major feature of the Hancock and Warm (1989) model is that in the large majority of situations (and even in situations of quite high demand) individuals succeed in adapting effectively to the input of the environment. They can tolerate high levels of either overload or underload without substantial change in performance capacity. Indeed, one can argue that the species is uniquely equipped to do so. Such adaptation results in a plateau of stable behavioral output from the individual and this is illustrated in Figure 1.2 as an extended-U shaped function. A second feature of the model is that adaptive responses occur at multiple levels. These levels are best represented as a series of nested functions. The nested structure, shown in Figure 1.2,

**Figure 1.1 A three-part differentiation of the concept of stress**

*Note:* The central adaptation part of the description represents the typical interactionist perspective on stress. It is common to consider this as the only definition of stress but that is an impoverished and limited perspective. The initial, input aspect of stress describes the physical characteristics of the surrounding environment. It is a deterministic description because it is expressed only in terms of physical metrics which are, by definition, measurable. It is a signature because it is a dynamic, time-varying representation. Thus, one could feasibly recreate any environment so described, but in the real-world this recreation would be practically impossible. However, it is an equally fundamental description of stress as the adaptation portion, just one that is more familiar to the physicist and the engineer than the behavioral scientist. The output component is tied to the on-going performance of the exposed organism. It is idiographic since all such exposed organisms react differently, exhibiting a capacity formally described as non-stationarity. An example may well be the change in capacity that accompanies chronic effects like learning or fatigue, or momentary acute changes such as transitional adjustments or momentary muscular spasms. The output focuses on what the animal or organism does. The input focuses on the challenges to be faced, the adaptation focuses explicitly on the spectrum of behaviors that mediate between the input and the output.
indicates that under most conditions the adaptive state of the organism is stable, it also shows that as either environmental underload or overload increases beyond a series of threshold values there are failures in adaptation reflected as loss of comfort, loss of behavioral response capacity and loss of physiological response capacity respectively. As humans are so effective at adapting to stress, examples of such extreme failure of physiological response capacity are, thankfully, rare in most work settings. One exception is in military conflict in which such dire conditions do occur all too frequently. When they do occur they are often catastrophic for both the exposed individual and the task they are seeking to perform (see Harris, Hancock and Harris, 2005).

A third and unique feature of this model is that it explicitly recognizes that the proximal form of stress in almost all circumstances is the task itself. Thus, the task itself is the primary form of input stress. One ramification of this conception is that a uni-dimensional axis (as given in Figure 1.2) is insufficient to describe the constellation of input forms of stress. To refine and elaborate on this multi-dimensional aspect of input stress, Hancock and Warm divided the base axis of the model into two distinct axes representing spatial and temporal components of any specific input. Information structure (the spatial dimension) represents how task and input elements are spatially organized, including challenges to such psychological capacities such as working memory, attention, decision-making, and response capacity. The temporal dimension is represented by information rate. This connotes the speed at which information and demand is presented. Together these dimensions can be used to form a vector (see Figure 1.3) which serves to identify the current state of adaptation of the individual. Thus, if the combination of task characteristics and an individual’s stress level can be

**Figure 1.2 Extended-U conception of stress and response capacity**

*Note:* On the base axis is the “input” aspect of stress, expressed here as an excessive or insufficient level of some particular physical characteristic. For example, extremes of heat and cold are both stressful for human operators. The “adaptation” aspect of stress is represented by the plateau at the apex of the extended-U which describes the regions of stable response in relation to the specific form of input stress. The “output” aspect of response is described by the respective curves which illustrate the breakdown in various levels of response capacity as the input stress exceeds adaptive response.

*Source:* Hancock and Warm, 1989.
specified, a vector representation can be used to predict the degree of behavioral and physiological adaptation and the associated degradation in response, if any. Note that the task dimensions can be combined with the aforementioned vector representing other environmental inputs (e.g., heat, noise, etc.). Indeed, Hancock and Warm (1989) conceived of tasks as another form of environmental input, in contrast to more traditional stress theory which viewed “stressors” as physical or social stimuli distinct from the task to be performed. The challenge lies in quantifying the information processing components of cognitive work (and see Hancock, Szalma and Oron-Gilad, 2005).

Although the model shown in Figure 1.3 describes the level of adaptive function, it does not articulate the mechanism(s) by which such adaptation occurs. Hancock and Warm (1989) argued that one way in which individuals adapt to stress is to narrow their attention by excluding task irrelevant cues (Easterbrook, 1959). Such effects are known to occur in spatial perception (e.g., Bursill, 1958; Cornsweet, 1969), and narrowing can occur at levels of both the central and peripheral neural systems (Hancock and Dirkin, 1983; Dirkin and Hancock, 1984, 1985). Recently, Hancock and Weaver (2005) have argued that distortions of temporal perception under stress are

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**Figure 1.3 Extension of the extended-U model through the differentiation of the base**

Note: The input axis is in two separate components, namely information rate and information structure. The effect of any individual form of input can be represented as a scalar imposed upon these base axes and multiple scalars (as represented by multiple forms of input stress which are always encountered in real-world settings) can be combined into one single vector representation. Emanating from the central “comfort” zone, the magnitude of the derived vector specifies the degree of interference with response capacity at the differing identified levels (e.g., psychological adaptability as represented in task response and physiological adaptability as represented in compensatory [homeostatic] processes).
also related to this narrowing effect. However, recent evidence suggests that these two perceptual dimensions (space and time) may not share uniquely common perceptual mechanisms (see Ross, Szalma, Thropp and Hancock, 2003; Thropp, Szalma, and Hancock, 2004).

### 3.3 Compensatory Control Model

The Hancock and Warm (1989) model accounts for the levels of adaptation and adaptation changes under the driving forces of stress. However, it does not articulate how effort is allocated under stress or the mechanisms by which individuals appraise the task parameters that are the proximal source of stress. The effort allocation issue is address by a cognitive-energetic framework described by Hockey (1997). This model shares the premise of Hancock and Warm (1989) that individuals actively adapt (compensate) to environments that are stressful or impose extremes of workload. The compensatory control model is based upon three assumptions: behavior is goal-directed; self-regulatory processes control goal states; and regulatory activity has energetic costs (i.e., consumes resources). In this model a feedback control mechanism allocates resources dynamically according to the goals of the individual and the environmental constraints. The mechanisms operate at two levels (see Figure 1.4). The lower level is more or less “automatic” and represents established skills. Regulation at this level requires few energetic resources or active regulation.

**Figure 1.4 The two-level effort regulation model by Hockey**

This model provides a mechanism by which an individual allocates limited cognitive resources to different aspects of performance.

and effort (cf. Schneider and Shiffrin, 1977). The upper level is a supervisory controller which can shift resources (effort) strategically to maintain adaptation and reflects effortful and controlled processing. The operation of the “automatic” lower loop is regulated by an effort monitor that detects changes in the regulatory demands placed on the lower loop. When demand increases beyond the capacity of the lower loop control is shifted to the higher, controlled processing loop. Two strategic responses of the supervisory system are increased effort and changing the goals. Goals can be modified qualitatively (change the goal itself) or quantitatively (e.g., lowering the criterion for performance). Essentially, this is adjusting the discrepancy between goal state and current state by increasing effort or changing the goal (and see Carver and Scheier, 1998).

3.4 Theoretical Challenges

Three key theoretical issues remain that limit the utility of many current stress theories. First is the status of mental resource concept itself. We have recently described the definitional problems associated with resource theory (Szalma and Hancock, 2007), and have asserted that the emerging field of neuro-ergonomics may serve to help clarify and more precisely quantify the resource concept (Hancock and Szalma, 2007). The second issue concerns mechanisms that underlie appraisals. Although recent work has applied connectionist models to understanding appraisal (Sander and Grandjean, 2005) this work has yet to be fully exploited for understanding the cognitive mechanisms underlying stress response in the context of human performance. The third issue is that of time. It has been well established that time is a key variable in the experience of stress (Hancock and Weaver, 2005), and that the duration of exposure to a stressful environment always interacts with the intensity of the stressor (Conway et al., 2007; Hancock et al., 2007). However, the changes in both the environment and the cognitive state of the individual that occur over time has been relatively neglected in research on stress and performance (although see Hancock, Szalma and Oron-Gilad, 2005). This despite the explicit argument by Lazarus and Folkman (1984) that transactions cannot be considered as isolated, discrete events, but rather must be viewed as continuous processes. Thus, human-environment transactions function in a way analogous to perception-action cycles. There has been some research on changes in stress state over time in the context of sustained attention (e.g., Szalma et al., 2004), but such analyses tend to examine large blocks of time (e.g., 10-minute periods on watch), and a more fine-grained temporal analysis is necessary if the mechanism underlying stress response are to be fully articulated.

4 The Problem of Stress Interactions

4.1 Illustrating the Interaction Problem

One of the most daunting, and as yet largely unaddressed issues in the research on stress, concerns the problem of interactions. Rather than plunging straight in to the technicalities, let us provide an everyday example, which we hope will serve to illustrate the problem in all its complexity. When anyone goes to the Doctor with a problem or ailment, they are likely to be prescribed some drug or other to alleviate either the problem itself or at the least the symptoms of the problem. However, prescribing drugs leaves both the physician and the pharmacist who supply the drug with a crucial question. Will the new drug interact with anything that the individual is already taking? In general, drug development companies seek to assure the regulating bodies that “new” drugs are not harmful in themselves and this must include field trials on people living in “normal” circumstances. However, in our modern world, and especially as one grows older, it is rare that a
person is taking only one single drug. They may be taking aspirin for cardiac preventative purposes. Many people are on cholesterol reduction regimens, beta-blockers are now common and a variety of pain suppression drugs are taken every day. How does the prescribing physician know that these existing drugs will not interact with the new prescription to produce a fatal cocktail? And, we must also remember, that the doctor’s knowledge of the individual does not include information on over the counter medications, recreational drugs, dietary supplements or even exotic foods. What’s a physician to do? This is the question of interactions with a vengeance. The practical way to deal with this issue is twofold. First, there is a tome entitled the “Physicians Desk Reference” (PDR) which can supply information on known dangerous interactions and this backs-up the physician’s own direct knowledge of drug effects and how systems within the body interact with each other. The second empirical way is simply to try it. The patient is actually a walking experiment in many of these cases and if there is an allergic reaction one would recommend stopping the most recent medication and perhaps trying an alternative. Such reactions rarely prove fatal and since health itself is a multi-dimensional concept, the patient (or customer in more modern parlance) is either happy with the treatment to a greater or lesser degree. In contrast with these empirical approaches, one could have a theoretical approach based much more on an understanding of human biology but either way, such complex, multi-way interactions often represent exploratory conditions whose effects are, by their very definition, unknown.

The same problem presents itself with respect to stress interactions. However, unlike the drug companies, stress researchers do not have a vast industry behind them devoted to testing specific products or conditions. However, there are some interesting parallels. In the same way that an individual drug is tested, we do have tests of and standards for individual sources of stress. Thus, there are ISO standards for thermal exposure (see Parsons, 2002), for vibration, noise, etc and these essentially represent the same concern for the main effects of individual drugs. We do also have several constituencies interested in the interaction issues. One prime example that we certainly know of is the military who are especially concerned with stress interactions. Many of the most recent conflict situations have occurred in locations with extreme climates and modern weapon systems often present inherent hazards such as noise and vibration. Added to these physical manifestations of stress, the acute and chronic effects associated with workload, fatigue, and uncertainty with respect to family and friends far away, all sum to make a veritable cornucopia of effects (and see Merlo, Szalma, M., and Hancock, this volume). How do these sources of stress interact and what can we know about these dynamic and multi-faceted effects?

4.2 Summated Stress Interactions

The primary reason that we know so little about stress interactions is that such studies are very expensive to conduct and difficult to evaluate. This is especially true if they are to be done correctly. The wrong answer can be provided rather cheaply but the right answer will certainly be expensive. In general, funding agencies have, somewhat understandably, baulked at supporting these very costly efforts. Those individual scientists who have tried to tackle this problem have been rare and as a consequence, reliable and insightful publications on the issue of complex, multi-way interactions are unfortunately sparse (e.g., Poulton and Edwards, 1974). A survey of the present state of stress research shows relatively little empirical work progressing on this front. However, many agencies still have to try to predict operator behavior under these multiple influences and so the present strategy is to use models to seek answers to this concern. Models are helpful to a degree and are, by and large, well-informed as to the stand-alone main effects of several primary sources of stress (e.g., Conway et al., 2007; Hancock, Ross, and Szalma, 2007). However, the assumptions which underlie many models of operator response about interaction effects are often impoverished
Figure 1.5 An exploration of the possible forms of interaction between two sources of stress on performance response

Note: There is no guarantee that this illustrates an exhaustive list of all such interactions for reasons made clearer in the accompanying text.
and occasionally so over-simplistic as to be misleading. And we can never forget that even bad models produce an “answer,” even if that answer is wildly wrong. One of us (PAH) was sufficiently perturbed by such concerns that an attempt was made to begin to plot out the interactive space of effects of only two sources of stress. The illustration in Figure 1.5 was the result.

While this illustration does serve to begin to indicate the overall complexity of the issue, there are a number of hidden concerns that have to be added to this circumstance, which must be considered the simplest case. Figure 1.5 shows the specific condition of two interactive sources of stress. On the base axis is a primary stress which varies in intensity from a normative level to a level of total intolerance. Embedded is a secondary source of stress whose effects are shown in the various interactive forms identified. The dependent variable of choice here is performance capacity and this is arranged so that poorer performance is represented as going up this vertical axis. What is intrinsic to this illustration but what remains largely hidden is time. With all of the identified interactive effects, we cannot guarantee that they remain stable over exposure time. That is, some interactive effects may prove to be beneficial over short exposures but then cause rapid and dangerous degradations as the exposure progresses. Since time is always a factor in such exposures, it becomes obvious that even the most simple of possible cases is composed of at least three factors (the two sources of stress and the time factor). This being so, we hope that we have illustrated satisfactorily to the reader that the combinatorial explosion which characterizes this realm of interactions rapidly defeats any hope of exhaustive empirical attack. As a community, we will be testing from now to eternity to plot out these combinatorial effects on a case by case situation. While we are certainly personally prepared to conduct a systematic experimental attack, funded extensively by any appropriate agency, we would not expect to see definitive results during our lifetime concerning the exploration of the realm of all possible conditions.

If we cannot solve this problem solely by the brute force iterative experimental procedures, what can we do? The answer is to improve on current theory. In fact, it is the primary role of theory to bridge the gaps between islands of factual understanding. There could potentially be a never-ending sequence of meta-analytic reviews of singular stress effects to establish these particular islands (and see; Conway et al., 2007; Hancock et al., 2007. However, when one surveys the literature of interactive sources it is evident that the number of studies required to derive meta-analytic results for interactive effects simply do not exist. The Hancock and Warm model seeks to resolve this impasse by converting different sources of stress into their spatial and temporal components. Most environmental sources of stress can be described as energy distributed over time and indeed the information intrinsic to task demands should, in theory, be also amenable to this form of decomposition. However, the devil is in the details and as yet there is no principled solution to this decomposition and subsequent integration process. The need to be able to express tasks and environments in language amenable to information-processing response is absolutely essential. Despite valiant efforts in psychology and the neurosciences, we have not yet really found a solid basis for identifying an answer to this crucial question. The ecological approach seems to offer such a possibility through the conception of “affordances” but that itself requires further elucidation in both qualitative and quantitative terms. These combined barriers mean that while we have some idea of the individual effects of singular sources of stress on generic performance tasks we still cannot provide satisfactorily accurate predictions for stress effects in challenging, real-world conditions. It is the further consideration of this limitation which is pursued in the following section.
5 Stress in the Context of the Real-World

Why is it then that we remain frustrated in the effort to predict someone’s actual response in a specific stressful situation? After all, in general it is not because we have not directed substantial effort, intellectual capital, and resources to this problem. Over the years, although behavioral scientists have not been funded and supported to the same extent as their medical or engineering colleagues, there has been a significant investment in trying to solve this question. Further progress toward an answer lies in two factors which we must now address if the situation is to be materially improved. The first issue is very much related to the aforementioned interactions problem and can be thought more generally as issue of complexity and immediacy of the real-world. As we have noted, the real-world has a plethora of interactive stresses but the stresses are themselves multi-faceted. There are immediate stresses such as the sources of environmental disturbance, heat, noise, vibration, etc and the task-related stresses (e.g., the information-processing demands of the mission requirements). These are the immediately evident, proximal stresses that we all recognize and with which we attempt to cope. However, there are distal sources of stress that can be just as disruptive but are not necessarily immediately evident. Fatigue is an example of one such issue. Often a low grade source of stress, nevertheless it is often pervasive, especially in operations that have to proceed on a 24-hour basis. Uncertainty is another low-level but ubiquitous form of stress. What is happening at other locations? How are your family, friends, and colleagues? What will be the up-coming demands and will you be able to respond to them? In the present conflicts, a persistent question is length of deployment, when deployed and frequency of future deployment when not on station. Unlike circumstances where bullets are flying and explosions are occurring, these forms of chronic, on-going real-world demand add to the level of stress to generate continuous, mal-adaptive circumstances. The second issue in real-world contexts is the problem of individual differences. Despite many institutional efforts at a common level of training and expertise for all individuals, we cannot assure that each and every person is exactly like the individual standing next to them. It is indeed fortunate that we are all individuals, but this blessing has a drawback as far as science is concerned which means we cannot expect a common reaction out of a group of even supposedly homogenous and trained individuals. Although the forces and other institutions go to great lengths to try to ensure these standardized responses, it still remains uncertain as to how each individual will react at times of extreme stress (and see Hancock and Weaver, 2005). Individual differences are evident sources of variation that we need to subject to further experimental attack and some of these efforts are proceeding as agencies and organizations still require this knowledge about their exposed personnel.

However, the issue of context is interwoven with these uncertainties and perhaps a brief, if somewhat simplistic example may be illuminating. Suppose we were to ask you to walk along a plank 3 ft. wide by 40 ft. in length while it was placed on the floor of a pleasant park area. For most healthy individuals this would represent only a minor challenge and they would accomplish it with ease. Now suppose we suspended that plank 100 ft. into the air? Although the physical circumstances might be exactly the same (e.g., no wind or vibration of the plank, etc) the task now can appear quite formidable. The reason for this is obvious. Although the involved motor patterns are exactly the same, the punishment for failure has now gone from an apparent level of zero to really quite substantial. Of course, an experienced steeplejack might consider this virtually no challenge at all while someone with vertigo will be severely threatened. The issue of surrounding context directly harks back to the question of appraisal, which may be directly matched to reality. Someone in significant danger may be quite oblivious to incipient threat while someone in no danger at all may see threat at every turn. What we have yet to derive is an effective language for these vital contextual effects. While the notion of an “affordance” from Gibsonian, ecological
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6 Summary and Conclusions

Many of the problems of stress that have attracted researchers, beguiled involved agencies and frustrated and affected exposed workers, continue to persist despite several decades of effort. We have made a number of important advances. Recognition that the task the individual is performing is the proximal source of stress is a good beginning. Understanding that people are, in most part, only exposed to stressful circumstances in order to do a job and if they are not doing that job effectively it does not matter that they can simply survive, has taken the emphasis away from medical and physiological limitations and placed the focus squarely on the information-processing capacities. That incipient failure in such complex cognitive tasks is diagnostic of approaching physiological distress is an obvious bonus. In future, all occupational stress exposure limits should be founded upon such performance and not on measures of systemic physiological change (and see Hancock and Vasmatzidis, 2003).

In terms of predicting response change under stress, some models such as IMPRINT and finer grained models such as ACT-R have begun to return interest on the investments that have been made in them. As well as giving practical advice as to performer limits, they also serve to direct our attention to problem areas that still need further evaluation and resolution. As is evident from the final chapter in the present text, our military forces are now facing a challenge for which, by and large, they have been poorly prepared. That is because many of the tasks they are now being asked to perform are not those which typically occupy the military mandate. That they do this so well argues for their professionalism and their adaptability but it brings in to play sources of stress and demand for which traditional military training provides little experience. The better the theories that we generate and validate, the better we will be able to help individuals exposed to new and largely unanticipated circumstances. If General Robert Scales is correct, and we believe that his prognostications are very enlightened, then we will in future fight the “cognitive” war (Scales, 2006). The future battleground will largely be the minds of other individuals and those individuals will certainly be under stress. It is crucial that we know about these issues if we are to resolve them effectively.

Stress research in general has suffered under the hands of rapacious attorneys. Ever watchful of opportunities to engage in litigation, these legal circumstances have meant that research Universities have become ever more wary of human experimentation, especially when it includes manifest sources of threat which could potentially harm and damage. As a result, the experimental evaluation of high level stress effects on performance has largely ceased in these public institutions and thus the importance of understanding the data we do have has increased. Yet in the real-world there are unstructured experiments that take place everyday into these multiple effects. Individuals still face these evident challenges and their periodic failure in doing so occupies the television screens of the world. As human beings continue to explore new and challenging situations, the issue of stress persists. As we try to go to Mars; as we seek to explore the depths of the oceans; as we push existence and exploitation of the more hostile regions of our own planet; stress is our inevitable companion. And we are also generating virtual worlds in which stressful demands
are placed upon the individual, sometimes intentionally so. For a life without stress, the nominal “dolce far niente” may initially sound appealing but such existence would rapidly pall. We need our stress and we need it in small and manageable doses. For stress defines us and develops us. We are the present product of the past stresses we have experienced, as our children will be of the conditions which stimulate their own unique evolution. To truly know ourselves, we need to know stress and this chapter and this text is, hopefully, one small step along that journey.

References


Introduction

A New Kind of Warfare

The military forces of some countries are facing threats that are completely different from any seen previously. These threats are characterized by enemies using catastrophic terrorism, extremist visions of religion/culture, and the use of highly sophisticated psychological warfare to attack our way of life. The wrenching events of September 11, 2001 made clear that the main problem is not confined to nation-state rivals, but includes disruptive and irregular threats from decentralized networks of non-state enemies.

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The terrorist attacks in New York and Washington, DC on September 11, 2001, caused the US military to grasp a new focus on a new kind of warfare which has been labeled variously as the “global war on terrorism,” “the long war,” “asymmetric warfare,” and “fourth generation warfare.” Whatever terms we use to describe the new practice of warfare it is clear that with it, along comes a new set of stressors, both psychological and physiological, our military forces need to prepare to face. Behavioral scientists, especially military psychologists, need to examine old paradigms of coping with stress and need to help combatants formulate new ones. Accordingly, Mangelsdorff (2006) and C.J. Kennedy and Zillmer (2006) assembled current state-of-the-science texts describing military psychology’s historical approaches to new challenges prompted by the changing face of national security.

Stressful changes At the dawn of the new millennium, western military forces are experiencing new forms of asymmetric warfare employing both high- and low-tech weapons and alternative tactics, exposing combatants and their support personnel to traditional battlefield stressors as well as to new ones. In the so-called Global War on Terrorism (GWOT) contemporary battles such as those in Iraq (2003–07) and Afghanistan (2001–07) constitute low-intensity warfare. Seemingly gone, for now at least, are the clear-cut battle lines familiar on more conventional battlefields. There is little readily marked terrain to be taken, and enemy targets to be nullified are no longer clearly identified through their wearing the uniform of a nation-state enemy. Relatively short, intense, all-out combat operations employing advanced state-of-the-art weaponry but lasting for only a few weeks or months, quickly transitioned to a daily sorting and identification of multicultural peoples viewed as friends and allies in need of nation-building and peacekeeping assistance. Or they are insurgent foes or terrorists intent on disrupting things by maiming or killing the newcomer military forces who may be viewed as occupiers. Centuries old tribal animosities bring cruel, crude, but sophisticated guerilla and terrorist tactics to the forefront, making personal safety and performance
difficult not only for the heavily armed “saviors” who came ashore to help, but for the indigenous “saved,” whose homeland becomes plagued by threats to safety and tumultuous turmoil.

For US military forces, actual combat activity on changing contemporary battlefields morphed into smaller-scale, comparatively less intense, shorter duration “wars,” often fought in urban city areas as opposed to out in the wide open expanse of conventional battlefields of the past. Military operations other than war (MOOTW) in the form of overseas peacekeeping, provision of humanitarian assistance, and nation-building missions have increased in frequency and dimension for deployed US military forces (U.S. Joint Doctrine, 1997; US Army Combined Arms Center, 2006). These new roles for combatants, involved in less traditional war fighting, give rise to the realization that new significant stressors impinge upon troops engaged in such activities. These circumstances warrant the attention of behavioral scientists wishing to make critical inroads into military human capital strategies, necessitating new personnel policies regarding selection, placement, training, employment, and retention of hardy, resilient soldiers, sailors, airmen, marines and coast guardsmen.

In large-scale, long duration wars such as WWI and WWII, indirect artillery explosives rained down on combatants for weeks and months to “battle-shock” thousands of troops, who literally developed forms of “battle fatigue.” These tactics have given way to insurgent attacks exposing soldiers to frequent exposures to direct, intense explosive bomb blasts accompanied by physical overpressures to cause brain concussions. Projectiles of broken metal, or of concrete and glass from so-called improvised explosive devices (IEDs) bring about severe bodily wounds not previously encountered in such large numbers. These tactics lead not only to higher incidence of limb loss and brain injuries; but for those who survive repeated attacks, and multiple brain concussions, make Post Traumatic Stress Disorders (PTSD) an even more likely outcome for hundreds of combat veterans.

It is always a challenge to sustain the health and performance of US forces deployed to geographical areas of harsh environmental and climatic extremes, hosting threats to hygiene, and increased risk of exotic diseases. Only a decade ago, military materiel development programs, and contemporary operational tactical doctrine on how to fight focused on equipping and training military forces to fight in a chemically- or biologically-contaminated battlefield (which since the First World War has yet to materialize). More recent efforts shifted to operating with high-tech network-centric warfare communication systems, which can electronically connect everyone to permit enhanced situational awareness; but which also can potentially inundate combatants with too much digital information. If the abundance of available information is not carefully managed and distributed, today’s soldiers can experience information overload at a time when rapid-decision making while operating under stringent “rules of engagement” dictating when and when not to shoot one’s weapon, is called for almost daily. Information age concerns even involve the presence of embedded news media personnel who can immediately turn quick on-the-spot battlefield military decision-making into news reports bringing about Monday-morning quarterbacking episodes of international note. Pressures abound to say or do the right thing, and not to do the wrong thing for the ubiquitous television cameras. New combat realities suggest flexible leadership, adaptive training, cognitive readiness, intuitive thinking and the ability to respond with the right amount of military moxie have never been at such a premium.

Chapter structure This chapter is meant to convey a sense of the growing number of incredible battlefield stressors both in contemporary and future military theaters that impinge on combatants and support personnel alike. The many stressors faced by soldiers, sailors, airmen, marines, and coast guardsmen can be categorized in several ways. In this chapter the interacting stressors combatants face are differentiated in three sections: 1) environmental and physiological threats
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and their effects on performance; 2) psychological threats and effects; and 3) newer technologies, enemy threats and effects. This chapter is intended to prepare the reader for extrapolations of reported research findings in this text to the field for today’s and tomorrow’s battles.

What is Soldier Stress?

Different communities of behavioral scientists cite different definitions and connotations for the terms: soldier stress, combat stress, battle fatigue, combat stress reaction, or stress casualty. These terms sometimes take on different meanings in discussions of large and small scale wars. For a research psychologist interested in the effects of stress on “fighting performance,” combat stress or operational stress is looked at – more as being the “stressors” or the stimuli in the environment. These stressor stimuli, both physical and psychological, impinge upon the person (soldier, sailor, airman, or marine) as the stressors affect his/her readiness and ability to engage in and succeed in a fight. For the clinical psychologist or psychiatrist interested in mental health, combat stress usually means the response of a combatant to multiple stressors on the battlefield or work environment to the point of exhibiting clinical symptoms. The physical and psychological responses of a person to operational stress stimuli, may include making the solider an ineffective combatant on the battlefield. A combat-stressed soldier is one who is physically able but is otherwise psychologically unable or unwilling to continue the fight as he/she experiences combat fatigue, combat stress reaction, or even a form of Post Traumatic Stress Syndrome (PTSD). Soldiers process or filter many stressors (stimuli) through organizational, social context, and personal variables. Social context variables that might influence how stressors get processed in the military environment are unit cohesion and leadership climate (Bartone and Kirkland, 1991; Manning, 1991). Person variables that influence or moderate the stress-outcome relation include past experience, pre-existing psychopathology, and personality characteristics (Bartone, 1998). For discussion of the different meanings of combat stress, combat operational stress reactions and how battlefield stress terminology changed over the past century, consult Jones (1986, 1995); Marlowe (1986); Campise, Geller and Campise (2006); Gifford (2006); and Bartone (1998).

For Marlowe (1986) the power of the battlefield to break men can never be overstated. As the intensity, lethality, and duration of time in which troops exchange direct and indirect fire (e.g. artillery) with an enemy increases, the potential for individual psychiatric breakdown and unit disruption increases. Using history as evidence of the influence of battlefield stressors, Marlowe’s point is that involvement of US armed forces personnel in the Second World War was substantially different from US combatants participating in the wars in Korea (1950–53), Vietnam (1961–73), and the Persian Gulf I and II Wars (1991 and 2003 – and continuing). These later wars were no less stressful or deadly to an infantry platoon engaged in a desperate firefight with the enemy. However, such actions did not have the scale, the intensity, and especially not the weeks and months long duration of the high-intensity main force battles between essentially equipotent forces using massive resources for indirect fire (artillery) as in WWII. For the US Army the overall rate of 101 per thousand battle fatigued troops per annum was biased by inclusion of data from the end of the Battle of the Bulge to the end of WWII hostilities in Europe. Marlowe (1986) suggested this was a period when the number of neuropsychiatric (NP) casualties was very low because imminent victory was in sight. That bias masks the fact that individual line regiments often suffered annual rates as high as 1,600 NP casualties per thousand per annum during the days or weeks of a heavy engagement.

To convey the historical flavor of the phenomenon of combat stress reactions, Marlowe (1986) quoted from a WWII psychiatric account:
The key to understanding the psychiatric problem is the simple fact that the danger of being killed or maimed imposes a strain so great that it causes men to break down. One look at the shrunken apathetic faces of psychiatric cases as they come stumbling into the medical station, sobbing, trembling, referring shudderingly to “them shells” and to buddies mutilated or dead is enough to convince most observers of this fact. There is no such thing as “getting used to combat. Each man “up there” knew that at any moment he might be killed, a fact kept constantly before his mind by the sign of dead and mutilated buddies around him. Each moment of combat imposes a strain so great that men will break down in direct relation to the intensity and duration of their exposure. Thus psychiatric casualties are as inevitable as gunshot and shrapnel wounds in warfare (Appel and Beebe, 1946: 84).

Partly in response to the overwhelming incidence of psychiatric casualties in WWII, incidence of soldier breakdown in the later wars was as much controlled by the calendar as by the outcome of combat with the enemy. By design, in these later wars, assignment rotation policies for US military personnel dictated how long an individual’s combat tour would last. In Korea, Vietnam, Bosnia, Afghanistan, and Iraq, individual tours in combat nominally have been for one year or less. Combatants in these later conflicts usually did not envision themselves as being committed for years at a stretch, to the end of battle, as was the predominant case in WWII. In contemporary battles, the shorter duration of sustained intense combat exposure has become more measured, and the incidence of psychiatric stress casualties on a percentage basis is substantially less than it was in wars such as WWII. It is not practical at this time to make meaningful statements of comparative rates in the present Middle East conflicts because the U.S. Defense Department recently implemented new policies and practices on early prevention, identification, treatment, and tracking of combat stress casualties in the numerous contemporary overseas troop deployments.

Bartone (1998) says to study soldier stress, or stressors, we should concentrate not only on the battlefield, but we should give consideration to the military setting, including: a) the garrison or home-station environment, b) the forward-deployed environment for troops stationed at overseas locations or on ships or submarines, and c) the deployed environment for troops on an actual military mission, i.e. ranging from intense stressors associated with an actual attack or rescue operation to the unique stressors prevalent in the several stages of performing less militarily glamorous peacekeeping and nation-building mission activities. Bartone says three outcome variables are influenced by stress: soldier performance, social adjustment, and health. Stress can lead directly to impaired performance, can contribute to a variety of physical and mental health difficulties, and can result in a variety of social adjustment problems such as family violence, divorce, and substance abuse. Psychological stress in military operations can have a range of serious consequences, including increased risk of death and serious injury from accidents, inattentiveness and errors of judgment, exposure (e.g. cold injuries, malaria), friendly-fire incidents, and suicide. Psychological stress can also increase the risk of soldier misconduct, alcohol abuse on the job, and violations of the rules of engagement, as well as diminish soldier mental health, morale, and psychological readiness to perform the mission.

This chapter focuses predominately but not exclusively on the stressors associated with the deployed environment of actual military missions.

Environmental and Physiological Threats and Effects

People haven’t changed People of the battlefield: soldiers, sailors, airmen, marines, and coastguardsmen have not changed much physically over the past few centuries. Likewise the indigenous threats posed to humankind by such harsh battleground environments as high mountains, deserts, and under-the-sea environs have changed barely at all. What changes of course are the military tactics and the continued technological advances of waging war by bringing ever more
sophisticated machines, weaponry and incredible new physical threats to the battlefield. The human combatant has been called the **limiting element** in military systems, and is often labeled as the “weak link” in the extremely harsh environments of battlefields more suited to newly developing smart machines and robots (Krueger, 1991a). However, wars still are fought by men, and now, since 1991, including larger numbers of women (Kennedy, 2001; Solaro, 2006; Wise and Baron, 2006). The weapons and machines no matter how sophisticated are still mere extensions of our human senses, our reach, and our “fists.” Combatants must continually adapt to the intensities of war, and especially to the environmental complexities, and stressors of the battlefield (Krueger, 1993).

**Overseas deployment of forces** Military forces, especially those of large nations, use rapid aerial troop deployments to transport combatants across time zones, and to significantly different climates. Before performing at their optimum soldiers must adjust or **acclimatize** to the new environment – to the extremes of heat, cold, or altitude. Acclimatization may be partially accomplished prior to deployment by operating for a period of time in temperatures or altitudes like those of the anticipated battle area. If not, sustaining outstanding military performance soon after arrival in the battle area may be difficult. Even after acclimatization, performance of many military tasks in harsh environmental extremes is difficult and often hazardous to health. Perhaps less physiologically, but rather more psychologically-based, deployed forces must also adapt to stresses of working in lands presenting them with entirely different cultures, languages, and other aspects of life that are foreign to their senses.

**Heat and cold stress** The amount of personal physical activity, the clothing worn, the load carried, the terrain, the climatic conditions (especially the degree of humidity) and the state of personal acclimatization to temperature extremes, all determine the amount of heat accumulated in the human body. In hot environments, sweating helps dissipate body heat. If lost body fluids are not replaced, dehydration follows, heat dissipation is hampered and heat illness results. To prevent excessive body temperature rises, combatants must hydrate by drinking fluids, preferably water, and must reduce body heat production by altering work-to-rest cycles to allow more frequent and longer rest periods consonant with conditions, and thus potentially work less per hour (for examples of recommended water consumption and sample work-rest cycles for deployment to deserts in the mid-East see Glenn et al., 1991).

Throughout history, military operations have been compromised as much by exposure of personnel to extreme weather conditions of both heat and cold as by actual battle casualties. Heat and cold exposure, particularly involving extreme climates generating thermal stress to the individual, can significantly impair operational performance of military personnel. With respect to heat, vigilance tasks appear to become impaired above 90 °F (32 °C) and below 85 °F (29 °C), with best performance at or about 85 °F with 63 per cent relative humidity. Cold effects generally are related to loss of manipulative ability; psychomotor tasks tend to be affected at or below temperatures of 20 °F (−7 °C), with reduced sensory sensitivity at somewhat higher temperatures around 32 °F (0 °C). Kobrick and Johnson (1991) provided a review of performance effects in hot and cold environments, and a meta-analyses of performance responses under thermal stressors is provided by Hancock and Szalma (2007).

Soldiers and marines on the ground in Iraq deserts routinely experience daytime working conditions in the hot season of upwards of 120 °F with high humidity along the coastlines. Sailors who work in engine rooms of warships in the tropics routinely encounter ambient temperatures of 145 °F, suffer dehydration, and high levels of fatigue. Weapon system crewmen, such as tankers or helicopter pilots, dressed in bulky chemical protective clothing ensembles, succumb to heat-related
stresses and claustrophobic sensations long before they accomplish their mission (Krueger and Banderet, 1997).

High terrestrial elevation  Forces deployed to very high mountainous terrain frequently must cope with acute mountain sickness and hypoxia effects at altitudes above about 8,000–10,000 feet above sea level, and are threatened with pulmonary and cerebral edema at higher altitudes above about 15,000 feet. Frost bite is also a threat at high altitudes. These threats limit their stays at high altitude and therefore lessen productive time on the job, with consequent performance effects attributable to high altitudes being noticeable above about 8,000 feet (Banderet and Burse, 1991).

Acoustical noise  Military personnel often operate in intense noise environments ranging from exposures of relatively long duration to those of repetitive impulse noises. Missile repairmen, communications personnel, air and ground vehicle crews are exposed to continuous noise, hindering communications, affecting performance, and threatening hearing loss. Exposure to high impulse noises from rifle and cannon fire is ubiquitous in military training and during operations. In addition to the “battle blast” imposed upon recipients of incoming artillery fire, a counterpart is that artillery crews that enact cannon fire are themselves also exposed to intense impulse noise. The effects such acoustic environments have on military personnel range from direct physiological damage to the auditory system, interference with attempts to communicate, and possible debilitation in health attributed to stress resulting from noise exposure (Moore and Von Gierke, 1991).

Wearing hearing protective devices, or electronically aided signal receivers and noise cancellers becomes critically important for maintaining performance in many military jobs, and for hearing conservation. Most infantrymen resist wearing ear protection on both ears in the belief they always need to have one ear unencumbered to be able to hear the enemy sneaking up on them through the brush. There are countless personal stories of military members, particularly artillerymen, tankers, aviation crews, and infantrymen who have experienced frustrations and stress associated with degraded hearing while they continued to do their jobs. Hearing loss is an ever present stressor for countless combatants. Veterans Administration figures portray the most frequent form of medical compensation for military veterans continues to be for hearing loss.

Toxic fumes  Military training and combat frequently exposes weapon system operators and crewmen to mixtures of potentially toxic fumes. Armor crewmen work in confined spaces amid short bursts of highly concentrated propellant gases from their own weapons. Battlefield smokes and obscurants used to disguise movements, as well as combustion products from projectile propellants, exploding munitions, fires, and vehicle exhausts affect the eyes, nose, and throat of vehicle crews and ground-pounding infantrymen on the battlefield. If the central nervous system (CNS) is affected by toxic fumes, even temporarily, errors or delays in action can reduce effectiveness of crews and affect survival of combatants and those who are dependent upon them to do their part in a timely manner (for effects of toxic fumes on soldier performance, see Benignus, 1991). Insuring exposure to toxic fumes is kept to a minimum, and providing appropriately designed crew compartment ventilation systems, filters, and protective masks, all are important from a health and a performance perspective.

Acceleration and vibration  Operators of high performance vehicles, especially military pilots, experience high acceleration levels, buffeting, vibration, electromagnetic hazards, and other intense environmental stresses. Some deleterious effects of vibration and acceleration on performance can be attenuated by paying attention to task requirements, through selection and loading to minimize such effects, through design of protective equipment (e.g., shock absorbers, air cushioning, etc.)
and through ergonomic design of controls and displays compatible with environmental stress levels. Individual differences between people must not be overlooked; training factors and overall operator performance have a large impact on the effects of environmental influences (for performance effects of acceleration and vibration, consult Von Gierke, McCloskey and Albery (1991; Conway, Szalma and Hancock, 2007).

Motion sickness Many ship and airborne missions are accompanied by motion sickness. Motion sickness occurs while using training simulators, especially those with computer generated visual imagery, and it occurs while using some virtual reality training devices. The effects of motion sickness on performance are not so easily measured; but clearly motion sickness affects mood and motivation and a person’s readiness to carry out tasks. Pre-selection, desensitization training, behavior therapy, biofeedback and pharmacological intervention are all useful countermeasures for motion sickness conditions (Rolnick and Gordon, 1991).

Carrying heavy loads Lieutenant Colonel Charles Dean (2004) liked to quote the famous military operations analyst and historian, S.L.A. Marshall (1950) who said:

On the field of battle man is not only a thinking animal, he is a beast of burden. He is given great weights to carry. But unlike the mule, the jeep, or any other carrier, his chief function in war does not begin until the time he delivers that burden to the appointed ground. In fact we have always done better by a mule than by a man. We were careful not to load the mule with more than a third of his weight.

Dean (2004) indicates that soldiers, especially infantrymen, carry heavy physical loads of assorted equipment including their protective uniform and helmet, perhaps body armor, weapons, ammunition, drinking water and food rations, first aid kit, and other items depending upon their mode of preparedness for actual combat. The US Army field manual FM 21−18 spells out that in planning military operations, the “fighting load” carried by an infantryman, including a bayonet, weapon, clothing, helmet, and load bearing equipment (LBE) and a reduced amount of ammunition should be kept to under 48 lbs. The “approach march load,” which adds a small assault pack, or lightly loaded rucksack, or poncho roll should be limited to under 72 lbs. The “emergency approach march” load may be heavier than 72 lbs while traversing terrain impassable to vehicles or without ground/air transportation resources necessitates that large rucksacks be carried and in that instance, loads of up to 120 lbs can be carried for several days over distances of 20 km per day. The Army field manual states: “although loads of up to 150 pounds are feasible, the soldier could become fatigued or even injured.”

Dean (2004) reported Center for Army Lessons Learned studies of over 750 paratroopers revealed that loads carried by the modern Army infantryman depend upon the particular position the solider is assigned within the platoon, and upon which weapon system a soldier is carrying. Fighting loads ranged from just over 40 lbs to almost 80 lbs, with automatic riflemen, machine gunners, and radioman-communications chiefs carrying the heaviest loads. Approach loads ranged from about 75 lbs to over 125 lbs; and emergency approach loads from about 115 lbs to about 148 lbs each person.

The Army and Marines work diligently through application of technological innovations to design lighter loads, and to reconfigure loads that soldiers carry on the battlefield (Sampson et al., 1995; Knapik, Harman and Reynolds, 1996; Knapik et al., 1997; Sampson, 2001). However, most discerning soldiers realistically anticipate that when weight savings are made in design of a particular item, their leaders will only figure out some way to add the weight back onto them by simply requiring them to carry more of some items (e.g. ammunition, food, water, more sensors, or weapons accoutrements).
The press of time From the first days of initial entry training, military personnel are made acutely aware of the importance of timeliness in almost every aspect of military operations. Achieving quick reaction times to signals or targets which soldiers must detect is often a mark of one’s attained soldierly skills. “Synchronizing watches and timepieces” and meeting precise rendezvous schedules is often paramount to precision launch of numerous military activities ranging from surprising the enemy, to use of simultaneous firing of weapons at targets, or conducting precision control maneuvers as when flying high performance aircraft in formation, and so on. Close adherence to timelines becomes an important driver in military operations. Time pressures serve as a stimulator to action, and in some cases, as stressors to soldiers and other combatants who experience difficulty getting things ready, or accomplished on time, or who respond fast enough to changing situations. Sometimes not responding quickly enough, making the correct decision or wise choices in the heat of battle can be costly in terms of mission success, and can increase incidence of accidents, casualties, or failures to perform well. Driskell, Salas, and Johnston (2006) report the importance of timeliness and time stressors in several defining moments of military crisis and advocate intensified skills training for decision making under stressful conditions.

There are many facets to the importance of timeliness in military operations. For example, from laboratory research we know sleep-deprived, fatigued soldiers tend to make classical speed-accuracy tradeoffs in performance of tasks as they frequently assign a premium to preserving accuracy over timeliness, and thus they correctly respond to tasks but they accomplish less work over unit time (Krueger, 1991b). As for other time-based phenomenon, Hancock and Weaver (2005) report that under conditions of extreme and life-threatening stress, people often report distortions of time perception. Distortions of perception of time can constitute additional battlefield stressors, and ranges from recognition that the presence of danger might alter sensory search behavior, to the phenomenon that often shooters in a close proximity gunfight claim they experience movements as slow-motion time sequences (Grossman and Christensen, 2004), and importantly in our information-laden systems, a recognition that one’s emotional state influences time-based information processing capability (Hancock, Szalma and Oron-gilad, 2005).

Sleep deprivation and fatigue Military forces now have sophisticated night vision technology and other battlefield sensors to give them the capability to fight through the night. These innovations brought about the tactical doctrine of continuous operations: fighting around-the-clock for successive days, even weeks at a time (Belenky et al., 1987). Combatants, especially “night fighters” who work during darkness and rest during the day, get only brief, scattered, fragmented sleep and often accumulate significant sleep debt. Sustained workload combines with fatigue, especially after one or more nights of complete sleep loss or longer periods of reduced or fragmented sleep, to degrade performance, productivity, safety, and mission effectiveness. Sleep loss interacts with workload, resulting in prolonged reaction time, decreased vigilance, perceptual and cognitive distortions, and changes in affect, all of which vary according to circadian rhythm time-of-day effects (Krueger, 1991b). The combination of sustained performance and sleep deprivation have implications for theoretical models of sustained perceptual and cognitive functioning (Hancock and Desmond, 2001).

For those who engage in round-the-clock combat for extensive periods, many of these environmental stressors listed above synergistically interact with sustained performance, sleep loss, and soldier fatigue, and thereby increase combat losses and psychiatric stress casualties. Wesensten, Belenky and Balkin (2005) portray how ubiquitous sleep restriction on the modern battlefield has combined with high technology weapon systems to produce several tragic friendly fire incidents. Careful assignment of personnel work/rest cycles, adherence to sleep discipline policies, especially for command and control personnel, and attention to preventive medicine and many other human
stress management details are all important for making that “weak link” the effective “productive link” on the battlefield (Krueger, 1991a and 1991b).

**Chemical, biological, or radiological (CBR) threats** Just knowing about the potential for use of CBR weapons in warfare can be very stressful to combatants (Oordt, 2006). Such concerns subject people to unfamiliar threats in highly ambiguous situations, in which people feel they may be wronged or that they are helpless. Maladaptive psychological overreactions or under-reactions may result (Stokes and Banderet, 1997). In the past quarter-century, military forces have concentrated on developing various protective measures against chemical and biological weaponry. These have included developments in protective uniforms and clothing designed to keep threatening chemicals off of the wearer; but the protective clothing itself also produces profound performance effects (Krueger and Banderet, 1997; Krueger, 2001). Administering preventive measures such as chemical prophylaxis can protect against bad acting chemical threats, either by themselves, or by helping to prepare the body to exhibit milder responses to chemical-biological challenges (Romano and King, 2002). Since the prophylactics affect the central nervous system (CNS) they also have effects on task performance (see special issue of Military Psychology journal by Romano and King, 2002). For performance effects of radiological factors see also Mickley and Bogo (1991).

**Disease threats** Minimal national attention was paid to potential biological weapon threats prior to the anthrax scares (October–November, 2001) midst the aftermath of the terrorist attacks in America on September 11th, 2001. The heightened awareness has caused the U.S. Department of Defense to redouble biological research efforts to protect our troops against not only biological threats that can be weaponized, but also against those disease threats indigenous to the harsh geographical environments of developing nations to which US troops are often sent. Most US soldiers and marines deploying to hygiene-free, disease-ridden, third world developing nations know full well the biological threats they face just by living in the field for months at a time. The fact that soldiers are concerned about those disease threats, and they worry about them, is another subtle form of stress facing troops overseas. Leaders must not only inform and warn their troops with credible information on disease threats, but also to impress upon them the importance of reliably and continuously adhering to proven preventive medicine countermeasures. Preventive medicine guidance must be delivered to the troops in a way that insists upon compliance, but also in a way that does not viscerally “scare the hell out of the troops” to the point that the realistic concerns over disease threats weigh too heavily on them and consequently affect their performance. Such a set of “user-friendly” preventive medicine guidance was produced for US troops deploying in 1991–92 to Somalia where infrastructure and national hygiene were completely lacking, and numerous disease threats greeted outsiders (see Modrow et al., 1992). Similar preventive medicine guidance was and still is developed by US military medical researchers and provided to troops deploying to other disease laden territories.

**Unique stressors for women soldiers** Most of the over 1600 US women who served in uniform in Vietnam were nurses – eight of whom died in that war. The US armed forces deployed over 40,000 military women to the Persian Gulf in the 1990–1991 conflict (Kennedy, 2001). In the subsequent decade and a half, additional tens of thousands of US women soldiers have been deployed to work and fight in combat, lesser skirmishes, peace-keeping missions and the like (Solaro, 2006; Wise and Baron, 2006). Much has been learned about the unique stressors experienced by military women. Of course, women soldiers are exposed to the same environmental, climatic, physical, and physiological stressors listed above as are the men. For the most part, with some exceptions attributable to subtle physiological differences between women’s and men’s bodies, the
above listed stressors affect women in ways similar to the way they affect men. There are some differences in bodily response pertaining to heat stress, vibration effects, etc., and there are some unique circumstances that affect women slightly differently – many of those are still under study. Freidl (2005) summarized a decade of physiological research on military women’s health and performance issues (see also Vogel and Gauger, 1993).

Studies of the psychology of women in uniform brings about immediate recognition of their individual experiences and a wide-range of considerations and potential stressors unique to their gender. These include: 1) struggles to succeed in jobs traditionally held by men; 2) real or imagined issues with physical strength and endurance normally attributed to men vs. women; 3) isolation due to gender or perceptions of it; 4) particular considerations of fraternization with or sexual relations with other military members; 5) real or perceived mistreatments by men, superior-subordinate relationships, bias in assignment selection, or promotion to higher rank, glass ceiling plateaus; 6) gender or sexual harassment; 7) in the field or during deployment women have considerations of female hygiene, gynecological care, and risks of diseases, pregnancy; 8) being singled out to handle issues concerning local national women, such as being required to search or attend to women detainees; 9) being shunned by local nationals because of religious or cultural customs; 10) potential capture and mistreatment as a prisoner of war; 11) spending lengthy periods of time away from one’s children during training or deployment. There are numerous other considerations that may or may not impose additional or at least different stressors (good or bad) affecting the performance of women soldiers.

For a brief summary of the psychology of women in the military, see Hoiberg (1991); for experiences as a POW in combat, see Cornum (1992); and achieving success and high rank in a 30-year military career, see Kennedy (2001); for recent experiences and issues concerning US military women in combat, see Wise and Baron (2006) and Solaro (2006); for additional research on military women, see Yoder and Naidoo (2006).

**Physiology and Psychology of Killing**

*Physiological responses in killing the enemy* Not commonly talked about in military psychology circles, is the set of physiological and psychological factors that often accompany the physical act of killing one’s enemy. David Grossman (a retired Lieutenant Colonel, US Army) published two books on the topic (*On Killing* 1995, and *On Combat* 2004). Grossman says his books offer Warrior Science™ and that by reading his books, and in attending the series of “Bulletproof Mind” lectures he presents to military and police audiences, he opens our eyes to a set of physiological and psychological variables not often studied in the arena of combat stress.

Grossman says that even though men have been at war for millennia, only today have people been willing to talk in depth about the reality of killing in combat. He says: “Knowing the truth about combat is of value to warriors, to citizens who rely upon warriors, and to those in power who send warriors into battle. Combat is not antiseptic or dry, it is just the opposite: a septic, toxic realm, wet with tears and blood.” Now we learn about auditory exclusion in that for most people in close combat, “the shots get quiet;” but for some, gunshot sounds are intensified in the dark. We learn too of slow motion time as warriors often experience gunfire action in slow motion (Grossman and Christensen, 2004; Hancock and Weaver, 2005); tunnel vision (peripheral vision narrows), loss of both near vision and depth perception, firing on autopilot, loss of bowel and bladder control, and posttraumatic response to killing another human being (Grossman and Christensen, 2004).

In the foreword to Grossman’s work, Gavin de Becker described *On Combat* as telling us how the body responds to lethal combat, what happens to one’s blood flow, muscles, judgment, memory, vision, and hearing when someone is trying to kill you. The reader learns what it is really
like to kill another human being, what you would feel right after you shoot someone, and what you would feel an hour later, a day later, a year later. Gavin de Becker portrays how courage is usually the star in war stories; but fear too does great things in combat. Fear readies the body for action by increasing blood flow in the arms and legs. Lactic acid is heated in the muscles, and our breathing and heartbeat become more determined. Most people know about adrenaline, but fear provides cortosol to increase our chances of survival, in that it helps the blood clot more quickly, just in case we get cut. The body can also react to combat in ways that are not at all helpful. Warriors might experience impairments to vision, judgment, and hearing, or they might experience reduced motor skills – and they likely will experience all this during violence – unless the mind and body are integrated. Where On Combat makes its contribution, de Becker says, is by teaching warriors what to expect. For an extensive treatise on the psychology and physiology of survival stress management and training, see Siddle (1995).

Grossman and Christensen’s (2004) extensive descriptions of the physiology of combat can be very educational for combat psychologists. Reading of the body’s parasympathetic backlash after a battle, in which combatants frequently fall fast asleep, reminds this author (Krueger) vividly of my own field research work. On a desert training grounds I attempted to interview combatants about their sustained performance experiences, but alas, immediately after the simulated battles were concluded, just as Grossman and Christen describe, I found the soldiers I intended to interview mostly asleep on their equipment and in their vehicles.

Psychological effect of killing the enemy Grossman says a human phobia is an irrational, overwhelming, uncontrollable fear of a specific object or event. He declares the number one universal human phobia to be interpersonal human aggression. Unlike threats from a tornado or other acts of nature, threats to our life made by another human being become very personal. When someone tries to kill us, it is simply not right; and if we are not careful, the phobic fear can destroy us. For Grossman, unchecked, extreme stress is an emotional and physical carnivore, as it chews hungrily on so many law enforcement officers and it does so quietly, silently in every corner of their lives. It affects job performance, relationships, and ultimately degrades health. Grossman says that as the firefighter must understand fire, so too the warrior must understand combat. Surely Grossman’s works have much to teach behavioral scientists about combat stress.

Campise, Geller and Campise (2006) seize upon the personal psychological experience of killing the enemy as being a key ingredient for some soldiers in development of combat stress. They repeat Grossman’s description presented in his book On Killing (Grossman, 1995: 231−240) of the five basic phases often seen in response to killing in combat. Grossman says these stages, like those of Elisabeth Kubler-Ross’s famous stages in response to death and dying, are generally sequential, but not necessarily universal. Some individuals may skip certain stages, or blend them, or pass through them so fleetingly that they do not even acknowledge their presence.

The first phase according to Grossman is the concern about being able to kill; wherein one asks oneself “how am I going to do?” Integral to this phase is the fear of letting fellow unit members down, or freezing when required to fire. The second phase is the actual killing experience, which is often done reflexively and without conscious thought: “without even thinking.” This reflexive action can be followed by a third phase, a sense of exhilaration, in which the combatant feels an intense satisfaction from putting months or years of training into successful action. This exhilaration, fueled by the release of large amounts of adrenaline, can create a high or rush, which in some cases can give rise to combat addiction. The fourth phase, remorse and nausea, follows exhilaration and is often associated with a kill at close-range: “a collage of pain and horror.” A sense of identification and empathy for the victim gives rise to intense sorrow, pain, and revulsion. The fifth and last phase, rationalization and acceptance, is often a lifelong process: “It took all
the rationalization I could muster.” Traversing this fifth phase is essential to the emotional and psychological health of the combatant, a phase strongly linked to the support and understanding of those on the home front, communicating that killing in combat was just and necessary. Grossman (1995) explains several studies have determined these phases are slightly different, and often involve less repentance or regret if the killing is done from a distance, such as by firing artillery or by dropping explosives from aircraft.

Psychological Stressors, Threats and Effects

**Intense combat vs. peacekeeping work**  It is tempting to stereotype the ultimate “stimuli” of military stressors closely to Grossman’s description of the psychological and physiological attributes of actual intense killing fields – those stressors associated with intense personal kill-or-be-killed combat action. Putting it all together with the descriptions above of soldier stressors associated with sustained artillery shelling, or the numerous harsh environmental stressors encountered on battlefields, one can easily envision a stereotypical scenario as being similar to the intense combat action depicted in Steven Spielberg’s opening scene of the June 1944 D-day assault on Normandy Beach, France in his movie *Saving Private Ryan* (circa 2000). We envision many combat actions are much like that.

However, large-scale sustained intense combat action on a conventional battlefield of the the Second World War type has actually been a relatively infrequent event. Since WWII, only twice did US military forces engage in similarly intense and sizeable-scale wars with sustained years-long combat action: in Korea (1950–53) and in Vietnam (1965–73). A growing number of other military engagements – more time-limited ones – have dotted our recent history (e.g. Panama (1989), Persian Gulf War (1991), Somalia (1993), Haiti (1994); Afghanistan (2001–02) and Iraq (2003). In these occasional low-intensity “skirmish actions” or even in mid-intensity wars, the actual ground combat phases were relatively short (days or weeks of intense combat) and by comparison to WWII, theoretically at least, these conflicts should have produced less “shell shock-battle fatigue.”

If duration of deployment is important to soldier stress production then we consider that US military forces have engaged in numerous additional overseas deployments of large numbers of troops on peace-keeping and nation-building missions for years, even decades, at a stretch. Overseas deployments of individuals generally ranged from a minimum of 3 months to as long as 2–3 years if soldiers of needed specialties were in critical need or the individual voluntarily extended his or her deployment period. Some of these lengthy deployments have been to such varied geographic locations as Germany, Korea, Okinawa, the Philippines, the Sinai, Bosnia, Kuwait, Iraq, Afghanistan, and others. For the most part, troops on such deployments have not witnessed much sustained intense combat of the WWII type. In many instances, the harsh environmental stressors still are there; occasional combat activities continue, but at a much reduced pace (i.e. since 2001 continuing in Afghanistan and since 2003 in Iraq). In February 2007, Robert Gates, the US Defense Secretary, indicated that improvised explosive devices (IEDs) caused 70 per cent of the US deaths and serious wounds in Iraq; and explosive devices killed over 1300 USA troops and wounded almost 12,000 in Iraq by the end of January 2007. No doubt these rising casualty numbers raise many anxieties and promote a certain amount of stress to US military forces in that theater of action.

It is these shorter action overseas troop deployments which Bartone (1998, 2006) says we should give particular focus to in examination of the dimensions of psychological stress during military operations. Soldier stressors involving the psychological well-being of the troops range from concerns about the care and security of one’s family (dependents) left behind during deployment,
to boredom, to lack of meaningful work, to ambiguity of the mission, to feelings of isolation, and of fears of sniper threats, and so forth.

Military psychologists at the Walter Reed Army Institute of Research conducted a series of survey studies to identify conditions or events – stimuli in the operational environment that can generate anxiety, tension, stress, or distress for soldiers, and which lead to impaired functioning and ultimately to health problems. Studying US forces deploying overseas during the 1990s, Bartone reported much of this work involved examinations of soldier stresses in various time-dimension mission phases. The stresses that concern soldiers change over time due to periodic changes in situational circumstances accompanying each mission. For various peacekeeping and nation-building missions these phases include pre-deployment, early deployment, mid-deployment, and return of forces or re-deployment phases. Bartone, Adler and Vaitkus (1998) summarized the more general categories of stresses observed as depicted in Table 2.1 (Bartone, 2006).

Whether troops are exposed to stresses of intense combat, or to those stressors associated with a less life-threatening peacekeeping mission, individual “responses” to “stimuli” (stressors) vary widely among soldiers: “stress is often in the mind of the stressed.” There is therefore a degree of importance to be given to both social (situational) and person (personality) variables in influencing how soldiers respond to combat stress. Bartone (2006, 1998) pursues notions of “stress hardiness” and “resilience” as an individual personality-based cognitive style that influences how a soldier processes stressful circumstances, interprets them, and makes sense of them in the context of one’s entire life experience. Persons high in hardiness have a strong sense of commitment to life, believe they can control events around them, and are interested and challenged by new things and obstacles (Kobasa, 1979; Maddi and Kobasa, 1984). For Bartone, the hardiness construct offers a useful framework for re-structuring work situations likely to increase stress-resiliency, which operates as a moderator or buffer of stress and can thereby reduce the negative effects of catastrophic stress, even combat stress, when it occurs. Personality hardiness Bartone says can protect against the ill effects of stress on health and performance (Kobasa, 1979); and it is under high-stress conditions that the resiliency effects of hardiness are most apparent (Bartone, 2006).

Subsequently, the military can strive to develop resilient soldiers and leaders, and “hardy units” wherein individual team members obtain a strong commitment to the work of the unit (our mission), a sense of control over their own destiny, and enjoy challenges (Bartone, 1998; Bartone, 1998; Bartone, 2006). These notions are quite compatible with those of the very important influences provided by unit cohesiveness (as espoused by Jones, 1986; Marlowe, 1986; Manning and Ingraham, 1987; Ursano, 2004, Siebold, 2006; and others) as a critical factor that moderates or buffers the impact of combat stress on military performance (Noy, 1991) (for a related treatise on soldier courage, see Castro, 2006).

Post Traumatic Stress Disorder (PTSD)  This chapter would not be complete without addressing some aspects of the phenomenon referred to as Post Traumatic Stress Disorder. During the US military involvement in the Vietnam War (1965−73) a large number of combat-stress-related psychological symptoms lingered for many Vietnam War veterans even months or years after soldiers returned to the USA. These lingering symptoms netted the terms post traumatic stress syndrome, but later took on the name post traumatic stress disorder when PTSD became an accepted medical diagnosis in 1980. The U.S. Department of Defense uses the term combat stress reactions (CSRs) to describe a set of symptoms as the “expected, predictable, emotional, intellectual, physical, and/or behavioral reactions of service members who have been exposed to stressful events in combat or military operations other than war” (for discussion of these terms, and reports of incidence of PTSD and CSRs in various conflicts since WWII, see Noy, 1991; and Campise, Geller and Campise, 2006). In early reporting on the incidence of psychological difficulties in the Iraq conflict, Hoge et al. (2004)
reported up to 17 per cent of US veterans who deployed to the Iraq conflict reported symptoms of
major depression, anxiety, or PTSD.

Campise, Geller and Campise (2006) suggest symptoms of combat stress can be roughly
grouped into six categories: physical, cognitive, behavioral, emotional, misconduct, and adaptive.
Recognizing combat stress is a function of the duration, frequency, and intensity of the symptoms,
one must closely examine an individual’s behavior. The presence of any of a lengthy list of symptoms
may be indicative of combat stress; whereas some of the symptoms might also be manifestations
of something else, such as physical injury, misconduct, or the reemergence of a previous mental
health disorder.

Table 2.1 Primary stressor dimensions in modern military operations

<table>
<thead>
<tr>
<th>Stressor</th>
<th>Characteristics</th>
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<tbody>
<tr>
<td>Isolation</td>
<td>Remote location</td>
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<td></td>
<td>Foreign culture and language</td>
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<td></td>
<td>Distant from family and friends</td>
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<td></td>
<td>Unreliable communication tools</td>
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<td></td>
<td>Newly-configured units; do not know co-workers; low cohesion</td>
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<tr>
<td>Ambiguity</td>
<td>Unclear mission or changing mission</td>
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<td></td>
<td>Unclear rules of engagement</td>
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<td></td>
<td>Unclear command or leadership structure</td>
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<tr>
<td></td>
<td>Role confusion (what is my job?)</td>
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<td></td>
<td>Unclear norms or standards of behavior (what is acceptable here and what is not?)</td>
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<tr>
<td>Powerlessness</td>
<td>Movement restrictions</td>
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<tr>
<td></td>
<td>Rules of engagement constraints on response options</td>
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<td></td>
<td>Policies prevent intervening, providing help</td>
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<td></td>
<td>Forced separation from local culture, people, events, and places</td>
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<td></td>
<td>Unresponsive supply chain – trouble getting needed supplies and repair parts</td>
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<td></td>
<td>Differing standards of pay, movement, behavior, etc. for different units in the area</td>
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<td></td>
<td>Intermediate deployment length – do not know when we are going home</td>
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<td></td>
<td>do not know or cannot influence what is happening with family back home</td>
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<td>Boredom (alienation)</td>
<td>Long periods of repetitive work activities without variety</td>
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<td></td>
<td>Lack of work that can be construed as meaningful or important</td>
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<td></td>
<td>Overall mission or purpose not understood as worthwhile or important</td>
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<td></td>
<td>Few options for play and entertainment</td>
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<tr>
<td>Danger (threat)</td>
<td>Real risk of serious injury or death, from:</td>
</tr>
<tr>
<td></td>
<td>Enemy fire, bullets, mortars, mines, explosive devices, etc.</td>
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<tr>
<td></td>
<td>Accidents, including “friendly fire”</td>
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<td></td>
<td>Disease, infection, toxins in the environment</td>
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<td></td>
<td>Chemical, biological, or nuclear materials used as weapons</td>
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<tr>
<td>Workload</td>
<td>High frequency, duration, and pace of deployments</td>
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<td></td>
<td>Long work hours and/or days during the deployments</td>
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<tr>
<td></td>
<td>Long work hours and/or days in periods before and after deployments</td>
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Source: Bartone (2006); permission to cite the table was granted February 19, 2007 by Colonel Paul T.
Bartone, at the Industrial College of the Army Forces at the National Defense University.
Physical symptoms of PTSD  The US Department of the Army (2000) identifies service members experiencing combat stress as ones exhibiting some or many of the following physical symptoms:

- respiratory (shortness of breath, dizziness, sensation of something heavy sitting on one’s chest)
- cardiovascular (pounding heart, accelerated pulse, rising blood pressure)
- digestive (nausea, cramping, vomiting constipation, diarrhea, loss of appetite)
- elimination system (increased frequency of bowel and urinary activity, wetting or soiling oneself)
- musculoskeletal (trembling, shaking)
- disturbances (insomnia, nightmares) and
- headaches, backaches, vertigo, exhaustion, constant agitated movement, or blurred vision.

Cognitive symptoms cover the range from mild to severely disrupting. The person may report or exhibit hyper-alertness; an exaggerated or delayed startle reaction to sounds, movement, or light; inattention; short attention span; concentration problems; difficulty in reasoning or problem solving; faulty judgment; loss of confidence, hope or faith; perception of oneself as a failure; memory loss; recurrent intrusive thoughts; flashbacks; delusions; or hallucinations (visual, auditory, tactile, olfactory or taste).

Behavioral symptoms may be the most readily apparent symptoms of combat stress. The person may exhibit carelessness (results in danger to oneself and others), impulsivity, freezing, panic, withdrawal from friends, an inability to relax, a low-energy level, immobility, erratic behavior, impaired duty performance, a loss of skills, a failure to maintain equipment, rapid speech, deterioration in personal care (i.e. hygiene), loss of or impairment in senses, stuttering, self-medication, or the infamous 1,000-yard stare.

The symptoms listed above can appear in varying amounts and at different times for individuals experiencing some aspects of PTSD or CSRs. It is known that these disorders are not a constant or static condition, but may wax and wane throughout a lifetime. This is mentioned here because sometimes it is difficult to determine: a) if individual military service members, at work on the job, have low grade PTSD symptoms, or b) whether or not remnants of the disorder remain from previous combat or deployment experiences, or c) they are experiencing some transient mood and motivational problems of the moment. Each of the several sets of “stressful circumstances” can impact job performance and health.

Campise, Geller and Campise (2006) suggest that emotional factors are contributory and there are several important questions to explore regarding who becomes a psychiatric stress casualty or a PTSD affected veteran. What was the person’s pre-combat mental fitness? Anxiety can be motivating if experienced in small to moderate amounts but incapacitating if too intense. Fear in battle seems to follow a bell-shaped curve, with an initial high level of fear of death, of letting others down, and of how one will respond under fire (Shaw, 1987). Fear tends to lessen with combat exposure and then gain in a cumulative fashion with increased combat exposure as resources are depleted (Swank and Marchand, 1946). The witnessing of the deaths and wounding of team members complicate one’s emotions. Unit losses represent more than numbers. Each member lost to injury or death is someone’s friend or role model. Disillusionment may set in when those viewed as indestructible or especially competent are lost, producing the realization that even soldiers with the greatest fighting skills can die. Survivor guilt can also arise and decrease one’s ability to function. Accidental killings can have a detrimental effect, especially if they are the deaths of civilians and children. During combat, allies are accidentally killed by friendly fire;
weapons accidentally discharge, killing or wounding unit members; machinery malfunctions cause death; and vehicle accidents take lives (Campise, Geller and Campise, 2006).

Military unit commanders, and their supporting staffs, must be trained to spot early symptoms of stress reactions (whether from combat or other military operational stress inducing circumstances). Troops should immediately see corrective actions taken, or receive appropriate treatment before the “stress disorder” becomes either disruptive to the unit’s mission or it becomes a longer term health problem for individuals concerned. The evolution of traditional care (Noy, 1991) for battlefield psychiatric stress casualties (stress affected soldiers) has settled upon three successful treatment principles, to: 1) identify and care for them immediately, 2) to do it in proximity or close to their units, and 3) to give them the expectation of a return to duty with their unit (Marlowe, 1986; Campise, Geller and Campise, 2006).

The exigencies of combat would seem to make the incidence of extreme psychological stressors likely in foreseeable battles in future combat scenarios. The incidence of soldier stress reactions in MOOTW would seem to be controllable if preventive measures and countermeasures are identified and implemented. Although PTSD remains difficult to diagnose (especially when soldiers are reluctant to admit they’re suffering from it) the US military services are much better prepared now to recognize the early signs. Generally, from a variety of sources, at least three principal PTSD prevention actions are considered:

1) Select the right people to send to war. Since WW I, the business of psychological screening and selection of military personnel for various jobs and tasks has been a fascinating and contentious issue for military psychologists. No doubt it will continue to be so. Can we, or should we select and train only stress hardy individuals with resilience personalities to staff our military units? [For selection, see Banks, 2006; Bartone, 2006; Picano, Williams and Roland, 2006; for a review of research on individual differences see Szalma and Hancock, 2005; and Szalma, 2007.]

2) Provide troops with very realistic training to produce a measure of “stress inoculation.” Troops deal with the stress of combat more successfully if they are trained to handle it. New preparation methods expose troops to “stress training” scenarios incorporating the kinds of traumas they likely will face in war (see Driskell and Salas, 1991; Doran, Hoyt and Morgan, 2006; Salas et al., 2006; Driskell et al., 2007). Bartone (2006) suggests not only can we select personnel based upon their levels of resilience traits but that perhaps we can train resilient leaders to influence their own hardiness and that of the troops they lead. Thompson and McCreary (2006) advocate developing adaptive coping and mental readiness training within the continuum of therapeutic techniques.

3) Minimize traumatic exposures as much as possible. Preparation of the troops by assigning competent, trust-worthy leadership, developing unit cohesiveness, and generally ensuring that troops are not put into harm’s way unnecessarily, all will go a long way toward lessening the impact of unexpected traumatic experiences when they do occur. Secondary prevention involves the action taken soon after exposure to traumatic stress to minimize its impact. This includes “psychological first aid” – getting people out of danger as soon as possible; connecting them with their social support systems; making sure their physiologic needs are met for food, water and rest; and assuring that people know where to get additional help if needed.

Once soldiers are actually exposed to combat, morale is a critical factor – regular contact with home, periodic rest and recuperation (R&R), decent food and living conditions, and confidence in their immediate superiors all impact soldiers’ abilities to deal with overseas deployments and war.
Readers who are interested in exploring a wider and diverse coverage of numerous psychological and sociological stress factors that affect not only military forces in the field, but how their families are affected as well, might consult a recently published set of four volumes called Military Life: The psychology of serving in peace and combat (Britt, Adler and Castro, 2006; Britt, Adler and Castro, 2006; Castro, 2006; and Britt, Castro and Adler, 2006).

Newer Enemy Threats, Technologies, and Effects

_Same old threats?_ Where does one start and end a section so labeled? Will our military forces again face nation-state sponsored linear conventional battlefields repeating the sustained and incredible stresses such as the massive deaths, injuries, and destruction encountered for several years at a stretch on European battlefields of the Second World War? Perhaps, but after the demise of the Soviet-Union and the dissolution of the Soviet–US cold war era (1945–1990) such scenarios do not appear so likely to us right now. What our forces experience now is occasional involvement in limited wars, ever-changing forms of asymmetric warfare (including the present conflicts in Afghanistan and Iraq) and of course the notion of a Global War on Terrorism (GWOT). Guerrilla tactics so prevalent in Vietnam, now manifesting in the middle-East, produce new stresses, and new fears of the numerous ways one can be injured or killed in combat; or for that matter, even be killed during so-called peacekeeping and nation-building efforts.

As in most combat environments, health issues are still at a premium. Threats of harsh natural environmental stresses are once again in the forefront of daily safety briefings to our troops, who often work at altitudes above 10,000 feet in the mountains of Afghanistan. Troops work in Iraq while wearing heavy equipment and body armor in ambient temperatures exceeding 120 °F. Exposure to toxic substances abound, including to industrial chemicals left behind in the broken urban areas and neighborhoods which have become the new battlefield. Preventive medicine guidance is at a premium in foreign lands where not only have our deployed troops suffered hundreds of casualties from such exotic diseases as Leishmaniasis (a skin disease), but are once again threatened with potential exposures to smallpox, anthrax, and malaria. Even the vaccines and prophylactic medications proffered by the military medical community produce stressful concerns over efficacy and potential lasting side-effects.

_New enemy threats_ Street-to-street and house to house fighting has become the new norm. Exposures to such tactics as use of IEDs and sophisticated roadside armor piercing explosives known as explosively formed penetrators (EFP) prompt concerns about an innovative and clever adversary who adapts both low and high technologies to keep all soldiers, combatants and support personnel constantly, anxiously on-edge. Threats of kidnappings, beheadings, and other bodily mutilations by one’s unseen adversaries heighten soldier awareness to personal safety issues; and these foretell new visceral reactions to add to the accumulation of stressors that affect a soldier’s cognitive readiness to fight.

_New technologies_ But how does one predict future stressors for our combatants? Newer weapons, both those we develop and adopt, as well as those employed by our potential adversaries, always produce new anxiety concerns. How do young military recruits react to press releases (February 2007) announcing the advent of new “ray gun technology” configured as the military’s new weapon that shoots an electronic beam to make people feel as if they will catch fire? The technology selectively bombards an individual with radiated energy waves to penetrate just 1/64 of an inch into one’s body, thereby heating the skin like microwaves, and creates an illusion of being on fire. We are told the technology, being referred to as the “pain beam,” is harmless as it provides
a non-lethal way to get enemies to drop their weapons. Do we believe that at some point such technology won’t be cranked up in energy levels and used for other more lethal applications? Is this technology’s modern replacement for the WWII flame thrower that put incredible fear into those who were about to suffer severe burns while being flushed out of foxholes?

Hone and Friedman (2002) outline nine important steps for a military force in transformation intent on harnessing new technologies. Developing a military doctrine for planned use is at the crux of their assessment. They and others foretell of other directed energy weapons which when netted together via electronic digital communications and advanced global positioning systems will certainly make quick and direct destructive strikes anywhere – anytime, even more prevalent.

Technology to aid soldier performance under stress  Traditional military research psychologists are always concerned about soldier performance, especially cognitive performance under stressful working conditions. In the past decade, it has been fashionable to imagine large numbers of soldiers fully interconnected on the battlefield through means of network-centric communications, electronics, and computer systems. Today, and tomorrow, solving real-world battlefield problems and making quick decisions in compressed time dimensions, puts incredible pressure, and stresses upon modern military leaders and command and control personnel at all levels, now even down to the level of the infantry squad leader wearing a Land Warrior-like computerized infantry system. These new technologies, issued in quantities to the troops, make more apparent the idea that team-cognition, and shared mental models are not only required at higher echelon command and control level, but that they are very much a part of the day-to-day operations of infantry teams even at the level of the ten-man squad (Krueger and Banderet, 2007). Wesensten, Belenky and Balkin (2005) portray advances in warfighter physiological sensor monitoring systems, tied into Land Warrior-like technologies – that one day soon will permit a soldier or his squad leader to monitor levels of cognitive readiness even in face of stressors, including severe sleep restriction during sustained military operations.

In explaining cognitive demands of networked warfare, Gompert, Lachow and Perkins (2006) paraphrase the writings of the economist Herbert Simon in describing the gulf between limited human minds and complex problem solving as in part being due to the inadequate ability of humans to form mental models to help them discern the intricacies of reality. They say that in particular our mental models of the causes and effects of complex and dynamic systems, such as warfare, are grossly simplified compared with the systems themselves. Since humans find it difficult to form sufficiently complex mental models themselves, they become trapped in a state of “bounded rationality” with shortcomings in attention, memory, recall, and information processing that limit the ability to comprehend and thus to make sound rational judgments. Gompert, Lachow and Perkins (2006) raise the question of whether or not applied information technology (IT) can compensate for deficiencies in human mental models and thus improve people’s ability to solve complex problems rationally.

Computers and networking – especially data networking, which both distributes and integrates computing power – have begun to free problem-solving humans from their limited attention, memory, recall, and processing capacity. For the military, a whole community of behavioral scientists has taken on these socio-behavioral-technological challenges (McBride and Schmorrow, 2005) – researchers who are diligently working on cutting-edge topics of augmented cognition (Muth et al., 2006; Schmorrow, Stanney and Reeves, 2006; Schmorrow and Reeves, 2007), and those who report results of their work in this present volume dedicated primarily to examinations of soldier performance under a variety of stressors (Hancock and Szalma, 2007). Augmented cognition focuses on using modern neuroscientific tools to determine the “in real time” cognitive state of an individual and then attempts to adapt the human-system interaction to meet a user’s
information processing needs based on this real-time assessment. Information networking should permit humans to formulate and solve complex problems as never before. However, as Krueger and Banderet (2007) portend, it is arguable whether the work of military behavioral scientists in examining such concepts as team cognition in network centric warfare is keeping up with either the technological advances, or the rapid changes in modern military operations and the new challenges being faced by front line soldiers and marines.

Strategic corporals abound: but do we have enough “military moxie”? In 1999, General Charles Krulak, the outgoing Commandant of the US Marine Corps, described “Operation Absolute Agility,” a fictitious humanitarian, peacekeeping mission requiring quick and effective decision-making by junior military personnel in very stressful sets of circumstances. General Krulak portrays a challenging three-city block street scenario facing young marines with a brewing problem that places enormous responsibilities and pressures on our youngest marine leaders. Krulak’s story requires a young strategic corporal to remain calm and cool, and to act with poise, to make precisely the right decisions or risk escalating the scene into one with international and strategic consequences.

Krulak says young marines are repeatedly being asked to deal with a bewildering array of challenges and threats, and success or failure will rest, increasingly, with the rifleman and with his ability to make the right decision at the right time at the point of contact. To succeed under such demanding conditions they will require unwavering maturity, judgment, and strength of character. Such tough missions will require young soldiers to confidently make well-reasoned and independent decisions under extreme stress – decisions that will likely be subject to harsh scrutiny of not only their leaders, but by both the media and the court of public opinion. Krulak says every marine is a fundamental institutional competency, for as often as not, the really tough issues confronting marines will be moral quandaries, and marines must have the wherewithal to handle them appropriately. In many cases, the individual marine will be the most conspicuous symbol of American foreign policy and will potentially influence not only the immediate tactical situation, but the operational and strategic levels as well.

Such pressures for so many junior military personnel to “do the right thing, to intuitively make the right decisions” undoubtedly brings with it a fair amount of stress for many of our front line uniformed soldiers and marines. More frequently then ever before, in modern military operations we require each individual to have a high level of technical competency, flexibility, adaptability, strong character, stress hardness, resolve, courage, conviction, as they seemingly are frequently called upon to exhibit just the right amount of “the right stuff” – an ability to do the right thing most of the time – traits that I like to refer to as having military moxie. The question is do we have enough military moxie to meet the challenges of today’s and tomorrows battlegrounds?

In his treatise of “Clausewitz and World War IV,” Major General Robert Scales, the former commandant of the U.S. Army War College, suggests the U.S. military is already engaged in World War IV, which he refers to as the Social Scientists’ War (Scales, 2006). His notion is that if we are to help develop more strategic corporals, then social scientists must help the military develop small teams of soldier-warriors who understand cultural context and who are skilled in governance, statesmanship, and diplomacy, so they can thrive in an alien environment to capture the psychocultural rather than the geographical high ground (Scales, 2006). The U.S. Army would call those warriors: “pentathletes” (Schoomaker, 2006).

We might also ask what new requirements of social / research psychologists are expected to come from the newest publication on counterinsurgency doctrine, or fighting “small wars,” – the latest military doctrine espoused in the December 2006 Counterinsurgency Manual (US Army Combined Arms Center and U.S. Marines Corps Combat Development Command, 2006).
What can psychologists say about measurement and prediction of performance for the current US combatants engaged in asymmetric operations in the Global War on Terrorism, but who have been trained as warriors, and then are expected to fight a not-so-well understood enemy, and then often quickly follow that by daily interactions with indigenous peoples in nation-building and homeland security missions?

*Happy reading* Let this volume of research findings, edited by Hancock and Szalma, serve as a sort of benchmark of the present state-of-the-art of integrating what we presently know from science, not only about the marriage of soldier brain power and computers, but about the stresses, both good and bad that affect soldier performance. Let the volume further serve to stimulate and spur on additional cognitive science research to assist our deserving military forces – who deserve our best “shot.”

**References**


Ursano, R.J., ed. (2004), *War Psychiatry Today: From the Battle Front to the Home Front* (Bethesda, MD: Uniformed Services University, Center for the Study of Traumatic Stress, Department of Psychiatry).


Overview of the Chapter

The deleterious impact on human performance of sustained workload, stress, and fatigue is well known. Context-specific computer assistance, or adaptive automation, provides a potential method for mitigating these effects in complex work environments, particularly since automation is already an aspect of many complex human-machine systems. In adaptive systems, those functions that can be performed either by the human operator or by automated subsystems are dynamically allocated during system operations, depending on context and operator needs. Adaptation can be based on the properties of the task, the environment, the operator’s performance, or their physiological state, and can be initiated by the system (adaptive automation) or the operator (adaptable automation). The goal is to regulate workload, stress, and fatigue in order to reduce their adverse effects and hence to optimize system performance. In this chapter we review the performance-enhancing effects of adaptive automation, focusing on balancing operator workload, reducing complacency, enhancing situation awareness, and improving safety. We also describe studies examining the effects of adaptive automation to minimize the effects of stress and fatigue. We conclude that adaptive automation is efficacious in a number of domains, but that additional work needs to be conducted to determine whether adaptation should remain in the hands of the operator or the system.

Introduction

The deleterious effects of sustained workload, stress, and fatigue on human performance in complex systems are well known (Hancock and Desmond, 2001). These effects can be extensive enough that system efficiency and safety can be seriously compromised. To an extent, training and educational efforts, as well as judicious job design can serve to minimize some of these effects. For example, when appropriate attention is paid to work hours, work-rest cycles, circadian rhythms, etc., workplace errors linked to fatigue or stress can be reduced. Moreover, effects of stressors can be incorporated into computational models of human-system performance to aid the design of new systems (see, e.g., Conway, Szalma and Hancock, 2007). However, the nature of modern complex, semi-automated work is such that even in well-designed systems, unanticipated events may still place operators under periods of very high task load and stress, and operational requirements and work hours may induce fatigue. Paradoxically, the automation that is often introduced into such systems in an attempt to reduce workload may itself be a source of stress (Wiener, 1988; Hancock and Szalma, 2007). However, this need not inevitably be the case. Automation designed to be adaptive rather than static, i.e., responsive to context and operator needs, can enhance system
performance and retain the benefits of automation while minimizing its costs (Parasuraman, 2000).

As systems and their operators are asked to do more and more, they approach their response capacity limits. As these limits are reached and subsequently exceeded, systems evidently fail. In general, these points of failure can be seen as equivalent as the “shoulders” on the edge of the extended-U conception presented by Hancock and Warm (1989), and see Chapter 1, Figure 1.2. If the task itself is the proximal source of stress, then an operator’s level of response to the task, i.e., their current performance level, is a good diagnostic of their experienced stress level. As the primary pragmatic concern is the continued effective functioning of these individuals, adaptive automation in all its many forms has an absolutely essential role. Assessment of operator state thus has two distinct but crucial roles. First, it informs the adaptive system about the acute or momentary capabilities of the operator so that immediate changes in task demand profile can, if needed, be made. However, the second function is to plot those operator capacities over time so that a profile of longer-term response capacity can be generated. It is from this chronic expression of responsivity that information as to fatigue, burn-out and potential collapse can be generated. While the momentary demands of the present may not push an individual ‘over the edge’ right now, the persistence of such mal-adaptive demands for an extended period can well do so. In short, adaptive systems are absolutely vital for the day-to-day success of individuals operating complex technologies under stress but the self-same information can be used to assess whether future problems are liable to arise so that such systems can be as proactive to chronic stresses as they are reactive to momentary demands. Given the clear importance of adaptive systems, it is important to look at their origin, their present status and their expected future directions.

**Adaptive Automation**

Adaptive automation represents an approach to automation in which the allocation of functions to human and machine agents is not set inflexibly at the design stage but is changeable during actual system operations themselves. The adaptive automation concept now has a long history (see Rouse, 1976, 1988; Hancock, Chignell and Lowenthal, 1985; Parasuraman, 1987; Parasuraman et al., 1992; Parasuraman and Mouloua, 1996). Only recently, however, have technologies matured to enable empirical evidence to be provided of the effectiveness of real-time adaptation. One example is the Rotorcraft Pilot’s Associate (RPA). This system, which aids Army helicopter pilots in an adaptive manner depending on mission context, has successfully passed both simulator and rigorous in-flight tests (Dornheim, 1999). Moreover, a number of human-in-the-loop simulation studies have shown that adaptive systems can enhance performance, and at the same time preserve the benefits that well-designed automation can bring (Scerbo, 1996; Hilburn et al., 1997; Moray and Inagaki, 2000; Prinzel et al., 2003; Kaber and Endsley, 2004). The performance costs of certain forms of automation, such as reduced situation awareness, complacency, skill degradation, etc. (Endsley and Kiris, 1995; Parasuraman and Riley, 1997; Sarter, Woods and Billings, 1997; Parasuraman, 2000), may also be mitigated with adaptive automation (Parasuraman, 1993; Scallen, Hancock and Duley, 1995; Parasuraman and Mouloua, 1996; Kaber and Riley, 1999). For a recent review of adaptive automation research, see Inagaki (2003).

Adaptive automation involves more than simply unloading (or engaging) the operator of a task. To be effective, the invocation process must be sensitive to the operator’s combined tasking environment, which depends on interactions among tasks as well as overall workload, stress, and safety considerations. The method of invocation is a key issue in adaptive automation. Parasuraman et al. (1992) reviewed the major adaptive automation invocation techniques and divided them into a number of different categories. These include: 1) critical events; 2) operator performance
and physiological assessment; 3) operator modeling and hybrids consisting of two or more of the identified methods.

1 Critical Events

The critical-event method is perhaps best exemplified by the early work of Barnes and Grossman (1985). In this approach, automation is invoked only when certain tactical environmental events occur. For example, in an aircraft air defense system, the beginning of a “pop-up” weapon delivery sequence leads to the automation of all defensive measures of the aircraft. If such critical events do not occur, the automation is not invoked. Hence this method is inherently flexible and adaptive, because it can be tied to current tactics and doctrine during mission planning. Another example of adaptive automation based on critical events is the use of conflict detection aids for air traffic controllers. As traffic load or complexity can be predictable at least to an extent (e.g., based on number of aircraft in the sector and other measures of “dynamic density” (Smith et al., 1998)) such aids could be adaptively provided only under high traffic load. In a high fidelity simulation study, Hilburn et al. (1997) showed that periodic implementation of a currently fielded conflict aid (the Center TRACON Automation System) at times of high traffic only led to more balanced controller workload and to improved overall system performance.

The critical-events method has the advantage of flexibility and relative ease of implementation. However, the flexibility of this method of adaptive automation is limited by whether the contingencies and critical events themselves can in fact be anticipated. Another disadvantage of the method is its possible insensitivity to actual system and human operator performance. The critical-events method will invoke automation irrespective of whether or not the operator requires or desires aid (e.g., because of high workload) when the critical event occurs. These sources of uncertainty mean that while the critical event method is indeed useful, it is not without its drawbacks.

2 Real-Time Assessment of Operator Performance and Physiology

One potential way to overcome the limitation of the critical-events method is to measure the operator’s performance and/or their physiological state. In these operator performance measurement and operator physiological assessment methods, operator mental states (e.g., mental workload, or more ambitiously, operator intentions) are inferred from the suite of measures taken (see Byrne and Parasuraman, 1995; Kramer and Parasuraman, forthcoming). This general conception is highly consistent with the emerging neuroergonomics approach to human-machine system interaction (Parasuraman, 2003). Measures that are taken are then used as inputs for the adaptive logic. For example, performance and physiological measurements can be used to infer that a human operator is dangerously fatigued or experiencing extremely high workload. An adaptive system that uses these measurements to provide computer support or advice to the operator (or supervisor) could in theory mitigate the potential danger (Hancock and Szalma, 2007).

Adaptive automation studies involving physiological measures include the work of Pope, Scerbo, and their colleagues (e.g., Pope et al., 1985; Prinzel et al., 2003). In these successful studies, an EEG index of operator “engagement” was used in a closed-loop adaptive system to allocate tasks to either the automation or to the operator. Another comparable and important series of studies has been conducted by Wilson and colleagues. For example, Wilson and Russell (2003) used a multiple measure approach to design a physiologically based adaptive automotive system. Participants completed the Multi-Attribute Task battery (MAT) at two levels of difficulty. A number of operator physiological variables such as EEG, ECG, EOG and respiration, were
measured during task performance. Wilson and Russell (2003) trained an artificial neural network (ANN) to recognize a weighted set of physiological patterns that differentiated states of rest, low task difficulty, and high task difficulty. The ANN was then used to determine which condition a participant was performing: when the high difficulty task was detected by the ANN, the monitoring and auditory sub-tasks of the MAT battery were automated. Results showed that the ANN reliably differentiated rest from low and high workload conditions in a training set of trials. Furthermore, the ANN could identify task conditions in a subsequent test set of trials. The ANN was used to implement adaptive automation, as a result of which tracking error decreased and performance on the resource management task increased compared with manual performance. In a more recent study using the same approach to adaptive automation, Wilson and Russell (forthcoming) confirmed and extended these findings to enhancement of performance in operators supervising multiple uninhabited vehicles (UVs).

3 Operator Modeling and Hybrid Methodologies

Operator status approaches to triggering adaptive automation rely primarily on fast, real-time assessment to provide the appropriate signals for task load adjustment. However, it is not always wise, or even feasible, to rely on reactive processing alone, especially when this has to be accomplished when, almost by definition, conditions are approaching their most loaded and hazardous state. One approach to “get out in front of the system” is to seek ways of accomplishing operator (and even system-wide) modeling of future possible states. In this way the possibility of proactive adjustment can be enacted and the very worst of conditions avoided. Modeling operator state (much less system-wide state) is not a simple endeavor. However, in the last decade and a half there have been significant strides in modeling capabilities. Today, we do possess a number of general architectures such as IMPRINT which can provide first-pass approximations of operator response in specified conditions. Further, we have more detailed cognitive models such as ACT-R which look to elucidate the underlying processes which contribute to outcome macro-level behavior. These are, of course, only a very limited sampling of a much wider set of models. As these respective capacities improve it will be possible to augment the more developed “reactive” strategies with these proactive approaches founded upon accurate modeling capacities.

Indeed, integration is certainly the watchword of future progress. We class these efforts under the general title of “hybrid” approaches since we view them as cooperative efforts between the various techniques that we have discussed. Primarily, the critical event marker will be seen as the principal reason and trigger for obligatory, acute changes in task distribution. While there are complex systems, there will always be occasional, sudden perturbations which will initiate the need for emergency response. Being prepared for these is a good initial step toward ensuring they are dealt with successfully. Thus, the future adaptive architecture will always reserve special response for these rare but highly demanding situations. Such response will still be founded upon the on-going momentary assessment of operator and system response capacity and the techniques and technologies that are now being developed to accomplish this will persist as the front-line of response in the foreseeable future. If critical events are highly unpredictable, perhaps operator response is more amenable to future projection. Thus, the hybrid development of combined proactive, moment-by-moment, and reactive methodologies which characterize hybrid architectures essentially represents the extension of adaptation is time from the immediate present toward the foreseeable future. Some form of this hybrid is almost certain to represent future human-machine systems and their mode of interaction.
Adaptive Control of Workload and Operator Reliance on Automation

While fully integrated, hybrid techniques are visions for the immediate future, real-time adjustment based on operator status is here today. The current results of studies using real-time assessment of operator physiological state indicate that adaptive systems can indeed enhance performance in high task load settings. More specifically, adaptive automation can balance workload between the extremes of over- and under-load. This is a potentially critical benefit given that it has been long known that operators of automated systems often experience unbalanced workload (Wiener, 1988). Hilburn et al. (1997) examined the effects of adaptive automation on the performance of military air traffic controllers who were provided with a decision aid for determining optimal descent trajectories of aircraft (the Descent adviser [DA]). The DA was either present at all times (static automation) or came on only when the traffic density exceeded a certain threshold. Hilburn et al. found significant benefits for controller workload (as assessed using pupillometric and heart rate variability measures) when the DA was provided adaptively during high traffic loads, compared with when it was available throughout (static automation) or only at low traffic loads. The workload-leveling benefit of adaptive automation was also demonstrated in a study by Kaber and Riley (1999), who used a secondary-task method to assess operator workload in a target acquisition task. They also found that adaptive computer aiding based on the secondary-task measure enhanced performance on the primary task.

These and other studies (see Parasuraman, 2000, and Inagaki, 2003, for reviews) indicate that adaptive automation can serve to reduce the problem of unbalanced workload, without the attendant high peaks and troughs that static automation can induce. Adaptive automation may also mitigate the problem of automation complacency. Under high workload conditions, operators typically allocate their limited attentional resources to the manual tasks under their command, as a result of which they typically do not effectively monitor the automated tasks in the system (Parasuraman, 1993; Moray and Inagaki, 2001; Bagheri and Jamieson, 2004; Hancock, 2007). Consequently, operators can miss malfunctions, or fail to correct sub-optimal performance by the automation because they are busy attending to other tasks. Metzger and Parasuraman (2001, 2005), reported similar findings with experienced air traffic controllers supervising “free flight” airspace with an automated conflict detection aid.

Adaptive automation, in the form of a temporary return of the automated task to human control, can help to mitigate automation complacency. In a study with the Multi-Attribute Task (MAT) flight simulation battery, Parasuraman and Mouloua (1996), showed that temporary return of an automated engine-systems task to human control benefited subsequent operator monitoring of the task when it was returned to automated control. Parasuraman et al. showed that the benefit of adaptive reallocation was found for either of the two methods of invocation described previously, a model-based approach in which the temporary return to human control was initiated at a particular time specified by the model; and a performance-measurement approach in which the adaptive change was triggered only when the operator’s performance on the engine-systems task fell below a specified level. A subsequent study showed that the operator (and system) performance benefit could also be sustained for long periods of time, in principle indefinitely, by repetitive or multiple adaptive task allocation at periodic intervals (see Mouloua, Molloy and Parasuraman, 1993). Such brief, periodic, adaptive reallocation of an automated task to human control can enhance overall system performance by either maintaining the operator’s awareness of the automated task parameters or by refreshing the operator’s memory (his or her “mental model”) of the automated task behavior. In support of the latter explanation, Farrell and Lewandowsky (2000) showed that they could successfully demonstrate a computationally model the complacency effect and the benefit of adaptive reallocation in a three-layer connectionist network with a memory decay function.
for nodes representing automation performance. These results show that adaptive automation can balance operator workload and reduce automation complacency. However, Parasuraman, Mouloua and Hilburn (1999) also showed that performance benefits can be eliminated if adaptive automation is implemented in a clumsy manner. This latter observation reinforces the concerns of Billings and Woods (1994) regarding the deleterious effects of inappropriate automation. Thus, adaptive automation does not relieve the system designer from the task of optimizing automation design but generates important design imperatives about the possibilities presented.

Mitigating Stress with Adaptive Automation

What we have examined so far are the conceptual and practical advances which have taken place with respect to adaptive automation. Within a few short decades, adaptive automation has gone from an advanced conception of what human-machine interaction can be, to fully-realized experimental and prototype systems. Indeed, the Augmented Cognition (AUGCOG) Program developed by the Defense Advanced Research Projects Agency has had a large influence in these latter phases of this development (and see Schmorrow, Stanney and Reeves, 2006) and promises further advancement in the near future. However, as we transition to the phase of widespread implementation, we have to ask pertinent questions about who needs this technological innovation and why? Of course, fully adaptive human-machine systems would be desirable for almost all users of computer systems and we expect to see this penetration in the decades to come. However, at present, the nascent technology is largely confined to a few user communities for whom augmented support is not a desirable quality but rather a practical necessity. As one might imagine, these user groups are those who have to perform in adverse and stressful operational conditions. From pilots of single-seat aircraft through exposure to ground combat conditions, the military have many situations in which stress attends the operational realm. The primary form of stress in the most arduous military environments is the threat of imminent death which can, as has been observed, “serve wonderfully to concentrate the mind.” The question for adaptive systems is how they encapsulate and incorporate this immediate, visceral level of stress into their effective operation? One primary concern is the difference between on-going assessment and simple task neglect. Suppose we were to try to implement adaptation based upon a soldier’s response to a secondary monitoring task. Well, in combat, the soldier might make no overt response to such a secondary task precisely because in a firefight situation it is secondary, not to say superfluous. A system founding its adaptation strategy on this information could be, and most probably would be, widely wrong. Similarly, a system basing its response on certain aspects of physiological functioning might make radical and tragic errors in redirecting task demand. Under such circumstances, we might anticipate that the primary action of the adaptive system would be off-loading of tasks from the individual and in most cases this would probably be justified. However, it is the overall context of performance which will be crucial and such adaptive systems must incorporate some assessment of context into their operational logic. Thus, soldiers running with heavy packs increase heart rate but also alter sinus arrhythmia, making adaptive strategies based on this aspect of the heart rate signal potentially unreliable. The effect of context on other forms of physiological assessment, especially those involving cognitive and neurological state, very much need to be evaluated in the near future.

If the issue of stress is a potential problem for practical, real-world implementation, it is also a potential benefit. Especially in underload situations, the ability to recognize that the individual is bored and frustrated with the “wait” element of the “hurry up and wait” situation can represent a welcome opportunity. If adaptive automation seeks to balance the momentary load on the individual, indications from stress research can begin to show us how to balance this load over much more extended periods of operation. Also, insights from stress research, as represented in the present
Mitigating the Adverse Effects of Workload, Stress, and Fatigue with Adaptive Automation

The practical user community we have identified as targets for first penetration of this technology is very much characterized as those who experience “hours of boredom and moments of terror” (and see Hancock, 1997). Each of the three phases involved, the boredom, the terror, and the transition between the two, represents a unique form of stress. Integrating the proactive, model-based form of adaptation into dealing with the boring (underload) phase, and the physiological/performance assessment based approaches into transitions represents a clear opportunity for immediate exploitation. As we understand more about the process of human stress adaptation, we can also transition such information into the architecture of adaptive systems to benefit from strategies that have developed as tried and tested responses to environmental demands. Such existence proof provides strong encouragement to designers who thus realize success is not merely possible but actually assured. Stress effects on performance are the central focus of the present text. This being so, adaptive, technological support to reduce or even mitigate these effects altogether, represents a strong answer to the essential problems posed.

Mitigating Effects of Fatigue with Adaptive Automation

Thus far, we have discussed the potential of adaptive automation for mitigating operator performance decrements due to sustained workload (for example associated with high task load or high tempo – time pressure) and stress. Fatigue is another major performance shaping factor in such work and transportation settings as driving, air travel over multiple time zones, night and shift work, and prolonged duty hours in medical personnel. Fatigue during long-distance driving is of particular concern. For example, fatigue and sleepiness account for approximately 56,000 crashes annually (Knipling and Wang, 1994). Moreover, fatigue has been shown to be a causal factor in about 30 per cent of crashes involving heavy trucks (and see Arnold et al., 1997). In an attempt to address this safety issue, the U.S. Department of Transportation is actively involved in developing technologies to track fatigue in real time in human operators. It is hoped that this may help manage the problem of fatigue and drowsy driving by developing an “intelligent vehicle” (Gorjestani, Shakowitz and Donath, 2000). This clearly represents an application of the adaptive automation concept to enhance safety during driving (see also Hancock and Parasuraman, 1992; Hancock and Verwey, 1997).

Collision avoidance systems (CAS) represent a form of automated support that may serve to mitigate fatigue-related impairment in drivers. Increased lane deviation, speed fluctuations, and slowing of response time to detect roadway hazards are among the many consequences of fatigue in drivers. These effects are particularly evident in monotonous conditions such as night or freeway driving for extended periods. But fatigue effects can also be observed after relatively short periods. For example, Thiffault and Bergeron (2003) reported increases in the frequency of large steering movements (corresponding to greater lane position variability) after only 40 minutes of monotonous simulator driving. This form of fatigue – typically referred to active or task-induced fatigue (Desmond and Hancock, 2001), generally increases lane deviation and decreases perceptual sensitivity, particularly when drivers are traversing along straight roads (Desmond and Matthews, 1997; Matthews and Desmond, 2002).

CAS’s have the potential to mitigate crash risk stemming from active task-induced fatigue. CAS’s represent one of a variety of automation aids that can be implemented to support the human operator, in this case the driver. As such, human factors evaluations of these advanced driver automation tools must be conducted so that their safety benefits can be fully realized (Hancock and Parasuraman, 1992). May, Baldwin and Parasuraman (2006) examined the effectiveness of an adaptive CAS to mitigate fatigue-related performance decrement during simulated driving. They had participants perform a simulated driving task in combination with a secondary task for
approximately 1.5 hours. When drivers demonstrated fatigue (as assessed by excessive lane position variability) a critical rear-end potential collision event was triggered. In a control condition, no automated warning was given. The modality of the warning was also manipulated (verbal or non-verbal). May et al. (2006) predicted that driver performance would be improved with both forms of the CAS, compared with the non-warning condition. Participants were licensed drivers in two age groups, young (18−35 years) and older (60−82 years). Participants completed approximately 1.5 hours of simulated driving consisting of a car following task and secondary speech processing task in both high density and no traffic freeway scenarios. They first executed a baseline car-following drive during which their mean lane position variability (average standard deviation of their lane position) was calculated. Task-induced fatigue was estimated when subsequent driving performance exceeded one standard deviation above this average (fatigue threshold). Towards the end of the simulated drive, a potential collision scenario involving a car following task with no other traffic was presented. Lane position variability was monitored in real-time to determine fatigue level. Once the participant reached his or her fatigue threshold, the lead car suddenly decelerated and came to a rapid complete stop. When the lead car slowed one of three possible CAS conditions occurred: no warning (control condition), non-verbal CAS (1,000 Hz tone), or verbal CAS (the word “danger”). Results showed that both CAS conditions reduced the crash rate under conditions of task-induced fatigue. Nearly 18 per cent of drivers crashed when provided no prior automated warning. When provided with either CAS however, only 11 per cent of drivers crashed. This represents a significant reduction in crash rate relative to the no-warning control condition. Furthermore, the CAS was particularly effective in reducing collision potential among the older drivers: when provided with a CAS, only one driver over the age of 60 was unable to avoid collision. However, there were no comparable significant effects of either CAS warning on crash rates in the younger drivers.

The significant reduction in crash rates among drivers provided with a warning indicates that CASs have the potential to reduce both occurrence and severity of fatigue-related rear-end crashes, especially among older drivers. The results point to the utility of auditory CAS warnings adaptively-linked to measures of driver performance decrement. In the May et al. (2006) study fatigue-related driving impairment was indexed by excessive lane position variability. After this fatigue inducement, warnings were presented in response to a high risk collision situation. Future research could examine a more prospective approach by investigating the potential benefit of providing drivers with low hazard level visual or auditory warnings when driving performance degraded, irrespective of a potential collision situation. The auditory CAS warnings examined in this study could also be presented using the other methods of adaptive automation discussed previously. For example, future research on adaptive automation to mitigate fatigue in drivers might also consider neuro-ergonomic measures, including EEG, blink rate, or eye movements (Parasuraman, 2003).

**Adaptive or Adaptable Systems?**

To this point, we have provided evidence for the efficacy of adaptive automation to mitigate effects of sustained workload, stress, and fatigue. However, before such systems can undergo widespread implementation, a critical issue that must be addressed is; who is “in charge” of adaptation? In adaptive systems, the decision to invoke automation or to return an automated task to the human operator is made by the system, using any of the previously described invocation methods. This immediately raises the issue of user acceptance. Human operators may be unwilling to submit to the “authority” of a computer system that mandates when and what type of automation is or is not to be used. Apart from user acceptance, the issue of system unpredictability and its consequences
for operator performance may also be a problem. It is possible that the automated systems that were designed to reduce workload may actually increase it. Billings and Woods (1994) cautioned that truly adaptive systems may be problematic because the system’s behavior may not be predictable to the user. To the extent that automation can hinder the operator’s situation awareness by taking him or her out of the loop, unpredictably invoked automation by an adaptive system may further impair the user’s situation awareness (there is evidence to the contrary from several simulation studies, but whether this would also hold in practice is not clear). As Wiener (1988) trenchantly noted about poor automation, it may well serve to increase workload when it is already high and reduce it when it is already low. Systems with this propensity are positively damaging, not merely at the moments that they fail to act but their failure serves to prejudice users against all such systems, even when they are actually effective.

In contrast with computer-initiated automation, if automation were explicitly invoked by the user then presumably system unpredictability will be lessened. But involving the human operator in making decisions about when and what to automate can reflexively increase workload. Thus, there is a trade-off between increased unpredictability versus increased workload in systems in which automation is invoked by the system or by the user, respectively (Miller and Parasuraman, 2007). Opperman (1994) characterized these alternatives as “adaptive” and “adaptable” approaches to system design (and see also Scerbo, 2001). In either case, the human and machine systems adapt to various contexts, but in adaptive systems, automation determines and executes the necessary adaptations. In contrast, in adaptable systems, the operator is in charge of the desired adaptations. The distinction is primarily one of authority. In an adaptable system, the human always maintains authority to invoke or change the automation, whereas this authority is shared in an adaptive system. Inagaki’s (1999) design concept of “situation-adaptive autonomy” is related to this view of an adaptive system, but in his approach, control of a process is traded off between human and computer in real time based on time criticality and the expected costs of human and machine performance.

In this chapter, although we have considered primarily how adaptive automation affects system performance under stress and fatigue, it is important to keep in mind that adaptable automation may provide an alternative approach with its own benefits (see Miller and Parasuraman, 2007). In adaptable systems, the human operator is involved in the decision of what to automate, similar to the role of a supervisor of a human team who delegates tasks to team members, but in this case, tasks are delegated to automation. The challenge for developing such adaptable automation system is that the operator should be able to make decisions regarding the use of automation in a way that does that create such high workload that any potential benefits of delegation are lost. There is a growing body of preliminary evidence from studies of human supervision of multiple Unmanned Vehicles (UV’s) that adaptable automation via operator delegation can yield system benefits (Parasuraman et al., 2005). However, much more needs to be done to determine whether such benefits would still hold when the operator is faced with the additional demands of high workload, stress, and fatigue.

Conclusions

When we look at how individuals adapt to their environment, we find that there are several strategies that human beings (and indeed all organisms) adopt in order to avoid or reduce the effects of sustained workload, stress, and fatigue. Such strategies include active physiological responses to external demands, cognitive adjustments to the ambient conditions and tragically, the periodic failure of these capabilities resulting in injury and ultimately death. But these strategies are metabolically expensive and most organisms, including human beings, prefer not to be profligate
with their energy. Thus, sitting by a campfire is preferable to a night spent shivering, while a suite at the local luxury hotel may be preferable to both. In general, it is a better survival strategy to anticipate and avoid the coming stress, rather than reflexively reacting to it. In general, these various strategies provide “envelopes” of protection around the organism in order to avoid, buffer, mitigate, or finally just tolerate episodes of stress. Human beings take this protective strategy and elaborate it to the nth degree. We have taken what are intrinsically endogenous response strategies and made them explicitly exogenous sources of protection. The most effective and evident expression of this augmented protection is technology.

As far as possible, technology is designed to tell us what is coming. Hence, we have a significant societal focus on disaster mitigation and a sense of outrage in modern times when (as in the case of Hurricane Katrina) such protective strategies fail to work as effectively as we might desire. We cannot, and indeed should not, seek to avoid all sources of stress. For stress is not ubiquitously a thing to be avoided. Some level of cardio-vascular challenge is important for health and some comparable level of cognitive challenge is crucial if we are not to fall into complete boredom and ennui. However, technology wraps us in a blanket of protection against the more damaging and indeed potentially lethal expressions of environmental stress. Protection seeks to preserve an acceptable level of demand. This demand, as we see in the case of boredom, is certainly not zero, but it should be both anticipatable and controllable. When we do encounter highly adverse circumstances, whether the source of stress is the environment or the task, or both together, technology can act as a buffer between ourselves and the expenditure of physiological and cognitive “energy” which we have fought so hard to obtain. But technology cannot do this in isolation. It must be programmed to understand where, when and how such support is needed. Until the present, such support has been very static. If you wanted environmental support, you had to go to a building, if you wanted cognitive support you had to go to a library. Technology to date has often been spatially static and organized to support the collective and not the individual directly. Now the world has changed. Technical support is becoming spatially and temporally ubiquitous and directed toward the individual and not the group. That these efforts in task support are first evident where humans are hardest pressed is no surprise. What we will soon see is the general penetration of these adaptive technologies into the global market and their rapid personalization so to follow. In this sense, technology is just another strategy that DNA uses to protect itself from damage and injury. As part of the on-going battle to “control” nature, we see how adaptive systems promise to tame uncontrolled cognitive demands. Whether that is to the general betterment of all humankind awaits the verdict of the future.

References


Hancock, P.A. (1997) Hours of Boredom, Moments of Terror - or Months of Monotony, Milliseconds of Mayhem. Paper presented at the Ninth International Symposium on Aviation Psychology, April, Columbus, OH.


Mitigating the Adverse Effects of Workload, Stress, and Fatigue with Adaptive Automation


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Abstract

Working in demanding or threatening situations taxes our cognitive capacity. Measures, support, and training aimed at improving this capacity, mainly focus on the cognitive capabilities, such as information processing, memory, knowledge, skills, etc. However, the magnitude of our cognitive power and its efficient use is also determined by other factors, such as emotion, motivation, and effort. These factors may be as important to augment cognitive capacity, in particular in situations involving disturbing factors, such as time pressure, conflicts, fatigue, and threat.

To describe and discuss the influence of these factors on cognitive processing a framework is developed in which the neglected concept concentration plays a key role. Concentration is defined as the ability to mobilize and coordinate one’s resources, in order to obtain and maintain an optimal state to perform efficiently and effectively. This concept is quite similar to the personality trait mental focus of Lee, Sheldon and Turban (2003) defined as the ability to concentrate and become absorbed in an activity, and to task engagement of Matthews and co-workers (2006), corresponding to energy, motivation, and concentration.

Where is Capacity Limited?

The human brain has an enormous capacity to process information. We only have to observe a pianist or a surgeon, to realize how capable a human being can be to perform very complex tasks at a high rate and apparently without much effort. In our daily life we manage to perform a variety of tasks, such as reading and car driving, without realizing how complex these tasks are. Of course, this level of mastery can only be attained after years of practice. Because the processing in these tasks has become automatic, they can be executed at a low level of attention and effort. In contrast, under adverse conditions (e.g., cognitive overload, fatigue, stress, and loss of motivation) performance may degrade rather quickly, even when the task is relatively easy and highly important. Although our processing capacity is very large, the above mentioned factors can inhibit and distort fluent information processing, with the result that operators report feelings of work pressure and stress due to a high cognitive workload.

However, this type of complaints may also be caused by negative factors other than high levels of workload. Several studies in work psychology (e.g., Karasek and Theorell, 1990; Neerinxc, 2003) have shown that inefficient and non-productive behavior is not only determined by the amount of work, but also by the way the work is organized, such as autonomy, task allocation, communication, coordination, work/rest-schedules, and feedback, and by psychosocial factors, such as social support, coaching, rewards, perspective on the future, and commitment with the work and the organization. Even under regular working conditions the absence of these factors may lead to strain, absenteeism, and in the long run to turnover, burnout and cardiovascular diseases (e.g.,
Karasek and Theorell, 1990). In combination with the above mentioned adverse conditions, such as threat and fatigue, the risk of negative effects on cognitive processing will be even much higher.

Therefore, measures to augment cognition should not only focus on improving cognitive abilities, but should also examine how cognitive processing depends on energetical, motivational and emotional factors, how this processing is degraded by stress, and this may be compensated by enhancing the positive factors in the work environment or person characteristics.

In this chapter a framework is presented in which concentration plays a key role, whereas attention, cognitive control, emotions, motives, energy and effort are the most important elements. The framework may be used to improve the organizational and psychosocial determinants of the work environment and to develop measures that enable operators to make optimal use of their resources in demanding situations, and to develop (informational or social) support systems that do not only focus on the cognitive state of the operator but also take into account the emotional, motivational and energetical aspects.

**Concentration Framework**

The aim of the present framework is to describe the factors that inhibit the functioning of operators, in particular under adverse conditions, which are assumed to effectuate their negative influence by degrading the concentration process. Concentration is conceptualized as a dynamic mechanism, which mobilizes and coordinates our resources in order to bring and maintain our mind and body in a state that is appropriate to perform a particular task. It triggers energetical mechanisms and focuses our attention to relevant cues enabling goal directed behavior. In other words our motives are transformed in activities that result in the realization of the goals we pursue. Concentration is always directed towards a specified goal, that is to a particular object or activity, as it is not possible to concentrate on “nothing”. This enables the discussion of the work and person characteristics in terms of facilitating or inhibiting the realization of a particular goal. For example, although anxiety mostly has a negative connotation, it can also be positive when it increases the likelihood that the goal will be reached. Thus, a negative emotion (e.g., anxiety) may result either in distraction and inefficiency, or may mobilize energy and enhance attentional focus on the task.

The framework describes the interaction between three types of processes necessary for an optimal concentration process: 1) the steering of attention towards the relevant aspects of the task; 2) the mobilization of energy to bring our brain and body in a state appropriate to execute the task; 3) emotions that drive our motives and thus the intent to do the task and realize the goal. These processes refer to different levels of functioning (cognitive, physiological, and affective), that originate from several research areas, such as cognitive psychology (attention, information processing), psychophysiology (activation, effort), work psychology (motivation, goal-directed behavior) and individual differences (personality and coping). The latter has to account for the large differences between and within individuals in the ability to remain focused on the task and to maintain goal-oriented behavior (see also Lee, Sheldon and Turban, 2003).

Although cognitive, energetical and affective processes have a complex interplay and continually influence each other, it is important to disentangle them, not only for the sake of theoretical argument but also for practical reasons. Different factors may influence these processes in different ways, and therefore ask for different measures to improve functioning or protect performance against degradation. The concentration model distinguishes six core elements of which two are cognitive, two are energetical and two are emotional (see also Figure 4.1).
The two types of cognitive processes are:

*Cognitive processing* refers to the online processing of information, mediating between input and output, between demands and outcomes.

*Cognitive control* refers to the metacognitive activities that control and evaluate someone’s own behavior in terms of the proposed goals, given one’s own abilities and the opportunities in the environment. The *task set* can be seen as closely linked to cognitive control, mediating between demands and task execution. It is regulated by the cognitive control before and during the task.

Energetical processes determine the biological, physiological, and hormonal state of the operator. These processes are considered in so far they are important for goal-directed behavior. Besides the influence of body rhythms and physical environmental factors energetical processes are determined by the demands of the task in two ways:

*Task-related activation* refers to the changes in energetical processes that occur automatically when we are planning and executing a task.

*Mental effort* refers to the process of changing energetical processes by intentionally mobilizing more energy.

Affective processes determine our feelings, mood, motives, attitudes, and beliefs, but they also affect the energy mobilization.

*Feelings* can be regarded as cognitive representations of the encapsulated affective processes. They signal our conscious brain that events are beneficial or a potential danger to our well-being. They are a guide for the planning of our behavior. They are not indicated in the figure because they influence all elements of the concentration process, as will be discussed later (section on *the role of emotion*).

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**Figure 4.1** The concentration model, illustrating the influence of the factors that affect cognitive processing
Motives are cognitive representations of the drives and aspirations we have in our life and work. They provide energy to engage in our work in the first place, not only because we need the salary to stay alive, but also because we want to realize our aspirations and to make our life worthwhile.

The core of the framework, illustrated in Figure 4.1, consists of the primary process at an executive level transforming the demands of the work into performance. This well-known process between input and output is influenced by two environments: the cognitive environment that is rationalistic and logical, and the psychosocial environment of blood, sweat and tears. The cognitive processes originate from the “higher” cortex, whereas the psychosocial environment is dominated by the older brain structures providing drive and energy for our activities. While making this distinction between two environments, we realize that there is no strict bifurcation and that there are multiple mostly complex interactions between cognitive and affective processes (see for example, Damasio, 2003). In fact, to understand these interactions sheds light on the disturbing effects of stress and fatigue on cognitive processing. On the one hand, cognitive processes, such as rational decision making and cognitive appraisal of the (stress)situation will be influenced by affective processes; in particular when we are uncertain and feel threatened, negative emotions dominate the cognitive processing and we tend to regress to basic, rigid behavioral patterns (e.g., Staw, Sandelands and Dutton, 1981). On the other hand, to some extent we are able to moderate our (negative) emotions by self-regulation (for example, reassuring thoughts, relaxation techniques, or proactive behavior). We may even be trained to remain concentrated on the task while having distracting negative emotions.

Cognitive Environment

Our performance is continually evaluated by our cognitive control (also called executive control). This is a metacognitive system defined as “cognitions about cognitions”, that is off-line: not in the loop of input – processing – output – feedback. While executing a task we are able to look back evaluating whether our performance meets the criteria in the task set, and we can look forward to estimate what we still have to do and whether we have to change our strategy and way of working. This is done on the basis of the feedback we receive from our performance, or from other sources (e.g., chief, colleagues, or computer). When necessary we may change our way of working by accepting more errors, or by mobilizing more energy through effort. We may also revise our planning by asking for help, or postponing our deadlines. Ultimately we may decide to give up the intended goal.

To evaluate our performance cognitive control makes use of the so-called task set, which encompasses the actual knowledge and information in working memory necessary to perform a particular task (see also Neerincx, 2003). It contains not only the targets and time schedule to accomplish our goal, but also the way of working and the performance criteria. Each time we engage in performing a task, the task set has to be actualized and refreshed in working memory. When a task is interrupted, the task set must be build up again when the task is continued. The more complex the task, the larger the task set will be, and the more time and effort is required to build it up. The task set has also an affective aspect (see Figure 4.1). Besides planning the task on a cognitive level we also need to be sufficiently motivated, not only to execute the task, but also willing to invest extra energy via effort and tolerate negative feelings of fatigue and stress when the situation is very demanding or threatening. Being highly motivated means that we highly value the realization of the goal and give it priority relative to other (interesting) activities we might want to do. The fulfillment of tasks with a low priority will be more vulnerable to aversive factors because motivation low, and therefore the intent to do the task is weak and the willingness to spend effort low.
Cognitive control also determines how our attention is distributed over the different elements of the task and considers whether a change in strategy is needed when the accomplishment of the task is in danger. When evaluating our progress we also take into account how adequate our current energetical state is to meet the task demands, and how much effort is still needed to accomplish the task. While doing this the relevance of the goal will be balanced against the time and effort already invested in the task. All these actions will require attention and effort. This type of attention is voluntary and consciously directed towards performing the task and realizing the intended goals. This is called directed attention, to contrast it with other types of focused attention that are not inspired by the current task goal, but evoked by stimuli or enforced by events that attract our attention.

Cognitive control and task set are discussed here because they play an important role in the way distraction, fatigue, and stress affect cognitive processing (Linden, Frese and Mijman, 2003). Interruptions, other motives, and negative emotions have in common that they tend to degrade the task set and demand attention, which costs energy and processing capacity that can not be used to execute the current task.

**Attention and Goal-Directed Behavior**

Concentration is conceptualized as a mechanism to create and maintain an optimal state, appropriate to apply our resources efficiently and effectively. It regulates our attention (directing, filtering, and switching of attention between elements of the tasks, etc.) and manages our energy supplies (preparation before task, distribution of energy over the work period, mobilizing extra energy through mental effort, deactivation, and recovery from work). The capacity to concentrate plays an important role in the organization of our activities, in particular in complex task situations. For example, the coordination between perceptual and motor processes, between cognitive processing on an operational level (task execution itself) and cognitive control on a strategic level (control of own performance and evaluation of the progress made), and between own performance and that of colleagues (cooperation, information exchange, offering help, etc.). This means that concentration not always implies that the focus of attention is on the execution of task itself. If the task can be performed with automatic processing, more attention can be allocated to cognitive control, or to the environment looking for relevant information, that may be used to improve performance or protect future performance from potential disruptions.

Concentration is a prerequisite to develop and maintain goal-directed behavior. In turn, we are better able to concentrate when we have a concrete plan to realize our goal. With a structured plan and a time scheme we are better able to divide our attention between activities, to distribute our energy over the total work period, to postpone less important subtasks, and to neglect interruptions, such as phone calls, e-mails, etc. The plan, which is a part of the task set, specifies the methods and means to be used, and a time schedule with milestones. The more rewarding the goal, the higher the priority and the more the operator is motivated to mobilize resources to realize the goals, even when confronted with drawbacks or negative feelings due to conflicts, fatigue, or stress.

In every task situation the current task goal has to compete with other goals we have. The intent to perform the current task is challenged by other motives that beg for attention and alternative actions. Distractions (e.g., reading e-mail), fatigue (e.g., need to rest) and stress (protect own resources) attempt to disqualify the current intent and undermine goal-directed behavior, causing performance deterioration. This illustrates how closely the processing on a cognitive level is connected with affective processing and energy mobilization.
Energy Mobilization

Under normal circumstances our energetical state is in line with the activities we want to undertake. Energetical mechanisms regulate our brain and body to bring them in an optimal state to process information. The majority of bodily processes are regulated automatically and unconsciously. The execution, and even the planning, of a task prompts energetical mechanisms to bring our brain and body gradually into a state that is optimal for efficient processing and therefore determines the available cognitive capacity. In most instances we do not have to pay attention to this continuous adaptation, which gives us the opportunity to concentrate on the other aspects of the work environment. Only when our state is far from optimal due to fatigue or strong emotions, we do realize how much cognitive processing is affected by our state. Since these effects are mostly outside our control, we can only attempt to modulate them, adapting to the current demands. When planning our daily activities, we may take into account possible fluctuations in our state, due to fatigue or time-of-day effects. Morning people may prefer to make difficult decisions early in the day, whereas evening types do not mind working overtime.

Besides the endogenous effects of our organism (e.g., circadian rhythm) and the influence of environmental factors (e.g., noise, sleep loss, and temperature) that influence our state autonomously, two types of task-related energy mobilization are distinguished: task-induced activation which refers to the stimulating effects of the task or the work environment in general; and internally-guided mental effort which involves voluntary energy mobilization. Similarly, Hockey (2003) distinguished two types of energy mobilization, one for routine regulatory activity and one for effort-based control.

Task-induced activation  When we know that a particular task has to be done in the near future, we will prepare for certain activities, not only on a cognitive, but also on an energetical level. Just thinking about the task to be done, affects the regulation of our state: energetical mechanisms are activated to reach an optimal state. The relation between state and efficiency is dependent on the demands of the task on the one hand and the availability of processing resources on the other. When processing capacity is abundant, a deviation from the optimal state will not result in a reduction of performance efficiency. Therefore, in well-trained tasks that do not require much capacity, the range in which performance remains optimal, is quite large. However, in complex or novel task situations that require all our resources, even a small deviation from the optimal may result in a performance decrement. We therefore prefer an easy task to a difficult one when we are tired. In the evening for example we may be too tired to write a technical paper, but we may still be able to correct a manuscript.

Mental effort  In contrast to task-induced activation this so-called “try-harder” response is a voluntary reaction of the operator to mobilize the resources needed to meet the task demands. Kahneman (1973) conceptualized effort as the action of maintaining a task activity (task set in the present framework) in focal attention. Since the energy mobilization under mental effort is voluntary is can be down-regulated at the moment the task is accomplished or given up. In contrast to energy mobilized by emotions, such as threat, may continue when the stressor is no longer active, inhibiting a proper recovery.

When we have accomplished the task, the effort process stops and the associated energetical processes are down-regulated. Mental effort can only be maintained for a relatively short period, since the physiological and psychological costs are high, in terms of strain and fatigue. Effort is needed, when there is a risk that lapses in attention result in performance deterioration (e.g., errors).
and possible loss of resources. This may be the case in the following, apparently quite different situations (see also Gaillard, 2001):

a) The energetical state is too low due to sleep loss or fatigue.
b) Emotions disrupt the energetical state and the directed attention.
c) The task requires controlled processing because of inconsistent or varying input-output relations, or heavy demands on working memory.
d) The task requires divided attention in a complex multitasking environment.
e) Skills have to be acquired in a new (learning) situation.

These situations have in common that operators may have problems keeping the task set in their focal attention. In a. and b., maintaining the task set is challenged by other goals, such as taking a rest period or paying attention to your emotions, problems, and complaints. In c. the task can not be performed automatically following the task set; due to inconsistencies and irregularities it must be monitored continually whether the task set is still appropriate; and in d., the task set has to be refreshed regularly when the operator changes from one task (or task element) to another. In e. a task set has still to be developed, which can be seen as part of the learning process.

From the above, it can be deducted that there is no direct relation between task difficulty and effort. Increases in task difficulty only result in the mobilization of extra energy through mental effort, when the operator is motivated to do so. This explains why aspecific motivational variables, such as feedback or bonus, have larger effects on indicators of effort than changes in task difficulty (Veltman and Gaillard, 1997). Whether effort is mobilized depends on three conditions:

1. **Motivation.** As was already outlined above explaining the affective aspects of the task set, mobilizing energy via effort is dependent on the motivation of the operator to accomplish the task. Only when the goal has a high value the operator is willing to tolerate the negative feelings of prolonged effort, and possibly of fatigue and stress the intent of the operator to maintain his performance level and to accomplish the task.

2. **Energy supplies.** There must be enough energy available. There is always a point where it is no longer possible to continue the task under demanding or threatening conditions, even if the operator is very motivated, well-trained and has a high stress tolerance.

3. **Type of task.** Mental effort only improves the task performance in the above described conditions in which more effort results in performance improvements. However, under threatening and demanding conditions we may still put effort in the task, simply because we are so motivated to accomplish the task, or are anxious that performance will fail.

**The Role of Emotion**

The role of affective processes has been largely neglected in cognitive psychology, human factors, and ergonomics (e.g., Eysenck, 1982; Niedenthal and Kitayama, 1994; Martin and Clore, 2001). Most theories only distinguish between state and process, dichotomizing between energy (e.g., arousal, activation, and effort) and cognition. Two hundred years ago, Pascal already introduced the idea of affective processing as a third layer between mind and body. Nowadays we would say the processing between a cognitive and a physiological level. Although emotions mostly have a negative connotation in both cognitive psychology and the stress literature, they can also have positive influences. Emotions play an important role in motivating people to embrace task goals in the first place, and to maintain goal-oriented behavior. At the same time strong emotions may interfere with cognitive processing. In particular under time pressure or threatening conditions, the
regulation of our emotions is a critical condition for efficient performance. When we are uncertain about our goal, our abilities to meet the criteria, or about the rewards to be gained, we may have difficulty maintaining our intent to accomplish the task. In particular, under adverse conditions, there will always be competition with other goals which attempt to degrade the intent to perform the current task. Since sustaining an effortful state is subjectively aversive and has its costs, it may conflict with other personal goals, such as maintaining well-being and health (see also Hockey, 2003).

Affective processing takes place in phylogenetic older structures of the brain (i.e., limbic system). Most of this processing is encapsulated and only reaches our consciousness in the form of emotional feelings. Compared to cognitive processing, affective processing is less conscious: we can hardly control our emotions or steer them in a particular direction. We can start and stop an activity when we want to, but we can not order our brain not to feel anxious or depressed. Emotions, such as anxiety, have considerable influence on the way we process information (e.g., decision making) and on our ability to remain concentrated on the task, in particular in combination with other negative factors, such as fatigue and loss of motivation.

Feelings can be regarded as signs that indicate how well we are doing in this world (Frijda, 1986; Lazarus, 1991). Positive emotions indicate that we move into the good direction towards our goal and negative emotions warn us that our intention to attain a particular goal is blocked, the realization of our goals is in danger, or that we even may loose some of our resources (possessions, honor, and ultimately our life).

Emotions influence our task behavior in several ways:

- They influence our goal setting. Our goal striving is determined by our needs and aspirations that are dominated by affective processes.
- They provide values and norms that guide the plans we make to reach our goals and therefore modulate the way we process information. They influence the direction of our attention and the way we filter information coming from the task and the environment.
- Feelings help to keep the goal in mind when the task set or goal setting is challenged by other activities or goals. This is important when our motivation to finish the task is attacked by drawbacks, stressors (heat, thirst and fatigue) and other problems unrelated to the task.
- Motives trigger the mobilization for energy either indirectly by our intent to execute the task (task induced) or by our efforts. When we are motivated we appear to have more energy supplies, and are more ready to mobilize them. In contrast, when we are not engaged in the task it takes a lot of effort to mobilize energy: when we are not sufficiently motivated to realize a particular goal, we will not be able to put effort in the task. This explains why it is so fatiguing to perform activities that you do not like or that you regard senseless or not feasible.

Although positive and negative emotions appear to have differential effects on cognitive processing, their influence is larger the stronger the emotional feelings are. Ultimately this may result in a state in which our thinking and therefore our behavior is (completely) dominated by emotions, as is the case with intense anxiety, anger, or panic (Staw, Sandelands and Dutton, 1981; Damasio, 2003). Strong emotions, in particular negative ones, have “steering precedence” (Frijda, 1986). They continually beg for attention and interrupt the ongoing processing of task information. Even the act of ignoring irritating feelings will cost effort and require some processing capacity, leaving less for performing the task.

Intense negative emotions may reduce performance efficiency in several ways (Gaillard, 2001):
They are distracting and reduce processing efficiency: operators may have problems following their line of thought and executing their plan (e.g., Eysenck and Calvo, 1992).

They may also affect the way of processing: they may result in more risky decision making, higher error tolerance, and reduced team interactions.

In extreme cases, goal-oriented behavior is disrupted, and operators will have doubts about their motives, the sense of the goal and the feasibility of their mission.

They may disrupt the state regulation, which makes it less optimal for task performance due to overreactivity (e.g., high adrenaline level, training champion, stiffness of muscles).

They may cause psychosomatic complaints (e.g., head ache, stomach ache, back pain, heart palpitations) which may degrade motivation, but also demand attention.

They may inhibit a proper recovery and result in sleeping problems that may deleterious effects in the long term.

To summarize, affective processes influence performance in several ways (see also Figure 4.1): they influence our motives and therefore direct our goals, plans, and behavior; they enable the mobilization of energy. In highly demanding and threatening conditions, however, they may evoke negative emotions that deregulate the energetical state and evoke energy that in most cases is not functional, disrupting the processing of information and dispersing our attention. Degradation of cognitive control and task set does not necessarily imply that task information can not be processed at all or that cognitive processing is changed fundamentally. Compromised cognitive control may lead to a reduced probability that task information is processed. Due to distraction or negative emotions the intent to do the task is very weak, and therefore the task set no longer is guided by the goal to execute the current task (Van der Linden, Frese and Mijman, 2003).

**Attention and Energy**

The distinction between directional, content-specific processes (e.g., cognitive control, and attention) and intensive, energizing aspects of our behavior (e.g., energy, arousal, and effort) has a long history in psychology (Kahneman, 1973; see also Hockey, Coles and Gaillard, 1986; Hancock and Szalma, 2007; Szalma and Hancock, forthcoming). As early as 1955, Hebb maintained that “arousal is an energizer, not a guide”, indicating that an optimal state of our brain may facilitate information processing, although it does not guide our behavior. It is an engine, not a steering wheel. Energetical mechanisms have to bring our brain in a state that is appropriate to meet the demands of the task.

The concentration process is characterized by a continuous interplay between on the one hand directing our attention to the task and guiding our behavior, and on the other hand the mobilization of sufficient energy to maintain an energetical state appropriate to process the task information. Under normal conditions the two types of processes converge, in response to the task demands and our motives. Only under extraordinary conditions we do experience how difficult it is to remain focused, when our energetical state is not appropriate for the task in hand. If anxiety or anger overwhelms you, or you suffer from sleep loss, it is difficult to keep your attention focused on the task. When planning our daily activities at work and at home, we take into account our current energetical state, and possible fluctuations in the future.

Figure 4.2 illustrates that under normal circumstances directing our attention and mobilizing energy are highly correlated. When we are daydreaming we spend very little energy and our attention is not directed to a specific goal, but is wandering without a concrete aim. When we concentrate on a goal, energy is mobilized and our attention is directed towards the activities planned. The level of concentration can vary from passive activities (watching TV), via routine tasks, to complex tasks,
which require the full capacity of our brain to meet the task demands. Concentration is assumed to be optimal when attention is fully directed to the task and our energetical state is optimal for the processing of the task information. This condition is similar to the state of flow (Csikszentmihalyi, 2003): a challenging situation, which makes maximal appeal to the operator to use his skills to meet the demands of the task. This is only possible when the task is stimulating and the goal to pursue well defined. The operator should be intrinsically motivated, have self esteem and not be hindered by personal problems or other distracting thoughts.

The diagonal in Figure 4.2 represents the situations in which there is a balance between attention and energy. In classical one-dimensional activation theories it is assumed that performance is sub-optimal when the concentration level is too low, given the task demands. Although recent models support this view, they differ in the expected effects, when distortions of the concentration process occur. Attention and energy do not converge in all situations. They are independent processes, which are affected by different factors in different ways. For the sake of argument two extreme situations are described that differ in energy mobilization and the direction of attention: stress and fatigue (see also Gaillard, 2003a).

**Stress**

In the stress literature controversy exists about the effects of high arousal on performance efficiency. In classical theories it is assumed that at high levels of arousal enhanced energy mobilization no longer improves, and even may reduce processing efficiency. Operators are no longer able to pay full attention to the task, which impairs effective, goal-directed behavior (lower right corner in Figure 4.2). When we are very aroused (for example by threat or extreme pleasure), we are
not capable to concentrate on the task, although we have a lot of energy, the energetical state is distorted and our attention is dispersed. In situations of threat (e.g., accident, fire, etc.), we tend to react with basic behavioral patterns, associated with a quick and intensive energy mobilization, similar to the well-known “flight/fight response”. This state can be advantageous to protect your life (“first shoot and then talk”), but it is not appropriate to perform complex tasks and make difficult decisions. Thus, only when arousal and emotions evoked by the situation will only be facilitate goal realization, when they are congruent with the required cognitive processes (see also Lazarus, 1991). In situations where the course of events is unpredictable and the outcomes uncertain, we tend to react with anxiety and to fall back on well-learned, basic strategies that are rigid and non-adaptive, but give a feeling of safety (e.g., Staw et al., 1981). With extreme threat people are no longer able to think in a flexible way, which inhibits their problem solving. In panic situations people may adhere to incorrect coping strategies, which may result in more damage than caused by the threat itself.

Thus, to obtain optimal performance the question is not whether energy mobilization is too high or too low, but whether the energetical state is appropriate for the processing required by the task. This raises the question, which factors determine the difference between the two states stress and flow (see Figure 4.2). In both states energy mobilization is high and attention is “narrowed”. However, under threat this so-called tunnel vision is forced by external events (e.g., fire, aggressive person), whereas with flow the narrowing self-determined and a result of concentration on activities needed to realize a specific goal. Thus, with flow attention is voluntarily directed by internal motives and goals. With threat attention is drawn automatically by external events, which results in rigid thinking, little control over our attention and in primitive behavioral patterns that may not be appropriate. Also the way in which energy is mobilized is different. With flow, the energy is elicited by the task demands and by mental effort, whereas with threat the energy is evoked by negative emotions, such as anxiety and anger. In the latter case, this type of energy results in a functional state which is less appropriate to process information in complex tasks.

There are large differences between individuals in their sensitivity to adverse conditions (distraction, fatigue and stress in Figure 4.3). Some individuals are able to maintain an appropriate energetical state and their attention directed to the core elements of the task. Other persons have a lot of energy and a large readiness for action, but at the same time have problems in focusing their attention at the same task, to follow a straight line of reasoning, and to maintain goal-directed behavior for a longer period. The capability to remain concentrated under time pressure, fatigue, and threat appears to be an important characteristic of stress tolerance (see also Gaillard, 2003a, b).

**Fatigue**

When operators have to work for a long period, they experience more and more feelings of fatigue, in particular when the task is continuous, repetitive or boring. As a result the working pace slows down and errors are more likely to occur. Operators have problems to remain concentrated on the task, and to keep the focus of their attention on the core elements of the task. Their thoughts easily drift away from the current task to daydreaming or other activities that are more relaxing, and give short-term satisfaction. The magnitude of these effects, however, is not only determined by the amount of fatigue, but also by the operator’s motivation. When we are very motivated, owing to high rewards or sanctions, we will fight fatigue. We are prepared to invest more effort in the current task and to resist the negative feelings that demand attention and attempt to convince the operator to stop executing the current task. Similar to negative emotions, feelings of fatigue have “steering precedence”: they are annoying to the effect that they can not easily be ignored. This implies that less attention, and thus capacity, is available for the processing of task information.
However, reduced performance may not only be caused by a depletion of energy supplies, but also by insufficient mobilization of energy due to loss of motivation. In the latter case, sufficient energy is still available but the operator is not willing to invest more effort in the task, either because the costs turned out to be too high (strain due to fatigue or enhanced effort) relative to the rewards to be gained. This results in a less favorable cost/benefit ratio which reduces our motivation to continue, whereas the current goal meets increasing competition from other motives which lowers the threshold to engage in alternative activities that appear now more interesting.

Even with a low-energy level, we may be able to concentrate on a particular activity. Meditation and contemplation are examples of concentration at a low-energy level. Also creative and associative thinking can be done at low-energy levels (e.g., due to sleep loss). However, this type of processing is only possible under optimal conditions, since the operator is very sensitive to distraction, such as interruptions and negative thoughts. Therefore, the task has to be interesting and the environment stimulating but stable (no unexpected events). Moreover, it certainly helps to work in a team, to receive regularly feedback on your performance, and high rewards for good results. Last but not least, one should be inherently motivated to do the job (enjoying the work and confident about the goal). Thus, working at a low expenditure level is possible, but only for a limited number of activities and under optimal conditions. This explains why in some tasks (monotonous vigilance and continuous reaction tasks) performance already deteriorates within 30 minutes, whereas in daily life people are able to remain focused for hours: for example, working on a paper, or driving in eight hours to a holiday resort after a day’s work (not to be recommended though).

**Intensity and Specificity**

When you concentrate on a difficult task, both attention and energy not only increase in intensity, but also in *specificity*. Thus, enhanced concentration does not mean that the operator pays more attention to everything in the environment and that all parts of the brain are activated. Attention is directed towards the relevant elements of the task and on realizing the goal specified in the task set.

The mobilization of energy is also specific; it is elicited by the task demands or by mental effort. Only those parts of the brain are activated that are needed to execute the task. As can be demonstrated with brain scans, the blood flow is directed to those areas in the brain that are needed for cognitive processing (e.g., Wilson, 2003; Warm and Parasuraman, 2007). This is in line with the idea that there is an optimal energetical state for every task, which implies that not every type of energy mobilization is appropriate for the performance of a particular task (Hancock and Weaver, 2003; Hancock and Szalma, Chapter 1, this volume; Hockey, Coles and Gaillard, 1986; Gaillard, 2001). For example, when you wake up because your house is on fire, you become highly activated within a short period. This results in a state appropriate to flee out of the house, but certainly is not adequate to write a difficult report.

As was discussed earlier, effort is regarded as a try-harder response, which attempts to compensate for any deviation from an optimal state, which endangers the proper performance of the task. Deviations may occur (see also Figure 4.2) because the energy level is too low, due to fatigue or to the task is not stimulating; for example, working in monotony or work you do not like. In the present framework it is assumed that effort not only compensates for a too low-energy level, but also for concentration problems (neutralizing negative emotions and thoughts, keeping the task set in the focus of our attention), or for disruptions in our energetical state due to threat or stress. In all situations, effort must prevent disengagement from the task and distraction of our attention to other activities that do not contribute to the realization of the current goal.
Concentration, Stress and Performance

Concentration and the Inverted U-Curve

In the classical one-dimensional concept of arousal energy mobilization and emotions are not seen as separate processes. In human performance research, increases in task demands are assumed to enhance the level of activation, either directly by task execution or via effort. However, studies on the relation between activation and performance efficiency have revealed ambiguous and contradictory results (e.g., Eysenck, 1982). Reliable results are found only at the extremes. Performance is reduced either because the energy level is too low, due to sleep loss or fatigue, or too high, due to anxiety or stress. The relation between the energetical state and performance efficiency is often assumed to be an inverted U-shaped curve (see also Hebb, 1955). So far the U-curve hypothesis has received scant empirical support, and a number of methodological problems have been raised against this type of research (e.g., Neiss, 1988; Hancock and Weaver, 2003). It has been questioned whether the inverted-U is a co-relational or a causal relation. It is quite possible that a reduction in performance efficiency and high activation is affected by a third factor. High levels of arousal are often accompanied by intense emotions, which not only enhance the energy level but also deteriorate directed attention. Events or manipulations, either in the laboratory or in daily-life that enhance the level of activation, may at the same time elicit emotions and distractions, which both reduce processing capacity and performance efficiency (see also Näätänen, 1973). Secondly, there is no agreement among researchers on how to determine objectively the different levels of activation. A third problem is that (one-dimensional) activation theories do not discriminate between different types of energy mobilization and do not specify the effects on emotional and cognitive processes, and the consequences this may have for the working behavior of the operator. As a result, arousal theories are not able to explain why under some conditions efficient performance is possible even with high levels of activation, whereas debilitating states that degrade performance may also occur at medium or low levels of activation. It appears that negative emotions can reduce performance efficiency, at all levels of activation (Gaillard, 2001).

The concentration model offers a framework in which these problems can be discussed. The current model is not necessarily contradictory with the notion of the inverted U-curve. It may be regarded as an extension of the U-curve. The two models diverge at the medium level where the U-curve bends downwards and performance efficiency is degraded due to the influence of negative emotions ending in a panic situation. In the current framework, however, efficiency may still increase with more energy mobilization as long as the mood of the operator remains positive. Thus, enhanced concentration may lead to the flow state resulting in enhanced efficiency. It is assumed that under optimal conditions, it is possible to mobilize a large amount of energy that enables operators to allocate all their processing capacity to the task. Thus, you can never have too much energy, as long as it is functional for the execution of the task.

This issue also has been discussed in the stress literature. It has been assumed that each form of overreactivity due to a high work load, would elicit too much sympathetic activity (mostly adrenaline) that has aversive effects on well being and health (Frankenhaeuser, 1986). However, it can be argued that overreactivity is not caused by the amount of work, but by negative emotions evoked by detrimental psychosocial determinants in the work environment (Karasek and Theorell, 1990). Moreover, it still has to be demonstrated why the enhanced physiological activation due to cognitive overload is bad, and jogging is supposed to be healthy (Gaillard, 2001).

Thus, the nature of the relationship between energy mobilization and performance efficiency appears to depend on the type of energy. It tends to be curvilinear, when evoked by negative emotions and linear when generated by the task or via mental effort. This leads to the subsequent question: what characteristics in the work environment lead to positive and which elicit negative effects on performance and well-being. Research on the influence of organizational and psychosocial
determinants shows that in a beneficial work environment operators regard the work demands as a challenge, prefer active coping strategies, and have a high job satisfaction and low health risks. When the models on work stress of various researchers (Frankenhaeuser, 1986; Karasek and Theorell, 1990; Csikszentmihalyi, 2003; Hockey, 2003) are compared (see Gaillard, 2001) a general picture emerges that may be relevant for the present discussion. In an optimal work environment a balance exists between positive (e.g., autonomy, rewards, and support) and negative factors (time pressure, fatigue, and stress). If the balance is positive, people can work under a high work load, with satisfaction and without adverse health effects. If the balance is negative, operators will react with negative emotions, strain, resulting in poor functioning and increased health risks. The positive state (flow in Figure 4.2) is characterized by efficiency, skillfulness, high control, engagement, and satisfaction; the negative state (stress in Figure 4.2) is characterized by low control, disengagement, and the underutilization of the operator’s skills and cognitive abilities. The work is threatening rather than challenging. The combination of high demands and low control results in strain, low efficiency and negative emotions, whereas high demands and high control lead to energy mobilization, active behavior and efficient performance. Thus, a high level of activation is not always accompanied by a reduction in performance efficiency, which implies that there are different patterns of reactivity to work demands that have different consequences for performance, well-being, and health.

Positive and Negative Energy

Whether operators are able to function efficiently and effectively under demanding conditions (e.g., information overload, time pressure, fatigue, and threat) is not only dependent on the amount of strain these conditions evoke, but also on the quality of the positive factors in the work environment (challenging environment, inherent motivation, engagement, and team awareness). Under normal conditions there is a balance between the factors in the work environment that generate positive energy and those that generate negative energy. As is illustrated in Figure 4.3 the factors that increase our resources are different from the factors that inhibit the proper use of resources. However, the compensation of negative factors by positive energy is not always effective. In a poor and unhealthy work environment, people will not work optimally, even when they receive a high salary.

Recent views on stress assume that the effects of work demands are dependent on the balance between positive and negative factors at work, which have been called inhibitors and energizers respectively (Gaillard, 2003b). Inhibitors refer to the cognitive, emotional and physical demands of the work, whereas energizers refer to the organizational and psychosocial characteristics of the work environment. Figure 4.3 illustrates how the level of concentration is determined by the balance between factors that motivate and generate positive energy, and factors that distort energy mobilization and the direction of our attention. Thus, complaints about cognitive overload may not always be caused by a shortage of cognitive capacity, but by a lack of motivation or by distortion of the concentration process due to distraction, fatigue, and stress.

When operators have to work under demanding conditions this balance may be distorted. To accommodate complaints about excessive work demands, one should not only examine whether the demands may be lowered, but also consider to improve the characteristics of the work environment that generate positive energy, and therefore increase the readiness to put effort in the task and to keep concentrated on the task goal.
Motivation
- rewards
- feedback
- social control
- interesting work
- stimulating environment

Distraction
- interruptions
- drawbacks
- other plans
- other goals
- other motives

Fatigue
- time-on-task/-at-work
- time-since-awake
- time of day
- fitness
- boring task
- monotonous environment

Stress
- time pressure
- unpredictability
- ambiguity
- conflicts
- loss of control
- threat

Concentration

effort

= inhibitors

Figure 4.3 The level of concentration is determined by the balance between factors that motivate and generate positive energy, and factors such as distraction, fatigue, and stress that inhibit or distort energy mobilization and attention

Performance Protection

Measures to augment or protect performance should be based not only on the cognitive abilities of the operator, but also on the operator’s motivation, readiness to mobilize energy, and the ability to remain concentrated; that is the ability to maintain the focus of attention on task-relevant cues. In demanding and threatening situations this may imply tolerating negative feelings and sustaining a hard time, and giving short-term goals.

In perspective of the current framework the following measures appear worthwhile to pursue: Increase the resources of the operator by generating positive energy. This can be done by making the task more interesting and the environment more stimulating, through feedback, rewards and teamwork, which enhance motivation, and therefore intent and cognitive readiness. Find ways in which the available resources can be used more efficiently and effectively by time management, IT support and task allocation (between operator and computer, or between team members). Reduce factors that are distracting, disrupt an optimal state, and inhibit the mobilization of resources. Protect the performance against the adverse effects of stress and fatigue by improving the psychosocial determinants of the work environment through coaching, feedback, and social support. Train operators to be resistant against the influence of distraction and negative emotions. To remain fit and motivated in the long run, operators should have sufficient rest and sleep. Recovery is not a luxury but a prerequisite to be able to meet the work demands under adverse conditions. On the basis of the “high tech, high touch” principle, high demands should be compensated with intensive care. Although some people feel this to be contradictory, there is no paradox between posing high demands during work and pampering operators after work.
References


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Chapter 5

Remote Command and Control, Trust, Stress, and Soldier Performance

Kip Smith

Abstract

In his book *Men Against Fire*, Marshall (1947) told the history of the impact of organizational structure and leadership style on soldier performance. One of his villains was the organizational structure known today as “remote command and control”. Marshall reported that soldiers found it stressful to obey orders from an unknown and remote leader. Soldiers were also less likely to complete a command issued by a remote leader than by a collocated leader. These findings are fully consistent with Social Impact Theory which holds that the impact of a source (e.g., a platoon leader) on an individual (e.g., an infantryman) is a function of the perceived immediacy (proximity) of the source.

We have conducted a series of four experiments using live but non-lethal fire to assess both Marshall’s claim about the impact of remote command and control and the prediction of Social Impact Theory on the impact of immediacy on soldier performance. Participants, whether active duty troops or civilian volunteers playing the role of soldier, completed oral commands more quickly when collocated with an unfamiliar leader than when that leader was sheltered at a remote location. Further, a questionnaire on trust in the leader revealed greater levels of trust in the collocated condition. The best-fit linear regression function reveals a significant positive association between self-reported levels of trust and response time, our measure of performance. We conclude from these results that Marshall was prescient: 1) remote command and control may indeed be a source of stress associated with a decrement in soldier performance and 2) at least a portion of this decrement is associated with a decrement in trust. Thus, trust appears to mediate the impact of immediacy. These findings support arguments against plans to remove the platoon leader from the platoon specifically and against remote command and control of the dismounted infantry generally.

Introduction

The armed forces of the United States and Sweden are planning to change the organization and training of the dismounted infantry in a fundamental way. One of the cornerstones of their independently-derived but similar plans is a reliance on remote command and control. With the advent of “Network-based defense”, fire teams may no longer receive orders in battle from a leader within visual range. Instead, their only connection with their commanding officers may be their radios and other portable information devices. Fire teams may receive orders from a remote leader or a group of leaders.

Remote command and control is a structure for distributed work in patently hierarchical organizations like the military. The leader or a group of leaders (officers) sits out of harm’s way
in a control center. The work teams (platoons of infantrymen) find themselves in geographically remote and potentially hostile locations. One advantage of remote command and control is that it makes it relatively easy to change leaders as the situation facing the team evolves (Brehmer, 1992). This is critical to the military because modern urban warfare is highly dynamic and rarely predictable. After all, “Stuff happens” (D. Rumsfeld, April 12, 2003). The environmental complexity and uncertainty of urban warfare and the criticality of the leader’s decisions are often cited as the major desiderata for adopting remote, rather than collocated, command and control (Adelson, 1961; Brehmer and Sundin, 2000). In addition, modern command and control centers are designed to give the leader(s) access to multiple sources of information that are not routinely available on the battlefield (Friman, 2000; Hébert, 2003). The centralization of decision making and of the flow of information facilitates the selective deployment of limited resources and speeds the cycle of decision making.

One implication of the proposed organizational change is that soldiers may not take the field with their (remote) leader. In the language of Social Impact Theory (Latané, 1981; Sedikides and Jackson, 1990; Latané et al., 1995), remote command and control should substantially reduce the impact of immediacy. Social Impact Theory maintains that the influence experienced by a target (the soldier) is an inverse function of the distance (immediacy) to the influencing source (the leader). Like a light bulb, a source has its greatest influence when it is close to its target. Social Impact Theory would predict that remote command and control should reduce the immediacy (both psychological and proximal) and impact of the leader on the soldier.

This theoretical argument against remote command and control is supported by the accounts of the military historian S.L.A. Marshall (1947). During the Second World War, Marshall was given free rein by the US Army to observe soldiers and officers in battle and to debrief them. He recounts tales of officers failing to exercise command because they failed to join force with their troops. He says:

Control is not to be considered as synonymous with the voice of authority. Control is a man-to-man force of the battlefield (Marshall, 1947: 148).

In Marshall’s account, an officer exercises control man-to-man, face-to-face. In the language of Social Impact Theory, immediacy matters. Marshall goes on to tell stories of officers who faded to the rear, out of harm’s way and who, as a direct result, lost control of their troops. These remote leaders often maintained radio contact but their platoons failed to hold the line or to advance because the soldiers were under fire and were unwilling to obey a leader they could not see or psychologically feel:

I hold it to be one of the simplest truths of war that the thing which enables an infantry soldier to keep going with his weapons is the near presence or the presumed presence of a comrade…. The other man may be almost beyond hailing or seeing distance, but he must be there somewhere within a man’s consciousness or the onset of demoralization is almost immediate and very quickly the mind begins to despair or turns to thoughts of escape…. It is far more than a question of the soldier’s need of physical support from other men. He must have at least some feeling of spiritual unity with them if he is to do an efficient job of moving and fighting…. It is that way with any fighting man. He is sustained by his fellows primarily and by his weapons secondarily (Marshall, 1947: 42–43).

As a result, remote command and control could become a recipe for demoralization:

Social pressure, more than military training, is the base of battle discipline, and when social pressure is lifted, battle discipline disintegrates (Marshall, 1947: 149).
Following Marshall and Social Impact Theory, the hypothesis that drives this research claims that a collocated leader is a stronger source of the requisite social pressure than a remote leader. As a result, a soldier will perform better when receiving commands from a collocated leader than a remote leader. The proposed mechanism for the hypothesized improvement in soldier performance is trust in the leader. Trust is predicted to mediate the impact of immediacy.

Trust is the willingness of one party to be vulnerable to the actions of another based upon positive expectations of the other’s behavior (Rousseau et al., 1998). The critical elements for its formation are reciprocal vulnerability and interdependence (Berg, Dickhaut and McCabe, 1995; McAllister, 1995; Meyerson, Weick and Kramer, 1996; Hoffman, McCabe and Smith, 1998). Where there is no interdependence and no vulnerability, levels of trust are likely to be low (Jones and George, 1998).

Remote command and control removes the leader from the field of fire. In contrast, a collocated leader assumes the same risk as the soldier. A collocated leader and soldier are reciprocally vulnerable and interdependent. A tacit awareness of these factors is proposed to be the foundation for the generation of trust in a collocated leader that is absent under remote command and control. By this account, retreating out of harm’s way removes the foundation for the formation or maintenance of trust.

Our experiments replicate an extreme realization of network-based defense: participants did not know the leader and had insufficient time to become familiar with the leader and to develop mutual trust (e.g., McAllister, 1995; Meyerson, Weick and Kramer, 1996). In the collocated condition, the leader and the soldier were both under fire. In the remote condition, only the soldier was under fire. The issue to be tested is whether we can observe and explain the disintegration of battle discipline seen by Marshall.

While the inferred benefits of collocation have been documented in a wide range of relatively sedentary work environments (e.g., Monge et al., 1985; Kiesler and Cummings, 2002), the utility of leader presence to the efficient operation of a military command and control system has yet to be documented. To that end, we conducted a series of four experiments that manipulated leader presence and the mode of communication in an ecologically realistic but ethically acceptable simulation of live fire.

The basic paradigm was the same in all four experiments, a repeated measures design with two or three conditions that manipulate leader presence. The second experiment tested the generality of the effect for leader presence found in the first experiment. The third eliminated some of the confounds present in the first two, and the fourth eliminated the confounds that remained in the third. Accordingly, a secondary theme of this chapter is the incremental nature of exploratory, situated research and the struggle to control potentially spurious factors.

The first and second experiments contrasted two conditions of leader presence (collocated vs. remote) to address the issue of whether individuals working with a collocated leader are faster to respond to verbal commands than when working with a remote leader. The third experiment introduced a third condition (collocated with a radio) to disambiguate the effects of leader presence (immediacy) and communication mode. The fourth experiment introduced a condition with a distracting stimulus to disambiguate demand characteristics from the effect of leader presence. The fourth experiment also administered a questionnaire on trust in the leader to assess the mediating influence of trust on soldier performance.
Experiment 1

Method

The dilemma we faced as experimenters was to create an experimental setting that simultaneously captured much of the look and feel of the battlefield and met the relevant standards for the ethical treatment of human subjects. The technology that made it palatable to run an experiment that exposed our participants to live fire is called paintball.

Paintball is a game that people of college age, mostly but not exclusively male, choose to play for fun. The source of fun is shooting non-lethal projectiles at your friends while trying to avoid being shot by them. Players (are required to) wear protective clothing and face masks. Concerns about allowing our participants to shoot each other were disarmed by the facts that 1) paintball is a pastime for the participants’ peer group, 2) we provided all participants with protective gear, and 3) a registered nurse was on site throughout the experiments. All participants signed informed consent forms and were treated in accordance with the standards set by the ethical review board of Kansas State University.

The purpose of the live paintball fire was to generate some anxiety so that the measures would more readily generalize to the battlefield. The major sources of stress were the fear of being shot and actually being hit by paintballs. The pain associated with being struck by a paintball is transient but real. Protective gear minimized the risk of injury. None of our participants received more than a few small bruises.

Participants

Twenty volunteers from Kansas State University (2 women, 18 men; median age 19, range 18–28) participated in Experiment 1. All were citizens of the United States. None had military or Reserve Office Training Corps (ROTC) experience.

Experimental setting and apparatus

Layout The assault lane and its layout, sketched in Figure 5.1, are based upon a training paradigm used extensively by the US Army. Figure 5.1 and all other figures can be found at the end of the chapter. The lane was delineated by eight staggered protective barriers, four on each side. A small cup containing five paintballs was placed behind each barrier. A protective wall containing two horizontal slots (0.5 m long by 0.2 m high) at shoulder height stood at the far end of the lane. The wall formed the sniper’s bunker. The slots allowed the sniper to shoot at (and be shot by) the soldier. Five targets, 1.5 liter plastic bottles filled with colored water, four red and one blue, were placed in random order in a row on a table directly in front of the slots in the sniper’s bunker.

The US Army provided access to a heated 25 × 200 ft (9 × 61 m) building at Range 52, Fort Riley, Kansas. Fort Riley is the home of the 1st Infantry and is an active training center for artillery. We set up our paintball assault lane in this building on several Saturdays.

Munitions The paintball rifle was the armament used in the experiment. Ammunition consisted of varicolored paintballs. Participants, both the soldier and the sniper, were issued protective clothing consisting of a face shield, knee pads, elbow pads, and coveralls.
Design

Experiment 1 used two conditions of leader presence in a repeated measures design to test the effect of leader presence on the response times to verbal orders. In the collocated condition, the leader was present in the assault lane one barrier behind the participant playing the role of soldier. The collocated leader issued verbal orders to the soldier directly, that is, in a normal speaking voice. In the remote condition, the leader stood outside the building where he could see but could not be seen by both the soldier and the sniper. By necessity, communication in the remote condition was mediated. The equipment used were walkie-talkies purchased at a local electronics supply store.

There were two types of orders, to move (advance to the next barrier in the lane) and to shoot (at the targets in front of the sniper’s bunker) in both conditions. The sequence of conditions, collocated and remote, was randomly assigned across participants. An equal number of participants was assigned to the two sequences of conditions.

Tasks

Soldier  Every participant played two roles, soldier and sniper, in random order. The task when playing the role of soldier was to move forward from barrier to barrier and to fire at the targets upon receiving orders to do so. Each participant completed the mission two times in the role of soldier. As far as the soldier’s mission was concerned, the collocated and remote trials were identical. The only difference was in how the orders were delivered and received.

Sniper  A second participant acted as the sniper. The sniper’s task was to shoot the soldier, that is, to instill anxiety and to slow his or her advance up the assault lane. The opportunity to play the role of sniper was a major inducement to participation.

The sniper’s bunker consisted of a protective wall at the end of the assault lane. The wall contained two slots that provided a clear view of the lane and insured that a soldier who was not crouching behind a barrier would be exposed to the possibility of sniper fire. The sniper was directed by the leader in the presence of the soldier to pause briefly when moving from one of the slots in the wall to the other. The reason for directing the sniper to move slowly between the slots was to give the leader grounds for judging when it would relatively safe for the soldier to move and to shoot. The leader asked both the soldier and the sniper to explain the implications of these instructions before the first trial started. The sniper was then issued 40 paintballs and asked to take a position behind the protective wall.

Leader  A research assistant who was also an army officer played the role of leader in every session and condition throughout the experiment. The leader wore a standard battle-dress uniform and issued verbal orders to the participant playing the role of soldier. The actual words used to issue the orders were “Move!” and “Fire!” The timing of these orders was based upon the position of the sniper and the leader’s judgment.

Procedure

Participants met in groups of four to six at the entrance to the library on the campus of Kansas State University where they were given informed consent forms which they were asked to read and sign. The consent form advised them about the possibility of incurring some pain, the need to shoot paintballs at another person, and the fact that the research was supported by the Army Research Office of the United States of America. Both the driver and the consent form encouraged the
participants to ask questions. Upon signing the consent forms, participants entered the university vehicle and were driven to Fort Riley. A one-way trip took 45 minutes and required passing through a security gate and a variety of active firing range complexes. All told, the experiment took at least four hours of the participants’ time.

On arrival at the assault lane, participants were met by the nurse who gave them a paper copy of the mission brief reproduced as Appendix 1 and answered their questions. The mission brief describes a fictitious scenario that provided the background for the task they would be asked to perform. The nurse, who never had to tend to a participant, was a valued member of the experimental team. She issued protective coveralls, a facemask, knee pads, and elbow pads and gave instructions on the use and safety features of the paintball rifles.

Participants then met their (male) leader for the first time. The leader told them he would be giving them two types of orders, 1) to advance up the assault lane from one barrier to the next and 2) to shoot at the targets in front of the sniper’s bunker. He instructed them to obey all orders as quickly as possible. The leader told the participants that they would be running the course twice in the role of soldier. A series of coin tosses was used to determine the sequence in which the participants played the roles of soldier and sniper.

Participants playing the role of soldier were sent down the lane individually. The soldier’s initial position was behind the barrier furthest from the sniper. After loading his or her rifle with the five paintballs from the small cup located behind the barrier, the soldier informed the leader, either by voice or by radio, that the rifle was “loaded.” On the leader’s order “Fire!”, the soldier attempted to knock down the four red (hostile) targets on the table in front of the sniper’s bunker without hitting the blue (friendly) target. When out of ammunition, the soldier informed the leader that the rifle was “out of ammo.” On the leader’s order “Move!”, the soldier advanced to the next protective barrier on the other side of the lane. The cycle was repeated at each of the eight barriers. The 40 paintballs, 5 at each barrier, were the soldier’s only ammunition. Whenever the participants took aim at the targets or moved between barriers, they risked exposure to the sniper’s fire.

In the collocated condition, the leader remained one barrier behind the participant playing the role of soldier and communicated in a normal speaking voice. In the remote condition, the leader went outside the building and observed the action through one of the many windows that lined both long sides of the building. The only contact between the leader and the soldier in the remote condition was by radio. The order of conditions was randomized across participants yielding two groups, a collocated-first group and a remote-first group.

Dependent measures

The purpose of the red and blue targets was to give structure to the mission and the soldier something to do. Measures of shooting accuracy revealed more about the participant’s familiarity with firearms than about leader presence and are not discussed further.

The dependent variable was the time it took for the soldier to obey an order from the leader as measured by a hand-held stop watch. Several research assistants served as timekeepers. The same researcher kept time in both trials for a given participant. Any errors associated with fallible operation of the stopwatch are assumed to be randomly distributed within and across participants.

The timekeeper was given a radio and hid (from the sniper’s fire) where he or she could hear the leader issuing orders and see when the soldier complied. The criterion for completion differed across the two types of orders. For an order to fire, the time interval ended when the soldier first opened fire. For the order to move, the time interval ended with the soldier came to a full, controlled stop behind the next barrier. Procedures for coming to a controlled stop varied across participants. The within-subjects design controlled this inter-participant variability.
Results

**Move times**  Figure 5.2 is a graph of the means and standard errors of response time to the command to move for both sequences of data acquisition. The open symbols show the data for the remote-first group. This group responded more slowly in the first trial when the leader was hidden outside the building than in the second trial when the leader was present in the lane. The closed circles, representing the collocated-first group, show that this group responded more quickly in the first trial, again when the leader was present in the lane.

A two-factor mixed-effects repeated-measures ANOVA was conducted to assess the significance of the manipulation of leader presence and the possibility of sequence effects. The sequence of data acquisition (collocated-first, remote-first) was the blocking variable at two levels. The repeated measure was the two conditions of leader presence. Neither sequence, $F_{(1, 18)} = 0.12, p > .73$, nor the interaction of participant-within-sequence and condition, $F_{(1, 18)} = 0.407, p > .53$, was significant. As expected, leader presence was significant, $F_{(1, 18)} = 8.48, p < .01$, power = .16. This result suggests that the manipulation of leader presence influenced the speed with which participants responded to commands to move.

**Fire times**  Figure 5.3 presents the corresponding graph for response times to the command to fire. The pattern of results is the same: both groups of participants responded more quickly when collocated with the leader. Once again, the repeated-measures ANOVA found that neither the sequence of data acquisition, $F_{(1, 18)} = 0.78, p > .79$, nor the interaction of sequence and leader presence, $F_{(1, 18)} = 0.78, p > .38$, was significant. As expected, the manipulation of leader presence was significant, $F_{(1, 18)} = 5.31, p < .04$, power = .14. These results suggest that leader presence influenced response times to commands to shoot.

Discussion

In line with Social Impact Theory, we hypothesized that response times to verbal orders would be faster when the order was given by a collocated leader than by a remote leader. The data from Experiment 1 support this hypothesis.

The data are also consistent with an alternative hypothesis concerning the experimental procedure and setting. In the remote condition, the leader was outside the building and looked through its windows to determine when it would be relatively safe for participants playing the role of soldier to move and to shoot. The participants knew this. It is possible that the participants thought that the leader’s external viewpoint deprived him of information that might be critically relevant to the timing of commands and, hence, to their own safety. By this hypothesis, the data showing an advantage for leader presence may merely reflect participants’ doubts occasioned by the experimental setting. Experiment 2 was designed to test this alternative hypothesis.

**Experiment 2**

To test the generality of the result from Experiment 1 and the alternative hypothesis concerning the completeness of information available to the remote leader, we moved the second experiment to an outdoors venue on-campus. The move had the secondary benefit of substantially reducing the travel time for participants.
Method

The method used in Experiment 2 largely replicated that used in Experiment 1. This section focuses on the differences in the setting and procedure between the experiments. An assault lane identical to that used in Experiment 1 was set up adjacent to a complex of dormitories in a grassy meadow between two lines of mature elms. The outdoor setting was the only difference in the layout of the lane.

The absence of walls made the remote condition less remote. In Experiment 1, the wall of the building kept the remote leader completely out of sight. This relative invisibility may have led participants to doubt his ability to act in their best interest when issuing orders to move and to shoot. To assuage this source of doubt in Experiment 2, the remote leader hid behind a tree approximately 30 feet (9 m) behind the lane. Not only could the remote leader see and hear the lane without impediment, it was possible for the participant to turn around and, on occasion, see the remote leader.

Participants

The experiment was conducted on sunny Saturdays and invariably drew a crowd of students. Some, but far from all, of the onlookers were eager to participate. Participants came from this self-selected sample of convenience. The public forum served our purpose well by ensuring that our participants were fully informed of the nominal risks posed by live paintball fire.

Twenty-two students from Kansas State University (3 women, 19 men; median age 19, range 18–26) participated in Experiment 2. As in Experiment 1, all were citizens of the United States and none had military or Reserve Office Training Corps (ROTC) experience. All three women and several of the men called themselves hunters and owned rifles. All participants signed informed consent forms and were treated in accord with the standards set by the ethical review board of Kansas State University.

Procedure

Participants tended to volunteer in groups of two to four. They were met at a registration table by the nurse who gave them the informed consent form and the mission brief, answered their questions, instructed them on the use and safety features of paintball rifles, and scheduled their times for participation. At the assigned times, participants were issued protective coveralls, a facemask, knee pads, and elbow pads. They then met their (male) leader for the first time. The leader briefed them on the tasks of soldier and sniper. A series of coin tosses was used to determine the sequence in which the participants played the roles of soldier and sniper.

Results

Move Times

The graph of Figure 5.4 shows the means and standard errors of response time to the command to move for both sequences of data acquisition in Experiment 2. The remote-first group, represented by the open circles, responded more quickly to commands to move in the second trial when the leader was present in the assault lane. It appears that the transition to a collocated leader and being spoken to face-to-face by a leader exposed to live fire improved the performance of participants in the remote-first group. In contrast, the performance of participants in the collocated-first group, shown by the solid circles, got no worse when taking orders from the remote leader.
The two-factor mixed-effects repeated-measures ANOVA found no effect of sequence (remote-first vs. collocated-first) on move time, $F_{(1, 20)} = 2.19, p > .15$. The interaction of sequence with condition, $F_{(1, 20)} = 4.32, p < .06$, was pragmatically significant. Thus, there may be a beneficial carry-over effect of previous experience with a collocated leader. As expected, the manipulation of leader presence reveals a differential effect of leader presence, $F_{(1, 20)} = 9.07, p < .01$, power = 0.53.

**Fire Times** Figure 5.5 shows the response time data for the command to shoot in Experiment 2. Open symbols represent the remote-first group and solid symbols the collocated-first group. Once again, both groups responded more quickly to commands to shoot when collocated with the leader in the assault lane. The ANOVA for fire times indicates no effect of sequence, $F_{(1, 20)} = 2.68, p > .69$, no significant interaction of sequence with condition, $F_{(1, 20)} = 0.91, p > .35$, and a significant effect of leader presence, $F_{(1, 20)} = 5.26, p < .04$, power = 0.15. As expected, leader presence made a significant difference in the speed with which participants obeyed commands to shoot.

**Discussion**

These results replicate those from Experiment 1 and support our hypothesis that participants will be faster to obey verbal orders from a leader when collocated with the leader than when the leader is in a remote location. The difference in the degree of remoteness of the remote condition across the two experiments had a negligible effect on participant performance. Accordingly, the data fail to support the alternative hypothesis that the experimental setting of Experiment 1 induced the delay in response times in the remote condition. The delay, or hesitation, is present even when there was no wall separating the remote leader from the participant playing the role of soldier. The hesitation occurred when participants were asked to expose themselves to live paintball fire under conditions simulating remote command and control.

Experiments 1 and 2 reveal that commands are obeyed more rapidly when issued by a collocated leader speaking face-to-face than when issued by a remote leader who uses a radio. These two conditions leave unanswered the question of whether the observed hesitation is due to immediacy or to the use of mediated communication. Experiment 3 introduced a third experimental condition that eliminated the confound of communication mode and directly tested these competing hypotheses.

**Experiment 3**

**Method**

Experiment 3 added a third condition, the collocated-with-radio condition, to disambiguate the effects of leader presence and communication mode. In this new “radio” condition, the leader was collocated in the assault lane and used a radio to communicate with the participant playing the role of soldier. If leader presence is the major source of the observed differences in response times seen in the first two experiments, then performance in the remote condition should be slower than in both the collocated and radio conditions. Further, performance in the collocated and radio conditions should be approximately the same. In contrast, if the differences are due to mediated communication, then performance in the collocated condition should be faster than in both the remote and radio conditions and performance in the radio condition should be similar to that in the remote condition.

Note that it makes no sense to stage the complementary fourth condition (a remote leader who speaks face-to-face). This fundamental constraint on distributed work precludes a fully crossed
design with two levels of leader presence and two levels of communication mode. The procedure in the assault lane differed from the previous experiments in two ways: the experiment was conducted in Swedish and participants ran the lane three times.

Participants

Eighteen volunteers participated in Experiment 3 (7 women, 11 men; median age 24, range 20–31). Most were students of nursing or were associated with the Department of Cognitive Science at the Högskolan (college) in Skövde, Sweden.

This sample differs in several respects from those in the first two experiments. The participants were all Scandinavian (15 Swedes, 2 Icelanders, and 1 Norwegian) and were older than their American counterparts. All but four had hunted game and owned rifles. Six had military experience of either 10 or 24 months. All participants read and signed an informed consent form approved by the Human Subjects Committee of Linköping University.

Layout

The experiment was conducted indoors at a commercial paintball facility in Tidan, near Skövde, Sweden. The layout of the assault lane was essentially identical to that sketched in Figure 5.1 but the dimensions of the lane were slightly larger and the barriers far more robust. The assault lane was delineated by eight large (2.5 m long by 1.5 m high) inflatable protective barriers, four on each side, 8 m apart. As before, a small cup containing five paintballs was placed behind each barrier. A protective wall containing two horizontal slots (0.5 m long by 0.2 m high) at shoulder height stood at the far end of the lane and formed the sniper’s bunker. A table made of shipping pallets was placed directly in front of the slots in the sniper’s bunker. Five targets, 1.5 liter plastic bottles filled with colored water, four red and one blue, were placed in random order in a row on the table.

An observation room above and behind the assault lane contained two screened windows that provided a commanding view of the lane, the soldier, and the sniper below. The time-keeper and the leader in the remote condition stood in this room away from the windows to avoid being inadvertently seen by the participant playing the role of soldier.

Design

There were three conditions of leader presence in a repeated-measures design. The remote and collocated conditions replicated those in Experiments 1 and 2. In the radio condition, the leader was present in the assault lane one barrier behind the soldier and used a radio to issue orders. Three of the six possible sequences of the three conditions (collocated first, radio, remote; radio first, collocated, remote; and remote first, collocated, radio) were used to collect data. Six participants were randomly assigned to each sequence. As in the previous experiments, there were two types of orders, to move (advance to the next barrier in the lane) and to shoot (at the targets in front of the sniper’s bunker).

Tasks

Soldier Every participant played two roles, soldier and sniper, in random order. Each participant completed the mission three times in the role of soldier. In the radio and remote conditions, the soldier used a radio equipped with a headset to communicate verbally with the leader.
Sniper A second participant acted as the sniper. The sniper was issued 40 paintballs. The sniper’s task was to shoot the soldier, that is, to instill anxiety in the soldier and to slow his or her advance up the assault lane.

Leader Three different officers from the military garrison in Skövde played the role of leader. These officers, all male, were dressed in military fatigues and had a military bearing. The leader issued verbal orders to the participant playing the role of soldier in Swedish. The orders that were given in all three conditions were “Eld!” (“Fire!”) and “Framåt” (“Advance”).

Having officers serve as leaders eliminated one of the confounds in the first two experiments. In those experiments, the role of leader was played by a research assistant with a keen interest in the hypothesis and the results. Thus, one of the experimenters played an active role in the creation of critical stimuli. It is possible that the assistant / leader may have unintentionally modulated the commands in a way that might have influenced the participants’ behavior. In Experiment 3, the leader had no stake in the hypotheses or the results, reducing the likelihood of this form of experimenter bias.

Procedure Participants were picked up in groups of three at the University of Skövde and given an informed consent form which they were asked to read and sign. The consent form advised them, in Swedish, about the possibility of incurring some pain, the need to shoot paintballs at another person, the fact that the research was supported by the Army Research Office of the United States of America, and encouraged them to ask questions. They were then taken by car to the indoor paintball arena in Tidan. During the 20 minute ride, they were given and asked to read a paper copy of the Swedish translation of the mission brief included in Appendix 1.

On arrival in the paintball arena, the participants were issued protective coveralls and a facemask. A member of the club that runs the arena instructed them on the use and safety features of paintball rifles. Participants then met their leader for the first time. The leader told the participants in Swedish that he would be giving them two types of orders and to obey all orders as quickly as possible. All other aspects of the procedure were identical to those in the first two experiments. All participants read and signed an informed consent form alerting them to the dangers of paintball impacts.

Dependent measures The dependent variable was the time it took for the soldier to obey an order from the leader. In a series of pre-trials, we attempted to use two goniometers (strain gauges), one attached to the leader’s right index finger and the other to the soldier’s right index (trigger) finger, to obtain data on when orders were issued and when they were obeyed, respectively. This idea was scrapped almost immediately when the goniometer attached to the second soldier in the test did not survive a high-velocity encounter with a paintball. We retreated to more reliable equipment, the hand-held stop watch. Research assistants were the timekeepers throughout the experiment.

Results Two-factor mixed-effects repeated-measures ANOVA were calculated for both the move time and fire time data. The blocking variable was the three sequences of data acquisition (e.g., collocated first, radio, remote); the repeated measure was the three conditions of leader presence.
**Move times**  Figure 5.6 is a graph showing the mean and standard errors for response times to the command to move for the three conditions of leader presence. Participants took appreciably longer to respond to the leader’s command to move in the remote condition. The ANOVA revealed no effect of sequence of data acquisition, $F_{(2, 15)} = .06, p > .55$, and no interaction of sequence and condition, $F_{(4, 30)} = 0.23, p > .18$. As expected, the main effect for leader presence was significant, $F_{(2, 30)} = 4.37, p < .03$, power = 0.28. The Turkey HSD post hoc comparison of means indicated that the remote condition differed from radio condition at alpha = 0.05 and from the collocated condition at alpha = 0.10.

**Fire times**  Figure 5.7 is the corresponding graph for fire times. Once again, participants took appreciably longer to respond to the leader’s command to fire in the remote condition. The ANOVA revealed no effect for the sequence of data acquisition, $F_{(2, 15)} = 0.61, p > .55$, and no interaction of sequence with condition, $F_{(4, 30)} = 0.73, p > .58$. The main effect for leader presence was significant, $F_{(2, 30)} = 3.35, p < .05$, power = 0.34. The Tukey HSD post hoc comparison of means indicated that the remote condition differed from both the radio and collocated conditions at alpha = 0.10.

**Discussion**

The addition of the radio condition disambiguates the effects of leader presence and mediated communication. Response times in the radio condition were statistically indistinguishable from those in the collocated condition. Using radios did not influence the participants’ willingness to obey a collocated leader’s orders. As in the first two experiments, participants playing the role of soldier responded more quickly to a collocated leader than to a remote leader. It appears that the observed hesitancy in the remote condition is due to the lack of leader presence and not to mediated communication.

Because the role of leader was taken by military officers rather than research assistants, Experiment 3 removed the potential confound of experimenter bias on the part of the leader. It did not however eliminate the potential confound associated with having research assistants record the response times. This problem was addressed in Experiment 4.

A second confound that remained in Experiment 3 was the potential for demand characteristics (Orne, 1962), contextual cues that may lead participants in an experiment to surmise what the experiment is about and, as a result, to modify their behavior. In the first three experiments, the manipulation of leader presence may have been a salient source of demand characteristics. Participants may have been able to infer that immediacy was the issue at hand. This problem was also addressed in Experiment 4.

**Experiment 4**

**Method**

Experiment 4 introduced three major changes to the experimental paradigm in order to remove the potential confounds of experimenter bias and demand characteristics. The first change was to have active duty soldiers run the experiment and record the response times. The second change was the addition of a third experimental condition with an apparatus – a buzzer – that was designed to be sufficiently salient to create the expectation that it, and not the manipulation of leader presence, was the focus of the experimental hypothesis. The rationale for the buzzer condition was that if demand characteristics were the driving force for the advantage in response time seen in the collocated
leader condition in the previous experiments, then a similar or greater advantage should be seen in the buzzer condition. The third change was the addition of a post hoc self-report instrument on trust in the leader.

**Participants** Three platoons of privates in the Swedish Army serving a voluntary term of service took part in the experiment, 52 men and 2 women. The soldiers’ age ranged from 18 to 22 years. These young people are a sample taken directly from the population to which the results are intended to generalize.

Three officers in the Swedish Army, two majors and a captain, volunteered to participate in the role of leader. The officers were not known to any of the soldiers and were not in their direct chain of command. An additional platoon of 18 privates served as confederates. Their responsibilities were to interact with the soldiers and run the experiment. They acted as time-keepers, data recorders, and the sniper. The confederates and officers were naive to the experimental hypothesis and all assumed the buzzer to be the focus of attention.

**Experimental setting** The experiment was conducted inside a 30 × 10 m hewn-timber barn on the training facility for the dismounted infantry at Kvarn, 25 km north-east of Linköping, Sweden. The assault lane was delineated by five barriers constructed from surplus materials (1.0 m wide by 1.5 m high). The down-lane distance between barriers was 5 m; the cross-lane distance was 6 m. A small cup containing five paintballs was placed behind each barrier. At the far end of the lane stood a protective wall with two horizontal slots (0.5 m long by 0.2 m high) at shoulder height. The wall formed the sniper’s hardened position. The slots allowed the sniper to shoot at (and be shot by) the soldier. Nine targets, standard-issue human-head targets (huvudmål), four red and five blue, were stapled randomly on the face of the sniper’s position. The confederates acting as time keepers stood in an observation area outside the barn where they could readily observe the soldier work his or her way up the lane.

**Design** There were three conditions of leader presence in a repeated-measures design. The remote and collocated conditions replicated those in the previous experiments with the exception that the soldier wore a military-issue vest containing a remote-controlled buzzer in all three conditions. In the collocated-leader condition, the officer was present in the lane with the soldier. The officer was under fire and, on occasion, got in harm’s way. In the remote-leader and buzzer conditions, the officer joined the time-keepers in the observation area, positioning himself so he could see but not be seen by the soldier.

The new “buzzer” condition replicated the remote-leader condition with one change. The remote-controlled buzzer package vibrated whenever the remote leader issued a command. The participant playing the role of soldier wore the package in all three conditions of the repeated-measures design but it was activated only in the buzzer condition. The buzzer package and the vest were designed to be visually and tactically salient in order to appear to be the focus of the experiment.

**Apparatus** The buzzer package had two parts, a tactile-stimulus unit and a communications unit. The communication unit consisted of two walkie-talkies, tuned to the same frequency, and a sound-activated relay. One of the walkie-talkies was the remote leader’s sending unit and the other the soldier’s receiving unit. The leader initiated a tactile stimulus by pushing the “call” button on the sending unit. This signal was received by the soldier’s walkie-talkie and sent electronically to a sound-activated relay. The receiving unit and the relay were worn on a waist belt by the soldier. The relay was, in turn, connected by wire to the tactile-stimulus unit.
The tactile stimuli were delivered by a small metal box containing an electric motor driving an eccentric cam. The stimulus was a mild buzzing rumble that lasted for 2 seconds. The box was fastened by a belt that wrapped around the shoulders and rib cage so that the box sat between the shoulder blades. The brief buzzing on the back was intended to simulate tactile communication by a collocated leader.

In all three conditions, the officer communicated with the soldier using a radio. As in the previous experiments, there were two types of orders, to move (advance to the next barrier in the lane) and to shoot (at the targets in front of the sniper’s bunker).

**Dependent measures** The behavioral variable was the time it took for the soldier to complete an order to “Move!” or “Fire!” Trust was assessed using the eight item questionnaire shown in Appendix 2. The basic template for the questionnaire was an instrument developed by the Swedish Defense Research Agency for the express purpose of assessing trust in leaders (Svenmark, 2005, personal communication). Several of the questions were modified to fit the paintball task. The instrument uses a 7 point Likert-type scale with anchors in the middle and on both ends. Half the questions were reverse-scored. The raw data are the average response to the eight questions.

Our measure of the mediating effect of trust is the strength of correlation across the manipulation of immediacy, that is, the correlation between the improvement in a soldier’s performance and the change in the level of self-reported trust across the remote-leader and collocated-leader conditions.

**Procedure** The procedure in the assault lane was identical to that in the previous experiments. This experiment was conducted in Swedish. All participants, both privates and officers, signed informed consent forms approved by the ethical review board of Linköping University.

The soldier ran the lane three times, once in each of the three conditions. The order of conditions was counterbalanced. Immediately after finishing the third trial, the soldier completed the trust instrument three times, first answering for the first trial, then for the second trial, and finally for the third trial.

**Results**

The hypotheses tested by the experiment were A) remote command and control is associated with a decrement in soldiers’ self-reported trust in their leader, B) remote command and control is associated with a decrement in soldiers’ performance as assessed by response time to the command to “Move!” and to “Fire!” and C) there is a significant inverse association between the decrements in trust and response time.

**Questionnaire data** A two-factor mixed-effects repeated-measures ANOVA was conducted to assess the significance of the manipulation of leader presence and the possibility of sequence effects. The sequence of data acquisition was the blocking variable at six levels. The three sets of answers to the trust instrument were the repeated measure. The raw data were the average of a soldier’s responses to the eight questions in the instrument.

Figure 5.8 is a graph showing the self-report data across the manipulation of leader presence for the two sequences of trials. The ANOVA indicates that only the main effect for leader presence was significant, \( F_{2, 96} = 16.56, p < .001, \) power = .80. Neither sequence nor the interaction of sequence and leader presence was significant. The Tukey HSD procedure indicates that the collocated condition is significantly different from the remote-leader and buzzer conditions and that the latter two are not different from each other. These results support the hypothesis that remote command
and control is associated with a decrement in soldiers’ self-reported trust in their leader. Further, there is no indication in these data of a “learning effect” and no sign of demand characteristics associated with the buzzer.

**Move times** A second three-factor mixed-effects repeated-measures ANOVA was conducted for the move time data. The raw data were the average of the soldier’s five responses to the command to “Move!” The sequence of data acquisition was the blocking variable at six levels. Figure 5.9 is a graph showing the move time data. The ANOVA indicates that the main effects for leader presence is significant, $F_{(2, 90)} = 6.76$, $p < .002$, power =.32. Neither sequence nor the interaction of sequence and leader presence was significant. Once again, the Tukey HSD procedure indicates that the collocated condition is significantly different from the remote-leader and buzzer conditions and that the latter two are not different from each other. These results support the hypothesis that remote command and control is associated with slower performance. Further, there is no indication in these data of a “learning effect” and no sign of demand characteristics associated with the buzzer.

**Fire times** The ANOVA for the fire time data found no significant differences across the three conditions. Inspection of Figure 5.10 suggests the reason for this null result. These active duty soldiers appear to have begun firing their weapons as quickly as possible. The data appear to contain a floor effect that precludes the detection of significant differences. This is the only difference between the data from the soldiers of Experiment 4 and the civilian participants of the first three experiments.

**Linear Association between Trust and Response Time** The horizontal axis of Figure 5.11 plots the difference between the soldier’s assessments of trust in the remote-leader condition and the leader-present condition. The vertical axis shows corresponding difference between the soldier’s two move times. Greater trust in the collocated-leader condition generates negative numbers on the horizontal axis. Faster times in the collocated-leader condition generate positive numbers on the vertical axis. Thus, our hypothesis leads us to expect this cross-plot to have a downward sloping trend.

To test that hypothesis, we conducted a simple, linear regression analysis. The resulting model is: $\text{Difference in time} = 0.40 - 0.30 \times (\text{Difference in trust})$. A one-sided $t$-test for the slope parameter ($\beta_1 = -0.30$) is significant, $t_{(52)} = -2.312$, $p < .012$. Analysis of residuals indicates no deviation from normality and satisfactorily constant variance at all levels of the predictor variable (trust). While trust explains only 9 per cent of the variance in the data ($r^2 = .09$), the model supports the hypothesis that there is a significant association between trust and performance, with soldiers trusting less and responding more slowly in the remote-leader condition.

**Discussion**

Experiment 4 was designed to eliminate the potential confounds of experimenter bias and demand characteristics. Debriefing interviews with many of the soldiers indicated that the buzzer and its vest were sufficiently salient that they could be expected to have had elicited demand characteristics. A platoon of active duty soldiers acted as confederates who recorded response time. Three active duty officers acted as leaders. Even though both the officers and soldiers assumed the buzzer condition was the focus of attention, data in the buzzer condition were statistically identical to those in the remote-leader condition. Thus, there is no evidence for either experimenter bias or demand characteristics.
The response time advantage in the collocated leader condition remains. Active duty soldiers, like their civilian counterparts in the first three experiments, responded to commands to “Move!” faster when the leader was collocated in the lane. This finding is consistent with the claim of Social Impact Theory that the impact of a source on an individual is a function of immediacy. The correlation between the levels of perceived trust and response times suggest that trust in the leader may, in part, mediate the impact of immediacy.

In summary, soldiers and civilians respond to direct verbal commands faster when those commands are issued by a collocated leader than by a remote leader. Soldiers trust a collocated leader more than a remote leader. These findings militate against the proposed transition to network-based defense and the removal of the platoon leader from the platoon. S.L.A. Marshall told us this was the case 60 years ago. Remote command and control appears to be associated with a decrement in soldier performance and at least a portion of that decrement is associated with a decrement in trust.

Acknowledgments

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References


Appendix 1 – Mission Brief

Situation

The Krasnovian Army has taken an unknown number of allied POWs. These prisoners are being held in a firing line and are about to be executed. You are now an agent of a multinational force and have been assigned to rescue these prisoners.

Mission

Your mission is to sneak into the enemy camp and eliminate all enemy targets while minimizing friendly casualties without being hit by sniper fire.

Procedure

Under direction of your leader, move from position to position on the lane to advance toward the enemy camp and to secure ammunition. Hit hostile (red) targets without hitting the friendly (blue) target. To avoid sniper fire, your leader will inform you when hostile snipers are under cover and not firing.

1. When given the order “Fire” you will attempt to shoot the red targets from behind your current position.
2. When you are out of ammunition, report to your leader “Out of ammo.”
3. When it is safe to do so, your leader will direct you to move by giving you the order “Move.”
4. When you arrive at the next firing position, immediately pick up the container of ammunition and load your weapon. Five rounds of ammunition will be located at each position.
5. Once loaded, report to your leader by saying “Loaded.”

All orders will be given by your leader. Do not fire until told to. Do not move until told to. Is this understood?

Any questions?
Appendix 2 – Questionnaire on Trust in the Leader

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1. Jag upplevde förtroende för ledaren (I felt trust in the leader.)
2. Jag upplevde att ledaren gjorde allt för att jag inte skulle bli träffad. (I felt that the leader did all he could so that I would not be hit.)
3. Jag upplevde inte att ledaren visste vad Han Höll på Med. (I did not feel that the leader was sure about what he was doing.)
4. Jag upplevde inte att ledaren visste vad som hände. (I did not feel that the leader knew what was happening.)
5. Jag upplevde inte att ledaren brydde sig om vad som hände mig. (I did not feel that the leader cared about what was happening to me.)
6. Jag upplevde att ledaren verkade kompetent. (I felt that the leader appeared competent.)
7. Jag upplevde att ledaren verkade närvarande. (I felt that the leader appeared to be there with me.)
8. Jag upplevde inte att jag kunde lita på ledaren. (I did not feel that I could trust the leader.)

Figure 5.1 Layout of the paintball assault lane

Soldiers started behind the barrier closest at the bottom right and, on command, advanced from barrier to barrier toward the sniper to obtain ammunition with which they, on command, shot at the targets. In the remote condition, the leader stood hidden in the viewing area.
Figure 5.2 Mean and standard errors of response times to the order to move for the two sequences of data acquisition, Experiment 1

Figure 5.3 Mean and standard errors of response times to the order to fire for the two sequences of data acquisition, Experiment 1
Figure 5.4 Mean and standard errors of response times to the order to move for the two sequences of data acquisition, Experiment 2

Figure 5.5 Mean and standard errors of response times to the order to fire for the two sequences of data acquisition, Experiment 2
Figure 5.6 Mean and standard errors of response times to the order to move collapsed across trial sequence, Experiment 3

Figure 5.7 Mean and standard errors of response times to the order to fire collapsed across trial sequence, Experiment 3
Figure 5.8 Mean and standard errors of the soldiers’ self-report data on the relative level of trust experienced in the leader-present (collocated), remote, and buzzer conditions showing higher levels of trust in the leader-present condition.

Figure 5.9 Mean and standard errors of response times to the order to move collapsed across trial sequence, Experiment 4.
Figure 5.10 Mean and standard errors of response times to the order to fire collapsed across trial sequence, Experiment 4

Figure 5.11 Scatter plot and best-fit linear regression function showing the significant negative association between the difference in experienced trust and the difference in move time between the remote- and present-leader conditions
1.0 Introduction

In his prescient description of the “three block war,” General Charles Krulak (1999) recognized that the battle zones of the 21st century would place remarkable stresses and responsibilities on the young members of our Armed Forces. As predicted, circumstances have led to the emergence of an increasingly complex, volatile, and lethal battlefield, largely urban in nature. It is in this setting that small unit leaders and Soldiers experience multiple stressors while making critical decisions that increasingly determine operational outcomes.

To support Soldiers in stressful environments we must understand the effects of stress on their performance. Despite copious literature on stress effects in general (see Hancock and Desmond, 2001), remarkably sparse research is available to provide insight explicitly into military cognitive performance under stress. A number of studies have failed to detect significant cognitive performance deterioration in stressful military settings (e.g., Elsmore, Naitoh and Linnville, 1992; Callister, Percival and Retzlaff, 1999; Slaven and Windle, 1999). A recent Rand Corporation review of stress and performance applicable to the military (Kavanagh, 2005) contains only a single page on stress and decision making, perception, and cognition.

Our recent research, conducted under the auspices of the Multi-Disciplinary University Research Initiative (MURI) provides useful insights as to the role of stress in military operations. In what follows, we provide an examination of operational performance changes during extended stress; discusses methodological issues related to field data collection, including measuring cognitive changes; and describe the results of our field studies, as well as the theoretical implications of these findings.

2.0 Operational Stress and Data Collection

2.1 Field data collection issues

Our research examines dismounted Soldier activity. Raaijmakers (1990) differentiated two levels of command each with different associated stresses and effects on decision making. At higher levels of command, many people are involved. There are myriad ways in which problems can be solved, and the emphasis is on the process. At the lower levels, cognition is more often action-oriented, time-pressured, and of high personal risk. Soldiers combine procedures they have learned with momentary judgments and decisions to produce performance. Successful discrimination can mean life or death to the Soldier on the ground. These intense periods of activity can alternate with mind numbing monitoring tasks to produce “hours of boredom and moments of terror” (Hancock, 1997).
We cannot simply assume that data derived from situations that are less demanding than actual operational environments accurately describes real-world change in cognitive performance. Yet, precise measurement of cognitive functioning in operational settings is rarely possible because personnel are performing critical tasks or preparing for future tasks. However, unique aspects of military operational settings demand that we attempt to understand field stress rather than only extrapolate from laboratory studies. Such operational conditions include: the presence of multiple sources of stress, extremely high levels of stress, and extended exposures. In addition, individuals working in these settings are unique. They have often met rigorous selection criteria, received specialized training, and have previous experience in the operational environment. Their reaction to such operational stressors would, therefore, be expected to differ from the general population. These aspects of operational settings suggest that despite data collection difficulties, field studies are essential for an understanding of the effect of operational stress on cognitive performance.

Field work on stress under realistic conditions is rare. Our findings, based on simulated conditions of realistic stressors, offer unique insights into cognition under the stress of field conditions. Training exercises include many of the conditions present in operational settings in order to prepare trainees for later work in the real-world, and they provide an opportunity to assess cognitive performance under realistic conditions. The dynamic nature of the operational environment makes precise measurement of stress level difficult. Although control of stress is not possible in training exercises, it can be observed and to a degree measured while the accurate assessment of cognitive changes is entirely possible.

2.2 The automated neuropsychological assessment metric (ANAM) Readiness Evaluation System (ARES)

Although there are few opportunities to control operational stress in field settings, cognitive performance can be defined and measured precisely. The cognitive abilities of individuals differ, and for each person their cognitive ability differs with the type of task they are being asked to perform. The number and types of these abilities have been argued (Cooper, 2002), but the concept of relatively independent mental abilities has been established. Measurements of cognitive functioning changes during stress should therefore assess a variety of tasks, which are selected because they evaluate the abilities critical in operational settings.

For the studies described in this chapter, we used the Ares (Automated Neuropsychological Assessment Metric [ANAM] Readiness Evaluation System) to measure cognitive performance. The Ares precursor, the Unified Tri-Service Cognitive Performance Assessment instrument (Englund et al., 1987), was developed to examine cognitive performance changes within individuals. The initial focus of this battery was to assess drug effects. The Unified Tri-Service Cognitive Performance Assessment Battery (UTC-PAB) uses classic tests of cognitive functioning to define important processing capacities. The UTC-PAB provides twenty-six subtests, which are classified into two broad categories: Processing and Selective/divided attention. Processing is further classified into three stages: 1) Perceptual input, detection and identification, 2) Central Processing, and 3) Output/response execution. By combining different sets of these individual subtests, batteries can be constructed to examine a variety of questions. Central Processing subtests are further divided into Memory, Linguistic/symbolic information integration/manipulations, and Spatial information integration/manipulation. The UTC-PAB was updated as computer capability increased, and the resulting Automated Neuropsychological Assessment Metric (ANAM; Reeves et al., 1991) provided increased user friendliness, while retaining the format and theoretical foundation of the UTC-PAB. The cognitive tasks in these batteries represent elemental skills that underlie real-world tasks (Thorne, Genser, Sing, and Hegge, 1985), and have proved to be sensitive to cognitive
performance changes following neurological insults such as exposure to radiation, toxic chemicals, high altitude, and underwater activity (Lowe et al., forthcoming). The ANAM tests have also proved useful in following cognitive changes after closed head injuries (Bleiberg et al., 2004). ANAM field administration is difficult because the battery is administered on a desktop or laptop computer, but development of the ANAM Readiness Evaluation System (Elsmore, Reeves, and Reeves, forthcoming) for handheld computers now allows rigorous cognitive function assessment in the field.

The Ares provides precise stimulus administration and response time measurement, and is capable of detecting subtle cognitive performance changes. The Ares includes cognitive ability subtests that assess those abilities present in operational performance information processing models (Wickens, 1992), and is therefore well suited for studies of operational performance change. The subtests in the studies described in the present chapter were specifically selected to assess components of cognitive performance considered to be important in operational settings (Wickens and Flach, 1988). Selected tests included Simple Reaction Time (SRT), Code Substitution (CDA), Spatial Processing (SPD), Logical Reasoning (LRS), two memory set tasks (i.e., Sternberg memory task [Sternberg, 1969] with a two-item memory set [ST2] and a six-item memory set [ST6]), and the Continuous Performance Task (CPT). Lack of findings in previous studies about stress and cognitive performance deterioration may be the result of procedures that masked complex cognitive task deficits by allowing the temporary efforts of the participants to sustain transient performance levels. Inclusion of the SRT, a task in which deficits are more difficult to mask, allowed us an easily administered measure to estimate the effect of stress on more complex functioning.

3.0 Effects of Stress on Cognitive Performance

In the present experimental series, we conducted a number of field cognitive performance assessments under a wide variety of operational conditions which presented a wide range of stress levels. The first of these studies was conducted at the Navy Survival, Evasion, Resistance, Escape (SERE) School at NAS Brunswick and was reported in Harris, Hancock and Harris (2005). Both the second (Harris and Hancock, 2003) and third studies were performed at Ft. Chaffee AK (and see Lowe et al., forthcoming). They assessed Army infantry during simulated combat field exercises,. The fourth and final assessed Special Forces Soldiers at the Army SERE School in Ft. Bragg, NC (and see Harris, Hancock, and Morgan, 2005).

A striking feature of each of these operational settings is the need for rapid change of cognitive functioning in response to fluctuation in stress level. Predicting cognitive functioning in operational settings is further complicated because people within the same operational setting are often exposed to widely differing conditions. However, three consistent relationships between operational conditions and cognitive performance can be described: 1) the dynamic nature of stress and cognitive performance, 2) the relationship between stress level and cognitive functioning change, and 3) a comparison of the relative sensitivity of cognitive functions to stress. We report the findings here in terms of these three aspects of stress and cognitive performance.

3.1 The dynamic nature of cognitive changes in stressful operational settings

Physical and psychological demands constantly vary in the real world, and cognitive performance is affected by current demands and the residual from previous conditions. Current stress can adversely affect performance, but response capacities recover during periods of low stress. Field studies provide the opportunity to examine such cognitive performance fluctuations in dynamic, real-world conditions.
The consequence of operational stress can be determined immediately, as performance is proceeding, or at varying time intervals following documented stress. For example, we assessed Special Forces soldiers immediately following a 1-week, high-stress Survival, Evasion, Resistance, Escape (SERE) training. They showed significant cognitive performance deficits (Harris, Hancock, and Morgan, 2005). Cognitive assessment of Navy and Marine personnel three hours after a similar physically and psychologically stressful SERE training found a different and less disturbing level of cognitive deficit (Harris, Hancock and Harris, 2005), and the Army Special Forces soldiers who had demonstrated significant deficits immediately following training exhibited little evidence of cognitive performance impairment 12 hours after training had ended (Harris, Hancock and Morgan, 2005). The rapid recovery of cognitive performance was also observed in simulated combat exercises at Ft. Chaffee. Minimal changes were observed when assessment following a 27-hour operation was delayed 15-30 minutes (Harris and Hancock, 2003), but significant cognitive deficits were noted when testing occurred within one minute of the simulated combat exercise (Lowe et al., forthcoming).

Further demonstration of the dynamic nature of cognitive responses to stress was provided by repeated cognitive assessments by the authors during one-week simulated combat exercises in the second study at Ft. Chaffee which was the third overall experiment that we completed (and see Lowe et al., forthcoming). In this experiment, response time increases that appeared during training were not present immediately after training. During the third day of a 5-day defensive operation, SRT was 13 milliseconds (ms) greater than baseline, and the response time on the complex tasks, Logical Reasoning and Spatial Processing, also increased. Immediately following the exercise, SRT, which had been 13 ms slower than baseline, improved to a marginally significant (0.07) increase of 9.4 ms, and all complex response times had returned to baseline levels. However, decreased accuracy was found in the post-action assessment, most notably on the Logical Reasoning and Mathematical Processing tasks. The dynamic nature of stress effects and the differing pattern of response time and accuracy changes were also demonstrated by response time and accuracy assessments of Special Forces soldiers 12 hours post stress (Harris, Hancock and Harris, 2005). Response time had returned to baseline levels, but Logical Reasoning and Mathematical processing accuracy deficits were observed.

These results indicate that during and immediately following an extended period of stress, people’s cognitive ability is severely impaired, but that a relatively brief recovery periods can significantly improve cognitive performance. While response time recovery appears to be rapid, the small accuracy decrements noted during stress appear to recover slower, or possibly increase after periods of high stress. Accuracy decrements appear to be primarily on Logical Reasoning and Mathematical Processing tasks. Accuracy decreases following periods of high stress is consistent with reports of increased error frequency during low workload when it follows high stress, high workload periods (Fowler, 1980).

In all of our experimental procedure, the participants who were Navy SERE students and Army soldiers respectively, repeatedly demonstrated the ability to perform a 15-min assessment at baseline levels after relatively brief periods of rest (Harris and Hancock, 2003; Harris, Hancock and Harris, 2005; and Lowe et al., forthcoming). However, lack of cognitive deficits during the relatively brief assessment does not speak to their ability to maintain baseline levels of performance for extended periods, or that they would be as capable of responding to acute stress as they do after a longer recovery period. The rapid performance recovery in field studies supports interventions that mitigate the effect of stress such as flight crew naps during long flights (Rosekind et al., 1994). The rapid recovery of cognitive functioning may also explain the apparent absence of cognitive changes in operational settings where short breaks would be expected to reduce the cognitive performance deficits produced by stress.
3.2 Stress level and cognitive change

The level of stress in an operational setting can be estimated and settings can be specifically selected to test varying levels of stress. However, unpredictable factors often modify what actually occurs. Post-hoc analysis can, however, be used to determine conditions that influenced stress level and this provides the opportunity to compare cognitive functioning during varying conditions. We ranked the respective studies we conducted from lowest to highest stress level using the following criteria; 1) Low control increases stress, 2) Aversive environmental conditions (temperature, humidity, insect bites, physical workload) increase stress, 3) Poor sleep quality and time deprivation are stressful, 4) Threat increases stress, 5) Increasing the time between stress and assessment (stress/testing interval) decreases stress, and 6) Longer exposure times are more stressful. Doing this allowed us to compare patterns of response across the various studies.

Low stress Simulated combat exercises, like real battles, seldom follow a planned schedule. Data collected in the field when few stressful conditions are present generated an unexpected result. Harris and Hancock (2003) found that the SRT of Soldiers in a low stress setting was 16.0 ms slower than baseline during the third day of field operations and degraded to 34.0 ms slower than baseline at the end of the week. However, speed and accuracy on complex tasks remained at baseline levels throughout the week. Their SRT changes were consistent with the Extended-U model (Hancock and Warm, 1989) confirming that hypostress does adversely affect performance. However, the decrement was limited to simple attention tasks, and no change was observed in more complex tasks. One explanation for this difference is that complex tasks were in themselves sufficiently demanding to increase arousal.

Moderate stress Soldiers assessed in a high demand exercise in which there was a high degree of control and the outcome was positive, and the assessment occurred in the field at approximately 30 minutes after active involvement in platoon activities exhibited little or no evidence of cognitive impairment (Harris and Hancock, 2003). SRT and complex task response time and accuracy did not change during the week of training. In another study, three hours following high levels of physical and psychological stress, Navy and Marine personnel SRT increased 10.4 ms and the response times and accuracy of complex tasks remained at baseline levels (Harris, Hancock and Harris, 2005). A three-hour stress/assessment interval suggests that the data do not represent cognitive changes during training. Examination of within trial performance indicated that post-stress performance deteriorated with time-on-task, but the deterioration was insufficient to decrease mean performance. When Soldiers participated in continuous, moderate intensity operations, but had little control over the pace of events, and the active training/assessment interval was decreased, SRT increased 13.4 ms and Logical Reasoning and Spatial Processing response times increased (Lowe et al., forthcoming). Immediately after the exercise, SRT had improved, but still remained 9.4 ms above baseline level. Complex task response time returned to normal but Logical Reasoning and Mathematical Processing accuracy were below baseline levels. Assessment immediately after a relatively brief (24 hour), high stress mission which occurred after Soldiers had been in the field for one week, found increased SRT (21 ms) and increased Logical Reasoning and Mathematical Processing response time (Lowe et al., forthcoming). Cognitive performance changes appear to occur in operational settings, but the level of change appears to be highly dependent on factors such as the precise timing of the administration and the participant’s level of control.

High stress When the factors that attenuate the effects of stress are not present, changes are more likely to represent the cognitive changes present during military operations. Harris, Hancock and
Harris (2005) assessed Soldiers immediately after one week of intense training in which Soldiers were exposed to uncontrollable stress, SRT increased approximately 21 ms and complex task response time on all complex cognitive functions (Logical Reasoning, Mathematical Processing, Spatial Processing, Spatial Memory, and letter Memory) also increased after this high stress, experience with no personal control of stressors, and assessment immediately following training activities.

An example high stress incident  It is very rare that a person can be assessed immediately following a high stress, indeed life-threatening, incident, but in our assessment of one Soldier, immediately following such a medical emergency, we found SRT was 30 ms above baseline level, and complex task accuracy had decreased and similarly response time was below baseline levels (Harris and Hancock, 2003). This contrasts with observations during less extreme stress, where accuracy was maintained and SRT and complex response time increased 10–20 ms (Harris and Hancock, 2003; Harris, Hancock and Harris, 2005; and Lowe et al., forthcoming). Although the results of this one case must be interpreted with caution, the pattern is exhibited by this Soldier is consistent with the performance disintegration previously reported in the field by Berkun (1964) and observed in other real-world events (Leach, 2004). Simple response slows but response to complex demands speeds up but with the correlate of a vastly increased error rate. The latter looks like a β level shift, or more formally, a propensity to lower the evidence criterion that triggers response.

Although precise stress levels could not be established, conditions could be divided into four stress categories; low stress, stress accompanied by conditions such as recovery periods that mitigated the effects of stress, high stress, and situations in which the person experienced a direct threat to their well being. The pattern of cognitive performance change was found to differ in each of these respective conditions.

Simple Reaction Time (SRT) follows a pattern consistent with the Extended-U Model (Hancock and Warm, 1989). Responding was slow during low stress. However, during moderate stress, SRT was faster than during either high or low stress conditions. When stress was high, SRT was slower than during moderate stress, and during a high stress incident, responding slowed to levels observed during low stress. Performance on complex cognitive tasks is different. Deficits were not observed during low stress, and there were limited indications of impairment during moderate stress. In a pattern similar to SRT changes, response time changes became more pronounced as stress level increased. Significant impairment of complex task performance only becomes apparent during high stress. Impairment is indicated by increased response times and little or no impairment of accuracy. When stress becomes extreme, rather than maintaining accuracy by increasing response time, the pattern appears to become responding quickly with little concern for accuracy.

These results suggest that it may be difficult to gain people’s attention during periods of low stress and arousal, but that once engaged they are able to process information accurately. As the effects of stress increase, an early indication is slower SRT, a change that also occurs following sleep deprivation (Dinges et al., 1990) and exercise (Bonnet, 1980). As stress increases, SRT continues to increase and complex task performance is slower, but still accurate. Only when the time to respond is severely limited would a small increase in response time become a problem. When stress reaches levels that the person cannot adapt to, performance exhibits a catastrophic not a gracefully decline, and responding becomes rapid but inaccurate (and see Hancock and Warm, 1989).
3.3 The variable sensitivity of cognitive functions to stress

Evidence from diverse disciplines indicates that the information processing events underlying cognitive performance differ with the type of information being processed (Hancock and Warm, 1989). Multiple resource theory indicates that cognitive resources devoted to information processing differ with the mode of information and the stage of processing being performed (Wickens, 1992). Selection batteries can predict operational performance by assessing the individual’s ability to perform the cognitive functions required in that setting (Gordon and Leighty, 1988). Although there is overlap in the nervous system components used to perform different cognitive tasks, nervous system activity is related to the cognitive task being performed and cognitive demands are related to nervous system activities (Drummand et al., 2000).

The earlier discussion of the relationship of stress and cognitive performance indicated that larger SRT increases are associated with greater complex task disruptions and reaction time has been used to predict cognitive performance decrements due to fatigue (Dinges et al., 1990). Although complex cognitive abilities are correlated, they are not identical, and complex cognitive task measurement should be included for a complete description of cognitive performance (see Tripp et al., 2006). The use of a cognitive battery with subscales that assesses differing cognitive functions is necessary to adequately describe the effects of stress and determine relative stress sensitivity tasks.

The assessment batteries we have used in Harris and Hancock (2003); Harris, Hancock and Harris (2005); Lowe et al. (forthcoming); and Harris, Hancock and Harris (2005) contained subtests to measure critical central processing functions; 1) linguistic/symbolic information integration/manipulations, 2) spatial information integration/manipulation, and 3) symbolic and spatial memory tasks (Englund et al., 1987). The effect of stress not only depended upon the stress level, it also differed with the cognitive task being performed. Three hours after participating in high stress training, SRT was 10.4 ms above baseline, and participants had difficulty maintaining Logical Reasoning speed and accuracy with time-on-task (Harris, Hancock and Harris, 2005). When assessments were obtained within 1 min of moderate stress field operations (Lowe et al., forthcoming), SRT slowed 13.4 ms and information manipulation task response time increases were most pronounced. When assessed immediately following a 27 h high stress mission the following week, the mean SRT of Soldiers was more than 20 ms above baseline and Logical Reasoning and Mathematical Processing response times were longer. When assessment occurred immediately following high stress training (Harris, Hancock and Harris, 2005), SRT increased to more than 20 ms longer than baseline and all information manipulation was impaired, however, maximum performance decrements occurred in the two memory tasks and in Mathematical Processing, an information manipulation task with a high memory load. Complex cognitive tasks appear to exhibit different sensitivity to stress. Information manipulation are more sensitive to low stress and continues to be impaired as stress level increases but memory deficits become most pronounced following high stress.

4.0 Implications for Future Research and Theory Development

The implications that can be derived from our studies are that: 1) the perception of control decreases stress, 2) not unnaturally conditions vary within operational settings, 3) stress level is related to previous operational experience, and 4) cognitive performance changes are not always readily observable.

Lack of control produces stress and contributes to the physiological responses observed during military survival training (Morgan et al., 2000). Perceived loss of control can produce panic and
Performance deterioration in operational settings (Douglas, 1989). Consistent with expectations, maximum cognitive performance changes were found in a training program in which participants experienced uncontrollable stress (Harris, Hancock and Harris, 2005). Different levels of control were observed within simulated combat exercises, and individuals with high levels of control exhibited the least stress-related disturbance.

It was evident when collecting data in the operational environment that conditions varied greatly within the same operational setting. The implications of differing stress levels within a single setting are that group averages do not predict the occurrence of cognitive impairment within individuals. Field data collection should therefore always include detailed situational information with each cognitive assessment.

In addition to the differences between conditions, the experience of people within the same operational setting also varies greatly. During training, Soldiers have similar experiences but great differences exist across operational units. It was observed consistently that in studies of operational units, less experienced Soldiers appeared to be experiencing more stress (Lowe et al., forthcoming). Cognitive performance deterioration during stress therefore plays a role in the performance of experienced Soldiers during combat.

While cognitive assessments indicate a variety of cognitive deficits during military operations, cognitive impairment is not obvious. Soldiers continue to act normally and complete routine tasks. The increased response time detected by assessment batteries that are the early signs of impairment are not apparent from casual observation and only become obvious as tasks become more difficult or time pressures increase. Field observations indicate the importance of constant personnel evaluation, particularly of inexperienced individuals during demanding operating conditions. This recommendation is not surprising. However, the subtly of changes during early impairment, the large variations in conditions and in the diverse reactions of individuals make it necessary to emphasize the importance of continuous assessment.

The primary objective of the series of studies discussed here was to document cognitive performance changes in combat environments for military equipment designers and military leaders. However, the data also provides an opportunity to evaluate the effectiveness of stress theories during conditions that cannot be ethically generated in the laboratory.

An extensive body of literature indicates that performance is most proficient at intermediate levels of intensity (Tiegen, 1994). This relationship is often referred to as the Yerkes-Dodson law. Yerkes and Dodson (1908) observed that mice learned a discrimination task faster when shock intensity was moderate than when it was either low or high (but see Hancock and Ganey, 2003). Based upon high, medium and low shock levels, the curve was described as an Inverted-U (although an inverted-V would have been more accurate). This implies that optional performance occurs only during a narrow range of conditions. Studies supporting the Yerkes-Dodson law use stimulus intensity expressed as a variety of environmental descriptors and organism states. Further, many different performance measures have been used. Teigen (1994) summarized the diversity of arousal and performance measures that have been related to the Yerkes-Dodson law. Independent variables include stimulus strength, punishment and motivation intensity, drive level, reward magnitude, emotionality, anxiety, tension and stress. Performance measures include habit formation, learning, performance proficiency and efficiency, coping, problem-solving, and memory. There is substantial support for the statement that cognitive performance is poor when a person is psychologically and/ or physically inactive and that performance improves as people become more active. Also that performance does deteriorate when environmental stimulation becomes excessive, or measures of organism state approach maximum levels (Teigen, 1994). Although the Inverted-U concept has provided a convenient heuristic, it is a fundamentally flawed scientific [conegation] (see Hancock and Ganey, 2003) that suggests a more detailed picture of the stress-performance relationship than
is shown by the simple inverted-U. An alternative formulation is given by Hancock and Warm (1989) who have questioned the assumption that maximum performance is limited to a brief period or an ideal level of arousal. They proposed an Extended-U model of the stress/performance relationship (Hancock and Warm, 1989). This concept hypothesizes that performance is stable except during times of either extremely low or high stress. The region in which stress has little effect on performance is labeled the “zone of adaptation”. The Inverted-U model prediction that maximum performance is limited to a brief arousal range is not consistent with human performance in the real world.

Describing arousal/performance and stress/performance relationships is inhibited by the extreme complexity of the concepts of arousal/stress and performance, and by the limited range of arousal/stress that can be examined in experimental studies. In addition to the constricted range of stress that can be used in laboratory studies existing experiments do examine the relationship between stress/arousal and performance typically use only a single measure of performance. Performance is a complex construct, and the assumption that all aspects of performance respond identically to stress is not warranted. Speed and accuracy represent different aspects of a response, while performance also varies with the cognitive demands of the task. Although it is impossible to measure all aspects of performance, a detailed assessment is needed to provide a complete description of the effects of stress on performance.

Multiple measures of performance during operationally stress provided the opportunity to evaluate the Inverted and Extended-U models, and determine whether stress effects apply equally to all aspects of performance. Post-stress cognitive performance changes varied with the cognitive demands of the task. SRT requires no information integration or manipulation, and has no memory demands. SRT was slowest during low and high stress, and was relatively stable during observations when stress levels were not extreme. Relatively stable performance during a wide range of stress levels is consistent with the Extended-U model (Hancock and Warm, 1989). More precise performance assessment provided by the computerized assessment procedure indicated that although performance was relatively stable, SRT increases with greater stress during the period of adaptation.

Tasks requiring information integration and management and memory tasks exhibited a different pattern of change in response to stress levels than did SRT. For these complex tasks, no performance change occurred during periods of lowest operational stress. It is questionable whether the least stressful operational environment can be considered stress at all. The high demand cognitive assessment task may have created sufficient stress to create moderate levels of stress during the assessment. Complex task changes might have been observed if stress level were lower.

Cognitive performance exhibited stability and decrements were minimal during the wide range of stress present in the sites examined. No accuracy changes were observed, but response times slowed with increasing stress. Thus, operational personnel take more time, but perform adequately during periods of stress. The statistically significant response time increases were not large and would probably not be operationally significant under most conditions. SRT was more sensitive to stress than complex tasks, and complex tasks were not equally sensitive to stress. At lower levels of stress, information manipulation tasks were more sensitive, but when stress increased, but had not become extreme, memory task slowing was most pronounced, and is consistent with reports that stress impairs working memory (Birnbaum et al., 2004), and with the Hancock and Warm Model. Not only is there no major performance deterioration as stress increases, it appears that accuracy is unaffected during periods of operational stress. However, it appears that response times increase slightly as the person adjusts to cognitive functioning deficits that increase with mounting stress. Maintaining performance by recruiting additional cognitive resources to meet greater demands is
consistent with the findings of Young and Stanton (2002), and the ability to maintain complex task performance with increased effort has been reported by Heuer et al. (1998).

Only one event occurred that was comparable to performance disintegration reported in real-world (Leach, 2004) or to Berkun’s (1964) simulated crisis’s. SRT increased, as would be predicted by both models, but complex task accuracy decreased response time also decreased. Long SRT during high stress suggest significant cognitive impairment, but rapid, inaccurate complex task performance suggests that little time or effort was applied to the assessment tasks. Decreased accuracy would be reflected in operational tasks.

The field studies summarized here indicate that cognitive performance exhibits few changes over the wide range of stress levels found in infantry operations. The large zone of adaptability in which performance is stable, proposed by Hancock and Warm (1989), is consistent with the data from these military studies. Two additional adjustments appear to be needed. The first adjustment is that while response time during the zone of adaptability is relatively stable, small response time increases with stress can be detected in precise assessments. Second, the stress level at which cognitive performance is affected appears to vary with the task. SRT is slow during low stress, improves during moderate stress, and increases again when stress is high. Complex tasks exhibited no decrements during low stress levels when SRT was elevated, suggesting that SRT is more sensitive to low arousal. Assessments occurred when stress levels were relatively low, but the possibility exists that complex task performance would have deteriorated with lower stress levels. Although complex tasks response times increased during the apparent zone of adaptability, complex tasks were less sensitive to stress than SRT. Furthermore, the effect of stress appears to differ with the demands of complex tasks. Information manipulation tasks were most sensitive to lower stress levels and memory tasks exhibit greatest changes when stress level was within the higher regions of the zone of adaptability.

Military personnel routinely operate in physically and psychologically demanding environments, and their success and survival require accurate decisions. The threat of hostile action is an important source of combat stress, but military personnel routinely perform dangerous activities and the effect of stress is also a safety issue. The combat environment has always been cognitively demanding and information sources continue to be complex, inconsistent, and often inaccurate. In addition, operational situations are dynamic. The “fog of war,” and the often heard statements that “plans go out the window with the first shot” aptly describe the complex, dynamic operational environment. Critical information is not available, and available information is often purposely distorted. Recent military system advances to support the modern war fighter increase information and tactical options but the key to success is still the Soldier’s ability to recognize critical elements and select the best option.

Field cognitive assessments were in general consistent with operational performance and the Extended-U stress/performance model (Hancock and Warm, 1989). Accuracy remained high during low, medium and high stress. The Extended-U Model acknowledges the need to adapt to varying levels of stress to maintain performance by labeling the period of stable performance the “zone of adaptability.” Increases in response time during stress may reflect the additional time needed to adapt to decreased cognitive capacity. It has been proposed that resources can be increased to meet increasing demands (Young and Stanton, 2002) and that complex task performance can be improved by increased effort (Heuer et al., 1998). Response time increases were sufficiently small that they would be unlikely to increase errors under most circumstances, but Gonzales (2004) warned that slower processing increases the likelihood of errors during large information processing loads and time constraints.

Field data suggest that not all tasks are affected equally by stress. Although stress might be expected to affect complex tasks more than SRT, SRT was more sensitive to operational stress.
SRT and complex task performance also follow different time courses during recovery from concussions. While a slower complex task recovery might be expected, SRT recovered slower than complex tasks following concussions (Bleiberg et al., 2004). SRT has been used as an indicator of fatigue (Dinges and Powell, 1985), but reacting to a simple stimuli 10 ms later is not significant in many operational settings. SRT sensitivity suggests that it may be a useful indicator that complex information processing changes are imminent. Information manipulation tasks such as Logical Reasoning appear to be the most stress sensitive, but with increased stress memory task deficits are more pronounced. Information processing time increases are small but changes when the effects of stress are most pronounced could produce errors under some conditions. Small processing time increases can affect cognitive performance when situations demand rapid decisions that require processing large bodies of complex material, if the individual is unskilled and has difficulty performing the task when not impaired, or if the person attempts to maintain low stress response times.

Operationally, significant complex task changes only appeared at very high stress levels when SRT was about 30 ms longer than baseline. However, 30 ms SRT increases also occur during low arousal, a minimum of one complex task should be included in any fitness for duty battery to differentiate SRT elevations due to high and low stress. Increased SRT and fast inaccurate responding appear to indicate the presence of serious impairment.

Operational settings expose personnel to extended periods in which stress level continuously varies, and the cumulative effect of stress is an important issue. Reversing the effects of extended hours in the cockpit with naps has suggested that even brief periods of rest can improve cognitive performance (Rosekind et al., 1994; Neri et al., 2002). Rapid recovery from stress is indicated by significant improvement in cognitive performance after 3 hours (Harris, Hancock and Harris, 2005), complete reversal of impairment after 12 hours (Harris, Hancock, and Morgan, 2005), and the absence of cognitive changes in an individual two days after a high stress incident all support the use of controlled recovery periods to maintain cognitive performance.

The patterns observed in field studies provide a general description of the relationship between stress and performance but the varying sensitivities of individuals and the inconsistencies of stress in any operational setting dictate that monitoring of individuals is essential to detect the sensitive person or the individual who has been exposed to higher stress levels.

Field observations that indicate that cognitive performance exhibits little change during a wide range of stress is consistent with the performance stability proposed by Hancock and Warm (1989). However, the data suggest that while performance accuracy is stable, small response time increases occur as stress increases. Furthermore, although a similar pattern change appears with tasks having different cognitive demands, tasks are not equally sensitive. The Extended-U Model appears to describe the shape of the stress/performance relationship, but the stress required to affect cognitive performance depends upon the cognitive demands of the performance. A family of curves is needed to describe the precise relationship between stress and performance of each cognitive task. Field data provide unique observations that can clarify the complex relationship of stress and cognitive performance. The lack of experimental control requires that caution must be exercised when evaluating conclusions, and findings should be used to guide further research.

5.0 References


Changes in Soldier’s Information Processing Capability under Stress


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1 Introduction

1.1 Vigilance in an Automated World

Vigilance or sustained attention refers to the ability of observers to maintain their focus of attention and remain alert to stimuli over prolonged periods of time (Warm, 1977, 1984: 1993; Davies and Parasuraman, 1982; Ballard, 1996). This aspect of human performance is an important concern for human factors/ergonomic specialists due to the critical role that vigilance plays in many operational settings, especially those involving automated human-machine systems. Advancements in technology have transformed the role of workers from that of active controllers to system executives who monitor the functioning of machines that do the work for them and intervene only in the event of potential problems (Sheridan, 1970, 1980). Consequently, vigilance is a critical component of human performance in a diverse array of work environments including military surveillance, air-traffic control, transportation security, nuclear power plant regulation, industrial quality control, and long-distance driving (Warm, 1984, 1993; Hartley et al., 1989; Howell, 1993; Satchel, 1993; Hancock and Hart, 2002). Vigilance also contributes to performance efficiency in medical settings, including x-ray and cytological screening and the inspection of anesthesia gauges during surgery (Weinger and Englund, 1990; Gill, 1996; Warm and Dember, 1998).

Although automation has reduced the information-processing load placed upon observers and has enhanced productivity (Wiener, 1984, 1985; Parasuraman, 1987), it appears to be a double-edge sword. Several studies have shown that accidents ranging in scale from minor to major are often the result of vigilance failures on the part of human operators (Molloy and Parasuraman, 1996). One solution to this dilemma would be to eliminate the need for the human component in automated systems. However, as Parasuraman (1987) has argued, a solution of that sort is not feasible because of the need for human operators to serve in a fail-safe capacity in the case of system malfunction. With this in mind, an understanding of the factors that influence vigilance performance and their underlying mechanisms is crucial for system integrity and public safety (Nickerson, 1992; Warm and Dember, 1998). This chapter addresses these issues in terms of the workload and stress associated with the performance of vigilance tasks and their implications for competing models of vigilance performance anchored in understimulation on the one hand and the exhaustion of information processing resources on the other.

1.2 Historical Roots

The term “vigilance” was coined by Sir Henry Head (1923) who used it to refer to a state of maximum physiological and psychological readiness to react. Early research on this topic was conducted by Wyatt and Langdon (1932) who described time-related variations in the performance of inspectors examining cartridge cases for flaws prior to packaging. However, controlled
laboratory research on sustained attention is generally considered to have begun with a military problem encountered during the Second World War when British airborne observers on patrol over the Bay of Biscay used “blips” on pulse-position radar displays to signify the presence of German U-boats on the surface of the sea below (Warm, 1984). This new and innovative technology should have given these observers a major advantage in combating the U-boat threat to the British war effort. However, after only about 30-min on watch, the well-trained and highly motivated observers began to miss the radar signals and the undetected U-boats were free to sink allied ships.

The Royal Air Force commissioned Norman Mackworth to study this problem. Toward that end, he created a simulated radar display called the “Clock Test” (Mackworth, 1948, 1950/61). It consisted of a black pointer that moved along the circumference of a blank-face clock devoid of any scale markings to serve as reference points. The pointer rotated around the face of the clock in 0.3-inch jumps at a rate of one jump per second. Occasionally, it would make a double jump of 0.6 inches signaling a critical signal for the observer to detect by pressing a button. In Mackworth’s pioneering experiments and most of the others that have followed, observers were tested alone for a prolonged and continuous period of time (2 hours in Mackworth’s case) under conditions in which the signals to be detected were clearly perceivable when observers were alerted to them, but were not compelling changes in the operating environment. The critical signals for detection occurred infrequently in a temporally unpredictable manner, and the observers’ responses had no effect on signal occurrence.

![Figure 7.1 The downs and ups of vigilance. The vigilance decrement as a decline in signal detection over time or an increase in response time to correct detections over time](image)

The “Clock Test” permitted Mackworth to confirm in a controlled laboratory environment field-generated suspicion that the quality of sustained attention is fragile, waning quickly over time. He found that signal detections declined from 85 per cent to 75 per cent within the first 30 minutes on task and continued to drop more gradually for the remainder of the 2-hour vigil. This drop in performance over time is known as the vigilance decrement or the decrement function. It
has been replicated in many subsequent studies and is the most ubiquitous finding in vigilance research (Davies and Parasuraman, 1982; Warm, 1984; Parasuraman, 1986; See et al., 1995; Warm, Dember and Hancock, 1996; Matthews et al., 2000). The decrement is illustrated schematically in Figure 7.1 which shows the tendency for the decline in detections over time to be accompanied by an increment in response time to correct detections.

Generally, the major portion of the decrement appears within the first 15-min of watch (Teichner, 1974), but it can appear within the first 5-min on task when conditions are highly demanding (Jerison, 1963; Neuchterlein, Parasuraman and Jiang, 1983; Helton et al., 2000 Temple et al., 2000; Rose et al., 2002; Helton et al., 2007). The vigilance decrement has been found with experienced as well as with inexperienced observers, and counter to the belief that the decrement may simply be an artificial laboratory phenomenon (Mackie, 1984), it appears in operational environments as well as in laboratory settings (Baker, 1962; Colquhoun, 1967, 1977; Schmidke, 1976; Pigeau et al., 1995).

2 The Workload of Sustained Attention

2.1 The Arousal and Mindlessness Models

From the description of the characteristics of the typical vigilance experiment described above, one could gain the impression that vigilance tasks are tedious and understimulating assignments that impose little workload upon observers. An impression of that sort has formed the basis of two theories of vigilance performance. One of these is the long-standing arousal or activation model that accounts for the vigilance decrement in terms of the lack of stimulation necessary to maintain alertness. According to that model, the repetitive and monotonous aspects of vigilance tasks reduce the level of stimulation needed by elements of the central nervous system – the ascending reticular formation, the locus coeruleus, and the diffuse thalamic projection system – necessary to succor wakefulness and alertness. As a result, the brain becomes less responsive to stimulation, and performance efficiency declines (Frankmann and Adams, 1962; Welford, 1968; Loeb and Alluisi, 1977; Aston-Jones, 1985; Nachreiner and Hanecke, 1992; Proctor and Van Zandt, 1994; Heilman, 1995). A more recent view, also based upon understimulation, is the mindlessness model suggested by Robertson and his colleagues (Robertson et al., 1997; Manly et al., 1999) in which the repetitive and tedious nature of vigilance tasks is considered to lead observers to withdraw attentional effort from the task and approach their assignment in a thoughtless, routinized manner. As noted by Dickman (2002) and by Helton et al. (2005), this approach reflects an endogenous modulation of attention rather than a decline in wakefulness and vigor accompanying lowered arousal. Both of these models point to a potential paradox of automation: although designed to reduce workload, such a reduction in the case of vigilance may place observers at a functional disadvantage due to understimulation.

Warm, Dember and Hancock (1996) have indicated, however, that the view of vigilance tasks as under-arousing stemmed from a rather superficial task analysis; it was not based upon the actual degree of underload inherent in these tasks. Warm, Dember and Hancock (1996) attempted to provide such evidence through measurements of the perceived mental workload or the information-processing load and/or resource demands imposed by such tasks (Gopher and Braune, 1984; O’Donnell and Eggeemeier, 1986; Eggeemeier, 1988) and found evidence to indicate that the cost of mental operations in vigilance is not at all consistent with the understimulation notion that gave rise to the arousal and mindlessness models.
2.2 Research with the NASA-TLX

In their effort to assess the workload of sustained attention, Warm, Dember and Hancock (1996) made use of the NASA-Task Load Index (NASA-TLX, Hart and Staveland, 1988). This instrument is considered to be one of the most effective measures of perceived mental workload currently available (Lysaght et al., 1989; Nygren, 1991; Hill et al., 1992; Proctor and Van Zandt, 1994; Wickens and Hollands, 2000; Farmer and Brownson, 2003). It provides a reliable measure of overall or global workload on a scale from 0 to 100 and also identifies the relative contributions of six sources of workload. Three of these sources reflect the demands that tasks place upon operators – Mental, Temporal, and Physical Demand – while the remainder characterize the interaction between observers and the tasks that confront them – Performance, Effort, and Frustration.

It is important to emphasize that the NASA-TLX is essentially a subjective scale, and Natsoulas (1967) has pointed out that there is always some question as to whether any form of self-report accurately reflects respondents’ true perceptual experiences. He suggested that this problem might be overcome by linking perceptual reports to psychophysical factors known to influence task difficulty. With this suggestion in mind, Warm, Dember and Hancock (1996) attacked the problem of measuring perceived mental workload in vigilance by linking workload ratings secured by the NASA-TLX to psychophysical factors that degrade performance efficiency on these types of tasks.

In one of their initial investigations, they found that the decline in signal detections over time was accompanied by a linear increase in overall workload as illustrated in Figure 7.2. In that study, the low ratings given to a simple card sorting task served as a control assuring that the observer’s workload ratings were not spuriously high in the performance of a vigilance task.

![Figure 7.2 The rate of gain of workload over time](source: Warm et al., 1996.)
In other portions of their extensive series of studies, Warm and his associates found that overall workload increases as signal salience decreases and that overall workload is positively related to increments in the number of displays to be monitored, the observers’ uncertainty as to the spatial location of critical signal appearances, and to increments in the rate of presentation of stimulus elements that need to be examined for the presence of critical signals, the background event rate. They also reported that perceived mental workload increases in the presence of acoustic noise. Declines in signal salience, and increments in the number of displays to be monitored, spatial uncertainty, and event rate are key stimulus factors that reduce performance efficiency in vigilance, and noise is an environmental factor that frequently has adverse effects on signal detection in the performance of vigilance tasks (Hancock, 1984; Warm and Jerison, 1984; Warm, 1993; Matthews et al., 2000). In all of these studies, the global workload scores fell within the upper range of the NASA-TLX scale. As such, they exceeded those typically observed with other types of laboratory tasks, such as memory search, mental arithmetic, grammatical reasoning, choice-reaction time, and simple tracking, and were similar to those observed with a motion-based flight simulator (Liu and Wickens, 1987; Sanderson and Woods, 1987; Hancock, 1988; Hancock et al., 1988; Hart and Staveland, 1988). In addition, these studies also revealed a consistent workload profile among the NASA-TLX subscales in which Mental Demand and Frustration were the primary components of the workload associated with vigilance tasks. The workload profile or “workload signature” is illustrated in Figure 7.3.

Figure 7.3 NASA-TLX workload profile for vigilance tasks
(MD = Mental Demand, F = Frustration, TD = Temporal Demand, E = Effort, P = Performance, PD = Physical Demand)
Source: Warm et al., 1996.

The results obtained in the studies described by Warm, Dember and Hancock (1996) have been replicated in several other experiments using the NASA-TLX (Deaton and Parasuraman, 1993; Dittmar et al., 1993; Finomore et al., 2006; Grier et al., 2003; Grubb et al., 1995; Helton et al.,
2.3 Theoretical Issues

In a recent review of the problems inherent in the need to sustain attention, Johnson and Proctor (2004) have noted that research with the NASA-TLX has important theoretical implications. They affirm that the finding of high information-processing demand in vigilance tasks challenges arousal theory and supports a view, such as that proposed by Parasuraman and his associates (Parasuraman and Davies, 1977; Davies and Parasuraman, 1982; Parasuraman, 1984; Parasuraman, Warm and Dember, 1987; Warm and Dember, 1998), that the workload imposed by vigilance tasks reflects the impact of focused mental effort and a drain on information-processing resources that are not replenished over time on task. A similar argument regarding the mindlessness model has been made by Grier et al. (2003) and by Helton et al. (2005).

A critical component of the argument that research with the NASA-TLX supports a resource model of vigilance is the belief that the high workload scores on the scale arise from direct costs associated with the vigilance task itself. However, Sawin and Scerbo (1995) and Scerbo (1998) have argued that before the direct cost belief can be accepted, it is necessary to eliminate an indirect cost possibility in which the high workload associated with vigilance tasks arises not from the information-processing demand imposed by those tasks, but from observers’ efforts to overcome the tedium and boredom also associated with such tasks. Hitchcock et al. (1999) and Alikonis et al. (2002) have carried out experiments employing converging operations to do just that.

Hitchcock et al. (1999) sought to disengage workload and boredom by providing observers with accurate cues as to the imminent arrival of critical signals. In this way, they expected the information-processing demand of the vigilance task to be reduced because observers would only need to inspect the vigilance display when cued to signal arrival. On the other hand, since the tedious and repetitive nature of the task environment remained unchanged under the cueing condition, boredom was expected to be unaffected by the cueing manipulation. As an additional vehicle for testing the direct-cost and the indirect-cost views of workload in vigilance, Hitchcock et al. (1999) included a group of observers who received knowledge of results (KR) regarding their performance efficiency. Knowledge of results has been shown to enhance the speed and accuracy of signal detections in vigilance tasks (Davies and Parasuraman, 1982; Dittmar, Warm and Dember, 1985; Szalma et al., 1999; Szalma et al., 2006) and to reduce perceived mental workload in such tasks (Becker et al., 1995). When operating under KR, however, observers are not relieved of the need for continuous observation and decision making, as they are in the case of consistent cueing. Observers receiving KR must still observe continuously in order to secure positive evaluations and avoid negative ones. Hence, the direct cost view in the Hitchcock et al. (1999) study led to the expectation that cueing should result in a greater reduction in workload than should KR. From the indirect cost perspective, however, the well known motivational effects of KR (Warm and Jerison, 1984) could be seen as a vehicle for reducing the monotony of the vigil, thereby reducing workload to a greater extent than would cueing, which would not relieve the monotony of the vigil. As shown in Figures 7.4a and 7.4b, cueing significantly reduced the perceived mental workload of the vigilance task relative to both a control group, which received neither cueing or KR, and the KR group, but cueing had no effect upon boredom. The low rating given to the computer game condition in Figure 7.4b ensured that the absence of boredom differences among the three
Experimental conditions could not be attributed to a lack of sensitivity on the part of the Task-Related Boredom Scale (Scerbo, 1998) that was used to assess boredom in this study.

Figure 7.4a Mean overall workload scores on the NASA-TLX for Control, KR, and Cue groups

*Note:* The results for a card-sorting task are provided for comparison. Error bars are standard errors. 
*Source:* Hitchcock et. al., 1999.

Figure 7.4b Mean boredom scores on the TBS for Control, KR, and Cue groups

*Note:* The results for a computer game are provided for comparison. Error bars are standard errors. 
*Source:* Hitchcock et al., 1999.

Alikonis and her associates (2002) sought to disengage workload and boredom in another way. Taking advantage of the fact that music has been found to be effective in modifying observers’ moods and emotions (Lewis et al., 1995; Hargreaves and North, 1999), Alikonis and her associates (2002) asked observers to listen to a pleasant musical selection while performing a vigilance task. They expected that the music would reduce the boredom of the task. However, since the musical...
background afforded observers no aid in regard to signal/noise discriminations, it was not expected to reduce the workload induced by the vigilance task. Consistent with these expectations, Alikonis et al. (2002) reported that boredom was reduced but workload was unaffected by the musical background. Clearly, vigilance research with the NASA-TLX has withstood the indirect cost challenge and has, therefore, been of significant value in identifying the presence of high information-processing demand in a task that had heretofore incorrectly been considered a quintessential example of task underload.

2.4 The Multiple Resources Questionnaire

To date, a considerable amount of research on the perceived mental workload of vigilance tasks which supports a resource theory of sustained attention, has been carried out with the NASA-TLX. However, Boles and his associates (Boles and Adair, 2001; Boles et al., 2007) have suggested that, as useful as it has been, this instrument is nevertheless subject to a potentially important limitation – it is overly restrictive with respect to the mental processes that it represents. More specifically, the NASA-TLX treats resources in the way that they were conceptualized in Kahneman’s (1973) original derivation of resource theory, as a pool of undifferentiated information-processing assets that could be parcelled out to one or more tasks as needed. However, multi-tasking studies in short-term attention and in vigilance have demonstrated that certain pairings of tasks or task components produce greater multi-task processing deficits than others, indicating that attention may not be unitary; the degree of interference in handling more than one task in a limited time envelope depends upon the demands that are made upon similar resource pools (Kantowitz and Knight, 1976; Navon and Gopher, 1979; Wickens, 1980; Wickens and Hollands, 2000; Boles, 2001; Azuma, Prinz and Koch, 2004; Caggiano and Parasuraman, 2004).

Table 7.1 Dimensions of the Multiple Resources Questionnaire

<table>
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<th>Subscales</th>
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<tr>
<td>Vocal</td>
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<td>Tactile Figural</td>
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<td>Facial Figural</td>
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<tr>
<td>Auditory Linguistic</td>
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<td>Auditory Emotional</td>
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<td>Visual Phonetic</td>
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<td>Visual Lexical</td>
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<td>Facial Motive</td>
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<td>Spatial Quantitative</td>
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<td>Spatial Concentrative</td>
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<td>Spatial Positional</td>
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<td>Spatial Emergent</td>
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<td>Visual Temporal</td>
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<td>Spatial Categorical</td>
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<tr>
<td>Manual Process</td>
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<td>Spatial Attentive</td>
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Note: * Item met inclusion standard. See below.

In an effort to address this concern, Boles et al. (2007) have offered a new instrument, the Multiple Resources Questionnaire (MRQ), in which observers are presented with a set of multiple
mental processes based upon a combination of dimensions drawn from Wickens’ Multiple Resource Theory (Wickens, 1984, 1991, 1992) and from factor analytic studies carried out by Boles (summarized in Boles et al., 2007) and Boles and Law (1998). The MRQ consists of the 17 resource dimensions listed in Table 7.1. Fifteen of the dimensions reflect encoding/central processing resources; the remaining two are response resources. Using a scale from 0 (no usage) to 4 (extreme usage), observers are asked to rate the extent to which a task they just performed utilized each dimension.

Research with the MRQ has indicated the instrument is able to uncover different key resource dimensions in tasks involving different skills such as reading bar graphs, determining the spatial position of a line, word interpretation, and minimally invasive surgery procedures in medicine (Klein et al., 2005; Boles et al., 2007). In addition, the MRQ has been successful in predicting the interference between tasks based upon shared resource dimensions (Boles and Adair, 2001; Boles et al., 2007; Phillips and Boles, 2004).

Accordingly, Finomore et al. (2006) provided the initial application of the MRQ to vigilance in a study designed to contrast the sensitivity of the MRQ and the NASA-TLX to variations in psychophysical demand and to identify the specific MRQ resources that are involved in the performance of a vigilance task. In their study, the 0–4 rating scale for the MRQ dimensions was expanded to a 0–100 scale to be more consistent with the NASA-TLX. The resources involved in the vigilance task were identified as those dimensions in which significantly more than 50 per cent of the observers gave a rating other than zero and the overall or global score was the mean of the ratings given to the dimensions meeting the greater than zero standard. Differential psychophysical demand was manipulated by defining critical signals as events containing a small vertical line in one of a spatial array of otherwise empty circles or as events in which the line was absent from one of the circles in the array. Considerable data from the search literature indicate that detecting absence is more capacity demanding than detecting presence (Treisman and Gormican, 1988; Pashler, 1998; Quinlan, 2003) and vigilance studies by Schoenfeld and Scerbo (1997, 1999) and Hollander et al. (2004) using the NASA-TLX, have shown that signal detection is poorer and workload higher in the absence than in the presence condition.

Finomore and his associates (2006) found that seven of the 17 MRQ resources, those denoted by stars in Table 7.1, met the inclusion rule for being considered resources involved in the vigilance task. Consistent with prior findings, they reported fewer correct detections in the absence as compared with the presence condition and that like the NASA-TLX, the global workload scores for the MRQ were greater in the absence condition. Moreover, in both conditions, the global scores for each of the workload measures fell above the midpoint of the scales. Perusal of Table 7.1 will reveal that many of the dimensions meeting the inclusion standard were spatial in character, befitting the spatial nature of the vigilance task employed. The Finomore et al. (2006) study indicates that the MRQ can be a useful adjunct to the NASA-TLX in measuring the workload of sustained attention. It also adds to the conclusion that rather than being minimal work assignments, vigilance tasks are surprisingly demanding assignments involving an array of several different information-processing resources.

2.5. Brain Imaging Support

Additional and perhaps dramatic support for a resource theory account of vigilance is provided by recent studies from our laboratory (Warm and Parasuraman, 2007), using a noninvasive neuroimaging procedure known as Transcranial Doppler Sonography (TCD). This procedure employs ultrasound signals to monitor cerebral blood flow velocity (CBFV) or hemovelocity in the middle cerebral arteries which provide a large proportion of blood flow to the brain. The logic
underlying this technique stems from biochemical changes that take place when an area of the brain becomes metabolically active, as in the performance of mental tasks. When that occurs, by-products of the activity such as carbon dioxide (CO$_2$) increase. The increase in CO$_2$ leads to a dilation of blood vessels serving the activated area which in turn, results in increased blood flow to the region to remove the waste product (Aaslid, 1986). Consequently, TCD offers the possibility of measuring changes in metabolic resources during task performance (Stroobant and Vingerhoets, 2000). Along that line, a substantial body of evidence is available to indict that CBFV increases over a resting base line in the performance of a wide variety of cognitive, perceptual, and motor tasks (Stroobant and Vingerhoets, 2000; Duschek and Schandry, 2003; Tripp and Warm, 2007).

Consistent with these findings, our studies also show that blood flow velocity during task performance is directly related to task demand, particularly in the right cerebral hemisphere (Warm and Parasuraman, 2007). The finding of lateralized effects is important for two reasons: 1) it accords with brain imaging studies using positron emission tomography (PET) and functional magnetic resonance techniques (fMRI) which also point to a right hemispheric system in control of vigilance (see Parasuraman, Warm, and See, 1998 for a review) and 2) it rules out the possibility that the hemovelocity effects were confounded by gross changes in systemic vascular activity such as changes in heart rate variability, blood pressure, and cardiac output, since these changes are not likely to be lateralized.

![Figure 7.5 The relation between the vigilance decrement and cerebral blood flow velocity
Source: Shaw et al., 2006.](image-url)

Key aspects of our TCD studies for differentiating the resource theory and arousal models are findings regarding the vigilance decrement. As noted above, the resource model accounts for the vigilance decrement through the exhaustion of information-processing assets that are not replenished over time. Consequently, that model would lead one to expect that the decrement would be accompanied by a temporal decline in CBFV; a result that has occurred in all of our studies. It is important to note, however, that it only appears when observers actively perform the vigilance task. Blood flow velocity has remained stable over time among control observers who passively looked at or listened to the vigilance displays without a work imperative. Due to a putative loss
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in wakefulness, the arousal model would also lead to the expectation of a decline in CBFV over time. However, that model leads as well to the expectation of a decline in CBFV in the passive control observers, since merely looking at or listening to a meaningless display for a prolonged amount of time would seem to provide the maximum case of repetitiveness and monotony needed for a decline in wakefulness. Clearly, that was not the case in our experiments. The findings with regard to the temporal decline in CBFV that accompanies the vigilance decrement are illustrated in Figure 7.5. The figure displays data from a study by Shaw and his associates (2006) wherein a decline in signal detections over time was paralleled by a temporal decline in CBFV in active observers while the level of CBFV remained stable over the same time period in passive controls.

3 The Stress of Sustained Attention

3.1 Appraisal and Regulation

Hancock and Szalma (Chapter 1; 2007) have recently noted that two central themes characterize modern theories of stress and performance. The first focuses upon an appraisal mechanism by which individuals evaluate environmental events, including the demands made upon them by the tasks that they must perform, in terms of their physical and psychological well being and their selection of coping strategies to deal with those events (Lazarus and Folkman, 1984; Hancock and Warm, 1989; Hockey, 1997; Matthews and Campbell, 1998; Stanton and Young, 2000; Matthews, 2001). Along this line, Lazarus and Folkman (1984) have defined stress as a transaction between an individual and the environment in which the individual views the demands of the environment as taxing his or her resources and endangering his or her well being. The second theme focuses upon individuals’ ability to respond to appraised threats including high task load by exerting compensatory effort to recruit the resources needed to maintain task performance. Thus, individuals may be able to maintain performance levels but only at a physiological and psychological cost (Hancock and Warm, 1989; Hockey, 1997). Vigilance is a case in point – the substantial demands on resource utilization imposed by vigilance tasks that are reflected in high levels of perceived mental workload are accompanied by elevated levels of stress as revealed through both physiological and self-report measures. Given that sustained attention tasks are components of many human-machine systems and mounting evidence that stress plays a role in lowering worker health, safety, and productivity (Sauter, Murphy and Hurrell, 1990; Nickerson, 1992; Huey and Wickens, 1993; Strauch, 2002; Miller, Chen and Zhou, 2007), the stress induced by the performance of vigilance tasks is more than just an academic concern.

In performance contexts, the transactional model of stress (Lazarus and Folkman, 1984) implies that the relationship between task performance and stress response is bidirectional. The pressures imposed by the task demands elicit physiological and subjective stress responses, which in turn feedback to influence information-processing and the operator’s strategies for coping with demands. Stress may thus affect performance either through influencing basic parameters of processing, such as availability of resources, or the person’s motives, goals and voluntary regulation of task demands. In the remainder of this section we will look first at the effects of the demands of the vigilance task on stress and second, at the reciprocal influence of stress on task performance.

3.2 Vigilance as a Stressor

There are various means for assessment of the stress induced by vigilance that provide apparently conflicting results. Measures of autonomic nervous system activity such as skin conductance and heart rate tend to suggest that arousal decreases during performance (Davies and Parasuraman,
Performance Under Stress

1982). Similarly, EEG studies (e.g., Smit et al., 2005) have tended to show that the most reliable effects of vigilance are an increase in power in the theta band, low frequency waves that may relate to sleepiness. The focus on lowered arousal as a feature of vigilance is consistent with the traditional arousal model of vigilance described previously. Measurements of other response indices are suggestive of increasing stress during the vigil. Studies reported by Frankenheuuser (e.g., Frankenheuuser et al., 1971; Lundberg and Frankenheuuser, 1979) showed that levels of both epinephrine and norepinephrine circulating in the bloodstream were elevated in the vigilance task. Elevated levels of these catecholamines are often employed as a stress index (Lundberg, 2005). O’Hanlon (1965) found elevated norepinephrine levels in observers who, having performed a vigilance task previously, were waiting to perform it a second time, as if the mere anticipation of performing the task induced a physiological stress reaction. Cortisol has also been used an index of fight-or-flight response. A study of US Army officers (Lieberman et al., 2005) showed that the stress associated with simulated combat exercises elevated cortisol and impaired vigilance and other tasks. However, our laboratory work failed to confirm that a high-workload, stressful vigilance task elevated salivary cortisol concentrations (Matthews, Warm and Washburn, 2005).

In addition to the circulating catecholamine findings, the stress of sustained attention has been revealed through several other physiological measures. Using electromyographic methods, Carriero (1977) and Hovanitz, Chin and Warm (1989) have found increased levels of muscle tension in observers during a vigil and Hovanitz, Chin and Warm (1989) and Temple et al. (1997) have reported that vigilance tasks can induce tension headaches in sensitive observers. Moreover, through the use of pulse transducers located under observers’ seat cushions, Thackray, Bailey and Touchstone (1977) found that observers become increasingly more restless over the course of a vigilance task and Galinsky et al. (1993) found increased levels of physiological tremor across the course of a vigil among observers who wore a tremor-monitoring system on their wrist as they performed the task.

The physiological data are paradoxical in suggesting that vigilance is simultaneously both de-arousing and stressful. The paradox may be resolved through recognition of the multidimensional nature of stress responses. The various response systems used to index “stress” may become activated or de-activated independently from one another. For example, Thayer (1989) has suggested that subjective dimensions of energetic arousal and tense arousal may index distinct biocognitive systems serving differing functional purposes – supporting, respectively vigorous goal-directed action (energy) and the “fight or flight” response (tension).

Work using subjective measures of stress has proved especially apt for exploring the multidimensional nature of the stress induced by vigilance. The initial investigation along this line was conducted by Thackray, Bailey and Touchstone (1977), who asked observers to use a 9-point scale in rating various qualities of their mental state at the beginning and at the end of a one-hour vigilance session employing a simulated air-traffic radar control system. The participants rated themselves as feeling significantly less attentive and more bored, strained, irritated, and fatigued after the vigil than before its start. Subsequent studies using the Thackray scales have reported similar mood changes following participation in a vigilance session (Hovanitz, Chin and Warm, 1989; Warm, Rosa and Colligan, 1989). In addition, Dittmar et al. (1993); Galinsky et al. (1993), and Warm, Dember and Parasuraman (1991) have reported that observers feel more sleepy after a vigil than prior to its start, as measured by the Stanford Sleepiness Scale (Hoddes et al., 1973) and a scale of symptoms of fatigue developed by Yoshitake (1978).

A report by Johnson and McMenemy (1989) on mood changes in US soldiers on sentry duty is consistent with the idea that vigilance tasks are stressful and provides evidence for the ecological validity of the findings described above. The soldiers in this study performed three-hours of simulated sentry duty during which they monitored a realistic target scene for pop-up silhouettes
of enemy troops upon which they fired when detected. Target detection deteriorated with time on watch and the soldiers’ predominant mood shifted from one of vigor at the outset to fatigue at the end.

These initial self-report studies are limited because the various scales employed appear to have been chosen somewhat arbitrarily, without reference to an over-arching psychometric model of stress states. While the scales of the Thackray questionnaire presumably tap different stress dimensions, the distinctions between the various dimensions have not been empirically validated and the Stanford Sleepiness scale and the Yoshitake scale only measure unidimensional aspects of stress states. To develop a more systematic multidimensional framework for understanding transient states of mood, arousal, and fatigue, Matthews et al. (1999, 2002) developed the Dundee Stress State Questionnaire to assess the various ways in which stress may be experienced as disturbances in affect, motivation, and cognition. The instrument features ten factor-analytically determined scales which measure energetic arousal (alertness-sluggishness), tense arousal (nervousness-relaxation), hedonic tone (general pleasantness of mood), intrinsic task motivation, self-focused attention (self-awareness, daydreaming, etc.), self-esteem, concentration, confidence and control, task relevant cognitive interference (worry about task performance), and task irrelevant cognitive interference (worry about personal concerns).

The scales are themselves intercorrelated and support a higher-order factor model that differentiates three broader dimensions known as Task Engagement, Distress, and Worry. Task engagement incorporates the energetic arousal, motivation, and concentration scales and contrasts enthusiasm and interest with fatigue and apathy. Distress encompasses negative moods and lack of confidence, while Worry reflects the level of intrusive thoughts and other negative self-referent cognitions (Matthews et al., 2002). Thus, the Task Engagement and Distress dimensions integrate affective, motivational, and cognitive aspects of stress, whereas the Worry dimension is primarily cognitive in character. The subjective states measured by the DSSQ correlate to a moderate degree with physiological indices of stress and arousal (Fairclough and Venables, 2006).

Studies employing the DSSQ to assess the stress of sustained attention use standard scores to compare ratings given at the end of an experimental session with those of an extensive norm group provided by Matthews et al. (1999, 2002). The studies have revealed that participation in a vigilance task typically leads to a loss of task engagement accompanied by increased feelings of distress and a decline in worry (Matthews et al., 1999, 2002; Helton et al., 2000; Parsons et al., 2000; Temple et al., 2000, Alikonis et al., 2002; Grier et al., 2003; Helton et al., 2004, 2005; Szalma et al., 2004, 2006). Illustrative profiles of state change, in z-score units, are shown in Figure 7.6 for four studies, each using a different vigilance task, ranging from simulations of air traffic control (Reinerman et al., 2006) and industrial parts inspection (Grier et al., 2003) to discriminating line lengths (Matthews et al., 2006) and configurations of digits (Beam, 2002). As discussed below, the pattern of state change varies somewhat with task characteristics, but Figure 7.6 represents a general, distinctive stress signature for vigilance tasks, since other demanding tasks elicit different stress portraits. For example, working memory tasks elicit increased distress along with increased task engagement (Matthews et al., 2002). A similar state change pattern generalizes to real-world tasks requiring sustained attention, such as prolonged driving in an automobile simulator (Matthews and Desmond, 2002; Saxby and Matthews, 2007). The seeming conflict between the effects of vigilance on the different physiological stress indices may reflect the multidimensional nature of the response. In terms of Thayer’s (1989) model, vigilance both increases tense arousal (as a component of distress) and lowers energetic arousal (as a component of task engagement). From a stress standpoint, the decline in worry after participating in a vigilance task may seem anomalous. However, this result has been found with the DSSQ in a wide variety of experimental tasks and most likely reflects non-specific learning effects in which participants become familiar
with task requirements and come to understand that they are not in danger of physical or emotional harm (Matthews et al., 2002).

![Figure 7.6 Patterns of stress state change in four studies of vigilance](image)

**Figure 7.6 Patterns of stress state change in four studies of vigilance**

Like the perceived mental workload scores, stress scores on the DSSQ are also tied to task characteristics. Thus, Temple et al. (2000) and Helton et al. (2004) found that levels of distress are greater with low as compared with high levels of signal salience. In addition, using the DSSQ, Szalma et al. (2004) confirmed an earlier finding by Galinsky et al. (1993) with the Yoshitake scale that observers tend to be less stressed while performing an auditory as compared with a visual vigilance task perhaps because observers in the auditory task are free from the negative effects of postural constrain and eye strain that accompany the performance of visual vigilance tasks (Hatfield and Loeb, 1968). Szalma et al. (2004) also explored the time course of subjective state change over vigils of differing durations, finding that operators appeared to adapt to the demands of the auditory task over time, but distress induced by the visual task rose monotonically with increasing task duration. The transactional model of stress implies that transitions in workload should tend to be stressful as the person is forced to accommodate to changing task demands. Consistent with this hypothesis, Helton et al. (2004) reported that distress scores increase when observers in a vigilance task are shifted unexpectedly from high to low levels of signal salience or from low to high levels. By contrast, task engagement scores decline when observers are shifted from low to high salience and increase when they are shifted in the other direction. Workload change of any kind appears to impact distress, whereas changes in engagement relate inversely to the direction of workload change.

As indicated in the introduction to this section on stress and sustained attention, the coping strategies that individuals adopt in order to actively regulate their handling of task demands in stressful environments is a critical feature in current approaches to stress (Hancock and Szalma Chapter 1, 2007). These strategies include task- or problem focused coping in which behaviors are directed at constructive action to change the stressful situation, emotion-focused coping designed to regulate the emotional consequences of the stressful situation, and avoidance coping through which individuals divert attention away from the task at hand (Matthews and Campbell, 1998; Szalma et al., 2004). Studies with the DSSQ reveal that all three strategies may be operative in
the effort of observers to come to terms with the stress of sustained attention, since a decrease in task engagement implies a loss in problem-focused coping (Matthews and Campbell, 1998), while increases in distress imply a use of emotion-focused coping and to a lesser extent, avoidance coping styles (Matthews et al., 1999, 2002).

The importance of coping may also be signaled by studies that have varied the operator’s actual or perceived control over task demands. The degree to which the task provides the operator with active agency and control, as opposed to passive monitoring, especially influences subjective task engagement. Hitchcock et al. (2002) found that providing a cue to imminent target onset serves to maintain engagement in proportion to the validity of the cue. Cueing allows observers to control their resource deployment strategically. Szalma et al. (2006) demonstrated that providing observers with the illusion of choice over the level of task demand also helps to elevate task engagement relative to a no-choice condition. In a military context, affording the person the opportunity to attack a designated target, as opposed to passively monitoring for targets, also appears to reduce perceived workload (Gunn et al., 2005) and to elevate task engagement (Parsons, 2007). In simulated driving, “passive fatigue” (Desmond and Hancock, 2001) associated with monotony and reduced vehicle control appears to induce loss of task engagement more rapidly than “active fatigue” related to sustained attempts to manage disruptions of vehicle control (Saxby and Matthews, 2007). Thus, while purely psychophysical attributes of tasks may influence stress response (e.g., Temple et al., 2000), manipulations that allow the operator to employ problem-focused coping in controlling task demands are especially linked to task engagement.

3.3 Task Engagement as a Predictor of Vigilance

Thus far, we have discussed how vigilance influences stress; next, we discuss how stress response relates to objective performance of vigilance tasks. Reviews of studies using traditional a.n.s. and c.n.s. measures of stress and arousal demonstrated that few measures are reliably predictive of performance (Davies and Parasuraman, 1982; Koelega, 1990), contrary to the arousal theory of vigilance. A few physiological measures appear to be more promising as predictors. The studies of Frankenhaeuser et al. (1971) and O’Hanlon (e.g., 1965) that we discussed previously demonstrated a positive correlation between the level of epinephrine and performance efficiency. Hockey (1997) proposes that epinephrine is an index of compensatory effortful control (rather than arousal or stress per se). Some studies have shown that slow wave EEG activity, especially theta waves that may signal sleepiness, relates to poorer vigilance (Davies and Parasuraman, 1982). Freeman et al. (2004) proposed that an index of EEG arousal based on the power ratio beta: [alpha + theta] can be used to drive adaptive automation. However, relationships between the EEG and vigilance in operational settings may be complex: Campagne, Pebayle and Muzet (2004) found that theta related to loss of vigilance during driving only in older individuals.

Studies of subjective state have also explored which components of stress are predictive of performance on vigilance tasks. Matthews and Davies (1998, 2001; Matthews, Davies and Lees, 1990; Matthews, Davies and Holley, 1990) conducted a series of studies that tested whether Thayer’s dimensions of energetic and tense arousal, measured prior to performance, predicted perceptual sensitivity on relatively short, high workload vigilance tasks. Generally, these studies show that energetic arousal was reliably predictive of higher perceptual sensitivity, whereas tense arousal was not. Matthews, Davies and Holley (1990) tested a processing resource model developed by Humphreys and Revelle (1984) against traditional arousal theory. The Yerkes-Dodson Law, as an expression of the latter, predicts that high arousal should tend to facilitate easy task versions but impair harder ones. By contrast, resource theory assumes that more demanding tasks are more strongly limited by availability of attentional resources. If, as Humphreys and
Revelle (1984) propose, arousal relates to higher availability of resources for sustained information transfer, then high arousal should facilitate performance of demanding tasks, but have little effect on undemanding ones. Matthews, Davies and Holley (1990) found clear support for the resource theory prediction; energetic arousal only facilitated performance of a vigilance task rendered difficult by use of visually-degraded (pattern-masked) stimuli. It might be argued that energetic arousal related not to some general resource but, more specifically, to encoding of degraded visual stimuli. However, further studies demonstrated that alternative workload manipulations functioned similarly as moderators of the association between energy and vigilance. For example, Matthews and Davies (1998) showed that high energetic arousal tended to facilitate dual-task performance more than single-task performance and successive task performance more than simultaneous task performance, consistent with the notion of a general resource limiting a variety of tasks using qualitatively different processing components.

In terms of the multidimensional model of stress states represented by work on the DSSQ (Matthews et al., 2002), energetic arousal is one of the core elements of the task engagement factor. Matthews et al. (1999) confirmed that task engagement correlates positively with perceptual sensitivity; similar correlation magnitudes were found for energy and for the higher-order engagement factor. Task engagement and energetic arousal may both serve as markers for resource availability, the quantity of resources available to the individual for information-processing. A formal test of this hypothesis using dual-task methods was also successful (Matthews and Margetts, 1991). The practical utility of the finding is supported by studies showing that energy and engagement relate to performance of complex tasks representative of real-world skills including aircraft operation (Singh, Molloy and Parasuraman, 1993) and vehicle driving (Funke et al., 2005). A recent study by Reinerman et al. (2006) compared task engagement with the cerebral hemovelocity index described in the previous section as predictors of a vigilance task resembling air traffic control. The study aimed to test the predictive validity of diagnostic indices by using assessments of response to a short task battery as predictors of perceptual sensitivity on the subsequent longer vigilance task. Both higher engagement and higher task-induced blood flow velocity predicted vigilance performance. A multiple regression analysis showed that the multiple $R$ using blood flow and subjective state as predictors was 0.36, a validity coefficient large enough to be practically useful. Thus, a field test of the engagement and blood flow responses to a brief task challenge may be diagnostic of a soldier’s fitness to perform a subsequent mission requiring sustained attention.

Research in our laboratory using the brief vigilance task developed by Temple et al. (2000) has also shown that changes in task engagement may play a critical role in mediating effects of environmental stressors on vigilance. Matthews et al. (2001) investigated the effects of cold infection on vigilance. Observers suffering from a cold performed more poorly than when in a healthy state, and also reported higher workload, higher distress, and lower task engagement. A multiple regression analysis showed that the effect of cold infection was directly mediated by lowered task engagement, indicating that measurement of engagement might be validly used to index the functional impairment resulting from the illness. Helton et al. (2002) tested the effects of loud jet engine noise. Perhaps surprisingly, loud noise elevated both vigilance and task engagement, relative to a quiet control condition. Again, regression analysis confirmed the effect of the noise was mediated by increased task engagement. This finding demonstrates how assessment of subjective states may serve to elucidate the conflicting findings regarding noise effects on vigilance (Davies and Parasuraman, 1982). Different noise stimuli elicit differing effects on subjective stress (Thayer, 1978), but direct measurement of the state response serves to predict the likely impact on performance.
3.4 Summary of Stress and Vigilance

The survey of the evidence supports the multidimensional approach to understanding the stress of vigilance that we have advocated. The demands of sustaining attention, especially on high workload tasks, elicit a variety of subjective and physiological responses, many of which, including traditional autonomic arousal measures, do not appear to be functionally linked to performance. The key element of the stress response may be loss of task engagement, which is reciprocally linked to vigilance. The monotony of vigilance, together with the operator’s inability to regulate task demands are liable to induce declining task engagement. In turn, loss of engagement is associated with loss of attentional resources, and objective performance deterioration. Those physiological indices (e.g., cerebral hemovelocity, epinephrine) that do predict performance may provide alternate indices of resources, or indices of control mechanisms that regulate effortful allocation of resources to processing (Hockey, 1997). At least some stressor effects on vigilance, including those of cold infection and noise, may be mediated by changes in task engagement.

4 Conclusion and Implications

Conventional wisdom about automation is that it leads to simplicity. However, as Woods (1994) has indicated, automation often complicates operators’ cognitive activities to a greater degree than anticipated. This appears to be the case where vigilance in the management of modern machine systems is concerned. As Howell and Goldstein (1971) pointed out many years ago, by divesting operators of more active activities in such systems, we may have unwittingly placed them in an awkward position. On the one hand, operators assume more responsibility as decision makers while on the other, automation may have created a work situation that is not conducive to their best efforts. Our research indicates that rather than being understimulating, vigilance tasks are exacting, capacity-draining assignments that are associated with considerable levels of stress in which the quality of performance efficiency wanes over time. Warm, Dember and Hancock (1996) have suggested that one solution to this problem might be to take advantage of our knowledge of psychophysical factors that can influence vigilance performance to design systems so as to enhance signal detection and lower operator workload. Another possibility may lie in the design of work environments that are more conducive to the operators’ role as a system monitor. More specifically, the dynamic interplay of task engagement and vigilance appears to be an important target for interventions. In line with Hancock’s (1997) view that work should be structured to afford enjoyment rather than drudgery, engagement may be maintained through radical task redesign to promote intrinsic satisfaction in the task and a degree of operator autonomy and challenge. The data reviewed above suggest that tasks that allow active regulation of task demands tend to promote task engagement, whereas highly constrained task configurations lead to disengagement. Thus, the vigilance findings endorse Hancock’s (1997) thesis that the work environment must be transformed, as far as is possible, to support operator engagement as a counter-measure to both the stress of vigilance and performance decrement.

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References


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Introduction

This chapter looks at some of the origins of what might be called time-stress; underlying relationships among temporal regulation and temporal cognition; and their separate and combined effects on and responses to stress. While there is much about the passage and regularity of time that is beneficial – the synchronicity of a symphony, the faithfulness of the Paris Metro schedule, the precision of a space launch all depend upon it – less positive effects may accrue as well. Time stress affects the harried executive, the anxious college applicant, the expectant mother, and not the least, our military servicemen and women. And, of course, the broader aspect of time holds its own fascination:

Time perception: Biological, psychological and cultural considerations. Psychological (subjective) time is the feeling of how time is now passing, how much time seems to have gone by. Our inner clocks, most often circadian, are postulated as basic to our sense of internal time. Light seems to be the most prominent zeitgeber, or time giver of biological rhythms [...]. The relation between psychological (subjective, perceived) time and the universal objective (physical, clock) time depends not only on the biological time sense, but also on learning, cognitive ability, experience, physical and social environment, personality, culture, age, and so on... From this point of view disruption of psychological time, or of the time sense, influences behavior [...]. (Anna Eisler, NATO Advanced Research Workshop 2002).

We consider three levels of temporal factors: biologically-driven time exemplified by circadian rhythm effects; psychologically-driven time as experienced both cognitively and via the timing of motor actions; and clock-driven time typified by performing tasks under external, system-orchestrated time pressure (see the illustration in Figure 8.1). The discussion in this chapter will progress from an exploration of temporal factors, which can variably constrain and direct fundamental phenomena including our biological clocks and effects of their disruption, to a review of the diverse, current thinking about the psychology of temporal cognition as a function of stressors and of its role as a stressor itself. Evidence is offered showing that it takes cognitive effort to balance a schedule or maintain a set rhythm; it is this seeking of homeostasis that is often defined as the effect of stress. Current timekeeper models are presented along with computational approaches for understanding temporal cognition. Finally, the chapter will conclude with some observations on designing systems with temporal cognition in mind including suggestions of ways to mitigate the mental workload required to perform temporal cognitive tasks in both human-machine and human-human interaction.
The documented history of the measurement of endogenous clock activity dates back at least to the 1880s. Cattell (1884) wanted to measure the time it took for “cerebral operations” to take place, that is, how long it took for light to act on the retina and generate the nervous impulse describing the features of that light, for the impulse to travel down the optic nerve to the “visual centre,” and how long for that center to process the meaning of the light and thus engender a change in the brain. While it was not possible at that time to measure the actual neuronal operations, it was thought adequate enough to measure the time lapsed between the onset of a light stimulus and some observable event occurring presumably as a result of that stimulus. Taking a slightly different tact, Peirce and Jastrow (1884) sought to provide an objective measure of perceptual differences (e.g., temperature, pressure) linked to the time interval it took to note a difference of a certain level of intensity.

William James (1890) examined a somewhat philosophical temporal issue that is fundamental to our understanding of time, the matter of what constitutes “the present.” He distinguished between an instantaneous perception, “the present,” and some amount of time that spans beyond that moment. James defined the concept in this way: “the prototype of all conceived time is the specious present, the short duration of which we are immediately and incessantly sensible.” In other words, “the present” is a cognitive aggregation of near simultaneous perceptions across some small amount of time, just as perception of a photograph is a spatial aggregation of many visual signals. Much later, Fraisse (1984), in his thorough review of the psychophysical literature related to the perception of time, is able to be more specific about the “present.” He determines that there are three levels of duration to be considered: less than 100 milliseconds (“instantaneity”) (p. 29, 1984); between 100 milliseconds and 5 seconds (the “present,” which is experienced essentially directly); and above 5 seconds, for which some form of memory is implicated.

The early temporal research of Cattell and James and their contemporaries necessarily relied upon conjecture and introspection. It was several decades before the temporal elements of stress effects related to endogenous biological functions began to be addressed more objectively. For example, Francois (1927) used quantitative measures of the effects of metabolism and body
temperature on time perception, providing evidence for biologically-mediated temporal cognition, later made explicit in the chemically-based internal clock proposed by Hoagland (1933).

While today we might comment on a lack of sophisticated diagnostic definition in that early work, for the most part the writers held their research open to fuller interpretation pending the arrival of improved methodologies and instrumentation. In the intervening decades, cognitive psychology provided new experimental methods and the medical community developed measurement technology such as functional Magnetic Resonance Imaging (fMRI), both of which have yielded increased understanding of the underlying brain structures and function by several orders of magnitude. Yet, the residual noise in the measures themselves and from the lack of convergence of measures (e.g., varying temporal and spatial resolution) suggests that both instrumentation imprecision and a still-inadequate knowledge of critical features remain. Recently, the common emergence of biotechnology, nanotechnology, information technologies, and cognitive science (National Science Foundation and US Department of Commerce, 2002) offers an invigorated expectation that we will find the means to measure fully and, hence, to mitigate severely disruptive effects on the human body’s evolved biological clocks. Already, physiological imaging, measurement, and manipulation techniques are being demonstrated that allow for the isolation and study even of individual neurons within small bundles of neuronal links (e.g., Herzog et al., 2000; Yamazaki et al., 2000) and the promise of a full understanding of the biological basis of temporal regulation and temporal cognition, and consequently a better understanding of time-related stress.

Biologically-driven time

This section will examine some of the types of endogenous biological clocks that serve to help regulate an increasingly chaotic existence as promoted by the introduction of metabolism-changing food supplements, the availability of medicines, the requirements of variable work-rest schedules, and the time zone-hopping travel opportunities available today.

Evolutionary development

Today, even among the most ardent students of stress as a psychological phenomenon (e.g., Hancock and Warm, 1989), there is recognition that stress is not exclusively psychologically-based (Hancock and Szalma, 2007). The evolutionarily cumulative biological and physiological effects of stress on the organism were, after all, necessary to our development as psychological beings in the first place. In fact, it was this evolution that led to our sense of time, which in turn supported our neuronal-level abilities such as pattern recognition.

As suggested by the term “implicit temporal processing,” one of the key features of the time sense is that we need not be aware of it. Considering the many varied forms of time-dependent pattern-completion steps involved in understanding language and visual space, often concurrently, it is apparent that we cannot be attentively aware of all the synchronized processes that constitute our organism’s perception. Thanks to evolution, pattern completion happens much too quickly, at too fundamental a level to support processing of continual and conscious psychological causation. Yet even without being attentive to the disruption of the endogenous orchestrated rhythms pacing our perception and activities, our systems can be affected by those disruptions (e.g., see jet lag discussed below).

It is important to recognize that there are definite neuronal and neurotransmitter systems that underlie our sense and perception of time, systems that help the organism maintain internal homeostasis as well as stay in harmony with others’ speech, music, and coordinated/collaborative actions. Indeed, here our increasing understanding of function and structure is impressive.
findings from systems biology are providing neuronal- and cellular-level windows into the basis of temporal cognition. At the level of neuronal bundles, protein luminescence factors have allowed examination of cellular ensembles with extremely fine precision (Liu et al., 2007). It is at this level that we can see how intercellular coupling provides the synchronicity that allows cells a robustness against possible mutation due to outside biological stressors, an internal push-back against threats to the organism. It is the occurrence of such mutations that are thought to underlie dysrhythmia-related stressors to health, such as sleep and mood disorders. Research into genetic transcriptional regulatory feedback operations, where changes in a gene’s “noise levels,” for example, can act as signals to moderate the organism’s response to change, is now opening the door to active monitoring and management of certain stress effects. Already in research with lower mammals, basic functioning of a critical time sense has been restored by grafting select cell bundles onto the hypothalamus (Tousson and Meissl, 2004).

As lessons learned from these pioneering efforts become better understood and more broadly inculcated, the potential for altering genetic aging and disease patterns via “temporal manipulation” brings a new ray of discovery and hope (Sinclair and Guarente, 2006). Our understanding of temporal stress, at least from the biological and psychological perspectives, is in for a series of reexaminations and redefinitions.

Circadian rhythm and homeostasis

Circadian rhythm, the approximately 24-hour cycle of awake-sleep activity in response to light-dark cues, has ancient, primitive origins. Argonne National Labs, in 1953, demonstrated the phenomenon of a biological clock in a single protozoan cell. Today, fundamental studies involving a number of organisms, including light-sensitive cyanobacteria, plants, insects, and mammals, generate key insights into the workings of biological clock systems (e.g., Doyle et al., 2006). Understanding the broad effects of the circadian clock system is certainly critical to understanding modern man’s technology-rich activities and roles, such as humans-in-automation (Hockey, Gaillard and Burov, 2003; Mallis, Banks and Dinges, 2006). Travel-related effects such as jet lag (Caldwell and Caldwell, 2003) have serious disruptive effects on cognitive processing, energy levels, and overall physical health.

Key aspects of the physiological structures affecting our sense of time, rhythm, and synchrony appear to be centered in the hypothalamus, a major time-control center in the brain. [The reader also is directed to an alternative perspective under study, one positing the basal ganglia and associated pathways as particularly implicit in managing the multi-dimensional accuracy of timing for motor control; Harrington and Rao, 2002.] Within the hypothalamus resides the suprachiasmatic nucleus (SCN), that bundle of some 10,000 neurons whose common synchrony has been implicated in driving the rhythm to which most organisms and their internal structures and tissues appear to respond in precise orchestration (e.g., Matthews, 2001). The SCN sits immediately atop the optic chiasm (hence its name), a position that allows it to receive signals from photo-receptive retinal ganglion cells through the retino-hypothalamic tract (RHT). Evidence to date suggests that, in mammals, the role of light (via the RHT) is to change the transcription rate of genes PERIOD (PER) and TIMELESS (TIM) in the regulatory circuit. The translation into proteins, and the subsequent activation and repression activities on other genes, make up a circadian gene regulatory-loop architecture. It is this looping activity that involves various multi-scale (circadian and more-frequent) molecular behaviors, all working in relative synchrony and regularity. This system helps provide for the homeostasis, predictability, and anticipation our systems require for both internal and cross-organism communications (Doyle et al., 2006).
Additionally, the relatively central location in the brain permits the SCN to easily interact with and upon a number of nearby brain structures via communications from its various cell types. The SCN contains, for example, vasopressive and vasoactive peptides (controlling vascular, hemodynamic activities) and neurotransmitters, the release of which controls the flow of blood and transmission agents to various cells and organs in order to maintain a running homeostasis. Thus, the SCN is an organism’s temporal system controller, providing for “just in time” delivery of hormones and neurotransmitters, and in this way, regulating oscillations in a variety of “peripheral oscillators.” In particular, the SCN influences other organs via its neuro-chemical link to the pineal gland, which secretes melatonin at night, thus preparing the body’s systems for restorative sleep. Synchrony with the SCN allows for smooth operation of numerous other distributed “biological clocks” (e.g., the heart beat, hormonal release-rate mechanisms, etc.).

One note, however, is the idea that the biological clock may be more focused on “relative” attributes of time, as opposed to strict period control. These ideas were articulated clearly by Pittendrigh and Daan (1976) some years ago: “A daily program is useless (indeed disadvantageous) unless it can be phased correctly to local time. Thus it is the phase-control, more than the period-control, inherent in entrainment that is the principal dividend selection has reaped in converting a daily program into an oscillator.”

Circadian rhythms and specific stress symptoms

How might the SCN generally relate to an organism’s stress? Maintaining homeostasis (and in many cases, acting in anticipation of its disruption) across many internal clocks (now hard-wired over aeons of evolution) may be its primary function. For example, when a normal sleep routine is disrupted, activity within and associated with the SCN is likewise disrupted. Given that the action of the SCN is generally indirect or intermediary, those disruptions extend to the other systems with which the SCN communicates. This effect is compounded by the SCN having to work overtime to regain an even keel so that the operations of as many vital functions as possible are kept intact (Rosenzweig, Breedlove and Leiman, 2002) or returned to some stable state.

What types of stress effects are associated with a disrupted circadian rhythm? Judging from media advertising, the most prevalent symptom includes the many forms of insomnia, and indeed this is a commonly reported symptom. No doubt the reader will recognize or have personally experienced several conditions resulting from being held to an irregular sleep-wake cycle. There is a direct interaction with an environmental (changes in time zone) or neurochemical (food additive, caffeine) stressor element that imposes change on the system. To complicate the sources-of-stress picture here, there is also evidence of hereditary sleep disorders, such as Advanced Sleep Phase Syndrome (ASPS), in which descendants carry an altered gene in the biological clock circuit (PER2), the manifestation of which is a shifted (in some cases, even a continually shifting) sleep cycle (e.g., Cermakian and Boivin, 2003). Stresses on health, performance, and social interactions may be severe if not managed appropriately.

Shift work Those working on a changing-shift schedule, such as working days for 2 weeks alternating with working nights for 2 weeks, are subject to a variety of direct and indirect stressors. Indeed, while a shift work policy may spread the misery evenly to all workers, it wreaks havoc on health, personal, and family lives (Shields, 2002). According to this report, in 2000 and 2001, 3 out of every 10 Canadians were employed in some type of shift work. Men working evening or other irregular shifts were found to experience a higher than normal degree of chronic health problems. Harrington (1984) cites in his review that shift work was found to increase the incidence of cardiovascular disease and death, gastrointestinal disease, and overall workplace accidents. For
all types of shift workers, there was a higher than normal difficulty in falling asleep, and the reported quality of sleep was lower than normal. The psychological effects of this type of sustained disruption of the circadian clock often included spousal and other family problems, likely leading to a secondary set of stressors. Stress-mitigating therapies here could include caffeine to improve temporarily such functions as alertness and vigilance (e.g., Kamimori et al., 2005). Doyle et al. (2006) also make a compelling case for acceptance of the emerging corpora of knowledge of activities at the cellular and genetic levels to consider circadian-clock control as a valid means of managing time-associated stressors.

Jet lag A problem faced by many whose lives require extended air travel is jet lag, or “desynchronosis.” Travel across several time zones leaves the internal body clock, and its attendant expectations of availability of light and other bio-social cues, in disharmony (desynchronized) with its new-destination environmental cues. The internal rhythms that prompt us when we need to eat, sleep, and be at our peak for the day’s activities are disrupted. The resultant stress is magnified by the relative dehydration and oxygen deficit experienced in today’s aircraft. The more time zones we cross, the more difficult it is for the body to automatically adjust its rhythms. There are wide individual differences in the adjustment process, but stress symptoms typically include fatigue and even exhaustion, changes in appetite, general head and body aches, and temporary disorientation (see Wright et al., 1983, for a more complete discussion). This does not make for a good start on a business or diplomatic meeting. To aid in combating sleep problems, and in getting back to a normal activity pattern, melatonin or stronger medications might be prescribed (e.g., Caldwell and Caldwell, 2005). Other recommendations include drinking plenty of caffeine-free fluids, moving about the cabin regularly to promote good circulation, and staying with easy-to-digest foods (e.g., Battelle, 1998). This type of temporal disruption is also related to the circadian rhythm. The reader interested in the broader area of sleep deprivation is directed to the recent National Academies of Science review (Colten and Altevogt, 2006).

Military and space applications For the military, the off-circadian effects of shift work and jet lag are usually compounded with fatigue or extreme sleep restriction or deprivation. Extensive research into these issues has been conducted by the US Air Force (e.g., Neville et al., 2000; Eddy and Hursh, 2001) whose pilots may cross many time zones in a single mission, by the US Army (e.g., Wesensten et al., 2003) whose soldiers perform extended and continuous operations, and also by the National Aeronautics and Space Administration (NASA) (e.g., Pfaff, 1968; Mallis and DeRoshia, 2005) whose astronauts do not have the usual external cues to day/night. Research has included investigations of the negative effects on performance and on potential countermeasures (e.g., Caldwell and Caldwell, 2003, 2005). The U.S. Army and Air Force have developed the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model. SAFTE incorporates effects of both circadian clock disruption and of sleep deprivation as predictors of soldier performance; however, it is somewhat incomplete in that currently it does not account for time-on-task effects. As part of a larger battery of interventions, it has proven to have utility as a commander’s scheduling tool (Hursh et al., 2004). Such models also offer promise when applied to predict soldier-system effectiveness under the effects of circadian disruption and sleep deprivation. It should be noted, however, that SAFTE represents a population average response and not an individual response as could be predicted from a more purely biologically-based model, thus highlighting an opportunity for further research into models that are integrated across biological and psychological levels.

Seasonal Affective Disorder (SAD) SAD affects people mainly in the winter months (Ennis and McConville, 2004). Based on the fact that there is less natural light available during the cold months,
and the fact that light-box therapy can serve as a successful form of treatment, one recognized cause of SAD is a shortage of available light. For those individuals suffering from SAD, the SCN cannot adequately manage the ebb and flow of hormones and other mainly autonomic functions. This effect on hormone flow may itself lead to stress via cumulative stress-syndrome symptoms such as weight gain, withdrawal from social activities, and exhaustion. Any or all of these effects can worsen into depression, at times to a state where pharmacological assistance is prescribed.

While the diurnal and circadian rhythms are at play here, SAD might also be examined as a form of infradian rhythm, one whose cycling periodicities are greater than 24 hours. It is the build-up of deprivation of light and its side effects that lead to eventual symptoms typical of stress and depression. Other phenomena, such as the human menstrual cycle, are better examples of infradian rhythm activity; these generally are divorced from light-associated aspects of the circadian rhythm, but related by virtue of a common hormonal basis.

The section above discussed some of the bases of evidence for biological clocks, and how disruption of those regulating mechanisms relates to stresses on the organism. A main objective was to examine whether temporal stress can be considered a simple psychological phenomenon or if, in fact, the evidence points to a complex mind-body phenomenon that dates back to the earliest forms of life on earth. The symptoms we see might well appear to be psychological and to have their own behavioral indicators, but their origins are deep in the DNA.

Evolution has provided several types of internal timing mechanisms, some commonly linked by the expenditure or build-up of internal hormones that must somehow be shunted off or otherwise neutralized in order to cyclically return to homeostasis; others respond to exogenous cues such as the rising and setting of the sun, others by effects of lunar gravity, others by changes in temperature resulting from a combination of endogenous and exogenous factors.

Psychologically-driven time

Thus, biologically-driven time is considered here as an imperative, a pervasive and global factor that can have significant stressor effects on performance. Psychologically-driven time, on the other hand, is the level at which time is perceived or “experienced.” It is subject to the influences of biologically-driven time, but is also mediated by cognition itself. Block, Hancock and Zakay (2000) hold that “Psychological time involves processes by which a person adapts to and represents temporal properties in order to synchronize actions with external events” (p. 1333). That is, individuals variably form duration judgments when deciding how long to stand in line, while waiting for a website to load, or when switching glances between the car radio and the road.

This section introduces the concept of explicit vs. implicit temporal processing as a lead-in to how stress affects explicit temporal cognition and an exploration of interactive relationships among various conceptualizations of temporally-associated stress. Emerging research in the use of computational cognitive models to examine the parameters of temporal processing and stress is presented as well.

Explicit and implicit temporal cognition

In discussing temporal cognition, it is useful to distinguish between explicit and implicit temporal cognition (e.g., Michon, 1990). Explicit temporal cognition refers to activities or actions for which the timing is a primary and deliberate part of the action. It includes actions such as estimating a past time interval, estimating how long a task will take, or changing the rate of performance to match an external rhythm or meet a deadline.
Implicit temporal cognition, on the other hand, is simply the temporal patterns that emerge from behavior. Thus, implicit temporal cognition gives rise to such seemingly simple things as walking where the choice to walk at a given speed is deliberate, but the precise coordination of limbs and muscles used for locomotion and balance is not. Implicit temporal cognition also underlies “multi-tasking” as it has come to be called, where diverse tasks are coordinated in time, even on the order of milliseconds (e.g., multi-tasking of a shooting task and mental arithmetic) (Kerick, Hatfield, and Allender, 2007). In most cases, then, implicit temporal processing also refers to the phenomenon of the brain’s temporal processes working much faster than our attentional ability to express or be aware of each step. Taatgen, van Rijn and Anderson (2007) propose that the distinction between explicit and implicit temporal aspects of time estimation tasks derives from explicit temporal cognition being knowledge-based and implicit temporal cognition being an aspect of the process itself. This explicit/implicit distinction parallels biologically-driven factors, that is, whether the associated cues are external, such as the onset of day or night or change in season; internal, such as the activities of the hypothalamus; or some combination of both, such as circadian rhythm.

Explicit temporal cognition is critical in many military or other high stress conditions, where coordination within a group or with an automated system is paramount to mission success. Likewise, implicit temporal processing is also critical if we are to develop manufacturing, medical, and military systems, for example, that have features of an intuitive human-system interface, one requiring less explicit control or attention (Sheridan, 2002; Parasuraman and Rizzo, 2007).

Models of temporal cognition

So, how does temporal cognition operate? Clearly, it is related to, but conceptualized differently from, the biologically-based clocks discussed previously. The basic notion is straightforward: that temporal cognition is controlled by a mental timekeeper. The two current timekeeper models are an internal clock model (Gibbon, Church and Meck, 1984) and an oscillator model (Miall, 1989; Church and Broadbent, 1990; Matell and Meck, 2000), although both settle into a common class of model called an accumulator and both assume a randomization function fairly consistent with Weber’s Law, which states that the size of a just noticeable difference is a constant proportion of the original stimulus value (see Grondin, 2001).

The clock model is just what one might assume: it describes a mechanism in the brain that measures out equal-sized, yet short-duration pulses. This is analogous to a clock that metes out second-long ticks and by doing so, is used to measure out longer intervals such as minutes, hours, and half days (see circadian rhythm discussion above). Judgments about how much time passed in an earlier interval (retrospective timing) are achieved by explicitly remembering the number of pulses that accumulated during the interval. Predictions or estimates as to when a certain amount of time has now passed (prospective timing) are achieved by “counting,” usually explicitly, the number of pulses that accumulated since the interval began. Although the count is obtained differently for retrospective and prospective processes, both rely on the accumulator timekeeping mechanism: The timekeeper issues a pulse; then the pulse passes through the accumulator, which keeps track of the number of pulses.

The oscillator timekeeper variant of the accumulator model differs from the clock model in the way that it issues pulses. Rather than the clock model’s same-sized pulses, the oscillator model issues pulses with a variety of periods via a host of oscillators. Note that this is consistent with a neurological or biological model with constantly pulsing neurons of different refractory periods (e.g., Ruskin et al., 1999). A further nuance on the multiple oscillator model supported by emerging biological research is the synchronization model, where a variety of oscillators and non-oscillators are entrained into a regular and precise period (To et al., 2007). This multiplicity of variable and
non-variable timing mechanisms represents a challenge for psychological models; however, it would seem to offer support for the observation that people can implicitly time more than one concurrent event.

Computational models

Computational modeling is a valuable approach to embodying theory and testing hypotheses. Specifically with respect to temporal factors, as computational modeling matures it may offer a specific means of linking our understanding of biologically-driven time and psychologically-driven time. Computational models of circadian timekeeping are arising out of the animal literature. For example, the gene network underlying circadian rhythm in flies and mammals has been the focus of detailed analysis in recent years (Reppert, 2000; Young and Kay, 2001; Goldbeter, 2002). With new experiments yielding clues to the detailed (and somewhat overlapping) molecular circuitry of both flies and mammals (Panda, Hogenesch and Kay, 2002) and the biological details coming into sharper focus, mathematical models are emerging (Leloup and Goldbeter, 1998; Scheper et al., 1999; Tyson et al., 1999; Lema, Golombek and Echave, 2000; Smolen, Baxter and Byrne, 2001) that range in complexity from simple two-state oscillators to more biophysically detailed, dynamic transcriptional feedback schemes.

Computational models of temporal cognition have recently been developed using the Atomic Control of Thought–Rational (ACT-R) (Anderson and Lebiere, 1998) architecture, a theory-based computer simulation of cognition. Taatgen and his colleagues (Taatgen, van Rijn and Anderson, 2004; Taatgen et al., 2005; Taatgen et al., 2007) have focused on implicit temporal cognition tasks, beginning with prospective interval estimation, but expanding to include the interaction effects of attention, learning, and multi-tasking on temporal cognition. Initially inspired by a neurally-consistent oscillator-type clock model (e.g., Matell and Meck, 2000), ACT-R modules were mapped to areas in the brain with the corresponding function such that the resulting temporal cognition module in ACT-R issues pulse beats of a given length that accumulate over time but which include noise that, in turn, either reduces or increments the accumulated pulse total. They go on to propose (Taatgen et al., 2007) that attentional effects play a significant role, largely with respect to how disruption of the timing task is managed rather than in a pure counting/accumulation fashion as in Zakay and Block (1997).

ACT-R was also used by Cassenti and Reifers (2005) to model an implicit temporal cognition task, but one that employed an explicit strategy for counting with uniform vs. varied intervals. Instead of using a separate timekeeper module, their model invoked the motor module that carried out time-keeping strategy via sub-vocal counting, that breaks down larger intervals (i.e., the time between events) into smaller intervals (the time needed to repeat one syllable of the number). The Cassenti and Reifers (2005) model points to the role of explicit strategies in temporal cognition that may, in some cases, overwhelm the basic clock timekeeper.

Another approach to modeling an aspect of temporal cognition, in this case, the effects of circadian rhythm and fatigue, in ACT-R was reported by Gross et al. (2006) where the effect was achieved by varying general alertness and the threshold for selecting an action. The result demonstrated a good fit between the computational cognitive prediction and the data as described by a biomathematical model, also demonstrating the relationship between the biologically-based and psychologically based approaches.
Clock-driven time: Assessing the interaction effects of stress and temporal processing

The assessment of performance under stress is a cornerstone of cognitive psychology, human factors and ergonomics, and, recently, of neuroergonomics (Parasuraman and Rizzo, 2007). Determining the limits, the breakpoints of performance—and what underlies those limits from the perspectives of psychology and neuro-physiology—is essential for designing systems that allow us to extend and otherwise manipulate those limits.

Measures of temporal processing

The classic measures of temporal processing were derived from psychophysics, the precise measurement of the perception of time relative to the external “stimulus” of clock time. (Although, Grondin in his review (2001) aptly notes that time is not a stimulus in the typical sense, but rather through the clock-type mechanism, is accumulated and even organized to the degree such that it comes to be expected. This notion of expectation, an internal psychological phenomenon as opposed to an external event only, may play a role in the variability (i.e., errors) in temporal processing discussed presently in this section.) As introduced previously, temporal processing can be prospective (where participants know in advance that some aspect of their temporal processing is to be considered during performance of a task) or retrospective (where participants know the form of their involvement only after the completion of some task). Common methods include duration estimates (judging how long has passed between a start signal and an end signal) and production (indicating by some action such as a key press when a target amount of time has passed after the start signal). Reproduction is also used in the examination of rhythms or patterns over time. The psychophysical measure of interest is the distribution of the responses around the “true” time, that is, the distribution of under- and over-estimations (i.e., error) around the objective clock time (Grondin, 2001).

The pursuit of the psychological mechanisms implicated in the under- and over-estimates and the degree to which they fall in line with Weber’s Law has generated volumes of research literature (see Grondin 2001 for a survey covering the literature back to 1946). Over these decades of research, factors that have been varied include the modality (visual, auditory, or tactile) of the starting and ending signals in duration estimation methods and, importantly, whether or not the time to be estimated is filled or not, and, if filled, with what type of activity. One robust finding is that people are fairly “accurate” at estimating times around a few seconds, but, as the time interval increases, the variability increases. Another common and seemingly puzzling finding is that verbal estimates of duration and physical production methods (e.g., typing) produce opposite results in what are otherwise similar conditions. As Hancock and Weaver (2005) summarize succinctly, “When verbal estimates indicate an underestimation of an interval, this is directly correlated with an overestimation using the production method” (p. 194). Regardless, variability in temporal processing can lead to the stress phenomenon: one’s schedule, interactions, and plans are subjected to disarray, and homeostasis is sought, at some cost.

Another factor of interest has been whether specific strategies for keeping time were employed, and to what degree they were effective in improving the duration estimates or producing target intervals. The employment of strategies is usually discouraged or prevented in research seeking the underlying timing mechanism, but is interesting with respect to understanding how people attempt to keep the correct “sense of timing” through the application of attentional effort (Grondin, 2001). The two ACT-R models discussed above are examples of temporal processing with (Cassenti and Reifers, 2005) and without (Taatgen, van Rijn and Anderson, 2004, 2005) employment of strategies.
Stress effects on temporal processing

The body of research investigating the effects of stressors on explicit temporal cognition can be divided into environmental and physiological effects (such as thermal or noise), personality or individual differences, and the effects of multi-tasking (i.e., being asked to perform tasks concurrently with explicit temporal processing).

Environmental and physiological effects  Hoagland (1933) was intrigued by his wife’s observation while suffering from a high fever that time seemed to pass very slowly. When asked to count at a one second rate, however, she counted at a faster pace than clock time; her perception had been skewed by her physiological state. Later studies (Hancock, 1984) report underestimations of duration under extreme heat stress. Consistent with Baddeley (1966); Wearden and Penton-Voak (1995) did not obtain an effect under cold stress. Related results from the medical community indicate that increased pain results in altered time perception (Somov, 2000), as does chronic insomnia (Tang and Harvey, 2005).

Although investigations of the effect of environmental noise on performance have been important in the attention literature (e.g., Hockey, 1970), investigations specifically with respect to temporal processing tasks have been limited. Ross, Szalma, Thropp and Hancock (2003) failed to find a significant effect of noise on temporal-related processing perhaps due to a ceiling effect, but did find a significant effect on participants’ assessments of noise stress on a temporal dimension, which has implications for understanding time as a stressor itself. Finally, the environmental factor of G-forces has been shown to cause underestimates in estimates of duration (Repperger et al., 1989), but that the underestimates were mitigated by an explicit counting strategy.

Individual differences Individual differences, both biologically- and personality-driven may emerge in numerous aspects of behavior. For example, recent findings suggest a genetic basis for both early – vs. late-risers as well as differing effects of sleep loss for each type. The early-riser faces greater cognitive degradation than does the late-riser (Viola et al., 2007). Thus, early-risers may feel more disorientation and cognitive stress under the kind of sleep-deprivation conditions often faced by firemen, medical workers, and those in combat situations.

Individual differences or traits have also been hypothesized to influence temporal processing. For example, personality factors such as Introversion/Extroversion were shown to correlate with time estimation performance (Zakay, Lomranz and Kazinz, 1984) such that, when the activity during the interval was simple, individuals who scored high in Extroversion estimated intervals to be longer than did individuals who scored lower. Other research has obtained mixed findings, but with some intriguing results showing differences in temporal estimation depending on scores on Extroversion and Emotional Stability (Szalma et al., 2006).

Activity effects Sometimes it is the case that the very activity being performed is a stressor that affects temporal processing, such that there is a continuum from no activity – doing nothing – to the extreme of a life-threatening experience. The psychophysical research on time perception has shown that duration estimates vary as function of whether the interval is filled or not and also according to the type of task activity. In other words, even within a normal, non-stressful range that we commonly experience, time perception varies. For example, when simply sitting and waiting or listening to a boring lecture, time seems to pass very slowly; whereas, while reading a good book or watching an exciting movie, it seems to pass quickly. However, at the extremes, time perception varies so widely as to become distorted. An extreme case of doing nothing (reported by Fraisse, 1984) is a man who spent 6 months in an underground cave. When he estimated the average time
between waking and lunch, it was on the order of 5 hours, while the clock time was closer to 10
hours, a case of time being estimated to pass much more slowly than the clock time (although in
this extreme, the effect was likely compounded by circadian effects in the absence of daylight
cues). At the other extreme is dangerous, life-threatening activity where time seems to expand.
Hancock and Weaver (2005) have examined this extreme in time perception distortion, including
reports of interviews with jet pilots who had ejected. While the marked slowing of time seems to
predominate at this end of the continuum, there are also cases of time seeming to pass even faster
than normal.

To accommodate this range of findings, Hancock and Weaver (2005) propose that temporal
processing is subject to narrowing of attention and change in cue utilization in the same fashion as
other types of cognitive processing (Easterbrook, 1959). Further, they propose that this narrowing
can be directed outward or inward. When directed outward to the environment, cues are sampled
more intensely than usual, resulting in more events per unit time and giving rise to the perception
of expanded time. When directed inward, discrete cue sampling is reduced, and time perception
is collapsed or shortened. These notions are consistent with an accumulator model of temporal
processing, which has also found neurophysiological support (Eagleman et al., 2005) in the
examination of predicting expected motion and motor action-consequence causal relationships.
Eagleman et al. (2005) term this adjustment of time estimates to match a more expected flow of
events “temporal calibration.”

Multi-tasking The other type of stress effects on temporal processing to be addressed in this
section is the stress of multi-tasking, being required to perform more than one task at a time when
one of the tasks is explicitly a temporal cognition task. Brown found in his own study (1998) and a
review of others’ studies (1997) that performance in temporal cognitive tasks is adversely affected
when there is a secondary task. Typically in workload studies the type of resource required for
the secondary task (e.g., visual, auditory) affects whether and how performance declines in the
primary task. If the two tasks differ with respect to the resources they require, then they may be
performed together without any performance deficit. In the case of temporal cognition, Brown
(1997) concluded that temporal processing is resource-consuming and requires attention. He
showed that a wide array of secondary tasks (e.g., tracking, visual search, and mental arithmetic)
adversely affected temporal performance, although the effect was not perfectly symmetrical. The
temporal processing task did not affect motor or visual search performance but did affect mental
arithmetic performance. This suggests that temporal cognition is not “free,” but requires some
degree of general, shared processing resources.

Thus, the evidence from a variety of perspectives indicates that explicit temporal processing
is attention-demanding; that, from a cue-utilization perspective (Easterbrook, 1959 and more
recently, Hancock and Weaver, 2005), stressors generally affect attentional resources, therefore,
also affect temporal processing. Of course, this is just part of the picture given that time pressure is
itself a stressor. Research bearing on this finding will be discussed next.

Time as a stressor on performance

Measures of performance pertinent to time stress Time stress is often operationalized by requiring
that a task be completed within a certain time window, with a penalty or negative consequence for
not completing the task within that window. Assessing the effect of time as a stressor means that
the measure of interest is no longer time estimation or time production per se, but rather measures
related to the task or tasks of interest. In much of the traditional cognitive psychology literature, there
are two basic task performance measures: speed and accuracy. Depending on which is stressed in
the instructions, unless performance is at the ceiling, there are speed-accuracy tradeoffs. Although there are a host of task parameters (e.g., payment or cost, strategy preference, risk aversion), that influence performance, when time stress is a factor, it tends to predominate.

In the human factors literature, the assessment of the effect of time stress often has been carried out under the rubric of mental workload, a valuable construct in understanding the perception of “how hard” a task is to accomplish, although it is noted that there is not always a one-to-one correspondence with performance (for a discussion, see Hart, 2006). Early on, mental workload researchers (Reid, Shingledecker and Eggemeier, 1981; and Hart and Staveland, 1988) recognized that mental workload was not a unified construct, that it was multidimensional, and also that individuals varied with respect to the weighting they would assign to the dimensions. The Subjective Workload Assessment Technique (SWAT) (Reid, Shingledecker and Eggemeier, 1981) uses three principal dimensions: time load, mental effort load, and psychological stress on which tasks are rated low, medium, or high (1, 2 or 3) with respect to the amount of spare time available, the frequency of interruptions, and the amount of overall with other activities. The National Aeronautical and Space Administration Task Load Index (NASA-TLX) (Hart and Staveland, 1988) comprises six dimensions, one of which is temporal demand. It is described as being the answer to these questions: “How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?” As originally conceived, the dimensions are weighted for each individual and combined into a single score. In a retrospective on NASA-TLX, Hart (2006) reports that very often the weighting is foregone, usually to simplify administration and instead, a simple additive score is used to reflect overall workload. At the same time the NASA-TLX subscales are often analyzed separately to examine dimensions of interest (as described in Hart, 2006). So, on the one hand, the capability exists to tailor subjective assessments of overall workload to reflect the importance or weighting an individual places on temporal stress relative to other stressors, and, on the other hand, to examine the rating of temporal stress directly. Finally, it can be noted that the NASA-TLX workload scale is not only widely-used (see Hart, 2006), but has been assessed as valid in comparisons with other workload scales (Hill et al., 1992).

A few studies have used a temporal task as a secondary task in order to assess the processing demand of a primary task. For example, Zakay and Shub (1998) examined the interaction of aviation-type tasks and verbal estimates vs. production estimates of duration length, with divergent results obtained as noted above (see Hancock and Weaver, 2005) where retrospective verbal estimates are underestimates and productions are overestimates. In an applied training setting, Lio et al. (2006) used time estimation as a secondary task during the performance of laparoscopic surgical tasks, with the rationale that temporal processing tasks and the employment of time-stressed surgical techniques would draw on the same fundamental processing resources. The findings showed that the production method varied as a function of the demand-level of the surgical task, but the verbal estimate did not. While not conclusive, this sort of research shows promise for understanding the processing requirements of temporal information in real-world task settings by the differential demands of concurrent, implicit temporal processing and the those of subsequent retrieval of temporal information from memory.

Performance under time stress The experience of working under a deadline is pervasive in today’s world. The common wisdom is that having limited time results in poorer performance, the ultimate in speed-accuracy tradeoffs. There are, however, some exceptions that will be noted.

The Vincennes incident, when, in 1988, an Aegis cruiser shot down a civilian jetliner, was the critical event that launched a multi-year investigation of tactical decision making under stress (TADMUS) (e.g., Hutchins and Kowalski, 1993; Morrison et al., 1997). The resulting findings
provided new insights into contributing factors (e.g., teams, naturalistic decision making) and to potential solutions (e.g., human systems interaction, training programs, enhanced decision support systems, and stronger safeguards) (see Driskell and Salas 1996 for one discussion). Of interest here is that one of the stressors was time, that is, the requirement to make a decision with only limited time to weigh, verify, and aggregate all the critical information. Over and above the noted general speed-accuracy tradeoff, Salas, Driskell and Hughes (1996) report that time pressure, or time restriction, can result in changing decision making strategies. Three common decision making strategies under time pressure are acceleration, adjustment, and filtration, each of which has associated costs. Klein (1996), on the other hand, notes that time-pressure does not always result in worse outcomes, citing that, in some circumstances novices may improve their performance (but that experts did not show the same improvement) and also that there can be beneficial effects of switching to strategies that are more proactive.

Finally, a word is warranted in this section on performance under time stress on the effects of multi-tasking. The dual-task paradigm is well-known as a way to understand workload generally, multiple processing resources, attentional limits, and so on. When multi-tasking is planned, the performance of those two tasks must be coordinated in time. Some tasks coordinate easily, but others are more of the “simultaneously listening and talking” sort, which require that attention must be paid to manage the multi-tasking. Thus, time management becomes a task in and of itself. When the multi-tasking is unplanned, that is, when the new task is an unexpected interruption, the same management requirements apply, plus an added adjustment. Hollnagel (2002) asserts the importance of considering that human performance – the various steps of which take time – occurs in dynamic temporal environments, such that there is a balance between controlled performance and time where the “loss of one may lead to a loss of the other” (p. 143). In other words, ineffective management of tasks over time or task interruptions will result in a loss of effectively available performance time and a shortened time window will require rapid adaptation of the control strategies employed.

**Designing for temporal processing**

There is a growing interest in the study of temporal processing as it can inform system design. Timing in system design is not new in and of itself; it has long been considered with respect to feedback (i.e., motor control mechanisms such as steering, timing the appearance of letter on a computer screen in relation to typing). However, the explosion of information availability via the Internet and networked systems coupled with the new research methods emerging under neuroergonomics (Parasuraman and Rizzo, 2007) mean that we are facing new design challenges but also have new tools suited to address the challenges.

Recently, Hildebrandt and Rantanen (2004) hosted a panel on time design – the examination of the theories and methods applicable to the design of the temporal features and characteristics of a system. In their outline of the temporal design space, they include four dimensions: time expressed in the system interface, in user behavior, in task requirements, and in the environment. The collective view of the panel was that time is not a hardware/software feature to be designed around, but rather, a property of the overall system that must be calibrated and orchestrated across the dimensions of the design space.

Drawing on this four-dimensional organization, Allender, Cassenti and de Pontbriand (2005) offer some suggestions for helping to manage temporal processing in the human-system interface. At the physical interface level, variability in timing, delays, and interruptions should be minimized. Additionally, the desire to “overbuild” a system beyond human limits (e.g., building in “too fast response times”), may actually frustrate users (O’Donnell and Draper, 1996). Identifying key
individual trait or state variables that may impact human-system interaction along the temporal dimensions will serve to mark the boundary conditions within which a system must be designed. Hildebrandt and Harrison (2003) argue for using time as a key element in dynamic function allocation. Indeed, doing so in real time, in the augmented cognition sense (see Bahr et al., 2005), is the idealized target for system design. Next, in the task dimension, the pace of the task or of the actions required to perform the task, must be moderated so as to produce the optimal strategy, guarding against time distortions that result in performance errors (Jobidon, Rousseau and Breton, 2004).

A case in point in designing with temporal cognition in mind is the growing field of human-robot interaction. Goodrich and Olsen (2003) discuss the notions of “neglect time” (e.g., the length of time allowable for the robot to roam autonomously before reporting back to the human) and “interaction time” (e.g., that period when the robot and human communicate what was observed and directions for the next leg of travel). Temporally-related stress is high in the neglect time period due to the uncertainty of what the robot is experiencing and whether it will in fact return a communication. Stress is also high during interaction time, for communication has to be swift, efficient, and accurate, in the event that interference or an interception abruptly or covertly end the mission.

Managing multi-tasking in time when the multi-tasking involves multiple systems has both explicit and implicit dimensions: de Pontbriand (2003) discusses the situation wherein the human operator must variably switch or shift attention from among several machines (e.g., robots) during the course of a mission or operational segment. Task-switching refers to a condition under which the operator has to drop attention to one robot entirely and refocus on another robot, presumably one that is in need of immediate redirection or has provided a mission-critical observation. Task-shifting, on the other hand, refers to a condition where operations of the initial robot cannot be dropped entirely, but must kept in mind (since it will have to be returned to shortly) while attention is temporarily concentrated on another robot. Both conditions place extreme time-management stresses on the operator, further argument that the timing characteristics of a system must be intuitive, fit with the user rather than become yet another feature to which the user must adapt.

Conclusion

From the ancient origins of our biological clocks, to the synchronous internal and social systems that depend on the regularity they support, there has been as steady influence of “stress” working upon those systems. Nature has provided that stress as a means of system development on a grand scale. The more we know about the characteristics of and interactions among those systems, be it from laboratory or field study or modeling and simulation, the more we can help harness, for the better, the emergence of technologies and the social structures in which they are being embedded. Temporal regulation is, of course, only one of the facets in the study of stress; the fact that time is so fundamental to everyday existence makes it a prime object of fascination and purposeful study.

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References


Positive Psychology: Adaptation, Leadership, and Performance in Exceptional Circumstances

Michael D. Matthews

Chapter 9

Introduction

As I listened to a series of papers on post-traumatic stress disorder (PTSD) among military personnel at a recent annual convention of the American Psychological Association (APA), it occurred to me that the clinical researchers were focusing on only what Peterson and Seligman (2004) refer to as the “negative psychology” approach to the problem. The researchers had carefully and systematically identified a host of negative personality traits, dispositions, and behaviors that served as predictors of PTSD, and of progressive symptoms following disengagement from combat. The message seemed to be that soldiers at risk for PTSD could be identified, to some extent at least, based on pre-deployment adjustment or, more often, screened and treated after deployments. In short, a reactive approach focused on treating “ill” behavior was stressed. While this is certainly important, I was struck by the notion that this approach seemed only half-way complete. Perhaps researchers should work equally diligently to identify positive traits, dispositions, and behaviors that predict successful adaptation to and subsequent adjustment following the stresses of a combat deployment. This latter approach is congruent with the emerging field of positive psychology, and represents a radical departure from the negative psychology paradigm that characterized the first hundred years of the discipline (Peterson, 2006). The purpose of this chapter is to review positive psychology and explore its potential for empowering soldiers or others involved in dangerous, life-threatening work to not simply survive the experience psychologically and emotionally intact, but to gain meaning and purpose from the experience itself.

A Brief description of positive psychology

The origin of the positive psychology movement has an interesting beginning. Following his election to the presidency of the APA, Martin Seligman reported an “epiphany.” His then 5-year-old daughter, Nikki, chastised him for his habitually grouchy, task-focused behavior. On reflection, Seligman realized that not only was he guilty of substantial negativism in his personal behavior, but that the field of psychology was characterized by a focus on weakness, deficiencies, and distress. This obsession with negative cognition, affect, and behavior had little to contribute to understanding human strengths, virtues, and flourishing. Seligman immediately energized a group of leading psychologists from around the world to define the scope of positive psychology and to begin making it an acceptable domain of legitimate psychological inquiry and research.

While there are clear historical roots to positive psychology, perhaps most obviously humanistic psychology (e.g., Rogers, 1951; Maslow, 1954, Erikson, 1963), an important feature that sets positive psychology apart from previous approaches is its emphasis on building a science of human strengths, virtues, and excellence. Toward this end, Seligman organized the Medici II Conference...
at the University of Pennsylvania, beginning in the summer of 2005 and continuing through the summer of 2007. The explicit purpose of the Medici II was to systematically and empirically explore tangible, quantifiable criteria that can be attributed to positive psychology constructs. To achieve this goal, a team of distinguished psychologists, instrumental in the foundation of positive psychology, were brought together in residence at the University of Pennsylvania under a grant from the Templeton Foundation. Beside Seligman, the senior scholars include Christopher Peterson, University of Michigan, Mihalyi Csikszentmihalyi, Claremont Graduate University, Ed Diener, University of Illinois, and George Vaillant, Harvard University. The Medici was divided into five projects, each exploring a domain wherein positive psychology constructs are thought to be important. These were: Project 1, Work, Productivity, and Health Indicators (Coordinators, Seligman and Peterson); Project 2, National Wellbeing Indicators (Coordinator, Diener); Project 3, Spirituality and Living Well (Coordinator, Vaillant); Project 4, Psychological Capital (Coordinators, Csikszentmihayli and Jeanne Nakamura); and Chinese and Spanish Positive Psychology Web sites (Coordinators, Peterson and Seligman).

The author was privileged to be included in the Medici as a Templeton Foundation Senior Positive Psychology Fellow, working on Project 1. Since the basic tenants of positive psychology are a focus on working with human strengths to improve quality of life, subjective happiness, and productivity, it immediately seemed obvious that the military is a “natural home” for positive psychology. The military is made up, by and large, of relatively young, physically healthy, and psychopathology free individuals. Thus, the application of negative psychology constructs to understanding adjustment, behavior and performance of such a population seems incongruous. Rather than focusing on negative factors that lead to maladaptive reaction to the challenges of military life, it seems to make sense to also build a military psychology that also focuses on human strengths that lead to health, resilience, and robustness in the face of such challenges. Moreover, because the military is such a large institution, including the different branches, the active component, the reserve component, the National Guard, and military families, the number of and diversity of research applications within the military is almost limitless, and also has the potential of improving the lives of millions of people.

Stress and positive adaptation

Perhaps reflecting the negative psychology bias, most stress research focuses on deleterious effects of stress, stemming from painful or unpleasant experiences, and leading to maladaptive behavior, cognitions, or affect. Interestingly, Selye (1956), a pioneer in stress research and theory, distinguished between distress and eustress. The former stemmed from negative, unpleasant events or situations and might be followed by a variety of maladaptive responses. Eustress, in contrast, was seen as stemming from positive events or situations, with its effects labeled as positive or desirable. To complicate matters, a particular event may induce distress or eustress, depending on how an individual interprets or appraises a given event (e.g., Lazarus, 1999; Semmer, McGrath and Beehr, 2005). Making a speech in front of a 1,000 people will paralyze some people with fear, but others may appraise the speech as an opportunity to influence people and achieve greater objectives. Similarly, soldiers are likely to appraise tactical situations encountered in the course of their duties in different manners, mediated by differences in training, experience, and personality.

The focus of the current chapter is on positive psychology and eustress as it may affect the adaptation and performance of soldiers and by extension others exposed to challenging and often dangerous situations. A complete review of the effects of distress on adaptation and performance is beyond the scope of this chapter, but the literature is rife with very good reviews that reflect the distress perspective (e.g., Monroe and Harkness, 2005). Within the military context, Campise,
Geller and Campise (2006) offer a review of combat stress from the distress perspective. I will begin with a review of recent research that focuses on positive traits, characteristics, and behaviors that are thought to be important in human adaptation to extreme situations from domains closely allied with positive psychology. This will be followed by a review of completed and ongoing work conducted explicitly from a positive psychology perspective.

In extremis

An emerging area of thought within the psychological and leadership domain that is relevant to understanding the role of positive factors in performance in and adaptation to exceptional environments is in extremis leadership. Most theories of leadership, to the extent they have an empirical foundation at all, are based on the study of college students and leaders or managers within corporations. Nevertheless, these theories are generalized – often without a legitimate conceptual basis – to other domains where their intervening variables and constructs probably don’t apply. Kolditz (2006) defines in extremis leadership as “giving purpose, motivation, and direction when there is eminent physical danger, and where followers believe that leader behavior will influence their physical well-being or survival.” Thus, from the in extremis perspective, leadership under conditions of mortality salience, that is, conditions where risk of serious injury or death is present, may require different skills sets than leadership in the corporate world or on a sports team. Kolditz (2006) also writes that “…men and women who lead people in places and through situations that most of us would find intimidating – if not outright horrifying – will often behave in ways that may provide insights into our own leadership.” Principles derived from such study may apply across a variety of domains, perhaps in less intense settings such as the corporate world, whereas the reverse may not necessarily be true.

An interesting aspect of the in extremis work is that leaders under these conditions do not show distress reactions. Indeed, the most common response is eustress. Kolditz (2006) summarizes studies of such diverse groups as SWAT team chiefs in New York City, mountain climbing guides, leaders of jungle expeditions, the US Military Academy’s national champion parachute team, special operations soldiers, an in-depth interview of the first armored cavalry commander to enter Baghdad in March of 2003, and interviews with 50 US soldiers and Marines, all of whom had had a peer from their own unit killed in combat operations within the past 30 days. From these interviews, a clear picture of the elements of successful in extremis leadership is emerging. It appears that such leaders share seven characteristics: inherent motivation for the task or mission, a learning orientation, a sense of shared risk, a common lifestyle, competence, the ability to develop trust from their subordinates, and loyalty to the organization.

It is important for the reader to note that the underlying approach to in extremis leadership is congruent with positive psychology. The goal is not to identify personal weaknesses or predisposing pathologies that result in maladaptive behavior, but rather to identify positive traits and behaviors that result in effective leadership. Peterson and Seligman (2004) identified 24 character strengths, organized into six core virtues, believed to be universal in our species. They maintain to the extent that we learn to utilize or exploit these strengths and virtues, we will not only adapt better to challenges, but rise above simple adaptation to achieve engagement and meaning in the activities. Although the positive psychology research and the in extremis work emerged separately and from different disciplines (psychology vice leadership), it is interesting to note that each of the seven characteristics of effective in extremis leaders identified by Kolditz (2006) map into Peterson and Seligman’s virtues of Wisdom (“a learning orientation,” “competence”), Justice (“shared risk,” “common lifestyle,” “the ability to develop trust,” and “loyalty to an organization”) and Humanity (“inherent motivation”).
The *in extremis* work is mostly conceptual at this point, with existing empirical work being purely descriptive in approach. It would be revealing to systematically and objectively assess the character strengths and core virtues identified by Peterson and Seligman among leaders – and followers – engaged in *in extremis* activities. How would their profile of strengths compare with the corporate leader – or follower? What strengths would predict successful leadership, performance, and adaptation in such situations? How might intrapersonal variables (strengths) interact with situational variables (task/environmental/mission) to influence effectiveness, adaptation, and performance? Fortunately, a reliable and valid metric exists to measure character strengths and core virtues – the Values-in-Action Inventory of Strengths (VIA-IS). Peterson and Seligman (2004: 627–633) describe the development and psychometric properties of the instrument. A systematic program of research in this area would be useful in expanding our understanding of exceptional performance under exceptional circumstances.

**Mortality salience**

A central concept to *in extremis* research is mortality salience. In this context mortality salience refers to the enhanced awareness that people engaged in dangerous tasks have of the likelihood of personal injury or death. Because soldiers and their leaders routinely find themselves in such situations, the impact of mortality salience on adjustment, performance, and leadership is important in a complete understanding of human performance in dangerous situations. Much of the research on mortality salience is conducted with college student participants (e.g., Jonas and Fischer, 2006). In such studies, mortality salience is induced by asking participants to reflect on death, in a hypothetical way. In contrast, soldiers deployed in combat are faced with daily reminders of the genuine threat of their own or others injury, mutilation, or death. In reviewing the mortality salience literature, it is important to keep this distinction in mind. Here is a case where a reliable and replicable finding obtained in a laboratory with college student participants may indeed not play out in combat operations, natural disasters, or other situations where real injury or death is possible.

Nevertheless, a review of recent research in mortality salience is interesting in that it reveals that such conditions may actually be mediated by or bring forth certain positive traits, reactions, or behaviors. For example, Taubman-Ben-Ari and Findler (2006) noted the seemingly paradoxical observation that higher existential threat is often associated with an increased willingness to engage in life-threatening behaviors. They go on to comment that it is commonly observed in Israel that citizens show a greater propensity and motivation to serve in the military when perceived threat is high, despite the increased chances of being wounded or killed in such times of threat while serving on active military duty. Taubman-Ben-Ari and Findler examined a large sample of men shortly before their conscription into the Israeli army and examined the relationship between self-esteem and mortality salience. They report that high mortality salience was associated with a higher motivation for military service coupled with a higher anticipation of physical hardships, but only among high-self-esteem participants. This increased motivation can be viewed from the positive psychology perspective as similar to the character strength of teamwork, and the willingness to endure physical hardships may relate to the strength of courage (Peterson and Seligman, 2004). Of course, what may be viewed as a character strength through one lens may be viewed as a negative outcome through another lens. Pyszczynski et al. (2006), in an intriguing study of Iranian college students, found that students who been exposed to a mortality salience treatment were more likely to support terrorist attacks that could kill large numbers of Americans. However, this effect was mediated by the political view of the participants, with the increased support of terrorism being viewed among politically conservative participants, but not among politically liberal ones.
The central findings of both Taubman-Ben-Ari and Findler (2006) and Pyszczynski et al. (2006) seem similar – in times of enhanced mortality salience one may be more like to exercise personal strengths of courage in support of one’s country or cause. Even positive character strengths can be applied to bad ends.

A truism in the military is “there are no atheists in a foxhole,” suggesting, of course, that when mortality salience is high then religious or spiritual tendencies are high. Jonas and Fischer (2006) tested this view from the perspective of terror management theory. This theory maintains that people may often cope with life-threatening situations with beliefs of “literal or symbolic immortality.” Jones and Fischer report three studies that manipulated morality salience and assessed its effect on religiosity as a response to dangerous situations. Using German college students as research participants, the authors conclude that religion serves to mitigate responses to mortality salience. People who are intrinsically religious may find religion to be a viable defense against thoughts of impending or possible death. Thus, religion and perhaps more generally spirituality may be an important mechanism that people engaged in dangerous work may successfully employ to maintain a healthy psychological or physical (Hill and Pargament, 2003) adjustment. Peterson and Seligman (2004) identify spirituality as one of the 24 character strengths universal to the human species. Empirical research using appropriate populations (soldiers, police, etc.) is needed to understand how the strengths of religiousness and spirituality play out in enhancing adaptation and performance in life-threatening situations.1

Gailliot, Schmeichel and Baumeister (2006) examined the effect of self-regulatory processes on mortality salience. Reporting a series of nine studies with a total of 979 participants, they concluded that successful management of situations with salient threat of death required effective self-regulatory mechanisms. For example, participants high in self-regulation responded with fewer death-related thoughts following a mortality salience activation. Gailliot et al. conclude that “self-regulation is a key intrapsychic mechanism for alleviating troublesome thoughts and feelings about mortality.” The implication for soldiers and others working in dangerous situations seems obvious. Self-control, also defined by Peterson and Seligman (2004) as a universally valued character strength, is useful in maintaining good adjustment in combat and other situations where death or serious injury is a frequent occurrence.

The possible role of other character strengths in adaptation to dangerous situations are suggested by other recent research. Peters et al. (2005) reported that reminders of mortality salience resulted in stronger grip strength. Peters et al. suggested that increased mortality salience serves as a motivation source resulting in greater effort. This can be viewed as similar to the character strength of persistence (Peterson and Seligman, 2004), and as an adaptive response to potentially dangerous situations. Although it is quite a leap from college students compressing a hand dynamometer to soldiers in combat or police or fire personnel in an emergency response situation, the possible adaptive value of increased motivation or task persistence is of obvious value to those who find themselves in such situations.

A popular development in the leadership literature is authentic leadership theory (Avolio and Gardner, 2005). Viewed from the positive psychology perspective, authentic leaders would possess many of the 24 character strengths defined by Peterson and Seligman (2004). Integrity and honesty clearly apply and, depending on the context, strengths such as persistence, teamwork, courage, and kindness might characterize an authentic leader. The authentic leadership model is garnering

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1 Religiosity may also be used by the military institution as a means of mollifying fear of death among surviving soldiers. The author recently attended the burial services of a West Point graduate killed in combat. A repeated theme of service was that the officer was not dead, but had merely moved on to another dimension. Such beliefs and verbal statements may represent a genuine religious belief, but also may serve a utilitarian function in assuaging fear of death among fellow soldiers and thus keeping them “in the fight.”
significant attention in military circles, as models of understanding leadership in extreme conditions are further explored. It may be important to consider the effects of context on leader efficacy (certainly not a novel concept). Cohen et al. (2004) reported that college students exposed to a mortality enhancement manipulation were more attracted to a charismatic leader than leaders with other leadership style. This is consistent with Army common practice, which emphasizes dynamic, charismatic leadership behavior such as “leading from the front.” But the leader qualities effective in combat might not be as effective, or even desirable, in garrison. An anecdotal account of this is described by Major Winters (2006) in his book Beyond Band of Brothers, where he applauds a company commander for effectiveness in training Easy Company for combat in the Second World War, but emphatically states what a poor combat leader the company commander would make. Nevertheless, in understanding leadership and adaptation in combat and other extreme situations, mortality salience may provide an important construct in understanding how leaders are viewed by soldiers and how effective they are in bringing out positive character strengths such as courage and integrity among their charges.

To summarize, an important component to a complete understanding of personal adaptation and leadership under exceptionally challenging and dangerous conditions is mortality salience. The research suggests that what matters to people under these conditions may shift. Religious people become more religious, people with strong self-regulation skills may utilize these skills more explicitly, and patriotic people may be more willing to join the military or perform acts of bravery. Of course, enhanced mortality salience may have negative consequences. For instance, Miller and Taubman-Ben-Ari (2004) found that low self-esteem scuba divers were more likely to take risks when given a mortality salience treatment. While risky behavior among soldiers in combat may sometimes be rewarded and recognized as courage, unconstrained risk taking would undoubtedly disrupt mission effectiveness in most cases. More research needs to be done with real soldiers operating in real combat environments to determine how mortality salience truly contributes to adaptation and performance under such conditions.

Resilience/hardiness

Clearly, the stresses of long deployments on soldier morale and adaptation are significant. One does not have to be a psychologist to imagine the difficulties of separation from family and the dangers inherent in engaging in armed conflict or mediating among warring parties in a peace keeping mission. Bartone, Adler and Vaitkus (1998) offered empirical evidence of the various dimensions of psychological stress during a lengthy peace keeping mission. They followed 188 soldiers deployed to a peace keeping mission in Yugoslavia over the duration of their deployment. A range of stressors were identified across the duration of the deployment, including “isolation, ambiguity, powerlessness, boredom, and danger/threat.” Bartone et al. report these stressors were linked to a variety of symptoms including low morale and depression. The traditional “negative psychology” approach to understanding the effects of stress on adaptation and performance would take such findings and point to approaches to treat the most severely afflicted soldiers. Bartone et al. anticipate in this paper the positive psychology approach by recommending proactive countermeasures to prevent such effects. The issue of resilience – or personality and organizational factors that allow people to adapt and perform effectively, and to derive positive effects from these situations – is based on this view.

A growing body of literature focuses on the role of hardiness or resilience in adaptation to difficult situations. Unlike some of the areas reviewed thus far, much of this work has been completed with military populations. Like positive psychology, this approach emphasizes psychological and organizational factors that set the occasion for adaptive responses to dangerous, high-stress
situations. As Bartone (1999), a prominent researcher in military hardiness and resilience has pointed out in commenting on military stress research, “Although previous studies show ill effects of stress on some of these personnel, few studies have sought to explain continued good health and stress resiliency maintained by the majority of veterans.” This view is in complete congruence with positive psychology’s approach that explores factors that contribute to health, excellence, and flourishing, rather than illness, poor performance, and maladaptive behavior. Indeed, the resilience work represents a rare empirically sound precursor to positive psychology.

A good place to begin with our review of the resilience work is Bartone’s (1999) study of the adaptation of Army reserve soldiers to duty in the first Gulf War. It is important to understand that deployments to war involve many challenges besides risk of death. First and foremost, there is separation from family and community. Before the combat deployment, there is considerable train-up time as soldiers prepare for actual combat. Days are long and demanding, both physically and psychologically. The soldier has only limited time to stay in communication with his or her family. Note Gulf War I predated ready availability of e-mail communication in military units and cell phones were not the ubiquitous tool they are today. Furthermore, reserve units do not have the institutionalized family support mechanisms found in active duty Army posts. In short, soldiers spent months of difficult training followed by deployment to a foreign country where they engaged in combat, with relatively weak social support mechanisms in place.

Under the conditions describe above, one might predict that continued stress and danger of deployment would have resulted in widespread adverse reactions among the deployed soldiers. Bartone’s research design allowed for sophisticated analyses of the effects of the type of deployment and hardiness on several dependent measures including measures of stress and health. Three different groups of soldiers were compared: Those called to active duty but not deployed outside the United States, those called to active duty and deployed to Germany (but not to the Persian Gulf), and those called to active duty and deployed to the Persian Gulf. The latter group, predictably, reported significantly more stressful life events, as measured by the Holmes-Rahe Major Stressful Life Events Scale (Holmes and Rahe, 1967), greater combat stress exposure, more health symptoms, and scored higher on the Impact of Events Scale than their counterparts who were not deployed or deployed in Germany. So, combat exposure did indeed result in increased stress among deployed soldiers. Interestingly, and relevant for the current analysis, was soldiers high in hardiness adjusted better than those with low hardiness in health measures, combat-related stress, and life stress. Indeed, the overall pattern of results “suggested hardiness protects against the ill effects of stress, under particularly high- and multiple-stress conditions” (Bartone, 1999).

Because of its relevant population and thorough research design, Bartone’s (1999) study serves as a model for empirically investigating the role that positive psychological traits or states may have in fostering a positive adaptive response to the extremely challenging conditions exemplified in his study. Although the work is correlational in nature, and thus limited in causal inferences that may be drawn concerning the nexus between hardiness and stress coping skills, the external validity of the study makes it very relevant to the question of interest in this chapter.

Other research on resilience and hardiness suggests several positive outcomes associated with the construct. War, by its very nature, taxes an individual’s personal coping mechanisms. In addition to the obvious deprivations of long deployments far from home and the dangers of combat, Bartone (2005) recently discussed the role of what he terms “existential boredom” that may result when soldiers perceive that their individual and collective personal sacrifices are not valued, or called into question as the result of widely publicized – but rare and atypical – accounts of wrong-doing among soldiers. The abuses of Abu Graib prison are an illustrative example. Bartone suggests that high hardiness may protect soldiers from suffering from such crises, and allow them to derive meaning from their experiences in the face of these challenging circumstances.
An interesting twist to the resilience and related literature is that the combat experience not only does not necessarily result in the absence of psychopathologies, but may even be related to positive outcomes, both short- and long-term. Aldwin, Levenson and Spiro (1994) reported a study of 1,287 male combat veterans. Members of the sample had seen combat in the Second World War, Korea, and Vietnam. The purpose of the study was to examine the positive and negative impact of combat on adjustment later in life, and in mediating possible PTSD symptoms. A major finding of interest in the current analysis was that the men reported more desirable effects of combat than undesirable ones. These effects – which included mastery, self-esteem, and coping skills – increased with length of combat exposure. Importantly, the perceived positive effects of combat mediated the observed negative effects of depression and PTSD. Although the paper did not explicitly discuss resilience or probe personality correlates of positive effects of combat, the study is important because it shows that the impact of combat is not uniformly or necessarily negative.

Other research points to other positive effects of stressful military deployments. Britt, Adler and Bartone (2001), studying US soldiers deployed to a peace keeping mission in Bosnia, developed quantitative models linking hardiness not only to engagement and meaning during the deployment, but also to derived benefits months following the return from the deployment. Bartone et al. (2002) studied 162 Norwegian Naval Academy cadets participating in a week-long combat leadership exercise. The purpose of the study was to identify factors that contributed to unit cohesion. Bartone et al. found that, among other things, the personal hardiness of team members contributed positively to small unit cohesion. Finally, Kelly, Matthews and Bartone (2005) found that the commitment and control subscales of the hardiness measure described by Bartone (1995) were predictive of military leadership scores and the commitment subscale was predictive of attrition among a large sample of West Point cadets from the Class of 2008, with hardier cadets being more likely to remain through cadet basic training.

The importance of the resilience and hardiness research is that combat and other stressful deployments not only inoculate the soldier against the situational and short-term negative consequences of the deployment, but are related to positive and in some cases long term positive benefits. It is worth pointing out, once again, that this expanded focus of the effects of stress on adaptation to difficult circumstances adds significantly to the traditional negative psychology approach to the topic. More explicit training protocols are needed to build resilience in soldiers before they deploy, thus providing a proactive buffer against negative outcomes of PTSD, anxiety, depression, and boredom. But such training protocols should result in value added, in terms of soldiers who interpret their experiences as yielding positive meaning to their lives.

Positive psychology

This brings us to a discussion of theory and research explicitly associated with positive psychology. The scope of positive psychology is as broad as that of traditional psychology, to include the study of all aspects of personal and social behavior. Seligman et al. (2005) offer an update on positive psychology, and point out there is both a science and a practice (e.g., Linley and Joseph, 2004) of positive psychology. Since a special issue of the American Psychologist devoted to positive psychology appeared in January of 2000, Seligman et al. report that hundreds of journal articles and numerous books have appeared that are explicitly related to the emerging field. Moreover, seemingly countless articles in the popular press and media have also appeared, serving to popularize positive psychology in the general population. It seems that the basic tenets of positive psychology resonate with scientists, practitioners, and the public, presumably because at last psychology has something of value to offer to the non-psychiatric population. The author’s experiences within the
The military is one of an enthusiastic embracing of positive psychology as it may be applied in military settings. For example, the counseling center at the US Military Academy is working closely with Seligman and Peterson to reframe itself into a center that offers services of value to cadets who want to enhance their adjustment and adaptability to the rigors of military education and training, beside just helping those who are in difficulty to learn to cope and get by.

There seem to be several areas of application of positive psychology to the military. These would include:

- Role of character in adaptation to combat.
- Pre-deployment training protocols to inoculate soldiers against the stresses of combat.
- Post-deployment training protocols to help soldiers re-adjust to state-side duty or the return to civilian life.
- The scientific analysis of the role of character strength and positive affect on tactical, operational, and strategic decision making.
- Positive psychological correlates of successful adaptation and performance in military training venues.
- Developing training strategies and interventions for special, high-speed combat units.
- The science and practice of the role of character strengths in helping the families of deployed soldiers deal more effectively with the unique demands they face.
- Developing special interventions for children of killed or severely wounded children of soldiers.
- Help existing organization, such as the Military Child Education Coalition, develop positive psychology based training and intervention programs to foster better adjustment in their targeted populations.
- Educate government agencies and healthcare providing organizations on the potential value of positive psychology based interventions in the populations they serve.

This list illustrates both the science and practice of positive psychology as it applies to the military. In some ways, all the items on this list relate to the topic of this chapter. Most explicitly, of course, is research on positive psychology and combat. However, military service by its very nature is demanding due to frequent moves, long working hours, and difficult working and training conditions. Therefore, applications to training milieus is appropriate within the scope of this discussion. For example, ongoing research reviewed below shows that a variety of positive character strengths are important determinants of the successful adaptation of cadets at the US Military Academy. Successful decision making is a critical component of individual and unit performance in combat. How might character strengths and positive affect influence this? Spouses, children, and the extended families of soldiers also face great stress. How may positive psychology – based interventions improve their ability to cope with the combat deployment of their loved-one?

The following discussion focuses on planned, on-going, and completed research and practice of positive psychology in the military context. It is hoped that this discussion will serve a heuristic function and help guide interested readers to intriguing and important research and practice applications. To date, relatively little published research in this area has appeared – this more reflects the newness of this field than it does paucity of effort. Much of the research that has been completed has been reported at conferences but has not yet made its way to the refereed literature. The current chapter may serve as an interim review of this state-of-the-art research in military positive psychology, and provide direction for researchers wishing to establish a research agenda in this domain.
In 2003 Marty Seligman visited West Point as part of a visiting scholars program and conducted research discussions with the faculty of the Department of Behavioral Sciences and Leadership. Through the next year, I continued discussions with Seligman and his colleagues at the University of Pennsylvania, and by the summer of 2004 a research plan was developed to begin assessing the impact of positive psychology constructs on the adaptation and performance of cadets at West Point.

An important underlying premise about this research plan centered on the notion of the uniquely challenging environment that a military academy poses to new cadets. Not only do new cadets encounter the challenges and obstacles facing traditional college students (academics, adjusting to a new environment, gaining new friends, growing apart from old ones, etc.), but also must adjust to military life. The adjustment is profound. Prior to arriving at West Point, the new cadets reported they slept an average of nine hours per night and arose at eight o’clock in the morning. At West Point, they awoke well before six o’clock and average only 4 hours and 50 minutes of sleep on school nights during the fall semester (Miller and Shattuck, 2005). Their day continues until lights out/taps at midnight. They must learn military customs, courtesies, and history. Male cadets receive a “high and tight” haircut, and women cadets must keep their hair within rigid grooming standards. Suddenly, they find themselves at the bottom of a rigid military command and control hierarchy – their mistakes (and there are many) are corrected on the spot with assertive, if not aggressive, corrections. Then they must complete basic training in the field, learning how to march, fire weapons, fight with bayonets and pugil sticks. The week before classes begin, field training concludes with a lengthy and grueling road march carrying a rifles and a combat field load, beginning at well before dawn.

If they make it through cadet basic training in their first summer, cadets then face a daunting academic schedule. The first 2 years consists of core courses in science, math, English, foreign language, and the behavioral and social sciences. There is no “curve” at West Point. Cadets must perform to a high academic standard or fail a course. Failing two courses ordinarily results in dismissal from the academy. Moreover, cadets must adhere to a rigid code of conduct and honor, violations of which may also result in this dismissal. In addition to academic courses, all cadets take courses in military science, physical training, and military development. All must compete in a sport – either intercollegiate or intramural. They do not get their summers “off.” Summers are spent attending Army schools like Airborne, Air Assault, and others. Between the freshman (or “Plebe”) and sophomore (“yearling”) year, they participate in a lengthy infantry leadership exercise. Between the yearling year and the junior (“cow”) year, they spend 3 weeks attached to an operational Army unit, many times in distant parts of the globe, serving as a “third” lieutenant. During this summer they also may complete a 3 week long academic internship. Upon graduation their senior (“firstie”) year, the new second lieutenants are obligated to spend a minimum of 5 years of active duty in the Army. These days, duty is dangerous. At the time I am writing this chapter, more than 55 West Point graduates have died in combat operations in Iraq and Afghanistan.

So it is in this context that we wanted to explore the role of positive psychology constructs on adaptation and performance. There were two related foci of the initial research. One of Seligman’s doctoral candidates, Angela Duckworth, had designed a new personality measure designed to assess a person’s passionate pursuit of long term goals. This scale, called grit, is a similar construct to persistence but with the added dimension of passion for the goal. Duckworth, a former Marshall Fellow, had observed that while her Marshall Scholar peers were certainly bright, the key feature that captured their special achievements was not their aptitude, but their “gritty” resolve to obtain long term goals. The development and psychometric properties of grit are described elsewhere.
(Duckworth, Peterson, Matthews, and Kelly, 2007), and preliminary research with the grit showed 1) it was widely predictive of performance in diverse circumstances, for example order of finish at the National Spelling Bee, and 2) grit is orthogonal to aptitude. That is, while both aptitude and grit are correlated with performance criteria, like academic grades, there is no correlation between grit and aptitude (Duckworth et al., 2007).

The second focus of the initial research was the relationship between character strength and adaptation and performance at West Point. Peterson and Seligman (2004) describe the development of a classification of human character strengths as well as a questionnaire for measuring them. They conducted a thorough review of the psychological literature and of the religions and philosophies of world, both contemporary and historical, and identified a tentative list of 24 character strengths they believed to be universal in the species. These 24 strengths are grouped into six clusters of moral virtues: Wisdom and Knowledge (creativity, curiosity, judgment, love of learning, perspective); Courage (bravery, persistence, integrity, vitality); Humanity (capacity to love, kindness, social intelligence); Justice (teamwork, fairness, leadership); Temperance (forgiveness, modesty, prudence, self-regulation); and Transcendence (appreciation of beauty, gratitude, hope/optimism, humor, spirituality). The Values-in-Action Inventory of Strengths (VIA-IS) was developed as the character strength metric. The VIA-IS consists of 240 questions, 10 for each of the 24 strengths, each associated with a five-point Likert scale with responses ranging from (with regard to a given statement), “very much like me” to “very unlike me.” Peterson and Seligman report the VIA-IS has robust psychometric qualities. The research question was, therefore, to what extent might objectively measured character strengths be predictive of the adaptation and performance of West Point cadets?

**Grit** The grit was administered to 1,223 new cadets who entered West Point in the summer of 2004. Their demographics were similar to past classes, with 16 per cent women, 23 per cent ethnic minority, and a mean age of 19 years. The testing occurred on the second or third day following their arrival at West Point. In addition to grit scores, 204 other aptitude, demographic, and assessed variables were available from their applicant file, and were merged along with grit into a single data file. The Baumeister Self-Control Scale (BSCS; Tangney, Baumeister and Boone, 2004) was also administered at this time. The sample was tracked initially through the end of their first academic term, to include, of course, cadet basic training. Outcome variables that were collected included attrition from basic training and academic, leadership, and physical fitness performance measures through the first semester.

The analysis showed the grit (alpha = 0.79) and the BSCS (alpha = 0.81) had relatively high internal validity. Because of the stressful nature of cadet basic training, retention was assessed at the completion of the summer, prior to the beginning of academic classes in the fall term. In this sample 94% (n=1152) completed basic training and 6 per cent (n = 71) dropped out. Given the large number of aptitude and other predictor variables, including a robust roll up of key admissions criteria including aptitude, leadership, and physical fitness measures called the Whole Candidate Score, we were somewhat surprised to find that grit predicted summer training retention better than any other variable. Indeed, cadets who scored a standard deviation higher in grit were nearly twice as likely to complete summer training than their counterparts. As Duckworth et al. (2007) point out, the magnitude of the relationship between grit and retention was impressive since West Point cadets are a very “gritty” population to begin with, scoring almost a standard deviation higher in grit than Ivy League undergraduates.

Grit is also related to adaptation of Norwegian Naval Academy cadets during a 10-week long sailing mission on a tall-mast sailing ship. Eid and Matthews (2005) administered the grit to 92 cadets 4 weeks prior to their setting forth on the mission aboard the Statsraad Lehmkuhl. Outcome
measures included self- and peer-ratings of six dimensions of adaptation on the mission: resiliency, sociability, productivity, flexibility, creativity, influence-ability, and responsibility. Grit showed high reliability (0.78), and the Norwegian cadets showed relatively high grit scores, but were significantly lower than West Point cadets (taken previously, see Duckworth et al., 2007). Grit was significantly correlated with self-ratings of influence-ability \( r = 0.39 \) and responsibility \( r = 0.32 \), and marginally correlated to the self-rating of productivity \( r = 0.23 \). Grit did not correlate with peer-ratings of adaptability. A regression model including grit in addition to self- and peer-ratings of adaptation combined to predict military development grades, \( F_{3,56} = 8.03, p < 0.001, r = 0.55 \).

**Character strengths** Army doctrine (US Department of the Army, 1999) emphasizes the importance of character in leadership. Seven “Army Values” thought central to successful leadership are loyalty, duty, respect, selfless-service, honor, integrity, and personal courage. A thorough reading of doctrine reveals that at least half of the character strengths postulated by Peterson and Seligman (2004) to be universal in our species are explicitly included in the leadership doctrine.

Army doctrine and its associated values are based on hundreds of years of operational experience rather than on empirical research. We thought it would be interesting to begin assessing character strengths, using the VIA-IS, and see how such strengths might map with official Army leadership doctrine. As a first step, we thought it would be interesting to compare entering West Point cadets with an appropriate comparison sample from the US population as a whole. Moreover, comparing West Point cadets with a sample of military cadets from another NATO country would be revealing, perhaps suggesting cultural differences that could influence behavior and leadership during multi-national operations. Toward this end, Matthews et al. (2006) compared 103 male West Point Plebes with 141 male Norwegian Naval Academy cadets and 838 US males between the ages of 18 and 21 who had completed some college on each of the 24 VIA-IS character strengths. Only males were included because the Norwegian academy only enrolled a handful of women, short of the number needed to make meaningful comparisons across comparison groups.

Matthews et al. (2006) found some interesting differences among the three comparison groups. First, in looking at mean scores for each of the 24 character strengths, West Point cadets were significantly higher than the US sample on 13 of the 24 character strengths, scoring higher on such strengths as bravery, teamwork, social intelligence, self-regulation, leadership, and honesty. Surprisingly, the West Point sample scored higher than the Norwegian sample on 22 of the 24 character strengths, with the only two not showing a significant difference being forgiveness and zest. While direct comparison of means between the two US groups may be defensible, the authors suggested that, given potential cultural differences between Americans and Norwegians in rating themselves on such instruments (e.g., see Silvera and Seger, 2004), a comparison based on the rank-orders of the character strengths would be more valid. The results from this analysis showed something quite interesting – the correlation between the West Point and Norwegian military cadet samples was substantially higher \( r = 0.82 \) than that of the West Point and US comparison sample \( r = 0.61 \). So, once cultural bias is controlled for by comparing ranked scores rather than raw means, it appears that the two military samples – from substantially different cultures – are more similar to each other than the US military sample is to US civilians. Furthermore, in both military samples character strengths related to leadership doctrine were among the highest ranked for both samples, with honesty, industry, bravery, and teamwork among the top half for both samples. In the US civilian sample, the highest strengths included kindness, humor, love, gratitude, and curiosity – all positive, good things to have, to be sure, but perhaps not as central to military leadership as the higher ranked strengths in the military samples.

Several important conclusions may be taken from the Matthews et al. (2006) study of military cadet character strengths. First, the character strengths held important to military leadership doctrine
are dominant in the military samples. The methodology of the study did not allow for researchers to determine if young people who seek to become military officers are more prone to be high in such strengths and thus come into the training institutions high in these areas, or if the training regimens and culture of the military academies help grow these strengths among their cadets. Probably, both factors are at work. Second, the high similarity of the two military samples despite the disparate cultures speaks of a “band of brothers” in terms of what future officers value and in character strengths relevant to military missions and culture. Finally, there are some differences in the two military samples that could impede communication, teamwork, and performance in multi-national operations. For instance, West Point cadets are highly spiritual, whereas Norwegian cadets rank spirituality dead in their hierarchy of character strengths.

Matthews, Peterson, and Kelly (2006) recently examined the role of character strength in the retention of incoming West Point cadets through cadet basic training. The sample consisted of 1,208 cadets from the Class of 2009, who began training in the summer of 2005. The research design was similar to that used by Duckworth et al. (2007). It was not feasible to administer the entire 240 item VIA-IS to these cadets due to limited testing time. However, unpublished results from a sample of 131 cadets from the Class of 2008 who had been administered the full VIA-IS showed that the correlations between full-scale scores and self-ratings (on a five-point scale) of each strength were highly correlated, in most cases $r = 0.70$ or higher. Thus, in the current study, cadets self-rated themselves on each of the 24 character strengths on the second or third day following their arrival at West Point. They were then followed through cadet basic training and retention was assessed at the end of this period.

Self-ratings of the 24 character strengths were compared between the cadets who were retained ($n = 1,135$) through basic training and those who had departed ($n = 73$). Cadets who were retained had rated themselves higher than those who ultimately left on nine strengths – bravery, enthusiasm, fairness, honesty, persistence (similar to and highly correlated with grit), optimism, leadership, self-control, and teamwork. There were no strengths where those who left rated themselves higher than those who stayed. Indeed, those who were retained rated themselves higher than leavers on 23 of the 24 strengths (including the nine that were statistically significant). Matthews et al. (2006) also collected full VIA-IS scores on three strengths – optimism, capacity for love, and persistence. Retained cadets were significantly more optimistic and persistent than leavers, but the two samples did not vary on capacity to love. In addition, Matthews et al. performed a factor analysis on the self-rated strengths that revealed five factors. Collectively, these five factors were a significant predictor of retention, yielding a multiple $R$ of 0.15, $F(5, 1,117) = 4.90$, $p < 0.001$. Factor 1, which consisted of the strengths of leadership, teamwork, and bravery, was the only one of the five factors with a significant beta weight (0.16), with those who stayed scoring higher on this factor than those who departed.

Eid, Matthews and Johnsen (2004) looked at the relationship between VIA-IS measured character strengths and the performance of cadets on the tall mast sailing mission, using an earlier class of Norwegian cadets than reported by Eid and Matthews (2005). The research design was similar to that described earlier by Eid and Matthews, but used the 24 character strengths measured by the VIA-IS as predictors of ship board adjustment rather than grit. The authors rolled the 24 strengths up into the six moral virtues described by Peterson and Seligman (2004), creating six factors to predict self- and peer-ratings of performance. For instance, the individual strengths of creativity, curiosity, open mindedness, love of learning, and perspective were summed to create the moral virtue of Wisdom and Knowledge. A regression model employing these six moral virtues as predictors yielded statistically significant ($p < 0.05$) predictions of self ratings of sociability, the ability to stay awake (an important behavior in long-duration and challenging missions), and coping skills. These moral virtues were marginally significant ($p < 0.15$) for self rated productivity,
self-confidence, and influence-ability; peer ratings of influence-ability; and observer-controller ratings of creativity. Collectively, these preliminary data suggest that character strengths may be important indicators and predictors of adaptation to stressful and challenging military training environments.

The 47-month long West Point educational and training may be viewed as an immersion in character building. This occurs through explicit instruction, exposure to powerful role models, and rigorous, relentless, and challenging training experiences. Given this, it might be expected that character strengths, as measured by the VIA-IS, might either increase in magnitude or shift in order of priority. To test for this possibility, Tuite and Matthews (2006), using a cross-sectional research design, compared a sample of Plebes (n = 132) with a sample of first-class (n = 100) cadets. Both samples were administered the full 240 item version of the VIA-IS. Surprisingly, the only difference between the two samples that was statistically significant was that first class cadets were less spiritual than the Plebes. When the scores of the two samples were rank-ordered, a correlation coefficient of \( r = 0.87 \) was found, suggesting only minor differences in the overall rankings of character strengths for the two samples. There was some evidence that collectivist strengths (e.g., teamwork) had become more important to the firsties, but there were no overwhelming differences between the two groups. It is doubtful that a strong environment like West Point has so little impact on character development. More likely, a ceiling effect may have occurred with respect to character as measured by the VIA-IS. As Matthews et al. (2006) found, the entering Plebes were very high in the 24 character strengths compared with US college age people. Moreover, character changes that result from the West Point developmental experience may be more subtle and perhaps deeper than might be detected by the VIA-IS. At a minimum, the strengths important to leadership and performance under stress and (later in their careers, fire) may simply be reinforced and made more resistant to change.

The character strength of optimism is linked to a wide array of outcomes. Eid, Matthews, Johnsen, and Meland (2005) assessed dispositional optimism of 77 Norwegian Naval Academy cadets using the Life Orientation Test – Revised. The cadets then took part in a grueling week-long combat survival course characterized by continuous operations, sleep and food deprivations, and a series of tactically, physically, and ethically challenging training events. At the conclusion of an infantry-based assault exercise, the cadets self-assessed their situation awareness. Situation awareness is a cognitive construct, thought to be vital to decision making, which consists of the ability to accurately perceive their environment, comprehend the meaning of what they perceive, and to make accurate projections about what is likely to occur next. Interestingly, Eid et al. found an inverse relationship between optimism and situation awareness. Under the special circumstances of this particular training environment and mission, they argue that highly optimistic individuals may not be capable of accurate self-assessment of their situation awareness or of the tactical situation.

Park (2005) offers a different look at character strength and adaptation to the military experience. She conducted a content analysis of the citations accompanying the Medal of Honor given to 123 soldiers, sailors, or airmen since the First World War. The analysis looked for mention of the 24 character strengths defined by Peterson and Seligman (2004). The awards were given across branch, age, rank, and wars. Most typically, they were given for doing one’s job despite danger and threat of death. Not surprisingly, bravery (at 100 per cent) was the trait most frequently included in the citation. This can be viewed as a given, considering the nature of the Medal of Honor. The next five most frequently cited traits were self-regulation (80 per cent), persistence (67 per cent), leadership (49 per cent) teamwork (39 per cent), and creativity (18 per cent). An interweaving theme across all the citations was the role of humility and selfless-service. A theoretical analysis of these strengths along the dimensions of focus on self versus focus on others, and strengths of “heart” versus strengths of “mind,” showed that the character strengths most often associated with
Medal of Honor winners were predominantly associated with a focus on others and a balance between strengths of the heart (e.g., kindness) and the mind (e.g., self-regulation).

Summary and concluding comments

If ever there is a sample of human beings who performed under the conditions of central interest to this chapter and this book, it is these just mentioned Medal of Honor recipients. Many were indeed killed in the action that resulted in the awarding of the medal, and almost all were wounded. To say the least, mortality salience was high. Thus, it is interesting to reach back to our review of the psychological and behavioral traits associated with mortality salience. The analysis of these heroes under fire validate much of the mortality salience work, reinforcing the notion that under the most dire circumstances, at least some humans will display the most valued markers of character and virtue.

One is tempted to look for some overarching theoretical framework to account for the mechanisms that we reviewed in this chapter. The underlying theme is human adaptability and performance in situations where life and personal well-being is in peril. Although beyond the scope of this discussion an obvious place to look is in the evolutionary psychology. Evolutionary psychology examines the evolution of behaviors in general, and social behavior in particular. A good example germane to our topic is altruistic behavior, or behaviors that may result in the death or injury to an individual but may benefit the social group. Wilson and Sober (1994) suggest that group selection is at work under such circumstances, and that altruistic groups will survive better than non-altruistic groups. Kalat (2007) maintains that reciprocal altruism and kin selection models offer better theoretical accounts for altruistic behavior. Nettles (2006) recently presented an intriguing description of how evolutionary principles may be related to personality. His analysis could easily be extended to the evolution of character strengths as important components of individual reproductive fitness. Regardless, it may be that there is a genetic predisposition for humans to behave in exceptional ways under exceptional circumstances, and this behavior improves the survivability of the social group (i.e., fire team, battalion, or nation) if not that of the individual.

In closing, the pattern that emerges from this review is that humans employ a variety of cognitive, affective, and behavioral mechanisms to respond to situations of high personal and social threat. The emerging interest in in extremis leadership is beginning to explore how people behave in conditions of high threat. The mortality salience literature – closely linked to the in extremis work – has a sound empirical foundation and shows many positive consequences when people are reminded of their own mortality. The resilience and hardiness research represents a refreshing approach to understanding soldier’s and others reaction to stress and threat of physical harm. Finally, the rapidly exploding research in positive psychology supports these other perspectives and shows the importance of character strengths and related personality traits in adapting to challenging military education and training events. The common thread running among these different streams of research is that to gain a complete understanding of human adaptation and performance under exception circumstances, we must focus not only on the correlates and predictors of failure, but also on the correlates and predictors of success. There is much more work to do in this domain. I hope this review will provide guidance and perhaps inspiration for others to extend positive psychology constructs to other situations where people must adapt to and perform in difficult circumstances.
References


Miller, N.L. and Shattuck, L.G. (2005) “Sleep Patterns of Young Men and Women Enrolled at the USA Military Academy: Results from Year One of a Four Year Longitudinal Study”, *Sleep*, **28**, 837–841.


Chapter 10

Stress and Teams: How Stress Affects Decision Making at the Team Level

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The operating theaters that soldiers face today are characterized by greater complexity than ever before. Changes in the global environment have led to an increase in asymmetric threats, growth in joint and coalition based military activities, and a shift to effects based operations. To succeed in these environments, not only do missions require the coordination between different branches of the military, the missions often require coordination and collaboration with military units and non-governmental organizations of various countries. These missions while combining elevated levels of interoperability and jointness that rely on a shared situational awareness (Warne et al., 2004) are also characterized by dynamism, ambiguity, and time pressure which serve to challenge team decision making as military teams face an enemy who is extremely adaptive in its use of unconventional warfare. Despite the increased complexity which characterizes such environments, leadership and decision-making activities are being pushed down to increasing lower levels than ever before in attempts to adaptively and flexibly respond to an unconventional enemy. The complexity of such environments is illustrated by the following blog from a soldier in Iraq (see Burden, 2006):

Two sedans, one closing. Carlson goosed the accelerator and we hit seventy the same instant it came from the far right lane. A blue sedan with black side windows swerved towards us – the kamikaze targeting technique. Carson floored it as I pivoted in the seat, pointed my pistol with a two-hand grip, started the squeeze but there is no space now this lane’s too narrow. We shot past the sedan’s enormous hood. In that short chasm – the broken second when I didn’t pull the trigger – I absorbed the face of the sedan’s frail driver; gray hair, gray mustache, hunched forward. An old man lost in a high speed haze… I didn’t shoot. The right call – the right decision in trumps… But on Baghdad’s streets the next Flat or Mercedes may be a kamikaze. Or is it a family sedan, or that old man looking for an exit? As the car rushes forward the soldier – whose life is on the line – has a split second to decide (pp. 106−107).

While the situation above illustrates the complexity present in many military environments, complexity within operating environments is not limited to the military, but appears in many public and private organizations (e.g., development teams, mission control teams, medical teams, SWAT teams). In today’s operating environment teams often operate in situations where cognitive demands can be overwhelming, leading to stress and corresponding catastrophic errors (see below).

A California police officer was shot and killed by a fellow officer during the execution of a high-risk search warrant. The officer’s team was serving a warrant at a house thought to be occupied by three heavily armed drug dealers. The house was subsequently found to be unoccupied. Smoke grenades had been deployed, reducing visibility. The officer was in a room when a fellow officer mistook him for a suspect with a gun. The officer was shot with a shotgun and died 30 minutes later at a local hospital. His wife sued the SWAT supervisor, the police department, and the city. She settled with the city for $3500,000 (Myers, 2005, p. 5).
Stress occurs when an individual perceives a stimulus (e.g., workload, time pressure) as exceeding their resources so that there is a discrepancy between their resources and the demands of the task and/or situation (Salas, Driskell and Hughes, 1996). At an individual level, both changes in performance (e.g., increased time on task and errors, decreases in accuracy; see Jones, 1983; Samman and Salas, 2002) and information processing have been documented (e.g., narrowed range of attention and surrounding inputs, Wickens, Gordon and Liu, 1999). These cognitive decrements can have disastrous consequences for decision making in that alternate cues and options are often ignored. There has been a myriad of work done on the impact of stress on individual decision making. Stress not only degrades the decision-making and performance abilities of individuals, but has also been argued to impact team performance (e.g., Hackman and Morris, 1975; Karau and Kelly, 1992; Johnston, Driskell and Salas, 1997; Cannon-Bowers and Salas, 1998). In an effort to maintain the central task (their own responsibilities), team members exhibit reduced attention to other members and teamwork behaviors (Driskell, Salas and Johnston, 1999). The narrowing of attention is especially harmful because it leads to reduced team situational awareness. Reduction in team situation awareness, in turn, impacts decision making and coordination. Research has also suggested that hierarchy and stress interact within teams, such that authority and decision-making activities shift to higher levels in response to stress (Hermann, 1963). Driskell and Salas (1991) reported that under stressful conditions low status members were more willing to defer to others and more hesitant to take action in emergencies. Some research suggests this is an adaptive response where responsibility is placed in the hands of those most central to the organization’s values and goals (Staw, Sandelands and Dutton, 1981). However, this results in subordinates that are hesitant to question authority under emergency conditions, sometimes to the extent of not offering valuable task information (Foushee and Helmreich, 1988). As technology is increasingly leading to decisions being pushed down to lower levels there may be no one else for subordinates to look to in times of stress.

Despite of the increasing importance of team decision making within the complex operating environments which characterize the world today, there is much that remains to be learned about the impact of stress on decision making. As it is our belief that nothing is more practical than a good theory (Lewin, 1951), we look to frameworks and corresponding models of team decision making as a first step in seeking to understand team decision making within complex environments. While the past several years have produced a handful of frameworks and/or models which report to be about team decision making within environments characterized by stress, many do not adequately focus on the “team” aspect of team decision making. Within each framework and model there are often pieces which address the “team” in team decision making, but there is a lack of an integrated framework or model. While much is known about individual decision making, much less is known about team decision making. This state of affairs is unacceptable, as many have argued that in day-to-day work environments decisions are increasingly being made by teams rather than individuals (Klein, 1993; Orasanu and Salas, 1993).

As such, there is a need to further develop a practical framework for examining team decision making under stress in order to address the deficiencies observed in the literature. Therefore, the purpose of the current chapter is four-fold. First, a brief review of the literature on decision making theory, team decision making, and stress is conducted. In reviewing the literature, the literature base surrounding stress and teams will be synthesized to provide a comprehensive knowledge base of what is known, while leveraging research on individuals and stress. Second, a conceptual framework concerning the impact that stress has on team decision making will be presented. From this framework propositions will be extracted that highlight key components. Finally, areas in need of future research will be highlighted.
Team Decision Making

Team decision making has been defined as, “the process of reaching a decision undertaken by interdependent individuals to achieve a common goal” (Orasanu and Salas, 1993: 328). Of the research that has been conducted on team decision making much simply assumes that team decision making is a simple aggregate of what happens at lower levels of decision making (i.e., individual). Similar to the argument that teams are more than merely the sum of their parts, it has been argued that team decision making is distinct from individual decision making and not simply an aggregate of the lower-level phenomena (Orasanu and Salas, 1993; Ilgen, Major, and Sego, 1995). Specifically, it has been argued that team decision making is comprised of multiple information sources and task perspectives which must be combined in some manner to result in a final decision. Therefore, team members must be willing to communicate personal knowledge and information to fellow members (Shaw and Penrod, 1964). However, team members may have different sub-agendas, motives, perceptions, and options despite the fact that the team as a whole may be working towards a common objective (Orasanu and Salas, 1993). Adding further complexity to the process is that research has indicated that in team decision making contexts shared information is more likely to be discussed and brought to discussions earlier than unshared information (Larson et al., 1996). This is despite the fact that it is the unshared information which often provides the synergy to decision making within teams. Research has indicated that leaders can mitigate this phenomenon by enacting an information management role in which they repeat more case information than other team members and over time repeat unshared information at a steadily increasing rate (Larson et al., 1996).

The type and amount of information that is shared within teams will influence the manner in which the problem is formulated, which in turn, impacts consequent actions in the decision making process (Payne et al., 1992). In addition, individual motives, perceptions, sub-agendas and experience levels influence the reliability, validity, and manner in which information is not only communicated, but combined. Adding to the complexity, is the multi-level nature of team decision making such that in attempting to understand team decision making both individual and team processes must be taken into account. For example, Ilgen et al. (1995) argue that at the individual level, each member reaches an individual decision based on the consideration of a set of cues and their individual weights. However, within teams, members may have information about different cues due to distribution in expertise and location/vantage point. Members may also have the same information about cues, yet assign different weights based on their past experience, expertise, and other situational factors.

In an effort to better understand the complexity present in team decision making several researchers have developed frameworks and models of the process of team decision making. Currently, developed models can generally be classified as falling into one of two camps: prescriptive or descriptive models. Those prescriptive models identified generally follow a rational, analytic paradigm, while those which take a more descriptive approach tend to speak to the use of heuristics in this process (e.g. naturalistic decision making). Below a brief review of several models that have been applied to team decision making are offered. While we argue that none of the identified models reflect a truly integrated model of team decision making, each contains important components that can be used to guide the development of an integrative framework. Models are categorized as primarily following a rational, analytic paradigm or a naturalistic decision making paradigm. However, there are a few models which attempt to integrate the two perspectives (i.e., mixed models).

Classical Decision Making Paradigm

While the classical decision making paradigm has traditionally been very popular in the area of individual decision making, it has received less attention within team decision making. This may be due to the environmental complexity that is often present within team environments. This complexity
often makes a rational approach where each alternative is evaluated in a systematic and linear manner unpractical in terms of time and resources (i.e., situations are too dynamic). However, a few such models were identified within the literature on team decision making and are presented next.

**Multi-Level, Hierarchical Team Decision Making Framework** Perhaps the most well-known rational theory of team decision making is that developed by Ilgen et al. (1995). Ilgen et al. (1995) argue for a multi-level theory of team decision making. The theory and corresponding framework has its early roots in Brunswick’s lens model. The underlying assumption within this framework is that individuals take a rational approach to decision making. Within this approach to decision making information is gathered in a systematic manner on cues deemed to be relevant. Once the information is gathered weights are assigned to cues based on their characteristics (i.e., importance, reliability), and this information is used to integrate the various pieces of information into a coherent decision. This framework extends earlier rational approaches by depicting situations in which teams are hierarchical, expertise is distributed throughout the team, and members often hold unique information. In an effort to better understand team decision making the framework specifies constructs at four levels (decision, individual, dyad, team) which are argued to contribute to team decision making effectiveness (i.e., accuracy).

The lowest level is the decision level and information at this level addresses the decisions made by individuals at a unique time (Humphrey et al., 2002). At this level, Hollenbeck et al. (1995) identified decision informity as the most critical variable. Decision informity can be defined as, “the degree to which each team member has all the information necessary to perform his or her role in the decision-making process” (p. 270, Hollenbeck et al., 1998). Decision informity aggregates to the team level and becomes team informity. At the team level, informity describes how informed the team is across all decisions.

The next level above the decision-level is the individual-level. The critical variable at this level has been argued to be individual validity or the degree to which each member can make recommendations to the team leader that will be predictive of the correct decision for the team (Hollenbeck et al., 1998; Humphrey et al., 2002). Once again, within decision making teams, individual validity has a counterpart at the team level (i.e., staff validity). At the team level this construct refers to the average level of individual validity and can be on any number of traits.

The third level which the framework specifies is the dyadic level. At this level, dyadic sensitivity is the most important variable. Dyadic sensitivity reflects the degree to which the team leader accurately weighs team member recommendations (Hollenbeck et al., 1998). Teams are constructed of multiple vertical (between a team member and the team leader) and horizontal (between team members) dyads. Each dyad involves a different relationship independent and interdependent with the remainder of the team. Given the different configurations of dyadic relationships, dyadic sensitivity can be aggregated to the team level when teams are comprised of more than two members. This, in turn, produces a construct known as hierarchical sensitivity. Finally, the highest level, the team level captures the aggregated effects of the decision, individual and dyadic levels while measuring team-level specific variables (i.e., cohesion and team efficacy).

The six constructs that have been identified above (i.e., decision informity, dyadic sensitivity, individual validity, team informity, hierarchical sensitivity, and staff validity) form the core of the model. Hedlund, Ilgen and Hollenbeck (1998) argue that these core variables mediate the relationship between conditions in the team’s environment (non-core constructs) and decision-making accuracy. Environmental conditions that were identified as being relevant within the context of the model are as follows: roles, person, tasks, physical/technical environment, behavior settings and social environment. Initial support for the model was provided by Hollenbeck et al. (1995), who reported 25 to 50 per cent of the variance in decision making accuracy was accounted for by core model constructs. Non-core constructs within the model accounted for less variance in team decision
making accuracy with most relationships being mediated by core constructs. Other studies have also tended to support the premise of the developed framework (see Hedlund et al., 1998).

Given the conditions noted above, the multi-level framework developed by Ilgen et al. applies most accurately to teams that are hierarchical in terms of structure. Team members play a role in the decision making process by providing the leader with information and recommendations based on their interpretation of the data available. Ultimately it is the team leader’s responsibility to integrate this information and select/propose the final recommendation. While the framework developed by Ilgen et al. is one of the few which begin to illustrate the factors considered in weighting team member inputs, it has been criticized due to its assumption of exhaustive search strategies. Models which tend to follow the classical, analytic tradition have tended to also be criticized for their lack of attention to the stage of decision making where the issue at hand is formulated (i.e., problem conceptualization) (Vidaillet, 2003).

Naturalistic Decision-Making

Naturalistic decision making (NDM) is a decision making framework which is grounded in the study of how experts make decisions in real world contexts (Zsambok and Klein, 1997). Research into how experienced operators make decisions in stressful environments have documented the narrowness of normative decision making models (Klein, 1989). First, normative models consider decisions regarding how to choose between alternative courses of action and fail to address decisions involved in making assessments of the situation. In contrast with novices, experts base their judgment on their situation assessment abilities, rather than on their reasoning abilities. Second, normative models do not describe decisions involved in scheduling various tasks to accomplish the selected option. In addition, reasoning and acting are viewed as sequential stages rather than as interweaved in a decision cycle approach (Weick, 1983; Connolly and Wagner, 1988). As Orasanu and Connolly (1993) put it “instead of analyzing all facets of a situation, making a decision, and then acting, it appears that in complex situations people think a little, act a little, and then evaluate the outcomes and think and act some more” (p. 19). Normative models do not account for the processes that operators rely upon to generate alternative options and evaluation criteria.

While classical decision making theory is concerned about how to choose between different options, NDM is less concerned with the actual moment of choice, but instead focuses on appropriate categorization of the situation (Klein, 1997). In further delineating naturalistic decision making from rational approaches to decision making five characteristics have been defined: proficient decision makers, situation-action matching decision rules, context-bound informal modeling, process orientation, and empirical based prescription (Lipshitz et al., 2001). Specifically, NDM models do not focus on the traditional input-output paradigm, but instead focus on describing the cognitive processes of skilled decision makers in the hopes of reinforcing these processes in less experienced decision makers. Second, NDM relies on situation-action matching decision rules. This refers to the fact that research has indicated that skilled decision makers determine which action to take after matching features of the current situation to their experience over a systematic evaluation of all available options. Third, building on the previous feature is that experience makes NDM a context-bound informal modeling method because proficiency is driven by experience. This is in contrast to traditional rational approaches and formal decision making models, which generally seek to be context independent. Finally, NDM is based on an empirical-based prescription where the value of a recommendation is determined by its implementation, not its optimization. This means that if a recommendation cannot be implemented, it is worthless.

Recognition-Primed Decision Model  While many different NDM models have been described (see Lipshitz, 1993), perhaps the most prevalent is recognition-primed decision making (RPD).
RPD has three main variations which differ in terms of resource availability (Lipshitz et al., 2001). The first variation occurs when time pressure is especially high. This variation leverages experience to evaluate the situation and respond with the first option identified. While often not optimal, the outcome of this variation is usually a feasible decision as the decision maker’s experience provides a guiding prototype of possible reactions for categorized events. This condition does especially well in situations of extreme time pressure, as it does not require deliberations or specific analyses (Hutton and Klein, 1999).

The second variation most often occurs when time pressure is lower, yet the situation is unclear. Within this variation, the decision maker will build mental simulations based on his/her experience. Mental simulations are modified to include features of the current situation. The strength of this variation is its ability to manage uncertainty by identifying key parameters of plausibility and categorization.

The third variation of RPD also employs mental simulation of a possible action, but continues the simulation to completion and examines possible consequences. If any of the outcomes are unacceptable, then the simulation is adapted and reexamined. The third variation is most common when the decision maker is not faced with environmental constraints and stressors; however, it has the same overarching benefit of all the RPD variations. RPD is not hindered by ill-defined goals because it is forward focused from conditions as opposed to backwards focus from the goal-state. For this reason, if the situation or goal changes quickly, RPD allows the decision maker to update the situation assessment without needing to restart the entire plan based on late-stage plans (Ross et al., 2004). Based on the variants of RPD, the following have been argued to be key cognitive processes: situation assessment, mental simulation to evaluate options in a serial fashion, and choice implementation (Salas and Klein, 2001). However, the variations of RPD are limited by the definition of decision making as straightforward pattern matching based on previous experience. Thereby, the role of metarecognition is limited within the RPD model.

Recognition/Metarecognition Model (R/M) While RPD views decision making as straightforward pattern matching based on previous experience, it limits the role of metarecognition. As an answer to this, the R/M model evolved and emphasizes processes such as critiquing and correcting (Cohen, Freeman and Wolf, 1996). Within this model, expert decision-making is fashioned around a two-tiered strategy for building stories that account for novel events. The first tier involves the recognition activation of expectations and associated responses included in the RPD model. The second tier includes the, sometimes optional, process of critiquing and correcting. In this way, the R/M model straddles the line between the highly specialized pattern-recognition and the broad generality of the analytical formal models (e.g., Bayesian decision making). Decision making in the R/M model follows four basic steps (Cohen, Freeman and Wolf, 1996). First, the decision maker identifies relationships within the situation and builds a model that accounts for all of the observed relationships. These relationships, called arguments, are critiqued on the basis of completeness and reliability. The arguments are also evaluated to see if they conflict with each other. Next, the decision maker corrects the model or plan to respond to any problems identified. Last, a control process is used, called a quick test, that regulates the entire process in terms of available time, costs of error, uncertainty and/or novelty (Cohen, Freeman and Wolf, 1996). These steps are then repeated iteratively until the quick test determines that the plan should be carried out.

Advanced Team Decision Making Model The Advanced Team Decision Making model combines multiple behaviors that are critical to decision making into three basic parts: team identity, team conceptual level and team self monitoring (Zsambok et al., 1992). Team Identity refers to the members’ awareness of the team as an interdependent unit. Teams high in team identity define their roles and functions to encompass a shared model of task responsibilities and separate purposes.
Team identity is also built through engaging every team members’ participation in achieving team goals and by compensating for other team members if they are unable to complete their assigned role. Another way of building and maintaining team identity is by studiously avoiding micromanagement. When team members focus on aspects of the goals with an inappropriate attention to detail, the team is diverted from their overall goal.

Team conceptual level defines the “team mind” as an intelligent entity fulfilling the demands of the task. High conceptual level teams are able to express the goals and process of the team in specific, concrete language. Their decisions are also made within the available time using all of the available information and resources. This information, in higher conceptual level teams, has been evaluated for gaps or ambiguity and these holes have been filled. Also, these teams are able to generate many divergent possibilities before boiling their ideas down into a final course of action.

Teams also vary in how well they use the above team decision making processes. In order to be successful, teams must balance two important behaviors: adjusting and time management. The ability to adjust is especially important for teams because it allows them to modify their current behavior or plan if a problem has been discovered. This iterative process allows the team to constantly adapt to changes in their goals, abilities or behaviors. Time management in a team guides their ability to meet goals before deadlines as well as distribute resources to achieve sub-tasks. Consistently, monitoring their progress against their goals and resources, allows teams to accomplish all of their tasks before the deadline, or to re-prioritize to ensure the most important goals are met.

**Mixed Models**

**Contingent operator stress Model (COSMO)** Kontogiannis (1996) developed a model which attempts to integrate the naturalistic and analytic approaches to decision making. The underlying premise within the model is that decision making can be seen as a continuum between recognitional and analytic strategies. The model, which has its origins within the domain of emergency response, depicts a decision making process which consists of seven stages (i.e., early appraisal, problem formulation, recognition and selection of option, situation reassessment, options/goals evaluation, plan task, implementation, and monitor). The model argues for an iterative process of making decisions about the nature of the problem, types of alternative solutions, and methods for risk minimization.

The model depicts the first stage as consisting of an initial appraisal in which individuals assess the criticality of the situation and speculate as to likely explanations. This serves as input into the second stage, problem formulation, in which system constraints are identified and preliminary ideas regarding requirements and initial direction are made. Once an initial formulation has been made, a choice concerning the familiarity of the situation must be made. Depending on the familiarity of the situation, the remainder of the decision making process differs. If the situation is deemed to not be familiar then it is reassessed. During this process additional information may be sought or new developments incorporated. This, in turn, may lead to explanations about causes to be revised as well as revisiting constraints and corresponding system consequences. This information is then incorporated to project ahead to the future (e.g., situation assessment). At the conclusion of the situation assessment process, goals and options are evaluated. When more than one option exists, evaluation of the various alternatives may occur concurrently or serially (Kaempf and Klein, 1993). Here criteria are prioritized, options are balanced against future changes, and compared. Once option evaluation concludes, task planning begins such that task steps are prioritized, progress monitoring steps are established, and risk mitigation strategies are discussed. Finally, the decision is implemented and progressively monitored.

Conversely, if the situation was deemed to be familiar, the situation reassessment and evaluation of goals/options stages are bypassed as members are able to recognize the situation as one they have
faced or is similar and, as such, they are able to select the option (course of action) based on prior experience. In this case, the decision making sequence is: early appraisal, problem formulation, recognize, select option, plan task, and finally implement and monitor decision/course of action.

Summary

The predominant number of frameworks and/or models that were identified as examining team decision making were found to primarily examine individual decision making that occurs in the context of a team as opposed to team decision making. While models that originate within the naturalistic decision making paradigm tend to represent the complexity present within team decision making there is a lack of recognition on the “team” aspect. While team decision making may take many forms, models within the NDM paradigm seem to not depict the manner in which input may be taken from other team members. However, these models do begin to illustrate how external factors, such as time pressure and expertise, may vary the processes which comprise decision making. Conversely, rational models of team decision making recognize the need for distributed information to be integrated, but fail to recognize that there is often not the time to go through the rational, all inclusive searches that are depicted. Moreover, increasingly teams may not be strictly hierarchical as decision making is being pushed down to lower levels and team functions are becoming shared across members.

While each of the reviewed models illustrate what we argue to be portions of the team decision making process, there still appears to be a lack of truly integrated models. Within the models and frameworks reviewed, the work of Kontogiaanis (1996) comes closest to that vision. This model notes in its description the importance of members communicating relevant information, however, still lacking is a specification of how information is shared, weighted, and combined.

Team Decision Making Under Stress

While frameworks and corresponding models of team decision making presented above offer a glimpse into team decision making they do not provide a complete picture when talking about teams operating in real contexts. Similar to the argument presented in the opening paragraphs, more often than not this process occurs within complex, dynamic environments where stress (and stressors) are ever present. Morgan and Bowers (1995) state that, “a review of the existing knowledge base regarding team decision making reveals only a few theoretical papers, and even fewer empirical investigations of the factors that influence decision-making performance [under stress]” (p. 263).

So what are we talking about when we mention stress? The past several years has shown a shift in how stress is being defined, from a stimulus response definition to more of a transactional paradigm (Cox and MacKay, 1981). There is a shift in that stress is being defined as the person’s perception of the balance or “transaction” between demands and abilities in coping with them (Cox, 1987). Similarly, Salas, Driskell and Hughes (1996) has offered the following definition, “a process by which certain environmental demands … evoke an appraisal process in which perceived demand exceeds resources and results in undesirable physiological, psychological, behavioral, or social outcomes” (p. 6). Delving deeper into examining stress, Morgan and Bowers (1995) identified eight distinct types of stress: psychological, cognitive, environmental, occupational, organizational, physiological, social, and teamwork. Similarly, Cannon-Bowers and Salas (1998) identified specific stressors that can affect individual or team decision making. Following the lead of Driskell and Salas (1991), Cannon-Bowers and Salas have categorized stressors into one of two primary categories: task and ambient. Task stressors include such things as: time compression, ambiguity, uncertainty, high amounts of data, workload, auditory overload (Cannon-Bowers and...
Stress and Teams

Despite the various types of stress identified in the literature, in examining the literature on stress and teams the majority of the work has been conducted on four types of teamwork stressors (ambiguity, time pressure, workload, team size, and team training load). Teamwork stress is considered to consist of “those stimuli or conditions that 1) directly affect members’ ability to interact interdependently or 2) alter the team’s interactive capacity for obtaining its desired objectives” (p. 267, Morgan and Bowers, 1995). This information will be summarized below and then utilized, along with the information contained within the models section, to delineate a framework that truly examines team decision making under stress as opposed to individual decision making within teams under stress.

Ambiguity

Given the complexity of the operating environments that many teams find themselves in, ambiguity is a common stressor. Within teams, ambiguity is commonly seen in relation to the team’s environment, goals, structure, composition, and member functions/roles. While in some cases, ambiguity can have a positive influence in team functioning by providing the team the opportunity to examine differences in opinions and uncover innovative solutions, ambiguity can also become a stressor when it is not identified or well managed (Zsambok et al., 1992). Given the often ambiguous nature of warfare, it may not be surprising that the predominant amount of work on the impact of ambiguity on team decision making has been conducted within military contexts. It has been argued that military leaders will always be asked to make decisions under conditions of uncertainty and ambiguity (Dubik, 2003). Failure to correctly interpret information within uncertain and/or ambiguous environments will lead to teams which produce less effective decisions and corresponding performance outcomes. For example, it has been estimated that up to 29 per cent of all fratricide events in the Persian Gulf War were due to target misidentification (OTA, 1993). This, in turn, can often be attributed to decrements in team situation awareness which is a key component of team decision making. Further supporting the impact that ambiguity can have is that research has shown that decisions are most difficult and error prone on the edges or boundaries of military units, coalition forces, and environmental/service (Penny, 2002).

Within team environments ambiguity is about more than merely correct interpretation, but it’s about ensuring that the information is shared. Teams must take a proactive approach to ensure that not only are members correctly interpreting information at an individual level, but that it is communicated (implicitly or explicitly) to team members. This includes not only having a shared understanding of goals, objectives, and situation awareness, but also ensuring that each team member has a clear understanding of their roles. Having a clear understanding of this information and sharing relevant pieces facilitates problem formation and option generation. Moreover, shared understanding of member roles and knowledge of where member expertise lies facilitates the weighting of individual member inputs to arrive at a final decision.

In order to manage the ambiguity team members must be able to determine: a) when the information is ambiguous, contradictory, or altogether missing and b) whether the team has developed a shared understanding of information availability and interpretation. Successful teams are able to interpret environmental cues correctly and take action based on these interpretations (Cooke et al., 2000). Ambiguity often impacts a team’s ability to accomplish the fundamental steps which form the basis of the initial stages of the team decision making process (as seen above). These decisions may range from determining when and how to step in to provide a team member back up support to correct detection of enemy personnel and vehicles. In situations in which
ambiguity cannot be directly combated, Zsambok et al. (1992) suggest that teams may be able to reduce the ambiguity by seeking out additional information to better understand the environment. When this additional information is unavailable, successful teams are those that integrate these ambiguities or unknowns into their plans and decisions. This integration may include developing contingency plans and regularly revisiting the available information throughout their performance as the situation unfolds to provide additional information or clear up the ambiguities. In some cases ambiguity regarding team member roles and responsibilities can be reduced by defining team goals and members' roles prior to performance. Through training approaches such as cross-training (see Blickensderfer, Cannon-Bowers and Salas, 1998), team members may be better equipped to identify when lapses are occurring within the team and better know how to adjust and/or provide back-up behaviors under ambiguous or uncertain conditions.

**Workload**

Team workload has been defined as, “the relationship between the finite cognitive capacities of a team and the demands placed on the team” (Bowers, Braun and Morgan, 1992). The association between workload and stress has been regularly examined in regards to impact on individual and team performance (e.g., Entin and Serfaty, 1999; Waller, Gupta and Giambatista, 2004). Primarily, workload and stress appear to impact performance due to errors that result from the difficulty of gathering critical information and making accurate decisions based on this information in high-stress situations (Kawano et al., 1991; Stanton, 1996; Waller, 1999).

Workload varies along a number of dimensions (Parasuraman and Hancock, 2001). First, workload may relate to the physical task load (i.e., number of tasks to be completed) or cognitive load. Second, workload may be continuous or occur in dynamic increases that may or may not be planned occurrences (e.g., accountants handling tax season versus emergency responders managing terrorist attack victims) (Cordes and Dougherty, 1993). Third, increased workload may be perceived positively (i.e., job enrichment, optimal arousal) or negatively (i.e., overload, job demand) depending on factors such as: perceived capacity (i.e., maximum sustainable performance), capabilities (Drabek and Haas, 1969; Scerbo, 2001), team composition (Kontogiannis, 1996), and the control/decision latitude teams have over how tasks are performed (Bliese and Castro, 2000). Each of these differentiations is important because they impact the amount of stress that will be felt. As such they may best be viewed as potential moderators of the relationship between the perception of stress and team decision making. Research in this area relates back to the argument that the absolute level of demand may not be the critical factor in the perception of stress (Kontogiannis, 1996). Further, because workload and stress is best managed through adaptation, these differentiations will impact how the individual or team must adapt in order to maintain optimal performance.

Several studies have suggested the impact that workload can have on team decision making. Some argue that simply participating in a team (e.g., coordination demands) can impose its own resource demands (i.e., workload) above and beyond those necessary to complete the task (e.g., Kidd, 1961; Naylor and Briggs, 1965; Johnston, 1966). Other results, however, have shown that the benefits of teamwork may compensate or even exceed the cost of coordinating with team members (e.g., Johnston and Briggs, 1968; Morissette, Hornseth and Shellar, 1975; Beith, 1987). In this vein, team participation has been argued to decrease the subjective workload of team members as resource demands can be distributed within the team. For example, on a complex cognitive task, individuals assigned to the team condition estimated their personal workload to be approximately 20 per cent lower than subjects assigned to individual condition (Beith, 1987).

Research has also been conducted on the impact that workload has on team processes, many of which can be viewed as integral components of the team decision making process. For example, Beith (1987) found that perceptions of workload actually decreased as communication increased
A slightly different perspective is illustrated by the work of Kleinman and Serfaty (1989) who found that workload altered communication patterns. Specifically, results indicated that as workload increased from low to medium, the frequency of task related communication increased (explicit coordination). As workload increased from medium to high, rate of communication decreased dramatically, so that most resource transfers were unsolicited. Similar to Kleinman and Serfaty (1989), numerous other studies show stressors such as workload not degrading performance, instead resulting in a strategy change in team processing (e.g. Serfaty, Entin and Deckert, 1993; Klein, 1996).

While the impact of workload on communication patterns is of importance to team decision making in that it impacts the gathering and communication of information for consideration in selection of a final outcome when multiple options are present, increases in workload have also been directly associated with changes in decision making. For instance, Drabek and Haas (1969) found that team members that performed semi-autonomously during periods of low workload used more consultative decision-making as workload increased. The actual pattern of consultation also changed under periods of higher workload such that requests for information by lower ranking team members began to be directed primarily to higher ranking team members. Furthermore, when workload increased team members began seeking methods to communicate more, including seeking methods to overcome the limitations of the structured communication systems that were used during lower rates of workload. More recent research has provided further support to Drabek and Haas’ (1969) findings such that stress often leads to a centralization of power/influence by leaders (De Grada, Kruglanski, Pierro, 1999; Pierro et al., 2003) and tendencies to conform with the decisions of the leader and/or the majority (Kruglanski and Webster, 1991; De Grada et al., 1999).

**Time Pressure**

Time pressure is the reduction of time available to complete a task and should be differentiated from time urgency, which is an awareness of time and a preoccupation with task prioritization or scheduling (Conte, Landy and Mathieu, 1995; Waller, Gupta and Giambatista, 2004). While near all would agree that time pressure does have an impact on team decision making, the manner in which the impact is felt is currently an area of controversy. While some have provided evidence that time pressure has a direct impact on team decision making and performance (e.g., Hollenbeck et al., 1997; Entin and Serfaty, 1999), others have argued for a more indirect effect on performance through team process. For example, some researchers have suggested that performance decrements do not occur under time pressure because team members become more focused on their task under periods of stress (Karau and Kelly, 1992; De Grada et al., 1999). This, however, is tempered by research that shows a curvilinear relationship such that too much stress will eventually lead to performance degradation (Urban et al., 1996; Entin and Serfaty, 1999, Adelman et al., 2003). The different arguments are highlighted below through additional research findings.

Time pressure is frequently found to be associated with changes in team processes (e.g., Urban et al., 1996; Hollenbeck et al., 1997; Volpe, Cannon-Bowers, Salas and Spector, 1996), many of which are involved in team decision making. Adelman and colleagues (2003), for instance found that while performance did not change due to time pressure, the cognitive processing of team members increased. Time pressure was also found to impact the decision-making processes used by both individuals and teams. Under time pressure, Adelman and colleagues (2003) found that teams make trade-offs between quality and quantity of decisions (i.e., some emphasized accuracy at the expense of making more decisions). Despite these tradeoffs, performance between teams did not differ. It was argued performance did not change because the team was able to make adjustments in other aspects of their performance strategies. This ability to adjust team processes and strategies to
counterbalance the impact of stress and time pressure has been found as a critical factor in avoiding performance decrements (e.g., Serfaty, Entin and Deckert, 1993; Entin and Serfaty, 1999; Mark, Zaccaro and Mathieu, 2000).

Serfaty, Entin and Deckert (1993) reported a nonlinear relationship between time pressure and aspects of team decision making. Results indicated that when experiencing low to medium time pressure teams speeded up cognitive processing and decrements in performance were seen. Conversely, under high time pressure a shift in decision making strategies were seen and output levels rose to the same level as low time pressure conditions. Serfaty et al. argued that teams were able to adapt their decision making strategies by shifting from explicit to implicit coordination strategies. This shift was facilitated by the presence of shared mental models and leader directed coordination. Providing further evidence for the impact of time pressure on the cognitive processing involved in team decision making are findings that indicate problem simplification and use of heuristic information processing (see Kaplan, Wanshula and Zanna, 1993; or Karau and Kelly, 1992 for a review). Although heuristics or cognitive shortcuts do reduce the amount of cognitive processing required to make a decision, these short cuts may or may not be appropriate to the situation at hand. As a result, the accuracy of the decisions made based upon heuristics may impact the performance of the team.

Dependence on heuristics not only occurs when there is time pressure, but also when there is little information available to make initial judgments (e.g., ambiguity). As a result, using the wrong heuristic may impact judgments later in the team’s performance because the team is likely to seek out confirmatory information (i.e., confirmation bias) or make insufficient adjustments over time based on initial judgments (i.e., anchoring and adjustment biases) (Wason, 1960; Kahneman and Tversky, 1973; Tolcott, Marvin and Lehner, 1989). Finally, speaking more towards the motivation of teams experiencing time pressure to persist in team decision making efforts are findings of Isenberg (1981) which suggested that as time pressure increases the task is experienced as less pleasant.

Structural Factors

Up to this point, the teamwork stressors that have been discussed dealt with task or environmental characteristics which may serve as stressors, next we turn briefly to a different type of stressor — those which are more related to the structural aspects of a team. While these types of stressors have traditionally received less attention than the more typical stressors (i.e., workload, time pressure, ambiguity), they are beginning to receive more attention as the dynamism of military environments increase and teams become more ad hoc in nature. Thus, their inclusion at this point.

Team Training Load The training of team members also influences the amount of perceived stress in teams. Specifically team training load is affected when trained team members are replaced by untrained team members. Research has found that, as might be expected, the impact of the replacement members on team performance depend on the competence of the replacement (Naylor and Briggs, 1965). Furthermore, findings suggest that less skilled members have a greater negative impact than competent members, who appear to have less, albeit positive, impact. Ultimately, the higher the percentage of unskilled replacements, the greater the performance decrements found (Morgan et al., 1984). However, this is not just because individual members can not effectively do their job. Rather, the incompetent replacement also has a negative effect on the ability of team members to interact effectively in generating team solutions to problems.

Team size, composition, and structure Research has also identified the impact of team size, composition, and structure on stress and performance in teams. For example, excessively large team size causes decrements such as interference in communication and increases in conformity causing a loss in flexible responses and socialization biases (e.g., group think), which negatively
affects team decision making (Morgan and Bowers, 1995; Cohen et al., 2000). However, Cohen et al. (2000) also point out benefits of large teams in that more members can increase overall efficiency, based on the generation of more ideas and possible solutions due to more and different perspectives. Regarding composition, the similarity of team members can decrease stress and lead to more cooperation, but there are trade offs as well. For example, diverse teams may increase stress and decrease cooperation, but including diverse members has been found to lead to increased team ability to engage in option or solution generation and questioning, which can lead to effective team decision making (Hoffman and Maier, 1961; Morgan and Bowers, 1995). Lastly, team structure can influence stress and team decision making in that it impacts the coping strategies team may select to deal with conflict and problems, thus affecting the amount of stress at the team level and their team decision making outcomes (Urban et al., 1996).

Extreme Conditions

In the paragraphs prior to this, five stressors and their potential impact on team decision-making and performance have been discussed. However, there has been an implied assumption that these stressors affect a team separately. Often this is not true. In fact, many teams perform in extreme environments or under extreme conditions in which more than one, if not all, the described stressors must be managed in the course of performing (e.g., emergency medical response, military command and control, expedition, and nuclear power production). These environments may be characterized by being dynamic, ambiguous, psychologically demanding, and time pressured. Further, these environments are likely to have high workload, information overload, and severe consequences for error (e.g., Criton and Flin, 2005; Rouse, Cannon-Bowers and Salas, 1992). As in most teams, but most especially in teams under high stress and extreme conditions, team skills such as situational awareness, coordination, communication, leadership, planning, performance monitoring, and backup behavior are needed to perform effectively (Flin, 1996; Essens et al., 2000; McCann and Pigeau, 2000). Effective decision-making becomes critical in these types of teams and extreme conditions because early-staged decisions will influence the subsequent evolution of the conditions the team is performing in. Poor decision made early in team performances may escalate the situation leading to greater pressures, demands, and potential for severe consequences. For this reason, when team first engage in a novel team task under extreme conditions, the decision making tends to be conservative and focused on rules or formalized procedures (Crichton, Lauche and Flin, 2005). Teams also initially depend heavily on recognition-primed or intuitive patterns of behaviors or responses (Crichton and Flin, 2002). This approach is often taken due to the limited (and sometimes conflicting) information available to the team, the higher time pressure that is typically involved in crisis-like events, and the uncertainty that exists as an event is unfolding. As more information is gained from the environment and more time is available, decision-making can become more strategic and teams will often become more analytical, consultative, and creative in identifying new solutions.

Driskell and Johnston (1998) describe the effects of stress on teamwork as causing a narrowing or loss of team perspective. In contrast, Cohen et al.’s list of general effects of stress on teamwork include: goal displacement or losing the overall team objective, groupthink in which the team is slow to change or innovate, and making every team distributed regardless of actual distance because of disrupted communication. Driskell, Salas and Johnston (1999) found that auditory distraction, task load and time pressure caused a loss of team perspective, which was then responsible for decreased performance. However, mediation analysis indicated that the loss of team perspective and not the stress itself caused the loss. Epstein (1983) found that the perception of stress decreased team cooperation and performance. Hollenbeck et al. (1997) found that uncertainty and time pressure
affected the ability to make a decision, the time to make a decision, and decision accuracy. Minionis, Zaccaro and Perez (1995) found that task load decreased coordination and performance.

Driskell and Salas (1991) found that under stressful conditions low status members were more willing to defer to others and more hesitant to take action in emergencies. Hermann (1963) noted that authority and decision-making activities shift to higher levels of a hierarchical structure in response to crisis. It has been suggested that this may be an adaptive response by placing responsibility in the hands of those most central to the organization’s values and goals (Staw, Sandelands and Dutton, 1981). The drawback to this response is that subordinates are more hesitant to question authority under emergency conditions, sometimes deferring to the extent of not offering valuable task information (Foushee and Helmreich, 1988). However, Driskell and Salas (1991) found that high status members were more receptive to task inputs of their partner. This is supported by research by Lanzetta (1955) who found an increase in equalitarian group contrast with the proposition that stress reduces teamwork behaviors due to a narrowing of focus, individuals may be more receptive to task inputs from other group members out of a greater desire to share or diffuse responsibility under the critical performance conditions imposed under stress. Given this, teams under stress may be more likely to behave in team-related behaviors such as mutual performance monitoring and back-up behaviors that have been shown to increase team performance. Thus, the negative effects of stress may be ameliorated when responsibility is diffused throughout the team rather than funneling to the top of the hierarchy.

Moderators

As has been discussed earlier in this chapter, stress is a function of individuals assessing the gap between the demand that is being placed upon them, the relevance of the demand to the individual’s welfare, the positive (e.g., growth opportunity) or negative (e.g., personal injury) interpretation of the event, and the resources available to cope with the demand (Lazarus and Folkman, 1984; Jones and Fletcher, 1998). That is, it is an appraisal of the situation and the personal resources available that trigger a stress reaction. Given this, the perception of the gap and the resultant stress may be moderated by individual differences that are held within the individual and the availability of support and resources (Caughey, 1996; Jones and Fletcher, 1998). Appley and Trumbull (1967) referred to this as a vulnerability profile composed of personality, demographic factors, past experiences, and motivation. A brief discussion of these moderating variables will be provided.

Personality

A number of studies have examined the moderating effects of personality (e.g., self/collective-efficacy; Jex and Bliese, 1999; Schaubroeck, Lam and Xie, 2000; Jex and Thomas, 2003). Self/collective-efficacy has a clear implication on stress perceptions because it is the subjective assessment of whether the individual or team has the skills necessary to perform the task (Gist, 1987; Bandura, 1997). If it is perceived that the skills needed to perform are available, it is likely to buffer the stress response by reducing the perceived lack of resources available to overcome the demand. Self-efficacy is believed to moderate stress perceptions due to differences in coping strategies that are used. Those with high self-efficacy are more likely to use effective problem-solving approaches, whereas low self-efficacy individuals are likely to use emotion-based strategies that involve worrying instead of problem-solving (Lazarus and Folkman, 1984; Kinicki and Latack, 1990). Collective efficacy is also expected to reduce stress levels within a team due to an increased propensity for helping and cooperation within the team during stressful situations (Cohen and Wills, 1985; Gore, 1987).

Motivation

Motivation is another variable that may impact stress reactions. In the training literature there has been a goal orientation dichotomy defined between individuals that are performance oriented versus those that are mastery oriented (e.g., Dweck, 1986; Winters and Latham, 1996; Gist,
Mastery oriented individuals are less concerned with their performance and are adaptive to challenges as opportunities for self-improvement and learning. Performance orientated individuals are more concerned with demonstrating high performance and avoiding task failure. Although typically discussed in relation to training outcomes, it is likely that those with a mastery orientation would be less likely to perceive the gap between resources and the demand as stressful but rather as a challenging learning opportunity. This is supported by research by Ben-Ari, Tsur and Har-Even (2006) that found that when a demand is perceived as a challenge (i.e., a learning opportunity) as opposed to threat, attitudes towards the team and the demand were more positive.

Perceived control Perceived control has been found to be a significant predictor of stress perceptions (Bliese and Castro, 2000). Some define perceived control similarly to the construct of self-efficacy such that is the belief that the individual or team has the requisite knowledge and skills needed to perform and the “ease or difficulty of performing the behavior of interest” (Ajzen, 1991: 183). Control may also relate to the influence one has over the environment or decision latitude and has been associated with perceptions of stress including team loyalty and commitment (e.g., Wingreen and Blanton, 2001). Using this second definition, stress may be moderated due to the employee’s ability to modify his/her environment and define his/her role thereby reducing ambiguity (Bliese and Castro, 2000).

Supervisor support/procedural justice Factors external to the individual or team may also influence the perceptions of stress. Two of these factors include supervisor support and procedural justice. A number of researchers have examined the moderating effects of leader support (e.g., Winnubst and Schabracq, 1996; Leather et al., 1998) and social support (Cassel, 1976; Cohen and Wills, 1985; Weaver et al., 1991; Winnubst and Schabracq, 1996) on stress perceptions. Related to leadership support is procedural justice. Procedural justice relates to an individual’s perception of the quality and fairness of the decisions and processes that he/she is faced with in the workplace. Brotheridge (2003) found that fairness affected stress perceptions, which in turn, affected employee’s effort and intent to turnover. Similarly, Ben-Ari, Tsur and Har-Even (2006) provided report results indicating that to the degree team members perceive there to be procedural justice, stressors are more likely to be seen as a challenge as opposed to a threat. As, stated earlier, perceptions of challenges versus threats can further influence the interpretations of stress.

Technology While a bit different from many of the moderators described above, technology is an important aspect to consider in terms of moderation. Within many complex decision making environments, technology is often implemented as a mechanism to assist team members in decision making and the corresponding sub-processes involved. Computers have been found to change communication amounts and type in teams (Hollingshead and McGrath, 1995), and technology has been found to improve team awareness and help communication. This may not only prevent information overloaded mental models, but also moderate the effects of stress on team decision making by providing some necessary ingredients for teams to build shared, mental models (Fussell et al., 1998). However, while technology has the potential to mitigate the perception and impact of stress on team decision making, often times the reverse happens. System designers must be careful to take human limitations and principles of good human-centered design in account in designing technology or else the exact technology that was expected to reduce workload and ambiguity, often does just the opposite serving as one more device that is stealing cognitive resources.

Taken together, a number of variables that impact the perceptions of stress felt by individuals and teams have been discussed herein. Although an exhaustive list of potential moderators has not been provided, the intent was to inform readers that stress can be modified by factors other than
stress reduction training as is the commonly suggested solution. Instead, attention is drawn to the fact that factors that are internal and external to the individual and team can also be influential.

**Building a Framework of Team Decision Making Under Stress**

Based on the scientific literature on team decision making, teams, and teamwork stress, we can begin to extract what we know to build a framework which not only integrates the various perspectives reviewed, but expands existing frameworks to illustrate the factors that impact how member input is integrated to produce a final team decision under stress. This framework (see Figure 10.1), can, in turn, be utilized to guide the development of training to facilitate team decision making under stress. Below we offer ten propositions that are related to the framework presented in Figure 10.1. The first eight reflect key components and their importance within the framework of team decision making under stress, while the last two reflect potential high level training strategies that can be used to mitigate the impact of stress on team decision making.

**Proposition 1 Team decision making is a multi-level phenomena**

Following the lead of the work of Ilgen and colleagues (Ilgen et al., 1995; Hollenbeck et al., 1998; Humphrey et al., 2002), it is argued that team decision making is a multi-level phenomena that is primarily composed of variables that exist at the individual and team levels. However, while not directly focused on the current paper, there exist organizational level variables that also impact this process and often serve as moderators as to the degree to which teamwork stressors are perceived to exist. Herein, team decision making is defined as: an emergent phenomenon which compiles over time from the unfolding of a recursive cycle whereby one or more team members utilize their cognitive resources to formulate the problem, extract critical portions to produce a situation/problem model. These aspects then guide the generation/selection of options which are then shared and used to integratively weight key information to determine the course of action (i.e., decision).

**Proposition 2 Team decision making is a bottom-up process**

Team decision making can be conceptualized as either a global property of the team or as a configural construct (Kozlowski et al., 1999). The definition of team decision making advanced above reflects an emergence process based upon configural compilation. When conceptualized as a configural unit property, team decision making can be seen as a continuously evolving phenomenon that compiles bottom-up across levels and time. Compilation is based on the assumptions of discontinuity or the configuration of different lower level properties to result in a higher-level unit property (Kozlowski and Klein, 2000). Constructs that emerge through compilation do not represent shared properties across levels, but rather are qualitatively different (i.e., constructs are characterized by patterns). It is the pattern of unique lower level team member and dyadic contributions which compile to characterize team decision making. The specific manner in which team decision making materializes and how that materialization is operationalized is contingent upon organizational context, workflow interdependencies, and other situational factors (e.g., Weaver et al., 1991; Ilgen et al., 1995; Salas and Klein, 2004).

**Proposition 3 Team decision making represents a cyclical process (see Figure 10.1)**

Team decision making is a complex process that consists of a series of cyclical stages as seen in the work of Kontogiannis (1996), as well as that of Hirokawa and Johnston (1989); Hirokawa and
Johnston (1989) argue that rarely are decisions made in a step-by-step manner, but they are cyclical and recursive. This can also be seen implicitly within frameworks originating within naturalistic decision making, as the process of mental simulation is conducted, findings may cause an individual to reexamine a particular step within the cycle. Although team decision making is often a complex process by which decision elements and cues are continuously presented, reexamined, and refined as the team moves toward a final decision, the pace at which this process happens will be impacted by the perceived stress felt by team members. Moreover, dependent on the levels of member expertise as well as perceived time pressure research has indicated that heuristics are often used within the process which may, in turn, short-circuit steps within the cyclical process (see Klein, 1998).

**Proposition 4**  
Under stress team members do not have the luxury of following a purely rational process

This principle is extracted from the work of Klein and colleagues who operate within the realm of naturalistic decision making. While the work of Ilgen et al. (1995) and others which follow the classical decision making tradition is informative to understanding team decision making when there is no perceived stress, in many operational environments the lack of perceived stress (i.e., time pressure) is often not a luxury that exists. Therefore, team members are not able to conduct an exhaustive search and systematically weigh each option. Instead, team members often use heuristics to make sense of the problem relying on mental simulation and storytelling to see how the problem characteristics which they are observing compare with situation models of similar circumstances which they have faced. Depending on the time pressure present, individual members may then communicate their recommendations to one another which are then weighted based on existing cognitive structures such as transactive memory (see Ellis, 2006) and team member mental models (see Converse and Kahler, 1992). If time pressure is high, the leader may look to the person with the most expertise on the team (i.e., guided by transactive memory) for their recommendation rather than asking for input from all members.

**Proposition 5**  
Depending on time constraints, risk, and experience sub processes within the stage problem formulation may differ

Building on the work of Kontogiannis (1996), the first step within problem formation is problem detection wherein a discrepancy is noticed between expected action and reality (e.g., a potential roadblock is noted) and an early appraisal is made as to the surrounding problem context and relevant cues. Next, the individual must attempt to make sense or assign meaning to the cues within the current context so that options and a course of action can be generated. There are several mechanisms that the individual may use to assist in the sense making process. Building on the work within naturalistic decision making, it argued that the person will compare the current problem/situation model to those which are stored in long term memory based on prior experiences. The goal here is to begin to examine if a similar situation has been faced which, in turn, might produce a satisfying solution. If the current situation is deemed not similar then one of two options may occur depending on the amount of stress in the environment. If the perceived stress is low then perhaps a refined information search will be conducted to attempt to gather more information or see how the situation progresses. However, if there is a fair amount of perceived stress then mental simulations might be conducted or if it represents a novel situation then stories might be built to try and help make sense. The later mechanism, is akin to what was explained earlier within the R/M model of decision making that exists within naturalistic decision making (see Cohen, Freeman and Wolf, 1996).
Proposition 6  Transactive memory, dyadic relationships, and team mental models are mechanisms which facilitate the correct weighting of member input within team decision making.

Despite the fact that it has been argued that very few decisions are made solely by individuals (e.g., without input from others) in today’s operating environments, the work of Ilgen and colleagues is one of the few team decision making models which explicitly recognizes this through their concepts (e.g., decision infirmity, individual validity, staff validity, and dyadic sensitivity). However, there is no description of the processes which lead to these judgments. Figure 10.1 expands the Ilgen work by beginning to illustrate some of the cognitive structures which may guide these decisions. Below we offer a brief explanation of each of the three proposed mechanisms (i.e., transactive memory, team mental models, dyadic relationships).

Transactive memory can be defined as “a shared system for encoding, storing, and retrieving information” (Ellis, 2006: 40). Transactive memory systems (TMS) are a combination of what everyone on the teams knows and an awareness of what team member knows what (Austin, 2003). Recently, within the team literature, TMS has been defined as a set of members’ individual knowledge directories and a shared understanding by the team of who possess what knowledge (Lewis, 2004). TMS enables team members to make expertise-member associations and know, in a given situation, who to turn to for expertise (Wegner, 1995; Moreland, 1999). As such, it provides guidance to fellow members as to potential weighting mechanisms for each member’s input. TMS is a team level phenomena which depends on individual team knowledge as well as knowledge that is shared by the whole team.

In speaking as to why dyadic relationships are important within teams and how they facilitate the weighting decision, we briefly introduce leader member exchange theory (LMX). The central premise of this theory is that effective leadership occurs when the leader and followers are able to develop...
mature working relationships (Graen and Uhl-Bien, 1995). Of most relevance to the current argument, is that the theory recognizes that leaders may have differential relationships with subordinates. Most recently, the argument has been made that LMX should be viewed as a system of interdependent dyads where the focus is on examining how differentiated dyadic relationships combine and interact to form larger systems and affect outcomes (see Tesluk and Gerstner, 2002). Within teams we would argue that the formation of these types of relationships is crucial in order to form the shared cognitive structures (i.e., mental models) that allow meaning to be assigned to member actions. Specifically, these relationships allow the formation and refinement of team member mental models which specify not only roles, functions, and the interdependence among team members, but also the preferences, characteristics, and likely actions of individual members. This, in turn, is useful in assessing the reliability and validity of member input into the decision making process.

**Proposition 7** Transactive memory can serve as a heuristic in the communicating and sharing of information when operating under stress

The communication and sharing of knowledge is often essential within team decision making as it serves to create the shared cognitive mechanisms that have shown to be important in team decision making (e.g., mental models, team situation awareness). However, research has shown that team members tend to share common information before they share unique information (Larson et al., 1996). This may be further amplified as teams operate under stress and cognitive resources are often limited; however it has been suggested that the team leader can play a key role in mitigating this by serving in an information management role.

A lack of the cognitive structures mentioned above have been attributed to many errors in team decision making, especially those that relate to issues such as fratricide and failure to recognize critical cues. These structures are also important as they serve to provide a type of common ground from which team members can operate within thereby often reducing the decision time as misunderstandings and miscommunication take up less time. These cognitive structures have been argued to facilitate implicit coordination and communication among team members (Kleinman and Serfaty, 1989) which, in turn, can often reduce much of the explicit communication that may be redundant (e.g., who do I need to pass this information to).

Another cognitive structure which can be especially useful in periods of stress is the use of transactive memory systems. These systems have been argued to be cognitive structures which contain information pertaining to who within the team holds what type of expertise. This, in turn, can be useful in determining who are the critical team members to extract information from given a time compressed situation as well as identifying the members to whom critical information is passed. Within the concept of transactive memory is the implicit argument that not all team members need to hold/share all information, but the information that is needed is driven by their area of expertise. Therefore, knowing who has the information and how that relates to each individual member is more important than members attempting to share all information, which is often a waste of precious time and team resources.

**Proposition 8** The degree to which consensus is garnered for the decision making outcome will vary

This principle ties back to the multi-level nature of team decision making and is fairly simple. The predominant number of models and frameworks that were identified illustrated a very hierarchical setting in which the team leader was responsible for the final decision that was to be made within the team, yet this is not always the case; sometimes it is truly a “team” decision. While we would argue that the cases where the final outcome is truly a team decision where input is taken from
all and then a consensus is reached among team members is fairly rare when teams are operating under stress it is a possibility that should be mentioned. For example, there may be a situation in which the consequence of error is so high that a forced consensus may be sought. However, in teams that are making decisions under the type of teamwork stressors which have been discussed in the current chapter more often than not the leader or someone assuming that leadership function will be charged with making the final decision. Even this may play out in one of two ways. It may be, as we would hope to be the case, that the team leader is taking input into the final decision from some portion of the team. Conversely, the leader could rely solely on his expertise and make the decision without further input although this is really more individual decision making within teams than team decision making.

The variety of inputs and distinct views is one of the strengths that teams offer in their decision making capability over individuals. However, in stressful environments this often must be weighted against the urgency of the situation; so once again it may be the tempo that changes and the leader satisfices by going to the person with the most expertise for their input instead of the entire team. Conversely, there may be situations where each member truly is seeing a different environmental perspective as is often the case with distributed teams. In these situations it might be essential to gain input from a predominant number of members, but do so in a time compressed manner.

Proposition 9  Scenario-based training offers a pedagogically proven instructional strategy that can be used as the guiding frame in designing training for team decision making within stressful environments

Extracting from what is known about human learning and the science of training (see Salas and Cannon-Bowers, 2001) we know that practice is essential to the translation of knowledge into actual skill. Not only is practice essential for the learning of skills, but practice should not be random or unguided. Scenario-based training (SBT) is a method which provides targeted practice opportunities and incorporates much of what has been learned about the science of training. Scenario-based training (SBT) or event-based training (EBAT), uses a priori defined events that are embedded within scenarios to structure and guide practice during training (Prince et al., 1993; Oser, Cannon-Bowers and Dwyer, 1999). The first step within this method is to conduct a task analysis and/or gap analysis to determine the training objectives and corresponding competencies. Training objectives serve to drive the development of the actual training scenarios and associated scripts. In crafting scenarios a priori “trigger” events are embedded within the scenario at several points. Ideally multiple events should be specified for each objective and should vary in difficulty. These events serve as known opportunities for trainees to exhibit those competencies targeted in training.

Once events and the associated scenarios are created, measurement instruments are developed that will be used to assess task performance during each a priori defined event. Measurement should allow the assessment of whether targeted competencies are learned (i.e., outcome) along with why performance occurred as it did (i.e., process) by being tied to learning objectives and more specifically scenario events. As performance measures are tied to previously defined events, the observer does not have to observe every instance of behavior (reducing workload) and the form of the measurement instrument has also been argued to allow near real time feedback to trainees. Event-based training represents the best of both worlds … practice and theory. When constructed well the scenarios appear transparent to the trainee (e.g., appear free-flowing), yet offer the trainer a level of control needed to ensure that learning takes place.
Proposition 10  Scenario-based training can provide a frame within which stress exposure training can be applied

The instructional strategy, SBT, described in Principle 1 has many benefits not the least of which is its flexibility. While often associated with simulation-based training methods, SBT can be applied to a variety of training formats and methods. With regard to training teams to make more effective decisions under stress, an especially relevant combination is the integration of SBT with stress exposure training/stress inoculation training (SET/SIT). SET attempts to train coping abilities under stressful conditions by purposely mimicking the conditions of the task in order to train teams to maintain high performance levels despite significant difficulties (Driskell and Johnston, 1998). SET focuses on providing trainees with knowledge and familiarity with the stressful environment, the skills needed to maintain performance standards and building self-efficacy in the face of stressful situations. SET is not a specific, prescriptive, training technique, but a model for training coping strategies that can be applied to contexts that fit the team’s needs. Thought the content changes based on the team and task, SET consists of three general stages. First, in the information provision stage, lessons prepare the team for stress and stress effects. During this stage, team members are trained to identify stress in themselves and in their teammates by learning basic strategies and findings from stress research. The second stage of training focuses on the behavioral and cognitive skills needed to mitigate the effects of stress (see Figure 10.1). For example, highly interdependent teams would learn the basics for implicit cooperation, and teams requiring a high volume of information exchange would learn the fundamentals of closed-loop communication. These skills are then applied and practiced in the last stage of training, during which trainees use what they have learned in conditions that gradually take on qualities of the stressful task environment.

In a meta-analysis of studies examining the efficacy of SET, Saunders, Driskell et al. (1996) determined that there are a wide range of performance effects. After receiving SET, trainees demonstrated improved task performance during stressful situations as well as reductions in anxiety-related behaviors and skill-specific anxiety. Trainees also improved in self-efficacy ratings and similar self-confidence variables, and reported less anxiety regarding their tasks and their task-environment. Overall, trainees will report, following SET, a greater belief in their own ability to respond to difficult situations, and will often hold high expectations for success. While SET provides a flexible means of preparing teams for stressful work contexts when combined with skill-based training, SET is especially effective in situations characterized by high technology or high workload conditions (Ross et al., 2004).

Concluding Remarks

Complexity of the environments within which teams operate is only expected to increase given technological advancements, global competition, and the types of asymmetric threats and effects based operations that military teams are expected to continue to face long into the future. While much is known about individual decision making, comparably less is known about the processes that comprise team decision making, especially in environments outside laboratory settings where there are many contextual factors including stress. Within recent years, researchers and practitioners alike have been increasingly working to understand effective team decision making within complex environments. Our review indicated that while some of the work on team decision making in complex environments has been conducted in laboratory environments, other is based on examination of teams “in the field”; both offer valuable insights into the nature of team decision making. However, there has yet to be a model which integrates these two perspectives while at the same time beginning to pull out the processes that underlie the interactions that occur among team members in these decision making contexts. Figure 10.1 is our initial attempt to illustrate a multi-level framework that depicts team decision making as a bottom-up cyclical process as well
as specify the stressors that have been most commonly associated with this area. It is our hope that the review offered herein and the corresponding framework will serve to drive future thought and corresponding research. While progress has definitely been made in understanding team decision making under stress, deeper thought is needed.

In examining the literature we have identified several areas where we feel future research would serve to increase our understanding of this complex phenomena. First, what are the processes or knowledge bases that serve to facilitate or inhibit each stage of the decision making process. We have begun to highlight a few within the framework presented, but this is only a start. Second, there has been quite an effort devoted to three or four teamwork stressors; however there are many more whose impacts remain uninvestigated or are only beginning to be examined. We need to expand our scope. Third, while we included a brief section on individual and contextual differences which might impact the perception of stress, this is an important area which needs to be focused upon as it might also highlight some potential mitigation strategies. And finally, as we recognize that the framework presented herein is only a first step and while it is built on prior work, the propositions that have been extracted need to be examined more thoroughly across different contexts.

References


Chapter 11

Mitigating the Effects of Stress through Cognitive Readiness

Linda T. Fatkin and Debbie Patton

The experience of stress has permeated our civilian and military workforce and is fueled by unrealistic expectations and incessant demands for optimal performance. The ability to maintain unit readiness and mission effectiveness in the midst of increasing technological demands ultimately depends on the skillful application of internal and external resources for coping with a variety of stressors.

The performance of quality Soldiers can be affected by various personal, situational, and organizational factors particularly within dynamic and stressful environments. While there are certainly numerous societal contributors to military stress, such factors are not, for a multitude of reasons, directly amenable to change. Therefore, individuals must adapt to these diverse and often rapidly shifting environments by applying effective coping strategies to mitigate the effects of stress. Stress has been defined by Lazarus and Folkman (1984) as a state produced when stressors (environmental or social) tax or exceed an individual’s adaptive resources. Congruent with their assessment, we have employed a conceptual definition of stress as “a multifaceted, dynamic, and interactive process with psychological and physiological dimensions,” emphasizing not only stressor variability (i.e., type, intensity), but also human variation in personality, perceptions, experience, and expectations as main factors for defining stress within a given individual. Our focus in defining the stress experience is the interaction between individual appraisals and situational factors that contribute to the adaptation necessary for effective Soldier performance.

Using this approach to diagnose the nature of the stress-performance relationship is also compatible with the Hancock and Warm (1989) maximal adaptability model and can provide the basis for effective guidance on enhancing one’s cognitive readiness. Cognitive readiness is the optimization and enhancement of human cognitive performance (Cosenzo, Fatkin and Patton, 2007). This state of cognitive readiness is the critical component for effective mission performance, especially for one performing multiple functions and for adaptation to dynamic threats. It is assumed that Soldiers are typically in a ready state due to their training to perform tasks specific to their military occupational specialties (MOS).

A standardized assessment paradigm which incorporates that interaction was developed for the comprehensive measurement of stress perceptions and readiness of Soldiers functioning under challenging and often extreme circumstances. The results of those assessments, along with the development of comparative stress-response profiles, will be discussed in this chapter. We will describe how to use the comparative profiles to determine the need-based interventions and countermeasures that enhance cognitive readiness.
### Table 11.1 Components of the Readiness Assessment and Monitoring System

<table>
<thead>
<tr>
<th>Measure</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Screening Measures</strong></td>
<td></td>
</tr>
<tr>
<td>General Information Question</td>
<td>Provides general demographics about a person to include age, education, rank, experience, skill level, general health, physical fitness, military occupational speciality (MOS), motivation, etc.</td>
</tr>
<tr>
<td>Life Events Form (Fatkin &amp; Hudgens 1990, 1994)</td>
<td>Identifies extraneous situations and factors that may influence or bias responses during the study.</td>
</tr>
<tr>
<td><strong>Trait Characteristics</strong></td>
<td></td>
</tr>
<tr>
<td>Revised Ways of Coping Checklist (Vitaliano, Maiuro, Russo, &amp; Becker 1987)</td>
<td>Identifies five individual coping efforts: problem-focused thoughts or behaviors, seeking social support, wishful thinking, blaming self, and avoidance.</td>
</tr>
<tr>
<td>Uncertainty Measures (Bar-Tel 1994; Greco &amp; Roger 2001)</td>
<td>Measure of an individual’s decision making strategies and coping styles used in situations with high degrees of uncertainty.</td>
</tr>
<tr>
<td><strong>State Characteristics</strong></td>
<td></td>
</tr>
<tr>
<td>Situational Self Efficacy Scale (Bandura 1977)</td>
<td>Measure of one’s perceived confidence to master new situations or adapt to changing circumstances.</td>
</tr>
<tr>
<td>Specific Rating of Events (Fatkin &amp; Hudgens 1994)</td>
<td>Rating of overall stress relating to a particular event.</td>
</tr>
<tr>
<td>Subjective Stress Scale (Kerle &amp; Bialek, 1958)</td>
<td>Detects significant affective changes in stressful conditions.</td>
</tr>
</tbody>
</table>
Readiness Assessment and Monitoring System (RAMS)

The Readiness Assessment and Monitoring System (RAMS), developed by the US Army Research Laboratory (ARL), allows researchers to quantify the cognitive-perceptual influences of performance with analytical rigor. The RAMS includes psychological measures for the assessment of trait characteristics and stress perceptions, and a field-practical, physiological measure of stress. These assessments identify various components of stress (e.g., anxiety, depression, positive affect) and are accomplished by using self-report measures that are correlated to plasma hormones (Fatkin et al., 1991). The RAMS has proven its sensitivity to the stress that individuals experience across a wide range of military and civilian scenarios. It includes several standardized measures that demonstrate high construct validity and high test–retest reliability within the stress research literature. Table 11.1 describes the components of the RAMS.

Based on the specific research question, selected components of the RAMS are administered at specific times tailored to the nature of the study and experimental design. The wording of instructions to participants is crucial to ensure they report their perceptions regarding the impending challenges. For example, when assessing stress perceptions of a specific event, participants are asked to answer the questions according to how they felt “…during the event you just completed” or, “…since you last completed these questionnaires.” This reflective approach is critical for the measurement of stress perceptions during a critical event and provides a more accurate assessment of the experience than asking participants to report how they feel “right now”. Field experiments can be designed to generate levels of stress similar to combat and non-combat experiences. The methodology described below provides a consistent approach through which metrics from the RAMS are applied.

Standardized Stress and Readiness Assessment (SARA) Methodology

Recruitment of Military Participants: Unique Issues

There are two unique experimental issues that need to be addressed when conducting research with military participants: 1) their concern regarding the confidentiality of their data, and 2) their position as a true volunteer for data collection.

Regarding the confidentiality issue, many military study participants are concerned that their responses will be provided to someone in their chain-of-command. In order to obtain candid responses on the RAMS measures, this concern must be addressed up front by describing the procedures for preserving the confidentiality of their data.

Prior to testing, all individuals are briefed on the purpose and procedures of the study and are read a volunteer agreement. Potential volunteers are given the required brief regarding confidentiality as directed by the Department of the Army (DA Form 5,303-R) and are informed that they have the option of withdrawing from the study at any time. However, in anticipation of persistent concerns regarding personal answers on some of the questionnaires, the investigators describe the deliberate actions taken when handling research data. In order to ensure that individual data will not be reported or revealed to anyone, each form is reviewed upon receipt by one of the investigators. If any identifying information appears on the questionnaires (such as name, social security number, birth date, etc.), the investigators delete the identifying information and replace it with a neutral code number. This code number becomes the participant’s identification number used in data files.
Secondly, when recruiting military research participants, a concern about their actual willingness to volunteer for a study may arise if higher-ranking personnel have “suggested” that they participate. Although incidences of this method of covert coercion have decreased in recent years, investigators need to address the possibility. Potential volunteers should be reminded that they can refuse or later withdraw from the study without penalty. We have been effective in getting genuine volunteers for our research studies by providing individuals an opportunity to communicate their desires to the investigators “off the record.” They are then presented with several options for refusing or withdrawing in a private manner. Potential volunteers seem to appreciate these actions, and have little problem providing honest and candid information to us. This is evidenced by the validation of subjective data with physiological indices collected in many of our studies.

**Timeline for Administering RAMS Components**

Prior to the challenging research scenarios being presented or assessed, general background and demographic information along with reports of significant life events are obtained to identify factors that may significantly influence or bias performance. The screening and trait instruments are generally given prior to the challenging event. The state measures are typically administered on a neutral day (Baseline), prior to (Pre-Stress), and then again during or immediately following (During or Post-Stress) the challenging event(s). When necessary, a post-test recovery measure is collected after the scenario is completed and there has been sufficient time to recover from the event (Recovery).

**Comparative Stress Response Profiles**

An integrated view of stress and performance should consider the task as the primary influence on cognitive stress (Hancock and Warm, 1989). The observations of the task effects are one element of the dynamic model of stress. The psychological state components of the RAMS were used to
develop a comparative metric for our research from which we evaluate the relative impact of a stressor on the experience of stress (i.e. psychological and physiological responses).

Table 11.2 Description of comparative groups

<table>
<thead>
<tr>
<th>Referent Groups</th>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oncology Surgery</td>
<td>ONCOL SURG</td>
<td>Men waiting in a hospital on a day when their wives were facing cancer surgery under general anesthesia</td>
</tr>
<tr>
<td>Medical Exam</td>
<td>MED EXAM</td>
<td>Medical students taking a written examination required for completion of the clerkship portion of their medical training</td>
</tr>
<tr>
<td>Independent Control</td>
<td>INDEP CNT</td>
<td>Men investigated during normal work days when they were experiencing no unusual stress</td>
</tr>
<tr>
<td>Weapon Competition</td>
<td>WPN COMP</td>
<td>Soldiers representing elite units in marksmanship competition</td>
</tr>
<tr>
<td>Army Recruiters</td>
<td>RECRUITERS</td>
<td>Army recruiters stationed throughout five battalions across the United States</td>
</tr>
<tr>
<td>Special Forces Assessment &amp; Selection</td>
<td>SFAS</td>
<td>Soldiers in the Special Forces Assessment and Selection course at the JFK Special Warfare Center and School</td>
</tr>
<tr>
<td>Chemical Decontamination Training Facility</td>
<td>CDTF</td>
<td>Soldiers in MOPP IV participating in chemical decontamination training in a toxic agent environment</td>
</tr>
<tr>
<td>Encapsulation Conditions</td>
<td>ENC</td>
<td>Soldiers participating in a field study wearing MOPP-IV while traversing obstacles and natural terrain</td>
</tr>
</tbody>
</table>

One useful way of assessing the level and intensity of an individual’s stress experience in a particular circumstance is to compare results from a single study (exposure to a stressful set of circumstances) with data from other studies in which identical psychological and physiological measures were administered. Comparisons from these “referent protocols” (see Table 11.2) provide a method for estimating the relative stress experienced in a given situation and for studying the links between stress responses and performance in a variety of settings (Hudgens, Malkin and Fatkin, 1992; Fatkin et al., 1999).

Selected Research Studies

To demonstrate the implementation of the SARA methodology and how the data collected can be used to recommend ways to mitigate stress, we will discuss four studies investigating the effects of stress on performance. These studies are categorized as those in which the stressor was experimentally induced, and those in which we conducted stress and readiness assessments of an existing situational stressor:

A. Experimentally-induced stress
   1. Marksmanship competition
   2. Encapsulation
B. Situational stress
   1. Recruiting
   2. Advanced Individual Training

*Experimentally-Induced Stress: Marksmanship Competition*

A weapon competition study was conducted as a field experiment to evaluate competition as an effective method of producing a known level of stress during Soldier-system performance testing (Fatkin et al., 1991). Psychological and physiological data were obtained to help determine whether the Soldiers’ experiences generated by the competition were stressful and determine how the level of stress related to their performance. If the competition generated in this study proved stressful, this method would be used for testing human-machine systems during stressful (and therefore more realistic) conditions.

Sixty Soldiers from two elite Army units, the 82nd Airborne Division and the 101st Infantry, participated in the marksmanship competition. In addition to the internal motivation individuals bring to competition scenarios (desire to perform their personal best), external factors were contrived to elevate the stressful nature of the competitive experience. Each unit competed for media recognition and for a trophy to bring to their commanding officer. Other methods included the construction of a public viewing area directly behind the shooter as he fired, and a scoreboard to record real-time hits and misses of each Soldier. A videographer was also present to tape each Soldier as they performed in the competition.

The SARA methodology described in Figure 11.1 was implemented. Trait questionnaires and Baseline state measures were obtained 2 days prior to the competitive firing event. Plasma hormone samples were obtained in conjunction with the completion of the Pre and Post state questionnaires.

The stress created by competition was assessed by comparing the psychological and physiological responses of the Soldiers firing competitively with the responses of Soldiers firing during noncompetitive, control conditions, and with the responses obtained from subjects in other stress protocols. For a detailed description of the experimental design, the method of obtaining blood samples, the weapon systems employed, or the target distance and presentation, see Fatkin et al. (1991).

The psychological and physiological data revealed that the Competition Group experienced more stress than the Control Group. The Competition Group participants expressed significantly greater state anxiety than those in the Control Group both before and after firing on record-fire day, and they rated the firing significantly more stressful than did the Control Group on the Debrief questionnaire. Additionally, those Soldiers in the Competition Group reported higher hostility and lower positive affect levels than the controls.

Fatkin et al. (1991) used cluster analyses to identify personality factors that contributed to marksmanship performance. Using the combined trait data from the two units, two distinct clusters of individuals emerged from the marksmanship data: one with a high stability profile (Low MAACL-R Trait – Negative Affect and ZKPQ-III Neuroticism scores), and the other with a low stability profile (High MAACL-R Trait – Negative Affect and ZKPQ-III Neuroticism scores). Individuals with a high stability profile performed significantly better than those with a low stability profile.
Figure 11.2 Mean (+SEM) MAACL-R Anxiety scores for referent groups collected after specific, challenging events

*Note:* See Table 11.2 for a description of the referent groups.

Figure 11.3 Mean (+SEM) MAACL-R Depression scores for referent groups collected after specific, challenging events

*Note:* See Table 11.2 for a description of the referent groups.
Figure 11.4 Mean (+SEM) MAACL-R Hostility scores for referent groups collected after specific, challenging events

Note: See Table 11.2 for a description of the referent groups.

Figure 11.5 Mean (+SEM) MAACL-R Positive Affect scores for referent groups collected after specific, challenging events

Note: See Table 11.2 for a description of the referent groups.
Significant differences between the Competition Group and the Control Group in stress perception measures on record-fire day demonstrate that competition can be used to reliably produce a moderate level of stress in Soldiers. Pre- and post-measures of state anxiety (MAACL-R Anxiety, Subjective Stress Scale (SUBJ), and Specific Rating of Events (SRE), and others) all indicate that the Competition Group was experiencing significantly more stress than the Control Group.

The stress perception data for the Competition and Control Groups were compared with response profiles from other stress studies using our methodology. Figures 11.2 through 11.5 illustrate the comparative response profiles based on data from the MAACL-R Anxiety, Depression, Hostility, and Positive Affect subscales. The anxiety expressed by the Competition Group is similar to levels reported by medical students taking a critical written exam. This pattern parallels the comparisons for the endocrinological data obtained and supports our interpretation that a moderate level of stress was experienced by the Competition Group (Hudgens et al., 1991).

While the Anxiety subscale is a measure of anticipatory stress, the Depression subscale is a measure of one’s sense of failure to perform as well as expected. For the weapon competition group, this was not an issue. As illustrated in Figure 11.3, the Soldiers reported levels that were not significantly different from the independent control group. The Hostility subscale (Figure 11.4), on the other hand, indicates that the weapon competition group experienced frustration levels comparable to the high levels reported by Army recruiters.

**Experimentally-Induced Stress: Encapsulation and Performance**

The US Army has a limited amount of data regarding the performance effects of encapsulation. These data are critical to the understanding of effective mission performance as well as the survivability capabilities of future dismounted Soldiers. Soldier encapsulation is defined as enclosing the Soldier’s body in such a manner that all skin is protected from exposure to the elements of the battlefield. Although research has been conducted on individual items of combat equipment and various components of dismounted Soldier systems, very little performance-based research has been conducted using a systems approach to validate Soldier-equipment compatibility. For example, the integration of the protective mask, laser, ballistic, nuclear, biological and chemical (NBC), and climatic protection is a requirement of the Future Force Warrior when Soldiers are operating in a suspected contaminated environment. By implementing the SARA methodology and using components of the RAMS, we provided a quick and effective way to measure performance changes related to equipment configurations and operational tasks.

One objective of this research conducted by Mullins, Patton and Garrett (2004) was to develop methods for further research on encapsulation effects of Future Force Soldier systems during military operations affording better opportunities to find predictors of performance effectiveness. Our standardized stress assessment paradigm was applied for this research. Baseline measures were administered on a routine day, pre-measures were administered immediately before the challenging events, at critical points during the events, and immediately after (Post).

While performing mission related tasks that included navigating through a cross country course, obstacle course, and performing weapon firing, participants wore each of the following equipment configurations: 1) Baseline configuration (no encapsulation, “ENC Baseline”) using the Personal Armor System for Ground Troops (PASGT) helmet and vest; 2) Current encapsulation configuration (“ENC Type I”), using the M40 mask and PASGT helmet and vest; and 3) Land Warrior encapsulation configuration (“ENC Type II”), using the M45 mask and the Joint Service Lightweight Integrated Suit Technology, Modular/Integrated Communications Helmet, and
Interceptor outer tactical vest. For a description of these test courses and ranges, along with a detailed experimental design, see Garrett et al. (2006).

Separate multivariate analyses of variance (MANOVA) were conducted for the MAACL-R, SUBJ, and SRE data. The MANOVA conducted on the MAACL-R stress perception data indicated significant main effects for stress perceptions and for equipment configuration (ENC Baseline, ENC Type I, and ENC Type II). Further analyses were used to determine exactly where the significant differences occurred within each subscale and configuration.

For Anxiety, participants reported significantly lower levels of uncertainty in the ENC Baseline configuration than during the ENC Type I configuration. Participants reported significantly higher levels of depression or a sense of failure to perform well during the ENC Type I and ENC Type II configurations when compared with the ENC Baseline configuration. For Hostility, participants reported higher levels of frustration during both encapsulation configurations than reported in the ENC Baseline configuration.

In order to put these stress response levels into perspective, results were compared with other research efforts involving encapsulation. The referent groups include: Soldiers performing patient litter decontamination (Patient Decon), where the participants wore Mission Oriented Protective Postures (MOPP-IV) and had to perform during day operations; Chemical Decontamination Training Facility (CDTF) students in six hours of MOPP-IV training to decontaminate weapons and vehicles in a live agent environment; and Special Forces Assessment and Selection (SFAS) participants in training to be selected for a Special Forces assignment.

Components of the RAMS showed sensitivity between encapsulation ensembles and indicated no significant differences among the tasks (navigation, obstacle course negotiation, and weapon firing). Anxiety levels that are significantly lower than other encapsulation research efforts demonstrate that these Soldiers were confident in their ability to perform the duties required of them. However, higher hostility levels were reported while wearing ENC Type I and ENC Type II vs. ENC Baseline which demonstrates levels of frustration due to the different weights and comfort of each ensemble. These levels of frustration are comparable to the other military referent groups particularly when new equipment is being researched. During the obstacle course portion, the SUBJ ratings are significantly higher for Soldiers wearing the ENC Type II configuration than for those wearing the ENC Baseline, comparable to SFAS and the CDTF training possibly because the mask in this ensemble did not fit properly. Not surprising, both encapsulation configurations are more stressful than the ENC Baseline configuration during the cross country due to the characteristics about the ensemble. There are weight factors, mask issues and the terrain to deal with during this scenario.

During the live fire exercise, Soldiers reported significantly lower SRE and SUBJ ratings than the other military scenarios. These relatively low stress ratings are believed to be associated with the actual firing event itself. Soldiers have a desire to fire live ammunition. Previous research using psychological and physiological measures conducted on the live-fire range (Fatkin et al., 1991) has shown that testosterone levels are high and vigor and vigilance reign, HOOAH! Their stress levels across all subscales and all configurations were lower during the live fire scenario.

The encapsulation research showed that the participants were well trained and capable of performing well regardless of stress level.

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1 MOPP IV is the US military’s highest level of chemical protectiveness, designating which level of personal protective clothing and equipment soldiers are to be wearing at a particular time on a contaminated battlefield.
The demand for high productivity in the midst of streamlined resources often results in personnel who see fewer tangible accomplishments, and are left with an overwhelming sense of ceaseless striving. Research conducted with Army Recruiters has classified recruiting as a high-risk occupation which includes consistently high levels of stress related to personal, situational, and organizational factors (Fatkin, Mullins and Patton, 1997). Commanders at different levels throughout the Recruiting Command concurred that although recruiters are highly motivated and receive special incentives to perform successfully, many have reported and demonstrated the experience of significant amounts of stress. Unit surveys have identified some probable sources of recruiter stress, including: persistent time constraints; stringent mission requirements; financial strain; lack of military medical support; conflicts between leadership behaviors and command values; social isolation; and lack of resources for self-management and for family needs (Benedict, 1989; Garrett, 1996; Fatkin, Mullins and Patton, 1997).

In spite of the common problems identified by active recruiters, some seem to possess stress-resilient characteristics while others are more vulnerable to the effects of stress (Fatkin, Mullins and Patton, 1997). As recruiters experience an increasing level of stress that is mission related, the effects become more pervasive throughout their duty and off-duty time. Other deleterious effects may include a decrease in levels of internal motivation and somewhat subtle degradation in physical and mental health. Extremely high recruiter stress levels are believed to be contributing to decreases in meeting mission requirements and to increases in high-risk behaviors.

Although much has been reported on recruiter experiences, our research investigation with Army recruiters addressed a need to empirically identify factors that contribute to recruiter stress and performance changes. It is common for organization leaders to be concerned that they may have to lower performance standards as a countermeasure for job-related stress (Frankenhauser and Gardell, 1976; Karasek, 1979). This assumption often triggers reluctance among the leadership to acknowledge the level of difficulty with which Soldiers are confronted. However, information obtained within the recruiting study served to objectively identify the specific factors that contribute to recruiter performance. This was accomplished by implementing the SARA methodology using selected RAMS components. Data obtained from these metrics provided pieces of diagnostic information needed to identify factors affecting performance. Specific recommendations for appropriate solutions were made once those factors were identified.

Participants for the study were active-duty military personnel currently assigned to the recruiter MOS (79 R) within five battalions throughout the US Army Recruiting Command. Ninety recruiters from urban, suburban, and rural environments took part in this study. The job performance data for each recruiter was obtained from unit production reports upon completion of the psychological profile data collection. The performance data corresponds to the same time period as the data collection, consisting of the number of recruits required to meet mission performance (as assigned by the Recruiting Command) and the actual number of individuals recruited by the recruiter. A performance percentage was calculated for each recruiter by dividing the number of individuals recruited by the number of recruits required for 100 per cent mission performance.

Data were analyzed by computing a cluster analysis for the trait and the Life Events measures of the RAMS. The resulting cluster groups were coded as a grouping variable and group differences in recruiter productivity (percent of mission accomplished) were assessed. See Fatkin, Mullins and Patton (1997) for a complete description of the experimental design and the statistical analyses.

Cluster analysis of the MAACL-R trait measure revealed two subgroups of recruiters with two distinct profiles. One group of 57 recruiters was assessed as having relatively low scores for trait anxiety, depression, and hostility (low dysphoria); the other group of 31 individuals was assessed
as having high scores on these measures (high dysphoria). Results indicated that the Soldiers in the low dysphoria group were significantly more successful than those in the high dysphoria group. Recruiters in the low dysphoria group accomplished 91 per cent of their mission, while the recruiters in the high dysphoria group accomplished only 69 per cent of their mission.

The Life Stress cluster analysis resulted in two subgroups of recruiters: a high stress group (n = 47) and a low stress group (n = 34). There were significant differences in performance productivity between the two groups, with the low stress group performing 105 per cent of their mission and the high stress group performing 75 per cent of their required mission.

Results from this research indicate individuals under chronically high levels of stress do not perform as well as those experiencing lower stress levels. This finding is compatible with the current speculation that declines in recruiting mission performance are related to a recruiter’s vulnerability to situational and organizational stressors. While some circumstances are beyond the individual’s control, leaders can be instrumental in adjusting organizational policies or structural resources to mitigate some of the stress related to high workload conditions. Past efforts to predict or identify correlates of recruiter performance focused on recruiter characteristics only. Our multidimensional approach included three critical areas contributing to mission success: personal factors, situational factors, and organizational factors. This approach allowed us to provide unit commanders with relevant recommendations for improving recruiter productivity.

Situational Stress: Advanced Individual Training

Commanders from the US Army Ordnance Center and School (OC&S) wanted to know if their students were too stressed, or perhaps not stressed enough, to successfully complete their training. Therefore, the primary objective for this research effort was to provide the OC&S Command Staff with an evaluation of stress experienced during Advanced Individual Training (AIT). As part of the ARL Cognitive Readiness initiative, the secondary objective was to assess the relationships between the students’ stress resiliency characteristics, their reported level of stress, and their academic performance. This included the identification of student characteristics, as well as situational and organizational factors that are related to their academic readiness and training completion. Student perceptions of command leadership and organizational effectiveness were also obtained (Patton, Fatkin, and Breitenbach, forthcoming).

Participants for the study were active-duty and reserve military personnel assigned to the U.S. Army OC&S. The students were from two different MOSs: a) Track Vehicle Repair, 63 H (Hotels); and b) Quartermaster/Chemical Equipment Repair, 63 J (Juliets).

Predictor and moderator variables were measured using selected components of the RAMS; data on family status, recent life events, personality characteristics, stress perception ratings, and coping strategies were obtained. The outcome measures included subjective performance ratings by the students as well as their objective performance data. The academic performance data for each student were obtained from the OC&S at the completion of their training. These data included the student scores on tests during training, and data about their success or failure to complete their training. Information on other situational factors contributing to the success of students completing training was also obtained.

Analyses of coping strategies revealed that problem-focused students were less likely to avoid problems, use wishful thinking, and were less neurotic. Also, they believed their training was important and that they could manage stressors. Students with less aggressive personality styles tended not to use wishful thinking, but rather used support seeking as a coping style. Students with higher education levels reported low levels of life stress. Students reporting high levels of life stress before a test had lower performance scores than those reporting lower levels of life
stress or those who used their available resources for dealing with the stressor. Also, students who reported high levels of life stress upon joining the Army (such as personal events, military events, or a combination) rated the training as less important. They also described themselves as less impulsive, were not problem solvers, had low confidence in their ability to complete their training, were less likely to handle stress well and tended to be smokers.

Components of our Life Events measure correlated significantly with performance on examinations. Students who were more resourceful in handling their current life stressors received higher scores on their exams at the beginning and at the end of their academic cycle.

The Situational Self-Efficacy scale measured the Soldiers’ level of confidence in their ability to perform well during their training. SSE scores were significantly and positively correlated with exam scores. However, students with higher levels of baseline frustration did not do as well on their exams.

The stress perception components of the RAMS were administered at critical times during the students’ training, following the methodology described in Figure 11.1. To evaluate these state stress perceptions, we conducted multivariate analyses of variance for the MAACL-R, SUBJ, and the SRE, which indicated significant differences in stress responses between pre, post, and score anxiety measurements. There were also significant differences in positive affect and overall stress levels for the pre-, post-, and score measures for Hotels only.

Salivary amylase is our field-expedient, physiological measure of stress because the assay takes less than five minutes and can be performed easily in the field (Chatterton et al., 1996; Fatkin et al., 1999; Patton et al., forthcoming). In previous studies, saliva and blood samples have been collected simultaneously along with the self-report measures listed in Table 11.1. Salivary amylase levels correlated with various subjective measures of anxiety as well as plasma concentrations of cortisol, growth hormone, prolactin, catecholamines, luteinizing hormone, and testosterone (Hudgens et al., 1989; Hudgens et al., 1991). In the AIT study, salivary amylase was collected each time the baseline, pre, and post stress perception measures were administered. While α-amylase levels provide us with the level of intensity of the stress experience, the psychological measures identify the specific components contributing to those stress levels.

In order to evaluate the relationship between amylase and the psychological measures, we ran correlations of baseline salivary amylase and trait measures. Students who were less likely to use self-blame as an overall coping mechanism had lower baseline amylase levels than those who focused on their faults. Students with low baseline levels of salivary amylase also reported higher levels of confidence in passing their final test.

The debrief questionnaire was used to measure students’ perceptions about organizational or situational factors, particularly which factors contributed the most or the least to their experience of stress. Results indicated that 31 per cent of the AIT students would not change anything, while 6 per cent said they would not have joined the Army. When asked about the most stressful part of AIT, 23 per cent of the students felt that adjusting to new peers and to the school were equal in stress, while only 15 per cent felt that dealing with their leadership was most stressful; and 7 per cent said their MOS training was stressful. When asked about the positive aspects of AIT, 30 per cent of the students felt that their free time was the best part; 20 per cent said being with peers; 8 per cent of the students felt that their leadership was the best part, and 6 per cent said the MOS training was the best part of AIT. This information was presented to the OC&S Command Staff. It provided insight to the positive measures that the command and staff were taking to make training at AIT conducive for learning. The stress levels of the students were similar to pilot trainees in a study conducted at the Naval Air Warfare Center (Kaufman and Fatkin, 2001) which found that pilot trainees with moderate levels of stress coming into training proved to be in a state of vigilance. Not surprisingly, those same students were the ones to successfully complete their training.
Determining Need-Based Interventions and Countermeasures

As indicated in the research studies discussed previously, data from the RAMS metrics are incorporated into stress response profiles. The identification of those comparative profiles from individuals in various high-stress environments (see Figures 11.2 through 11.5) assist in the selection of appropriate interventions or countermeasures. This is in contrast to the postulation that a single intervention, such as practice, is the ultimate prescription for performance enhancement across tasks. For example, when performance degradation occurs, a common assumption is made that more training or experience is required to prevent or halt further task degradation. Although this is a plausible assumption, the implementation of training as a solution must instead be based on the actual factors affecting performance of the task at hand.

The assignment of additional training as a magic bullet, without the support of empirical data, is off the mark and it is risky. Not only is the assumption misleading, but it may preclude the consideration of other bona fide factors that affect performance such as equipment functions, system characteristics, leadership issues, or other individual, situational, or organizational factors. The implementation of potential performance multipliers such as additional training should not be based on the previous scope of acceptance or convenience of implementation. Instead, the proposed solutions must be tailored to the identified problem or concern. The use of our comparative stress response profiles provides a way of reviewing the data in order to customize appropriate strategies that can be applied within future operations.

More specifically, the comparative profiles derived from MAACL-R stress perception data provide a method for quantitatively estimating the relative stress experienced in a given situation. The Anxiety subscale of the MAACL-R is a measure of anticipatory stress or a measure of the uncertainty component of stress. If anxiety levels are higher than the independent control and comparable to levels reported by the oncology group, operational performance is often degraded and the application of additional training would be appropriate (Fatkin and Hudgens, 1994). Under those conditions, providing more training or relevant information at critical times may significantly lower anxiety levels and subsequently enhance performance. On the other hand, if anxiety levels are within the moderate range (e.g., similar to the medical students taking a critical exam or Soldiers involved in weapon competition), they reflect levels of vigilance or arousal that correlate with successful performance (Hudgens et al., 1989; Fatkin et al., 1991).

The Depression subscale is a measure of one’s sense of failure to perform according to expectations. When depression levels are significantly higher than the independent control, they reflect a sense of ceaseless striving and negatively correlate with levels of morale and cohesion (Blewett, Ramos and Redmond et al., 1994). Under those circumstances (e.g., recruiters experiencing chronic levels of stress and low productivity), the stress experienced is pervasive and the countermeasures or interventions vary. For factors under the individual’s control, resiliency training will build on current strengths and coping abilities. For structural influences, there must be a resolution of any mismatch between organizational values, unit procedures, and Soldier needs. These internal and external countermeasures serve to mitigate depression levels, leading to enhanced states of cognitive readiness that augment performance.

The Hostility subscale of the MAACL-R is a measure of frustration, usually resulting from a mismatch of the system and the human, or from malfunctioning equipment and equipment delays. Stress levels reported on this subscale have correlated with the workload frustration subscale of the NASA-TLX (Glumm et al., 1998; Dixon et al., 2006). By providing accurate and smooth information flow, or checking equipment problems and procedure delays, frustration levels may subside and performance enhanced.
It is an individual’s stress response pattern that will point to a customized plan of action for mitigating the effects of stress. For example, in the study with Army recruiters, anxiety levels were moderate, while depression and hostility levels were the highest of all the military and civilian populations we have investigated. These response patterns provide critical clues for predicting the effectiveness of methods intended to improve performance.

Depression and hostility levels typically are not a part of the anticipatory stress response associated with anxiety. Consequently, the application of additional training in marketing and sales as a countermeasure for Army recruiters did not improve productivity rates. Recruiting performance improved only after organizational and other structural changes (such as changes in policy for time off, providing recruiters with practical resources, etc.) were implemented. Note that those changes were directly associated with the high depression and hostility levels reported by recruiters. Decisions to implement stress countermeasures in any domain must consider those interactions among the individual, situational, and organizational factors associated with mission success.

Discussion

The implementation of the SARA methodology using the RAMS components provides a quick and effective way to measure stress and its effect on subsequent performance. The methodology is distinct from traditional approaches which use tests and measurements designed for the clinical assessment of pathological symptoms. Instead of using a disease-centered approach that focuses on pathology, ours is a research-based approach designed to identify significant predictors and correlates of readiness states. Identifying stress-resilient characteristics of individuals is at least as important as identifying their vulnerabilities. Also, until recently, research in the area of attrition has been limited to the identification of student profiles consisting of selected demographic characteristics based on post-hoc data collections. These profiles include information on marital status, age, ethnic background, education level, smoking status, and the Armed Forces Qualifying Test (AFQT) category, but rarely include personal characteristics that can contribute to mission or training success. Resiliency characteristics identified through the RAMS trait measures point to efficacy-based interventions for enhancing performance.

Personality Characteristics and Performance

This approach for identifying strengths and weaknesses to augment performance was recently discussed by Detrick and Chibnall (2006) in their extensive review of the literature identifying personality characteristics of various high performers. Their resulting profile of neuroticism and impulsivity scores matched the personality profiles for the low-performing groups. These results are in line with our research conducted on the Soldiers participating in the marksmanship competition, the AIT students, and the Army recruiters. Detrick and Chibnall, too, recommend that the identification of individual strengths and weaknesses be used to build on the strengths while remediation efforts are aimed at areas of personal vulnerability.

In addition to the information obtained from the trait assessments, the comparative stress response profiles provide a quantitative estimation of the relative stress experienced in a given situation. We already know that the interaction between situational factors and individual stress perceptions (cognitive appraisals) plays a crucial role in adaptation. However, most researchers typically do not measure the contribution of that interaction. Therefore, the quantification of individuals’ cognitive appraisals or stress perceptions has been one of the gaps in the stress and performance research arena. The RAMS metrics are field-expedient tools that provide this
important piece of analytic information needed for a comprehensive identification of the problems or issues that affect performance under stress.

Although knowledge and skill are primary contributors to effective performance, they are not the only factors. We can possess the knowledge to perform a task and we can have the requisite skills necessary to perform, yet can still fail to perform well. It is our appraisal of the situation, our perceptions and thoughts, that mediate the transfer of our knowledge and abilities to proficient performance. It is the interaction between individual appraisals and situational factors that plays a crucial role in the process of adaptation to extreme environments. Our self-report measures capture this component and allow us to accurately quantify the stress perception levels that are at the core of this adaptation process.

For example, the Soldiers participating in the marksmanship study rated the competition as moderately stressful, a level of distress that was not high enough to affect their record-firing performance. Wilkins (1982) stated that not only must a situation be of a given intensity to lead to stress; it must also be of a given kind for a particular person. The study consisted of top-notch airborne troops highly qualified for the task of firing for record. In other words, the task demands alone would not necessarily have an overwhelming effect on marksmanship performance. Some emphasis must be given to the individual reactions of the Soldiers during the weapon firing. In addition to the individuals’ expectations or demands of themselves, we must take into account their ongoing assessment of their possible success or failure (Wilkins, 1982).

**Situational Self-Efficacy**

It is not surprising that the Situational Self-Efficacy (SSE) scores were consistently predictive of performance in several studies investigating correlates of Soldier performance (Fatkin et al., 1991; Hudgens, Malkin and Fatkin, 1992; Fatkin and Hudgens, 1994; Rice, Butler and Marra, 2006). Self-efficacy ratings taken at baseline, ranging from 3 weeks to 1 day before the key event, are significantly correlated with marksmanship performance, and with successful completion of training scenarios including chemical decontamination training, Special Forces Assessment and Selection training, and combat medic advanced individual training.

Individuals are constantly assessing their range of capabilities (Bandura, 1977, 1995, 1997). These assessments are used to guide and influence subsequent behavior. For example, if Soldiers perceive their capabilities as somewhat limited, they will tend to minimize efforts, perform less effectively, or avoid relatively new situations. Therefore, the information obtained with the SSE is extremely valuable to instructors and commanders concerned about Soldier performance and attrition.

We performed correlations between both objective and subjective data to provide insight into the relationships between student resiliency, organizational procedures, and training completion. High confidence levels correlate with lower overall stress levels, lower trait anxiety, depression, dysphoria, and higher positive affect levels. Low confidence levels in completing the course were associated with using self-blame and wishful thinking coping mechanisms. Low confidence also correlated with smoking behavior.

Situational self-efficacy also correlated significantly and negatively with stress levels obtained from the field-practical, physiological stress measure, salivary amylase. AIT students with low to moderate baseline levels of salivary amylase had high confidence levels in passing their final test. Students with high levels of baseline salivary amylase also reported high stress levels during their final exam and after specific tests. Recent investigations of salivary amylase measured within various training scenarios suggest that baseline amylase levels are indicative of resiliency characteristics and adaptation to stress.
Mitigating the Effects of Stress through Cognitive Readiness

Exposing Illusions of Wellness that Mask Stress Effects

When troops are experiencing distress, some methods employed to reduce stress levels comply with organizational policy, but are not always effective. The SARA methodology can be used as an objective assessment of the efficacy of such stress-reduction techniques. The blanket assignment of additional training, for example, as a method of preventing performance degradation under stress can perpetuate illusions of wellness among the troops and their commanders. Another way that many military and civilian organizations unknowingly perpetuate illusions of wellness is with the belief that implementing mandatory stress management programs will decrease stress levels of unit members and their leaders. Unfortunately, when stress management programs are implemented without first systematically assessing stress perception levels (e.g., using the SARA methodology) they may be ineffective and often waste the valuable time of commanders and their troops. The generic application of stress management procedures is typically ineffective for four reasons: 1) the content of most stress management programs addresses general causes of stress; 2) the onus of responsibility is placed on the individual versus the inclusion of multiple sources; 3) the analyses of various sources of stress rarely include organizational structure, policy, or values; and 4) the focus rarely includes the core issues that can mitigate the stress (Orioli, 1996). However, the application of the SARA methodology for quantifying cognitive appraisals can assist in both selecting appropriate interventions or countermeasures and evaluating their efficacy.

Army recruiters were found to be functioning at high workload levels for extended periods of time at great cost to their psychological and physical health (Fatkin, 2001). Their relentless efforts to meet increasing demands for productivity eventually led to an increase in the incidence of high-risk behaviors. Those consequences were initially masked by the illusions of wellness that helped them to maintain their remarkably professional persona during times of internal turmoil. However, data from the metrics administered from the RAMS provided a window through which their distress could be perceived, quantified, and subsequently addressed. The high stress levels were comparable to the life-threatening stress experienced by the Yellowstone firefighters and were characterized as career-threatening stressors that had a pervasive effect throughout the recruiters’ personal and professional lives. Specifically, the data from the MAACL-R Depression subscale proved to be a measure of ceaseless striving and was correlated with psychological, physical, and behavioral distress symptoms experienced by the recruiters. Hence, the illusions of wellness that initially masked the chronic stress effects were uncovered. Recommendations for mitigating the effects of stress were made to the command staff, and were subsequently implemented within the 2 years following the study (Fatkin, 2003).

The SARA methodology is an efficacy-based approach which includes the identification of factors that significantly contribute to individual and organizational strengths. For example, in the OC&S study, all students completed their AIT. Our assessment revealed that the students assigned high ratings to the quality of their training, the structure and proportion of classroom instruction and hands-on training, the flow of communication between drill sergeants and students, and the unit response time for addressing student concerns. These data were included in a final report to unit commanders.

Summary and Future Implications

Several years ago, Peters (1999) described his observations of the military tempo: “We live in an age of unprecedented change… Never before has so much happened on so many levels with such breathtaking speed. Developments in a wide range of disciplines tumble over one another in a practical and psychological avalanche” (p. 24). This pace continues today. Amid the myriad of
cognitive challenges associated with high workload, system integrations, time pressures, multitasking, and complex decision making, a primary objective is to assist individuals in achieving at optimal levels of performance and to do so consistently (Harmison, 2006; Krane, 2006). When individuals perceive a balance between situational challenges and their abilities to meet related demands, readiness can be maintained for longer durations. The information obtained from our stress and readiness assessments will assist in obtaining that balance between situational demands and personal capabilities.

In summary, the application of the SARA methodology enables us to: 1) obtain rapid and reliable assessments of psychological and physiological stress and readiness levels; 2) identify stress-resilient characteristics of individuals, teams, and organizations; 3) assess the realism of simulation training; 4) monitor chronic stress levels that may have deleterious effects on health and performance; 5) provide input into decision aids for leaders and medical personnel to assess readiness states and to determine redirection if needed; 6) use amylase field assay results as a measure of adaptability and motion sickness susceptibility; 7) determine appropriate, need-based interventions and countermeasures; 8) use reliable, field-practical tools for assessing the efficacy of interventions; and 9) provide data-based input to augment readiness, retention, and training models.

Future considerations should include assessments of what individual factors might influence team interactions. Each member of a team brings their own characteristics, cognitive appraisals, and adaptation strategies to a situation. Research needs to examine how team dynamics are affected by combinations of team members’ attributes. Effective interaction between individual capabilities, team interactions, and system functions will enable improved situational understanding, unsurpassed mobility, quick responses, and sustainability within continuous operations.

The implementation of customized countermeasures and or interventions will assist in maintaining or building a heightened state of readiness. The mitigation of stress effects through cognitive readiness will enhance Force effectiveness by enabling the Soldier to function effectively even in the face of unanticipated incidents within hostile environments.

References


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Chapter 12

Fatigue and its Effect on Performance in Military Environments

N.L. Miller, P. Matsangas and L.G. Shattuck

1 Introduction

Saddam Hussein and his sons must leave Iraq within 48 hours. Their refusal to do so will result in military conflict (President George W. Bush, 17 March 2003).

My fellow citizens, at this hour, American and coalition forces are in the early stages of military operations to disarm Iraq, to free its people and to defend the world from grave danger. On my orders, coalition forces have begun striking selected targets of military importance to undermine Saddam Hussein’s ability to wage war. These are opening stages of what will be a broad and concerted campaign (President George W. Bush, Address to the Nation, 19 March 2003).

With these words, US President George W. Bush announced to the citizens of the United States that Operation Iraqi Freedom had begun. The campaign commenced with the US Air Force bombing Baghdad and other strategic targets. Shortly thereafter, on Thursday, March 20, US and Allied Coalition Ground Forces crossed the Kuwaiti–Iraqi border and began their attack north to Baghdad and other key locations. Over the next few days, Coalition aircraft flew between 1500 and 2000 sorties per day, warships launched 500 cruise missiles, and ground troops traveled hundreds of kilometers often meeting fierce resistance along the way. Coalition forces pressed on day and night with little rest. According to the 3rd Infantry Division After Action Report (AAR), a senior leader noted that he “slept for about half an hour at the assault position and really did not rest again until 24 March. The troops did not rest either.” The AAR also stated that another leader “recalled that at one point [his] battalion moved only to discover that it had left a battery asleep by the side of the road.”

Reporters embedded with the ground forces and military analysts provided vivid descriptions of the impact of prolonged wakefulness on performance. Here are a few comments from them.

- A Marine Company Commander stated, “I didn’t get my first hour of sleep until after 48 hours, and I’ve been catching 20-minute catnaps ever since.”
- A soldier confided, “Yesterday I finally got a little bit of sleep. The three days with only three or four hours sleep was pretty rough.”
- A correspondent reported, “In the fifth day of their race northward, troops of the U.S. 3rd Infantry Division were showing the effects of sleeplessness and tension…. Drained by an armored march that U.S. commanders said was unprecedented in size, speed and distance traveled, drivers of tanks, Bradley fighting vehicles and humvees kept falling asleep at the wheel and veering off course. Then a soldier behind them would fight through the sandstorm on foot to wake a sleeping driver and get him moving again.”
A military analyst discussing the numerous accidents that occurred in the initial stages of *Operation Iraqi Freedom* stated, “Fatal mishaps soon will ‘level out.’ They are apt to rise again with ‘fatigue and combat stress,’ as the war gets longer and tougher. The biggest killer is fatigue, and right now we have a whole Army running toward Baghdad on zippo hours of sleep.”

Aside from the few references to fatigue cited in the 3rd Infantry Division AAR (above), many official documents seem to avoid the subject of fatigue completely. There appears to be an attitude that, similar to casualties, sleep deprivation is inevitable in war. Giving in to this viewpoint is akin to asking combatants to engage in warfare without ammunition or food and water. Consider the following comment by Shay (1998):

Pretending to be superhuman is very dangerous. In a well-led military, the self-maintenance of the commander, the interests of his or her country, and the good of the troops are incommensurable only when the enemy succeeds in making them so. It is time to critically reexamine our love affair with stoic self-denial, starting with the service academies. If an adversary can turn our commanders into sleepwalking zombies, from a moral point of view the adversary has done nothing fundamentally different than destroying supplies of food, water, or ammunition. Such could be the outcome, despite our best efforts to counter it. But we must stop doing it to ourselves and handing the enemy a dangerous and unearned advantage.

The impact of fatigue is not restricted to the military, nor is it unique to recent military campaigns. This chapter, however, will focus on the effects of fatigue on performance in military environments. We begin with a discussion of circadian rhythms, sleep requirements, sleep architecture, and sleep debt in humans. We then examine the relationship between fatigue and human performance. Specifically, we describe the effects of insufficient sleep, both acute and chronic sleep deprivation, and the effects of circadian rhythm disruption caused by shift work or crossing time zones. We then review research efforts (historical and recent) to assess the operational effects of fatigue and sleep. After examining various behavioral and pharmacological countermeasures currently available for use in military populations, we conclude the chapter with suggestions for the direction of future efforts.

### 2 An Overview of Sleep

#### 2.1 Circadian Rhythms

Over the course of a 24-hour day, human alertness waxes and wanes in a highly predictable manner. This naturally occurring pattern is known as the circadian cycle (circa = about, dies = day) and is mirrored in the diurnal pattern of sleep and wakefulness. Many other physiological parameters are governed by this same circadian rhythm, e.g., core body temperature and endocrine function such as cortisol and human growth hormone (HGH). Evolving over millennia, this circadian pattern is consistent across mammalian species, including humans, and is highly resistant to change. Most humans have adapted to the standard 24-hour Earth Day although research indicates that without light or other temporal cues, most humans have an innate 24.5 to 25.0 hour clock (Horne, 1988). This 24-hour circadian clock is regulated by cues or “zeitgebers” such as exposure to light, meals, exercise and social cues.
2.2 Sleep Requirements in Humans

In many ways, sleep remains a mysterious, yet vital, commodity. Sleep has been the topic of extensive scientific study for years – yet no one fully understands its purpose. Horne (1988) defines sleep as “the rest and recovery from the wear and tear of wakefulness”. Approximately one-third of our lives are spent in this elusive condition known as sleep. In fact, there is almost universal acknowledgment that healthy adult humans require approximately eight hours of sleep per night to maintain full cognitive effectiveness (Anch et al., 1988). Like many other physiological parameters, there are individual variations in this requirement for sleep with some individuals requiring more and some less than eight hours of sleep per night (Van Dongen and Dinges, 2000).

Additionally, sleep requirements are known to change in a fairly predictable manner over the course of a lifetime. Figure 12.1 illustrates the changes in sleep patterns that are seen over the lifespan.

As can be seen in the figure, newborns have very little contiguous sleep. However, by the time they reach one year of age, children typically sleep through the night. Napping is common in babies and young children but for the most part, napping disappears as children reach elementary school age. In adolescents and young adults, there is another shift in sleep patterns. This group actually requires significantly more sleep than their adult counterparts, approximately 0.5 to 1.25 hours more per night. Corresponding to the pattern of melatonin release in this age group, bedtime is delayed with later awakenings (Carskadon, 2002, 2003; Carskadon et al., 1995; Wolfson and Carskadon, 1998, 2003. It is important to recognize that many individuals serving in the military, especially those in the junior enlisted and junior officer ranks, are still in this adolescent and young adult sleep category and require from 8.5 to 9.25 hours of sleep per night (Miller and Shattuck, 2005). By the time individuals reach their mid-20s though the middle age years, sleep requirements are fairly stable at around 8 hours per night.
Morningness-eveningness preference is also a significant determinant of sleep patterns. From a very early age, individuals display differences in alertness from morning to evening and this characteristic has been called the morningness-eveningness (M-E) preference and tends to remain fairly constant over the lifespan (Horne and Östberg, 1976). Individuals who prefer to wake early and retire to bed early have been termed “larks”, while those individuals who stay up late at night and sleep in in the mornings are referred to as “owls”. Individuals who do not exhibit a strong morning or evening preference are called “robins”. The requirement for 24–7 operations makes it important to have individuals representing all of these categories of ME preference, taking advantage of the natural tendency for individuals to maintain alertness at differing times.

2.3 Sleep Architecture in Humans

At one time, it was thought that the brain was quiet during sleep. However, we now recognize that there are times in which the sleeping brain is more active than during its waking state. When we are asleep, we cannot monitor our own behavior. Scientists have developed elaborate methods (e.g., polysomnography or PSG) to gain insight into the activities of the sleeping brain (Kryger, Roth, and Dement, 2000). These methods include monitoring the electrical activity at the surface of the brain using electrodes placed on the scalp (i.e., electroencephalograms or EEGs). Similar electrodes record the muscle activity associated with eye movements (i.e., electro-oculograms or EOGs).

Recordings show that over the course of a typical eight-hour sleep period, the human brain experiences two types of sleep, rapid eye movement (REM) and non-rapid eye movement (NREM). These two sleep types have different functions and are characterized by distinctive behaviors. NREM sleep can be further divided into four progressively deeper sleep stages (Stage 1 through Stage 4). Stage 0 refers to the awake state. Typical sleep stages over the course of a night’s sleep are illustrated in Figure 12.2.

![Figure 12.2 Sleep stages over a typical eight-hour sleep period](image-url)
As shown in Figure 12.2, we experience these sleep stages in approximately 90 minute sleep cycles. In the first half of an eight hour contiguous sleep event, relatively more time is spent in deeper sleep (Stages 3 and 4) while Stage 1 and 2 and REM sleep are more prevalent in the latter half of an eight hour sleep period.

Adequate amounts of both REM and NREM sleep are necessary for optimal functioning in humans. In a sleep laboratory, humans can be deprived of a single stage of sleep, known as partial sleep deprivation or PSD. When allowed to sleep following PSD, the body will then rebound into the sleep stage from which it was deprived, recovering the lost sleep. Total sleep deprivation or TSD, occurs when the research participant is kept awake continuously and may be seen in both laboratory and field conditions. When allowed to sleep after experiencing total sleep deprivation, the body will rebound by rapidly entering deep stages of sleep, leading scientists to speculate that these deep stages of sleep are very important. When awakened from deep sleep, a condition known as sleep inertia is common and is characterized by reduced alertness and cognitive functioning. Although a brief period of sleep inertia typically occurs upon awakening from a normal night’s sleep, sleep inertia may last even longer when awakened from deep stages of sleep. In operational environments where humans are deprived of adequate amounts of deep sleep, both conditions, the rebound into deeper sleep stages and the resultant sleep inertia when awakened from deep sleep, may be a recipe for disaster.

2.4 Insufficient Nightly Sleep or “Sleep Debt”

Events such as travel across time zones, shift work, prolonged wakefulness and foreshortened sleep will all contribute to insufficient sleep (see Figure 12.3). Unfortunately, all of these conditions are remarkably common in modern military environments in which continuous or sustained operations are required. In the worst of cases, a condition known as circadian desynchrony may occur in which this natural pattern of sleep and wakefulness is completely disrupted.

![Figure 12.3 Categories of insufficient sleep](image)

Sleep has been likened to a reservoir, filling over the course of a night’s sleep and depleting during hours of wakefulness. When this sleep reservoir is not full, there is a “sleep debt”, which can accrue in multiple ways. See Van Dongen et al. (2003) for a review of sleep debt. Sleep debt can be caused by acute sleep deprivation resulting from a single period of sustained wakefulness. Acute sleep debt is commonly seen in continuous operations such as those frequently experienced in military and emergency operations such as firefighting and emergency medical and response activities. Sleep debt can also be caused by chronic sleep deprivation from multiple nights of less than eight hours of sleep and is commonly observed in individuals during sustained operations. All too frequently,
sleep debt results from a combination of both acute and chronic sleep deprivation conditions, and sometimes has catastrophic consequences. Unfortunately, operational environments are prone to both continuous and sustained conditions that almost inevitably lead to insufficient sleep.

3 Relationship between Performance and Fatigue

Studies examining the effects of sleep deprivation on human cognitive performance have led scientists to the conclusion that the two are inextricably linked. In particular, tasks involving vigilance are exquisitely sensitive to fatigue caused by sleep deprivation. In well-controlled laboratory experiments, sleep deprivation has been linked to degraded cognitive performance, exhibiting a highly convincing dose–response relationship (Belenky et al., 2003; Driskell, Hughes, Willis, Cannon-Bowers and Salas, 1991; Driskell and Salas, 1996; Hursh and Bell, 2001; Van Dongen et al., 2003). Findings from these studies address the profound effect of both acute and chronic sleep loss on cognitive performance. They further demonstrate that recovery from severe sleep loss will not occur overnight or even after three nights of normal sleep. Additionally, the studies allude to the insidious nature of chronic sleep deprivation: although performance is severely degraded, only those individuals who are in the most severely restricted group report being sleepy.

In the scientific literature, learning and memory have been associated with REM sleep, with the assertion that memory consolidation occurs during REM sleep. However, research indicates that deep stages of sleep are also needed for memory. Debate persists regarding the relative importance of various sleep stages but increasing evidence supports the idea that adequate sleep is a requirement for effective learning and memory (Karni et al., 1994; Wilson and McNaughton, 1994; Gais et al., 2000; Stickgold, James and Hobson, 2000; Fenn, Nusbaum and Margoliash, 2003; Walker et al., 2003).

Physical health also depends on receiving adequate amounts of sleep. Research shows that resistance to disease is degraded when deprived of sleep. Studies of antibody production have demonstrated that sleep enhances immune response (Lange et al., 2003). Unquestionably, without sleep, both our cognitive and physical performance as well as our health, suffers. Sleep is a critical requirement for humans. Indeed, in the harshest of terms, exposure to total sleep deprivation for an extended period of time will result in death (Coren, 1997).

4 The Effects of Fatigue and Sleep Deprivation in Operational Environments

In combat, the consequences of degraded performance can be much greater than those in the civil arena. Military members not only have to cope with a hostile environment, they must also apply lethal force against a dangerous enemy, maintaining vigilance and exercising good judgment, while ensuring they protect those in their own unit. Since the Second World War, numerous studies have attempted to evaluate fatigue in military operations and to assess the effects of sleep deprivation on military performance, for example (Baird, Coles and Nicholson, 1983; Majors, 1984; Nicholson, 1984; Steele et al., 1989; Meyer and DeJohn, 1990; Neri and Shappell, 1993, 1994; Shappell and Neri, 1993; Belland and Bissell, 1994; Neville et al., 1994; Kelly et al., 1996; Paul, Pigeau and Weinberg, 1998; Nguyen, 2002; Doheney, 2004; Sawyer, 2004). For reviews of these research efforts, see Krueger, Barnes and Fort Rucker (1989), and Krueger, Cardenales-Ortiz, and Loveless (1985). Despite the overwhelming evidence that sleep deprivation has a profoundly negative influence on performance, it is not uncommon in the military environment to encounter the belief that fatigue can be overcome by adequate motivation. For millennia, the “myth of the warrior” has haunted military operations (Shay, 1998). However, research has shown that motivation can only
partially compensate for sleep deprivation (Pigeau, Angus and O’Neil, 1995). The bottom line is that warfighters, despite their objections and assertions to the contrary, need sleep to perform at anything near their optimal level.

Sleep is only one of the many stressors found in the military operational environment. These stressors do not always occur in isolation: they frequently occur in clusters and their effects can be additive or multiplicative and they may be mitigated by other factors. Depicted in Figure 12.4 are some of these stressors and mediators and their influence on human performance. The left column of Figure 12.4 lists various categories of stressors, all commonly seen in military operations. The middle column lists mediating factors that can change the effects that stressors have on cognitive and physical performance, pictured in the column on the right.

The difficulty of assessing war fighter fatigue in the operational environment has led researchers to the evaluation of fatigue and sleep deprivation effects through the simulation of military tasks, for example (Naitoh, Englund and Ryman, 1987; Neri, Shappell and DeJohn, 1992; Lieberman et al., 2006).

In an experiment conducted by Haslam (1985b), a number of soldiers participated in a field exercise of restricted sleep over a 9-day period. The soldiers were divided into three sleep groups: no sleep, 1.5, or 3 hours of sleep per night. At the end of the 9-day period, vigilance and cognitive tasks performance was decreased to 50 per cent of the pre-test levels. This deterioration was cognitive in nature; physical performance was relatively unchanged. The platoon that received 3 hours of sleep/night completed the study, whereas the other groups failed to finish. Only 50 per cent of the 1.5-h sleep platoon completed the 9 days of the study, whereas the no-sleep platoon was militarily ineffective after 48 hours without sleep. As noted by Haslam (1982) “In the event of war, motivation to see and fire at the enemy will be high, but, none the less, vigilance in any situation, and especially under conditions of sleep loss, will almost certainly deteriorate over time”. When sleep loss becomes great, against their will, individuals will fall sleep for brief periods of time, known as micro-sleeps.
Research has shown that the effects of fatigue include decreased vigilance, mood changes, perceptual and cognitive decrements (Krueger, 1991). An important skill for soldiers, marksmanship is also known to be affected by sleep debt and circadian variation (Tharion, Shukitt-Hale and Lieberman, 2003; McLellan et al., 2005). Killgore, Balkin and Wesensten (2006) examined how sleep deprivation affects judgment. In their study, they found that individuals who are sleep deprived make riskier decisions on the Iowa Gambling Task. These findings suggest that decision-making under conditions of uncertainty may be particularly vulnerable to sleep loss and that this vulnerability may become more pronounced with increased age.

Task characteristics and complexity are major mediators in the effect of sleep on task performance. In a 48-hour field trial, Ainsworth and Bishop (1971) found that tasks which required consistent, sustained alertness were most susceptible to sleep loss. This finding is consistent with laboratory studies of impaired performance in 24 hours of sustained, continuous work (Mullaney, Kripke and Fleck, 1981). Angus and colleagues also reported performance reductions of 30 per cent during the first night and 60 per cent during the second night when sleep deprivation was combined with continuous cognitive work (Angus, Heslegrave and Myles, 1985). In a simulated sustained operations environment of an artillery fire direction center, performance decrements were evident in the first 24-48 hours; planning and maintaining situational awareness were among the tasks most affected (Banderet et al., 1981).

Cumulative sleep debt results in reductions in overall performance, but also results in longer and more sleep inertia. Sleep inertia is characterized by confusion, disorientation, and increased response latencies (Downey and Bonnet, 1987), and may be exacerbated by circadian desynchrony and the level of sleep debt (Dinges, Orne and Orne, 1985). Operational environments share common characteristics such as long work hours, working conditions that vary from boring to extremely stressful, less-than-optimal working and sleeping environments, occasional high operational tempos, sustained operations which may lead to continuous operations, and reduced staffing. In addition to their primary job and responsibilities, military personnel frequently have demanding collateral duties, e.g., pilots are required to participate in detailed mission planning, briefing, and debriefing as well as flying the mission.

Although fatigue due to sleep loss is common in all branches of the military service, it has been difficult to objectively assess due to operational considerations and equipment limitations. Until relatively recently, objective measures were extremely hard to capture so subjective evaluation was used extensively (Pereli, 1980; Chidester, 1986; Shappell and Neri, 1993). In current field studies, wristworn activity monitors (WAMs) make the process of quantifying work and rest cycles objective and fairly easy. Used along with activity logs or sleep diaries, WAMs or actigraphy measures can give unbiased estimates of quantity and quality of sleep (Ancoli-Israel et al., 2003). In both civil and military aviation, pilot fatigue poses a significant problem because of the unforgiving nature of the aviation environment. For a review of this research, see (Caldwell, 2005). Fatigue is known to lead to less accurate flight maneuvers, increased error rates, and to significant lapses in judgment (Billings et al., 1968; Pereli, 1980; Krueger, Armstrong and Cisco, 1985). Studies in US Naval aviation during fleet operations have found correlations between pilot performance and increased levels of fatigue (Briceton, McHugh and Naitoh, 1980; Briceton and Young, 1980; Briceton, 1990). In studies conducted with soldiers deployed in Bosnia (Operations Joint Endeavor I and II), 56 per cent of respondents reported that the number of hours worked was a stressor. According to research, lack of sleep was a common occurrence in deployments in Haiti, Bosnia, Somalia, and Kuwait (French, 1995).

During Operation Desert Shield and Operation Desert Storm, a study was conducted onboard the USS AMERICA using A-6 and F-14 pilots. Although, fatigue was evident in both campaigns, flight operations during Operation Desert Storm were found to be more fatiguing due to differences
in the time of day the missions were flown, mission length, and the type of aircraft involved. In both campaigns, no evidence of fatigue accumulation was found because of effective management of air combat operations (DeJohn and Neri, 1992; Shappell and Neri, 1993). In the same study, the researchers noted that pilot fatigue level was reduced with circadian synchronization. During Operation Desert Storm, surveys of C-141 aircrews (airlift operations) reported occasions when the aircrew was fatigued to the point that they felt unable to function (Neville et al., 1994).

Research conducted on Navy surface ships and submarines has shown that work conditions on naval vessels (shift working, and lack of natural light) leads to increased fatigue due to circadian desynchrony and reduced sleep (Steele et al., 1989; Comperatore, Bloch and Ferry, 1999; Horn et al., 2003; Arendt et al., 2006).

5 Fatigue Countermeasures and Intervention Strategies

5.1 Fatigue Countermeasures

Perhaps due to the high incidence of sleep deprivation in its ranks, the US military, the US Coast Guard and to the US transportation industry have all continued to search for ways to combat the effects of sleep deprivation. These agencies have sought to develop fatigue countermeasures which are safe and effective for individuals working in their organizations. Although the best way to overcome fatigue is through adequate amounts of quality sleep, this may be quite difficult to
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achieve in the operational environment. To the extent possible, military operations should include interventions in all the factors that are known to interfere with or contribute to sleep hygiene.

Fatigue countermeasures can be placed into two categories: pharmacological agents (i.e., drugs of either the prescription or non-prescription variety) and non-pharmacological agents (Figure 12.5). These interventions may also be divided by their mode of action: stimulants/performance boosters or sedatives/sleep aids.

<table>
<thead>
<tr>
<th>Non-pharmacological Interventions</th>
<th>Pharmacological interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Sleep conditions</td>
<td>• Prescription stimulants or alerting drugs</td>
</tr>
<tr>
<td>- Dark</td>
<td>- Dexamphetamine (dextroamphetamine)</td>
</tr>
<tr>
<td>- Quiet</td>
<td>- Modafinil</td>
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<tr>
<td>- Temperate</td>
<td>• Non-prescription stimulants or alerting drugs</td>
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<tr>
<td>- Safe</td>
<td>- Caffeine</td>
</tr>
<tr>
<td>• Work/rest schedules</td>
<td>• Prescription sedatives or sleep aids</td>
</tr>
<tr>
<td>• Naps, rest breaks</td>
<td>- Ambien (zolpidem)</td>
</tr>
<tr>
<td>• Exercise</td>
<td>- Restoril (temazepam)</td>
</tr>
<tr>
<td>• Environmental stimulation</td>
<td>• Non-prescription sedatives or sleep aids</td>
</tr>
<tr>
<td>• Physical fitness</td>
<td>- Melatonin</td>
</tr>
<tr>
<td>• Task attributes</td>
<td>- Benadryl</td>
</tr>
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<td></td>
<td>- Tryptophan</td>
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</tbody>
</table>

Figure 12.5 Fatigue countermeasures

5.2 Non-pharmacological interventions

Many non-pharmacological interventions have been tried, some with more success than others. Figure 12.5 lists a variety of these non-pharmacological interventions in the column on the far left. While recognizing that these conditions are highly dependent on the combat conditions, sleep quarters should be designed for dark, quiet, temperate and safe conditions while sleeping. Light exposure has been shown to be especially important for sleep and is associated with suppression of melatonin release. A study by Miller and Nguyen (2003) on the USS STENNIS during night operations examined the role of sunlight exposure and sleep. Sailors in this study had wakeup call at 18.00 while bedtime was at 10.00. This study showed that Sailors who worked belowdecks with no exposure to sunlight before bedtime had much better sleep than those Sailors who worked topside and received several hours of exposure to sunlight before retiring for bed. This finding is in agreement with research on light exposure in shift workers.

Sleeping in an unfamiliar environment is also known to affect sleep quality. A recent survey of Army pilots revealed that, even during peacetime, 26 per cent of pilots complained of poor sleep while in the field or while traveling away from home compared with only 5 per cent complaining of poor sleep at their home post (Caldwell et al., 2000). In combat, this unfamiliarity with sleep conditions is compounded by concerns about one’s physical safety and the many other psychological stressors that accompany combat.

When work is extended to include schedules other than a standard eight hour workday during daylight hours, appropriate scheduling of work and rest for individuals is crucial. Tools are available to assist in optimizing scheduling. The Fatigue Avoidance Scheduling Tool or FAST™
Fatigue and its Effect on Performance in Military Environments

is one such tool that is used by various military services including the US Air Force, US Navy and US Marines (Eddy and Hursh, 2001). Using the Sleep and Fatigue, Task Effectiveness (SAFTE) model developed by Hursh and others, FAST™ uses the 72 hour sleep history of an individual to predict their cognitive effectiveness at a given point in time.

Output from FAST™ is displayed in Figure 12.6. Predicted effectiveness is shown on the left and ranges from 0 to 100 per cent while blood alcohol equivalence is shown on the right. The three horizontal bands indicate level of predicted effectiveness with the top narrow band representing the safe zone (greater than 90 per cent effectiveness), The middle band is the cautionary zone and the lower, darkest band is the danger zone where lapses in attention are greatly increased. Predicted effectiveness for 5 days of work and rest are shown for a single individual and are represented by the undulating gray line. Circadian peaks and troughs are distinct with dips in the wee hours of the morning and in the afternoon. The first 3 days show predicted effectiveness while receiving eight hours of sleep while the last 2 days show what happens to predicted effectiveness when sleep is reduced (day 4) and eliminated (day 5). The FAST tool can be used as a retrospective instrument as well as predicting future performance. The USAF uses the dotted line (the “criterion line”) on the FAST plot as a cutoff point when scheduling pilots for long-range missions. At all times in their flight profile, the pilot-in-command must have performance above the dotted line. During mission critical phases of flight (e.g., takeoff, landing, weapons delivery) predicted effectiveness must be in the 90 per cent or above band. For extended missions, e.g., B 2 flights of 40 hours duration and two pilots, in-flight napping procedures have been used to ensure these criteria are met in USAF pilots.

Figure 12.6 Fatigue Avoidance Scheduling Tool (FAST)

Sleep debt can be reduced through napping which has been shown to moderate the effect of fatigue on human performance (Haslam, 1985a; Rosekind, Gander and Dinges, 1991). Unfortunately, napping may be impossible when combat conditions become intense. Although napping is not as effective as contiguous nocturnal sleep and the time spent in naps is not equivalent to night sleep (Moses et al., 1975), in operational environments, napping may be the only route to provide sleep
to individuals in combat for extended periods (Haslam, 1982). So as to optimize the beneficial quality of napping, Naitoh noted three factors that should be considered: the amount of prior wakefulness, the timing, and the duration of the nap (Naitoh, 1981). Warfighters should be allowed to take naps when possible, given the operational limitations. Strategic naps can help alleviate sleep-deprivation-related performance decrements in situations where naps are feasible (Dinges et al., 1988). An excellent review of napping is available in a thesis by Godfrey (2006).

Physical fitness has been shown to be important for sleep quality. However, heavy exercise immediately before sleep is not recommended since it may delay sleep onset. Light exercise such as jogging in place and jumping jacks has been shown to have an immediately alerting effect that dissipates quickly. Nutrition is also important for sleep and timing of meals should allow for digestion to occur before the major sleep episode (i.e., no heavy late night meals). Alcohol ingestion, while sedating, has an adverse effect on sleep quality and is not recommended.

5.3 Pharmacological interventions

The second category for countering fatigue is through the use of pharmacological agents, either prescription or non-prescription. Pharmacologic agents can be thought of as falling into one of two categories: those that promote sleep and those that promote wakefulness. Historically, the use of pharmacologic agents to promote either sleep or wakefulness extends back to the Second World War. Also called “go-no go” pills, amphetamines and sedatives have been used by American, British, and German aviators since the Second World War and their use is also documented in conflicts in Vietnam, the Falkland Islands, and Iraq in Operation Desert Storm (Winfield, 1941; Graf, 1946; Nicholson, 1984; Nicholson, Roth and Stone, 1985). Caffeine, slightly less effective to amphetamines in terms of its alerting effects, was used in flight operations in Iraq during Operation Southern Watch (Belland and Bissell, 1994).

Unfortunately, both interventions (i.e., promoting sleep or wakefulness) are challenging to implement in military operational environments where chaotic “sleep windows” (i.e., those time periods when individuals can sleep) may be unscheduled, disrupted, or of short duration. Some pharmacologic agents that promote sleep may impair performance after awakening, causing “hangover effects” (Giam, 1997). Similarly, sleep impairing agents may degrade the amount and quality of sleep when the opportunity to sleep does become available. Numerous pharmacologic agents have been used in various military missions, like bombing, very long air transport flights, and long-range reconnaissance patrols. The pharmacological intervention information presented in this chapter is meant to convey the history and current state of use in military operations and represents only a small fraction of the information available on this topic.

5.3.1 Stimulants or alerting pharmacological interventions

The use of the prescription drug, dextroamphetamine, as an alerting agent for aviators in the combat environment has been hotly debated for years, but its use is still fairly widely accepted during periods of combat or extreme operational necessity when approved by higher authority. The street name for this medication is “speed” and its use by the USAF, US Navy, USMC and the US Army must be approved by a flight surgeon who may prescribe it. Modafinil is a recent prescription medication that is now available for pilots and may have fewer side effects than dextroamphetamine.

Over the counter (OTC) medications are also available in the form of caffeine and nicotine. Caffeinated beverages include coffee and soft drinks such as Jolt and Mountain Dew. Chewing gum augmented with caffeine is now marketed and is included in Meals Ready to Eat (MREs). Marksmanship, affected by sleep debt and circadian variation, is improved by the use of caffeine (Tharion, Shukitt-Hale and Lieberman, 2003; McLellan et al., 2005). The effects of sleep inertia
have also been show to be greatly reduced from use of caffeine (Van Dongen et al., 2001). Chronic exposure over long periods of time reduces the effectiveness of caffeine and nicotine.

5.3.2. Sedatives or sleep aiding pharmacological interventions  Prescription sedatives or sleep aids are available for use when prescribed by a flight surgeon and include zolpidem (Ambien) and temazepam (Restoril). Both medications are currently being prescribed for use by aircrew. However, their use must be timed carefully so that their sedating effects have worn off before personnel are expected to engage in mission-related tasks. The US Navy gives guidance to flight surgeons on the use of prescription in their manual authored by CAPT Dave Brown (NASA astronaut on the Columbia) Performance Maintenance During Continuous Flight Operations (Brown, 2000).

Non-prescription (OTC) agents are also used by military members to aid in getting sleep. These include melatonin and tryptophan as well as medications with sedating properties such as Benedryl and Tylenol PM. The use of OTC medications by aircrew is not approved since their side effects can be potentially hazardous during routine or combat operations.

6 Conclusion

Warfare has become a “24-7” activity and requires highly skilled practitioners to operate complex systems. In addition, the military services have reduced personnel strength and project additional manpower decrements. Individuals in demanding operational environments are almost certain to experience some level of sleep deprivation and the resultant performance decrement. In an eloquent article about the implications of fatigue for warfighters, CAPT Nick Davenport describes fatigue as “…the big gray elephant we muscle out of the cockpit when we fly, step around when we enter the bridge, and push aside when we peer into the periscope” (Davenport, 2006). Ignoring the “big gray elephant” of fatigue in operational settings has not been effective in the past. The “myth of the warrior” (Shay, 1998) is, unfortunately, alive and well.

A few years ago, a general officer in the US Army was asked how many hours of sleep leaders needed each day to remain effective during sustained operations. Essentially, he stated that leaders only needed about three and a half hours of sleep every 24 hours – two hours between 2.00 and 4.00 and then a nap later in the morning. He said that this pattern of sleep, coupled with a lot of caffeine and staying “actively fearful of screwing up” will sustain a leader indefinitely. His answer is contrary to decades of research in sleep and the effects of sleep deprivation.

How do we protect warfighters from buying in to the “myth of the warrior?” There are several possibilities. Since this chapter is scholarly in nature, the reader might assume that we would first recommend additional research. And perhaps additional research is warranted in certain areas of sleep and fatigue. However, since there are hundreds of articles and books that have already been published in these areas, it is doubtful that the argument for the need to reduce the effects of fatigue will be bolstered by additional research. Another possibility is education. The National Sleep Foundation maintains an excellent website (http://www.sleepfoundation.org/) which contains a wealth of information. However, it is not likely that this website is visited regularly by leaders in the military and other organizations engaged in sustained, risky, and demanding activities. These professions need to acknowledge the “big gray elephant” and educate the practitioners on how to cope with the debilitating effects of fatigue. In the military, such information should become a part of the curricula at all schools.

Education, however, often is not enough. Many professions (e.g., commercial trucking and airline industries) are governed by regulatory policies that dictate the amount of rest required. Other professions (e.g., medical, police, firefighting) have less formal policies. In the military, such policies are restricted almost exclusively to aviators. Those who work on the aircraft, those
who drive tanks, or those who stand watch on warships are not governed by any formal policies. The work-rest schedules of these warfighters are governed by the availability of personnel, the requirements of the mission, and the standard operating procedures of the organization. Given the complexity and inherent danger in virtually any job in the military, it may be time to consider implementing formal policies for all warfighters, similar to those that govern aviators.

Another area in which work needs be done is the improvement of the existing tools for assessing and predicting the effects of sleep deprivation. The Fatigue Avoidance Scheduling Tool (FAST) is excellent for modeling and assessing performance given an individual’s sleep schedule but its use is not widespread it is not in a form that is usable at the tactical level. A similar tool that could assess and predict performance of multiple individuals (e.g., teams, squads, platoons) given their sleep schedules is being developed by researchers at the Walter Reed Army Institute of Research (WRAIR) but is not yet available.

None of the possible solutions discussed above truly get at the heart of the problem. More research, better education, formal policies, better assessment and predictive tools, and even non-pharmacologic and pharmacologic interventions will help warfighters do more with less for only so long. Beyond a certain point these warfighters bump up against the inflexible boundary of human capacity. It is imperative that we acknowledge these human limitations and design our work environments so that practitioners function within these limitations.

A more holistic approach must encompass solutions offered by such areas as manpower, personnel, and human factors engineering. Increasing manpower will have a direct effect on work schedules. While this is a costly solution, it is, in the long run, less costly than a human life or than a fighter aircraft. Personnel solutions could include screening candidates to identify those who will perform well in continuous and sustained operations. Investments in training can lower the cognitive demand of many tasks and, therefore, reduce the likelihood that those tasks would be affected by warfighters experiencing mild amounts of fatigue. Finally, carefully designed human—machine systems also may help to reduce the effects of fatigue by reducing the workload of human operators. In the end, if we employ a comprehensive and holistic approach to the design of military organizations and the technological systems of warfare, we should be successful in assisting them to reduce their fatigue and to improve both their sleep patterns and their overall quality of life.

References


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Chapter 13

Multi-Modal Information Display under Stress

T. Oron-Gilad and P.A. Hancock

Introduction

In modern combat environments information superiority and the associated communication systems are paramount to operational success. Considerable efforts have and are being applied to the tasks of gathering, collating, synthesizing, and conveying this vital information. The same level of energy needs to be brought to bear in devising innovative and effective methods for communicating this information to the end user; the soldier. The modality in which the information is presented is critical in this process in that it differentially influences behavioral response, especially when tasks are either learned or subsequently performed in stressful circumstances. The multiple attentional resource theory (Wickens, 1980, 2002) has had a particularly strong influence on the professional practice of human factors, especially in interface development where it arguably remains the strongest behavioral heuristic for system design. In identifying the visual and auditory modality Wickens specified the two major avenues through which any individual usually assimilates sensory information. However, this does not exhaust all the input processing possibilities. The multiple resource model accounts mostly for situations where task demand is high (overload) and much less for situations where the demands are low that is the critical and often hidden issue of underload (and see Warm, 1984). Mismatch between task and environmental demand and the individual can induce stress and degrade performance. Dynamic models of stress and attention (Hancock and Warm, 1989) are based on the notion of adaptation to task demands. The Hancock and Warm model suggests that it is difficult to adapt to conditions of both under-load and over-load. According to this model, the individual is often able to compensate for dynamic variations in workload and environmental factors that moderate levels of stress. As such, when task demands are relatively low, the modality of presentation appears to be of somewhat less importance and operators are able to process information with less sensitivity to presentation modality. Alternatively, when task demands are high, the modality of presentation becomes critical and plays a significant role in operator effectiveness. In this chapter, we examine the effects of cross-modality of information presentation and retention from an applied perspective. Our focus is mainly on summarizing results from experiments conducted under the MURI-OPUS research program. Through examining data from various systematic studies, we aim to identify theoretically consistent patterns (and exceptions to these patterns) in order to direct attention to gaps in knowledge and theory. This bottom-up approach is vital for the development of future advances in theory and subsequent design practice for interface development in stressful conditions.

Organization of the Chapter

In our chapter’s first section we seek to describe briefly the scope of the problems we are addressing and the fundamental theoretical perspective which influences information presentation and processing under stress. The second section provides summaries of three specific studies that
have been conducted under the MURI-OPUS research grant. This section is sub-divided into studies of military-simulated task environments concerning the visual and auditory modalities. The concluding section summarizes our overall observations.

A Brief Overview of the Theoretical Background

It is important to separate the various types of information source that the operator should attend to under the stress of combat. These can be grossly categorized into three components: i) information related to the immediate task at hand, ii) information related to the goal or intent, i.e. the longer term purpose and; iii) information related to the operational environment itself. Within the military context, these three sources can be translated into the immediate operational tasks (e.g., shooting, friend-foe identification, attending to alarms, or navigating), commands and warnings (warnings to inform individuals of the potentially hazardous nature of the environment prior to the interaction/event rather than alert them of immediate danger or change in situation). Warnings also inform individuals of the compliance behaviors that they should follow in order to help protect them from bodily injury. Each one of these sources of information needs to be presented at all times and the possibility of overloading the operator particularly under stress is a most likely eventuality. Furthermore, as Hancock and Warm (1989) noted, tasks themselves induce stress. As such, it is important to examine how to distribute information assimilation in a way that is most effective and less stress sensitive.

Task demand is described as the number of activities imposed on an individual at any one time. Given the amount of information that might require to be processed at once and in high stress, high workload situations, such demands often threaten to overwhelm the operator. Confusion exists in the literature between the idea of workload and task demand. Thus, it is important to differentiate between the two. Hilburn and Jorna (2001) have suggested that task load represents the demand imposed by the task itself and workload reflects the subjective experience of that demand. Thus, task load is the demand placed on the individual while performing a task, while workload is an experience that the individual has while attempting to adapt to the external demands (see Parasuraman and Hancock, 2001). Many tasks impose a steady, uniform demand on the individual. Other tasks fluctuate in demand ranging from low, to medium, to high and back again in either a systematic or a random fashion. Historically, vigilance tasks, as performed in the laboratory, have been apparently of low task demand, as an abundance of studies seem to attest (Davies and Parasuraman, 1982; Warm, 1984). This perception concerning vigilance as underload is changing however (Warm, Dember and Hancock, 1996). Although there has been prolonged interest in tasks of prolonged low and prolonged high demand, relatively few studies examined workload transitions (and see Hancock, 1997). However, it has been asserted that demand transitions are especially prevalent in real world tasks (Huey and Wickens, 1993). For instance, soldiers have to wait in a low demand environment until they are jolted into combat (bombing, weapon firing, etc.). Such epithets characterize the modern military combat environment, as well as other professions such as law enforcement and medical emergency responders, etc. It is concerning these interactions between task demand profiles and information modality effects that the following experiments were conducted.

MURI-OPUS Findings on Modality and Stress

The MURI-OPUS (Multiple University Research Initiative–Operator Performance Under Stress) represented a program of study of stress effects on the modern battlefield. The following
experiments were performed under this program. Two different areas of investigation are discussed: information presentation and information processing within the auditory-visual modalities, and auditory and visual modality presentation differences in adaptive automation. One interesting initial question was whether we could use Wickens’ multiple resource model as a good heuristic to design various presentation formats for combat-related tasks. If we follow Wickens (1980) conception, then the communication of information in the visual field should be limited to the information from the battlefield imagery which cannot be conveyed by other means (i.e., the area itself, navigation within an area, video imagery derived from UAVs, shooting, or target detection tasks, etc.). To inhibit cross-modality interference, warnings and other communications should be conveyed through the auditory channel. The first study was related to such warning presentation and message retention under stress. Here we examined the effect of task load, presentation format and presentation-response compatibility on compliance to a warning in military related tasks. One of the interesting practical questions here concerned whether the superiority of a particular modality remained dominant even under stress or whether as stress increases the differences among presentation formats would dissolve?

i) Warning Presentation and Retention under Stress

The donning of military protective gear is invaluable in order to protect soldiers from severe injury and even death in combat. It is crucial that soldiers are warned when a hazardous situation arises and what action it is that they are to take to protect themselves. When communicating warnings specifically, one must consider that they are not presented in isolation but most often presented while the soldier is engaged in performing high-priority operational tasks and again, often under stress. Thus, warning messages must attract the soldiers’ attention, inform them of the hazard, and persuade them to comply while they are engaged in another primary task. The format in which a warning is presented is not standardized. Presentations of hazard warnings are commonly found in pictorial, written, or auditory formats. Consequently, the literature pertaining to format is unclear as to which type of presentation is most memorable, salient, or effective in generating the highest compliance under stressful conditions (cf. Standing, Conezio, and Haber, 1970; Paivo, 1971; Penney, 1975; Ells and Dewar, 1979).

![Pictorial-Color combination](image)

![Written-Color combination](image)

![Verbal-Color combination](image)

![Boots...Black](image)

![Narrated](image)

![Black](image)

![Narrated](image)

Figure 13.1 Example of the pictorial, written and verbal WCCOM (top) and the color stimulus (bottom) that elicited the key press response.
We developed the Warning Color-Combination (WCCOM) compliance task (Helmick-Rich et al., 2004, 2005), in which warnings were coded into various colors. The warning-color combinations consisted of one of ten warnings (e.g., gloves, helmet, mask, etc.) paired with one of ten colors (e.g., red, blue, yellow, etc.). The WCCOM consisted of both storage and processing; through memorization of the color associated with each warning. Warnings were presented in one of three ways, either pictorial, verbally, or in written form. An example of presentation of the WCCOM is shown in Figure 13.1. In this example the warning which shows a pair of boots, is paired with the color black. The number of association cues that the operator had to retrieve were manipulated to be two, four, or eight, depending upon the experimental trial.

Full details of the experimental set up and methodology have been given elsewhere (see Oron-Gilad and Hancock, in preparation). The WCCOM task and the primary operational task were presented simultaneously. Six experimental conditions were designed. These varied in the operational task that participants had to perform, which was either a shooting task or a navigation task, and also in the way participants had to respond to the warnings (response format) – key-press of an icon (pictorial) labeled keys, or on written labeled keys, or verbally. All three warning presentation formats were presented in each experimental condition. A trial consisted of a two-minute session of the operational task during which the color portion of the WCCOM was presented at random times. The participant’s task was to remember the correct pairing of the warning and color combinations and respond to the cue according to the experimental condition. For example, in the written response condition participants responded to the cue by pressing the appropriately labeled key with their right hand.

In order to examine the summary compliance to the WCCOM task, collapsed data from all six experimental conditions were obtained. Significant main effects for response format, presentation format, and task demand were found. There was also a significant interaction between response and presentation, response and task demand, and presentation and task demand, as well as a three-way interaction between response, presentation, and task demand. Participants were significantly more likely to comply when the response format was verbal ($M = 0.789, SD = 0.028$), than either in pictorial ($M = 0.679, SD = 0.026$), or in written form ($M = 0.589, SD = 0.023$). Thus, verbal response proved to be the superior response mode. However, for presentation format, participants were significantly more likely to comply when the presentation format was either written ($M = 0.745, SD = 0.017$) or pictorial ($M = 0.716, SD = 0.023$) as compared with verbal presentation ($M = 0.595, SD = 0.012$). No significant differences were found between the written and pictorial presentation format. Thus, both written and pictorial presentation format were superior to verbal warning presentations. As expected, participants were significantly more likely to comply at level two ($M = 0.826, SD = 0.012$) than at level four ($M = 0.711, SD = 0.019$) or eight ($M = 0.52, SD = 0.017$). As the level of task demand in WCCOM increased compliance scores decreased.

With regard to the presentation format by response format interaction, shown in Figure 13.2, the verbal presentation format and response format resulted in higher compliance than when the presentation was verbal and the response format was either written or pictorial. For the pictorial presentation format the verbal response format was best, followed by the pictorial response format and then the written response format. No differences were found when the warning presentation was written. Hence, the written presentation format was not as sensitive as the other two formats to variations in response mode, while the verbal presentation format was the most sensitive of the three.

Analyses also revealed a difference between presentation formats for a fixed level of task demand, as shown in Figure 13.3. Written and pictorial warning presentations yielded greater compliance than verbal presentation. Furthermore, for the written and pictorial presentation formats the difference in task demand between levels two and four was not significant.
With regard to response time, participants responded significantly faster at levels of two ($M = 2,136.5 \text{ m}, SD = 82.9$) and four ($M = 2,522.9 \text{ m}, SD = 88.1$) than at level eight ($M = 2,776.5 \text{ m}, SD = 76.87$). With regard to response times and presentation format interaction, there were no significant differences between written and pictorial response conditions. However, for the written response format, a significant difference in response time was found between verbal ($M = 2,297.2 \text{ m}, SD = 116.1$) and written format ($M = 2,673.2 \text{ m}, SD = 132.7$). This implies that in the verbal presentation, participants responded faster and that this quicker response perhaps affected the accuracy of their response.

Our first hypothesis was that participants would have a higher rate of compliance when warnings were presented in verbal compared with written and pictorial formats. In this respect, auditory modes of communication have been generally found to be superior to written information (see Penney, 1975; Watkins and Watkins, 1980). In addition, greater behavioral compliance has often been found when warnings are presented in a verbal format (Jaynes and Boles, 1990; Wogalter and Young, 1991). We expected that our results would follow the pattern that had been previously observed. However, as is evident from our results, none of our experimental conditions yielded the verbal format as the superior mode of warning presentation. Compliance across presentation formats did not differ when the response mode was verbal.

Most previous warning studies have been based on single task performance. That is solely upon processing the warning itself in isolation. Recall is dependent on the task that fills the interval of time between presentation and retention (Broadbent, Vines and Broadbent, 1978; Klee and Gardeiner, 1976). If the interval between presentation and recall is silent or if non-verbal distractions are present, auditory information is recalled at a greater rate than visual information. Distracters, of both a verbal and a visual form reduce the rate of recall on visually presented words. Our second hypothesis was that verbal warning would be the superior mode of warning presentation since the operational task in this study was inherently visual/spatial in nature. Contrary to our predictions, we found that auditory warnings were the inferior mode of presentation across all conditions. Verbal
warning presentations did not result in superior response. Furthermore, the operational task did not degrade response on the visual warning presentations (pictorial and written warnings) more than the verbal warnings. In addition, the format of warning presentation did not affect performance on the primary shooting or navigation tasks.

The written and pictorial warnings presentation format proved to be the best. Yet, the analyses for response format indicated that participants were significantly more likely to comply when the response format was verbal compared with pictorial or written. Therefore, it is vital that the combination of presentation and response format should be considered, especially when high-stress, high workload, conditions can be anticipated. Few studies have examined the combination of presentation and response mode (Gardiner et al., 1977). Our results emphasize the importance of considering both the presentation and response format interaction in the design of systems. These findings are important for designing soldier warnings for the use in combat. However, warnings are only one dimension of the soldier’s response requirements, in the following section, we focus on the issue of ever-increasing task demand.

**ii) Testing Response Effectiveness under Increasing Task Demand**

Battlefield conditions can act to incapacitate some soldiers, but at the same time the very same conditions have no effect on the performance of others (Mareth, 1982). In combat, failure to fire one’s weapon has been highlighted as just one type of critical performance decrement produced by stress (Marshall, 1947). This finding has been demonstrated also in simulated battlefield conditions (Villoido and Tarno, 1984). Wickens and Flach (1988) predicted that performance decrements in combat produced by stress result because military decisions involve a wide spectrum of information-processing components, and stress impairs each of these different information-processing stages (see also Hancock, 1986; Wickens, 1996). In seeking to test such propositions, Scribner and Harper (2001) imposed secondary task demands on soldiers during a primary shooting task. They were instructed to maintain performance of an enemy-friendly-discrimination shooting task while simultaneously performing a secondary mental arithmetic task in one condition and a memory
task in another. Results showed stable target discrimination accuracy and shooting performance of the soldiers across single- and dual-task conditions but performance decreased for both mental arithmetic and memory tasks when performed during shooting versus when they were performed alone. These findings indicate the high attentional demands involved in identifying and firing upon enemy targets and also provides evidence of limited information-processing capacity. The implications of this study are that use of attentional resources of soldiers may be at or near their full capacity during battle and provides insight as to how real-world friendly-fire incidents might occur (Scribner and Harper, 2001).

Our study was designed to examine the ability of the soldier to perform friend-foe target discrimination and maintain shooting accuracy, with varying levels of concomitant cognitive demand. The level of accompanying cognitive load was manipulated using a working memory recall task. To perform this experiment, we used the Small Arms Simulator Testbed (SASTII), which is a high fidelity simulator with real weapon test facilities. SAST II is a single user testbed designed to precisely measure and record the performance parameters of both user and weapon in a controlled environment (see Figure 13.4).

Our detailed description of the experimental set up and the precise experimental methods are given elsewhere (Burke, 2007). The primary operational task, was friend-foe discrimination. It consisted of two different types of stimuli/targets, which are shown in Figure 13.6. The non-target was the individual figure holding an M-16 rifle, while the target was the figure holding an AK-47 rifle; both stimuli/targets being superimposed over a common silhouette. The discrimination was based upon the weapon alone. Three of these armed figures were presented simultaneously, one of which was a target, and two of which were non-targets. This occurred on 50 per cent of the trials while on the other 50 per cent of the trials only non-targets were presented. The spatial location of each stimulus (targets/non-targets) in relation to the background silhouettes was randomly generated to prevent the predictability of the appearance of a target. Each stimulus was presented for a total of three seconds.

Figure 13.4 The SAST II facility including the weapon and the visual display
The memory recall task consisted of the headphone presentation of cue words which simulated unit battalion call numbers and locations. This task was designed to provide varying demands on working memory. The rationale for presenting the secondary task in an auditory mode was to avoid the structural interference with the primary shooting task (in the visual-motor modality), which we talked of earlier in this chapter in relation to warnings. The stimuli included the presentation of the battalion numbers (e.g., 21, 23, etc.) and associated words which simulated the location of the battalion (e.g., north, south, east, and west). There were three secondary task conditions which varied based on working memory task demand of zero, two, or four item combinations. During the practice routine in each condition, the participant learned two or four combinations of the cue and association words. During execution of the primary task, participants were presented with secondary task cues. The participants responded to the secondary task stimuli by using three buttons mounted to the weapon. One button was pressed in response to the presentation of a valid cue word and true association word, the second button was pressed in response to the presentation of a valid cue word and false association word, and the third button was pressed in response to an invalid cue word.

![Figure 13.5 Screenshot from the SAST II displaying the two types of stimuli/targets superimposed on the silhouette stimuli.](image)

*Note: At the right corner we have added the two rifles (this did not appear in the original image).*

Each session consisted of administration of the baseline subjective measures, training and practice on both the primary and secondary tasks, and of the presentation of three conditions of the secondary task. The respective conditions included four blocks of 16 trials each. Each trial consisted of the simultaneous presentation of one of two types of target stimuli (target, or non-target) and in half of the trials, the presentation of the secondary task. The results showed a distinctive link
between working memory demand in the secondary memory recall task and performance on the primary and the secondary tasks. These findings are shown in Figures 13.6 and 13.7.

The use of a high fidelity simulator using a real weapon, adds to the physical and the hand-eye coordination demands of the task. Contrary to our expectations, when the task was most demanding (both primary and secondary tasks were present in the highest working memory demand condition), participants were more accurate on the shooting task when the secondary task was present than when there was no secondary task. One possible explanation for these results is that there was a combination of practice and fatigue effects. Also, because participants were significantly less accurate on the recognition task in the same high demand condition, it is possible that participants stopped attending to the secondary task and focused all of their attention on the primary, more salient shooting task. This is consistent with the Hancock and Warm (1989) model indicating that participants were no longer in their comfort zone and were unable to maintain an optimal level of performance on both tasks. The results from this study can provide evidence of performance-workload association, with performance of the primary task improving while the secondary task performance is decreasing (and see Hancock, 1997). Further investigations of this important relationship remain a necessity. Since this type of dual task demand is common in combat, further evaluation of this counter-intuitive finding is both practically and theoretically important. Let us suppose, however, that subsequent research confirms this important pattern of stress-related decrement. What could we do about it? One avenue of resolution is to use technology to regulate these extreme demands and provide an augmented support system to help the soldier. It is to such a proposition that we now turn.

Figure 13.6 Interaction between the presence of a target and working memory demand on the secondary task
iii) Multimodality in Adaptive Automation

The specific purpose of this study was to examine how adaptive allocation should adjust to the individual operators’ personal characteristics in order to improve performance, avoid errors, and enhance safety (and see Hancock and Scallen, 1998). We hypothesized that the personal attribute of attentional control (AC; Derryberry and Reed, 2002) contributes to the level of performance for target detection tasks for different levels of difficulty as well as preferences for different levels of automation. A temporal discrimination task was chosen because stimulus presentation time is a characteristic that can be manipulated in both auditory and visual displays. The visual and auditory tasks for this study were specifically chosen because they have been previously psychophysically equated (Szalma et al., 2004). However, previous studies have shown that auditory signal detection has superiority over visual target detection in terms of speed, accuracy, and resistance to the vigilance decrement (Davies and Parasuraman, 1982; Warm and Jerison, 1984; Szalma et al., 2004). The reason may be the coupling differences between the modalities (Hatfield and Loeb, 1968); as auditory processing is omni-directional, whereas visual processing involves selective attention to scan for information (Wickens and Hollands, 2000). Thus, auditory perception and auditory stimuli appear to be more closely coupled than visual stimuli (Hatfield and Loeb, 1968). There is looser coupling between visual perception and visual stimuli, however, as the observer can avert his or her eyes and turn his head away from the stimulus, impairing performance. This can be somewhat overcome by requiring the observer to maintain a fixed posture facing the display. However, this requirement can increase workload and effort. Literature, however, has not shown a modality effect for perceived mental workload in vigilance tasks (Warm, Dember and Hancock, 1996; Szalma et al., 2004). The result is commonly a preference for auditory alerts over visual alerts (Simpson and Williams, 1980; Sorkin, 1987).

The experimental set up and method is described in detail elsewhere (Oron-Gilad et al., in preparation). Each participant undertook the role of the supervisor of a machine decision-aid which had 90 per cent accuracy in correctly identifying targets and non-targets in a series of perceptual discriminations. Participants were given the choice of four different levels of automation (LOAs) in which to complete the perceptual tasks, based upon both their preferences for operator-machine interaction and their needs in order to assure accurate target identification. Participants identified

![Figure 13.7 The effects of working memory demands (secondary task) on shooting accuracy](image)
Participants were able to change the level of automation (LOA) according to their preference throughout the course of the task. There were four LOAs available to the participants: “1 Full Operator”, “2 Mostly Operator”, “Equal Sharing”, and “4 Mostly Machine”. In LOA “1 Full Operator” work was conducted solely by the operator without the machine aid. LOAs 2, 3, and 4 provided the machine decision aid. In LOA 2, the operator responded first and then received a machine suggestion. In LOA 3, and intermittent level of automation was used. Here for the visual stimuli the display screen was divided into two equal parts (left and right) and the task was equally shared between the machine and the operator. For the auditory stimuli the load was divided by the source of the signal, signals to the left earphone or to the right one, respectively. Thus, the operator responded first to all stimuli in the left field of the display and then received a machine suggestion, while in the right field of the display, the machine responded first and the operator could veto the machine decision. In LOA 4, the machine responded first and then the operator had the option to input her own response if it differed from the machine response. Participant’s preferences for the different LOAs were assessed by examining the percentage of time that participants chose to be in each one of the LOAs, relative to the entire duration of the task.

In the visual-only target detection task, participants differentiated between black vertical lines (32 mm in height) presented at either a short (125 m) or long (250 m) period of time upon a white background. Targets were lines appearing for the shorter period of time, while non-targets were lines appearing for the longer period of time. Target and non-targets were presented in random orders. During the visual-only task, the auditory task was fully executed by the computer, and the participant was instructed to ignore the auditory task.

In the auditory-only target detection task, participants distinguished between sounds (400 Hz C4 triangle waveform) that were either short (200 m) or long (250 m) in presentation time. During the auditory-only task, the visual detection task was fully executed by the computer, and the participant was asked to ignore the visual task. In the audio-visual combined task, both the audio and visual target detection tasks were presented simultaneously. The participant and machine were responsible for performing none, one, or both tasks according to the participant’s chosen LOA and method of operating the LOA. As in the visual-only and auditory-only tasks, both lines and tones were presented in random orders, but did not overlap temporally or spatially such that only one stimulus was presented at a time.

Four separate conditions were analyzed: visual-only and auditory-only, both of which were the single-task conditions; and the visual portion of the audiovisual-combined task (referred to as “visual-combined”) and the auditory portion of the audiovisual combined task (referred to as “auditory-combined”), both of which were the dual-task conditions. Thus, two load conditions were assessed; single-task conditions encompass the visual-only and visual-combined tasks, and dual-task conditions encompass the visual-combined and auditory-combined tasks (i.e., the entire audiovisual combined task). Furthermore, we analyzed the responses of the operator in relation to the decision aid (with and without machine aid). Hence there were two levels of responses: operator-alone and machine-aided. Operator-alone involved the participants’ responses independent of the machine aid, while machine-aided involved the participants’ final responses after using the machine decision-aid.

**Signal detection performance—d’ (sensitivity)** The signal detection theory (SDT) measure of sensitivity (d’), represents the participant’s ability to correctly identify the stimuli as targets or non-targets. It is one of the most commonly used measures of sensitivity in detection theory (Green and Swets, 1966). Sensitivity improves as d’ increases. Low sensitivity is characterized by
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Figure 13.8 Mean β by AC group and modality

A 2 (Modality) x 2 (Load) x 2 (without-with Machine Aid) within-participants repeated measured ANOVA was conducted, with AC (attentional control) as the between-subjects variable. There was a main effect for modality, such that the d’ in the auditory task ($M = 2.163, SD = 0.572$) was significantly higher than the d’ for the visual task ($M = 1.143, SD = 0.552$). Comparisons between tasks revealed that there was a significant interaction in the operator-alone d’ between the visual-only and auditory-only tasks, such that the operator’s d’ of the auditory-only task was higher than the operator’s d’ of the visual-only task ($M = 2.036, SD = 0.991$, and $M = 0.902, SD = 0.779$, respectively). In the dual-task condition, the operator-alone d’ of the auditory-combined task was significantly higher than that of the visual-combined task ($M = 2.193, SD = 0.898$, and $M = 1.169, SD = 0.735$, respectively). There was a main effect for use of the machine’s decision-aid, as it significantly improved d’ across tasks and modality. For the visual modality, there was a significant effect for use of the machine decision aid, such that the operator’s d’ was significantly higher when the machine was used ($M = 1.251, SD = 0.589$) than the operator’s d’ without the machine aid ($M = 1.036, SD = 0.659$). Across the auditory modality, however, there was no significant improvement for using the machine aid.

Response bias—β (Beta)  β refers to the operator’s response bias in identifying stimuli as targets or non-targets. Macmillian and Creelman (2005), refer to it as a particular favoritism towards a response type. The value of β ranges from 0 to greater than 1. Values in which $β > 1$ indicate that the individual tends to classify more stimuli as non-targets (the miss rate exceeds the false alarm rate), resulting in more misses than hits. Conversely, values in which $β < 1$ indicate that the individual tends to classify more stimuli as targets (the false alarm rate exceeds the miss rate), thereby resulting in more false alarms than hits.

Figure 13.8 Mean β by AC group and modality
A 2 (Modality) x 2 (Load) x 2 (Machine Aid) within-subjects repeated measures ANOVA was conducted, with AC as a between-subjects variable. There was a significant main effect for AC, such that participants with high AC had a significantly higher mean β than those with low AC ($M = 1.286, SD = 0.491$, and $M = 0.920, SD = 0.229$, respectively). There was no significant difference in machine-aided β between those with low and high AC ($p > 0.05$). There was also significant interaction between AC and modality revealed that in the auditory modality, those with high AC had a significantly higher mean β than those with low AC ($M = 1.570, SD = 0.749$, and $M = 0.940, SD = 0.386$, respectively). However, there was no such difference within the visual modality. See Figure 13.9 for a depiction of the mean β in each modality grouped by AC.

Subjective workload ratings Workload measurements were taken three times over the course of the present experiment: after the visual only condition, after the auditory condition and after the combined condition. A 3-way (Task) within-participants repeated measures ANOVA was used with AC as a between participants variable. *A priori* tests of simple effects found that the high AC group reported significantly higher overall workload in the visual-only task than the low AC group ($M = 51.37, SD = 11.948$, and $M = 41.95, SD = 12.909$, respectively). Although not significant, there was a trend for the high AC group to report higher overall workload in the auditory-only task ($M = 46.97, SD = 7.710$, and $M = 44.07, SD = 11.597$, respectively) and in the combined task ($M = 53.94, SD = 48.19, SD = 13.858$, and $M = 48.19, SD = 13.180$, respectively). Figure 13.10 provides a graph representing the overall workload reports in each task by AC group.

![Overall Workload](image)

**Figure 13.9 Mean overall workload rating in each task for low and high AC groups**

Statistically, LOAs 1, 2, and 4 were equally preferred across tasks and levels of AC. Thus, participants from both AC groups found them all to be equally usable and useful. Participants equally preferred various amounts of assistance from the machine, ranging from no assistance (i.e., LOA 1), to supervising the machine as it made all of the discriminations and intervening only when a machine decision error was suspected (i.e., LOA 4). LOA 2 was also frequently chosen;
participants may have preferred completing the tasks at this level as they received performance feedback from the aid, even if 90 per cent accurate. Participants of both the low and high AC groups spent minimal time at LOA 3 of equal sharing, when given the choice of the four different LOAs. LOA 3 required even less operator responsibility than LOAs 1 and 2, both of which were more preferred than LOA 3. It was also less popular than LOA 4, in which minimal operator responsibility was required as a supervisory role was assumed. This suggests that LOA 3 may have been least preferred for reasons other than workload and responsibility. One possible reason may be that operators did not wish to filter stimuli, such that they were required to attend to certain stimuli (i.e., left fields) while ignore others of equal perceptual intensity and modality type (i.e., right fields).

No significant main AC effects were found in terms of LOA preference, however, there were trends for those with low AC to spend more time at LOA 4 than those with high AC, collapsed across tasks. Also, those with high AC spent more time at LOA 1 than did those with low AC. Thus, lower AC levels were conducive to the preference for more automation and higher AC levels were conducive to inclinations towards less automation. This supports the prediction that AC is inversely proportional to automation use. However, the preference for LOA 2 was roughly equivalent for both low and high AC groups; indicating that both types of individuals liked using LOA 2, a moderately-low amount of automation.

Although it was not subject to an organized hypotheses, we did observe that, participants were generally more sensitive to auditory stimuli than visual stimuli, as evidenced by the higher d’ for the auditory tasks. Despite prior psychophysical equation of these two discrimination types by Szalma et al. (2004), the auditory discriminations proved easier than the visual discriminations. This modality effect in d’ also replicated the results by Szalma et al. (2004). Additionally, this modality d’ difference persisted in individuals with both low and high AC. Significantly higher reports among the high AC participants occurred in the report of their overall workload rating in the visual-only task. The reasons for this may include the tendency for those with high AC to spend more time in LOA 1 than those with low AC. Conversely, the low AC participants spent more time in LOA 4 overall. Another possible explanation for this is that the high AC participants may have been attending to the nature of the task more so than the low AC participants. Thus, the high AC group may have been more engaged in the tasks, and therefore more prone to noticing their own feelings of workload. It is also important to note that although three of the available LOAs (1, 2, and 4) were equally preferred, and task performance was variable (neither floor effects nor ceiling effects were observed), operators may not have necessarily judged their need for various LOAs accurately. As noted previously by Morrison and Rouse (1986), there can be a discrepancy between need and preference. This experiment was aimed toward determining preference in LOA rather than determining the need for automation. And thus the operator’s ability to assess the need for automation may have not been fully realized.

**Discussion**

In combat conditions soldiers have to perform any number of mission critical tasks. Many of these are either combined or overlap so that the soldier is not performing one thing, but its really accomplishing many things at any one time. Even if apparently engaged in only one formal task, the soldier still needs to monitor the surrounding environment, be aware of his fellow soldiers and the possibility of attack, as well as remaining prepared to respond to ancillary demands such as orders from a commander. Inherently, these multiple task situations, in uncertain conditions are, in and of themselves stressful. But it is not just these high levels of cognitive demands that make the soldiers’ task so testing. It is the intrinsic threat of death and injury to both self and
comrades that add immeasurably to the already heavy burden. Performance responses that do well in relatively neutral conditions can be seriously impeded by the fog of war and the threat of attack. In general, the human factors community has done extensive and informative work on performance in high cognitive load circumstances. There is a library of useful data and several strong design recommendations as to how to deal with such circumstances. However, these data do not derive from the context of the high-stress, combat environment. Initially, it might be suspected that stress exerts a uniform, linear and degrading effect on performance and acts like a simple negative gain function in reducing response capacity. But this simply is not so. Stress exerts evident non-linear effects where individuals can even improve in their performance as stress continuous to grow. What we propose here is that such stress effects are non-linear in respect to sensory perception, decision-making and response capacities. Stress interacts with both task and context to produce a complex patterning of performance outcome. Although this patterning is complex it is not random. Performance under stress is often sub optimal, i.e., satisfied, driven by the demands of the task, the context, and the source of intention (passive, reactive to stimuli from the environment, or/ and to commands, versus active, initiative, while engaged in an activity). It is very difficult to predict or measure satisfied performance which reinforces why it may also be difficult to identify consistent patterns in performance under stress, in real life. Laboratory studies, on the contrary, are often driven by optimized performance, therefore reservations on the ability to generate clear cut design guidelines for multimodal displays under stress based on laboratory studies can be made. Such concerns have always been part of the human factors scientific community concerns and were initially raised by Chapanis (1967) 40 years ago. Our program has made some attempts to approach this problem by conducting a continuum of studies; from controlled laboratory studies, through higher fidelity simulator studies, to field studies where not all parameters can be controlled as shown in Table 13.1. Unfortunately, as the fidelity increases one is forced to reduce the demands of the secondary task. Then, from a scientific perspective, the comparison among the experimental results most often becomes impossible, as the comprehensive information derived from various levels of fidelity never reaches the requested quality of experimental design of planned controlled experimental methods required for scientific publications.

Table 13.1 Levels of fidelity used as MURI-OPUS studies

<table>
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<tr>
<th>Level of Fidelity</th>
<th>Tool and Environments</th>
<th>Specific studies of interest</th>
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<tr>
<td>Controlled Laboratory Studies</td>
<td>Basic Stimuli</td>
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<td></td>
<td>PC based Simulations, e.g.,</td>
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<td>Ghosts recon®; Airbook®</td>
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<td>High fidelity simulators and Mixed reality environments</td>
<td>Small arms simulation testbed</td>
<td>SASTII</td>
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<td>UCF-IST Mr Mout urban terrain</td>
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<td></td>
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<td>mixed environment</td>
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<tr>
<td>Field studies</td>
<td>Training field with police officers</td>
<td>With military soldiers</td>
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Wickens’ “Box model” remains the most common design heuristic in our field. Its popularity and success lies in its simplicity and the fact that it makes sense (and see Hancock, Oron-Gilad, and Szalma, 2007 for a broader discussion of this matter). However, Wickens himself commented
recently (Wickens, 2007) on the ability to predict multitask performance. He highlighted six theoretical and methodological issues of applied attention research. We wish here to focus the latter part of our discussion on three of these issues, with regard to the studies presented in this chapter as well as other experiments in our program.

The first issue raised by Wickens was “Total demands versus resource similarity”. He emphasizes the independent contribution of three components to predicting dual-task interference: a) the total demand for resources, b) the similarity between the two tasks, and c) the resource allocation policy. All three are of concern for the dismounted soldier in combat. Study i) was an example of display-response compatibility. The consistent findings of this study, summarized in Figure 13.11, are somewhat contradictory to the box-cube model. Compliance with the WCCOM Task was significantly higher when presentation format was visual rather than verbal. This pattern could be an artifact of the experimental procedure. However, as we have tested our hypotheses on six different conditions and results were consistent across all six, it is more likely that his pattern can be attributed to the relatively high level of stress/workload imposed by the task, to the retention component of the WCCOM, or to a combination of both.

Study ii) provided a scenario for processing efficiency in a military context and in a high fidelity simulator. Here the total demands for resource was the dominant factor. Evident changes in performance were found for both the primary and the secondary task as the global demands of the task changed, indicating that it is not the case of one task dominating the other. Contrary to our hypothesis, when the task was most demanding (both primary and secondary tasks were present in the highest working memory demand condition), participants’ were more accurate on the shooting task when the secondary was present than when there was no secondary task. It is possible that participants stopped attending to the secondary task and focused all of their attention on the primary, more salient shooting task. This would be consistent with the Hancock and Warm (1989) model indicating that participants were no longer in their comfort zone and were unable to maintain an optimal level of performance on both tasks. Furthermore, such patterns could also be explained using Hockey’s (1986) compensatory control model. Specifically, it may be that as attentional demand increased participants regulated their effort downward on the secondary task to free resources required to successfully engage the primary task. Unlike study i) where no effect on the primary task was found regardless of presentation format for the WCCOM task, in study ii) an association between primary and secondary task performance appeared. Furthermore, memory demand for the secondary task was lower in study ii) than in study i) (up to 4 items versus up to 8 items). This implying perhaps that the association pattern found in study ii) could be attributed to the higher fidelity of the primary shooting task which included the physical and hand-eye coordination demands of the shooting task, as well as the physical feedback from the weapon.

Study (iii) examined the use of automation on two tasks (audio and visual) with similar structure and psychophysically equated stimuli. For both tasks, what differentiated a target from a non-target was a temporal difference in presentation time. Furthermore, auditory and visual stimuli were never presented at the same time; there was always only one stimuli present at a time. The results showed clear performance differences between the auditory and visual modalities. Participants were generally more sensitive to auditory stimuli than visual stimuli, the machine decision-aid improved the operators’ d’ in the visual modality, indicating that use of the automation was helpful and effective as intended. However, it did not increase d’ in the auditory modality, likely due to the fact that the auditory d’ was already high and perhaps approached a ceiling effect in which additional aid was no longer useful to the operator. Thus, there may have been less need for automation in the auditory tasks. The visual tasks, which were more challenging, influenced participants to implore the machine for more assistance, as is to be expected in light of automation’s intention to relieve operator demand for tasks that are difficult in terms of sensory thresholds. Difference in
response bias $\beta$ was driven by modality effects, as well as individuals’ AC level. $\beta$ was only higher for the high AC group in the auditory modality. High AC participants were more likely to report identifying non-targets in the auditory tasks than they were in the visual task. There were no such differences in modality for the low AC group. The use of the machine aid moderated this effect on the high AC group. This study was an initial attempt to show that modality effects can interact with other factors, such as personality traits and that this interaction can have significant design implications.

Summary

During combat soldiers are busy. They have no time or inclination to answer the probing questions of concerned behavioral scientists. Nor would we do them a good service by insisting that they did so. Rather, it is we the scientists who have to generate innovative and non intrusive strategies to get this information so that the next engagement is more successful than the last. This is not an easy endeavor. We often use models, simulations, and experiments to gain crucial insights but however informative these studies prove to be, they are not actual combat. In contrast with the chaos of conflict, such laboratory and field studies we conduct tend to be both constrained and controlled in their nature. The uncontrolled interactions that derive from the uncertainty and disorganized nature of combat can be the very influences which make the context, the all-important, controlling factor. Thus, to predict response under real-world extremes and most importantly to design systems, technologies and procedures to permit the soldiers to do their job, we have to wrestle with the conundrum of context. Notwithstanding these previous observations our bedrock knowledge must be grounded in theory and informed by empirical observation. What we have presented here are a series of crucial experiments that form a foundation of both insight and design recommendation. We derived understanding proposes while the real world disposes. By identifying crucial ways in which high-demand, high stress conditions act in context to affect known input-output relationships we can approach a deeper understanding of the almost unique circumstances of military conflict and can seek to serve those who put themselves in harms way of others.
References


Zijlstra, F.R.H. and Van Doorn, L. (1985), *The Construction of a Scale to Measure Perceived Effort* (Delft, the Netherlands; Dept. of Philosophy and Social Sciences, Delft University of Technology).
Chapter 14

Stress Exposure Training: An Event-Based Approach

James E. Driskell, Eduardo Salas, Joan H. Johnston and Terry N. Wollert

It is important to define, at least in a broad sense, what we mean when we use the term stress. According to Driskell, Salas and Johnston (2006), stress is defined as a high demand, high threat situation that disrupts performance. It is time-limited, events occur suddenly and often unexpectedly, quick and effective task performance is critical, and consequences of poor performance are immediate and often catastrophic. Thus, at a very general level, we use the term stress to refer to high-demand, high-risk task conditions. It is also important to note that stress is a multi-dimensional construct, and this general term may be used to refer to any number of specific stressors or demands that may be present in a given task setting, including stressors such as noise, threat, time pressure, task load, coordination requirements, fatigue, and other task and environmental demands. In brief, we equate stress with high demand and high risk – a stressful task situation is one that imposes high demands and high risks on the operator. For greater precision, we adopt the definition of stress proposed by Salas, Driskell and Hughes (1996): Stress is a process whereby environmental demands evoke an appraisal process in which perceived demand exceeds resources, and that results in undesirable physiological, psychological, behavioral, or social outcomes.

The purpose of this chapter is to discuss stress training – training that is designed to counter stress effects. Despite the general tendency for authors to note the lack of progress in any given field, we feel that research on stress training has been quite promising. In fact, we know a great deal more about stress training than we did a decade ago. There have been a number of valuable books (Cannon-Driskell and Salas, 1996; Bowers and Salas, 1998), book chapters (Johnston and Cannon-Bowers, 1996; Keinan and Friedland, 1996), technical reports (Staal, 2004; Helmus and Glenn, 2005; Kavanagh, 2005), and research articles (Saunders et al., 1996; Morris, Hancock and Shirkey, 2004) that represent a considerable advance over previous conceptualizations of stress training.

One factor that underlies the current renaissance in stress research is the enhanced military requirement that reflects the realities of the high-technology battlefield. However, the current military emphasis on performance under stress has not always been the case, and it is somewhat paradoxical that although military combat operations epitomize a high-demand environment, the military has been slow in embracing the stress training concept. We believe that there are several reasons for this hesitance. The first problem is the ambiguity of the stress construct itself. Driskell, Johnston and Salas (2001) conducted a database search of the term “stress management” and uncovered over 1,900 articles in PsychINFO related to stress management published since 1990. These articles covered topics as diverse as aerobic conditioning, biofeedback, yoga, play therapy, hypnosis, diet, and Transcendental Meditation. It seems that the terms stress and stress training have been used so broadly as to mean almost anything. It is no wonder that the military officer or program manager may be hesitant to slog through this mixed bag of psychological techniques.

Second, stress research had its genesis in medical/biological research and still retains many of the trappings of a psychoanalytic paradigm, with an emphasis on abnormal behavior and coping
mechanisms. The consequence of this approach is that early stress research led to a preoccupation with illness and with those individuals who are overcome with chronic stress. As Salas, Driskell and Hughes (1996) have noted, the study of illness is only marginally related to the understanding of stress and performance in a normal population. Therefore, stress research has historically emphasized disordered behavior and coping behaviors, and almost ignored the effects of stress on performance, effectiveness, and productivity in real-world environments. Accordingly, many military managers equate the term stress with illness or psychological deficiency and fail to see how it relates to their day-to-day concerns. On the other hand, if stress is discussed in terms of task demands and efforts to maintain performance in operational environments, then the military manager will often immediately recognize this as a critical requirement.

A third problem is that, frankly, stress training is hard to do in a military environment. It is difficult enough, aboard a ship or in a company of soldiers, to accomplish the basic training that is required on a day-to-day basis. In other words, it is a difficult enough task to ensure that personnel are trained to “classroom” standards, so that they can perform basic tasks proficiently. It is another, and more difficult, thing altogether to require that they can perform those tasks under the demands of high time pressure, noise, and smoke, with multiple other tasks demanding attention, and with sudden and unexpected events impinging on the operator. Granted, this is “real-life” in a combat environment, but in many cases it is just too difficult to deal with this, and easier to conduct training so that at least basic skills are learned in a standard operating environment.

Nevertheless, ignoring the requirement for specialized stress training in a military environment would be a grave error. Consider the demands of the modern electronic battlefield. The network-centric warfare environment requires dispersed, distributed forces to communicate, collaborate, and achieve joint outcomes across services, agencies, allies, and coalition partners. At the core of this concept is the networked team: A network of dispersed, decentralized, semi-autonomous, often ad hoc teams that must perform proficiently to achieve desired outcomes both within the team itself and in collaboration with other coalition teams. This performance environment is characterized by a high pace of operations, high task load, and the requirement to operate with multiple coalition partners in an isolated networked environment making high-stakes decisions with little feedback of outcomes. Clearly, this places a high demand on these military personnel, and military experts have noted the severe challenges that arise from these operational requirements. In fact, there are very few settings outside of the military that impose such a high demand on personnel and in which there is such a substantial potential for risk, harm, or error.

Moreover, failure to prepare for these conditions can exact a high price. Stress may result in physiological changes such as increased heartbeat, labored breathing, and trembling (Rachman, 1983); emotional reactions such as fear, anxiety, frustration (Driskell and Salas, 1996); cognitive effects such as narrowed attention (Combs and Taylor, 1952; Easterbrook, 1959), decreased search behavior (Streufert and Streufert, 1981), longer reaction time to peripheral cues and decreased vigilance (Wachtel, 1968); and social effects such as a loss of team perspective (Driskell, Salas and Johnston, 1999) and decrease in prosocial behaviors such as helping (Mathews and Canon, 1975). Helmus and Glenn (2005) note that, during intense combat operations, rates of stress casualties may nearly equal the number of physical causalties in some units.

Stress Training

In order to organize the following discussion, we wish to present three straightforward and fairly simple propositions. First, there is a significant difference in what it takes to perform a task such as troubleshooting or bomb disposal in a benign environment and what it takes to perform that task in a hazardous or high-demand environment such as the military combat setting. This difference
is the *contextual environment*—the organizational, environmental, social, and task demands that are imposed upon the operator. Consideration of the contextual factors that impinge on task performance is critical to maintaining effective performance in real-world settings.

Second, the distinction between *training* and *stress training* is the extent to which the training attends to these contextual factors. The primary goal of training is skill acquisition and retention. Most training takes place under conditions designed to maximize learning, such as a classroom setting, under predictable and uniform conditions. Thus, the primary purpose of *training* is to ensure the acquisition of required knowledge, skills, and abilities. However, many tasks must be performed in the real world in conditions quite unlike those encountered in the training classroom. For example, high stress environments include specific task conditions (such as time pressure) and require specific responses (such as the flexibility to adapt to novel events) that differ from those found in the normal task environment. Thus, the primary purpose of *stress training* is to prepare the individual to maintain effective performance in a high stress operational environment.

Third, the primary objectives of stress training are to provide pre-exposure to the high-demand conditions that may be faced by the trainee in the operational environment and provide the specialized skills training required to maintain effective performance under stress conditions. Kavanagh (2005) has noted that stress training can moderate the effects of stress on military performance and that attention should focus on “developing training that realistically represents the environment that the soldier will be expected to perform, is targeted on particular skills (and) builds the soldier’s ability to adapt” (p. xiv).

Driskell and Johnston (1998) have developed an integrated stress training approach, termed stress exposure training (SET), that provides a structure for designing, developing, and implementing stress training (see also Johnston and Cannon-Bowers, 1996; Saunders et al., 1996). According to Driskell and Johnston, an integrated stress training approach must achieve three objectives:

- *Enhance familiarity with the task environment*. Training must provide trainees with basic information on stress, stress symptoms, and likely stress effects in the performance setting.
- *Impart high performance skills*. Training must incorporate specialized skills training to enhance those skills that are required to maintain effective performance in the stress environment.
- *Practice skills and build confidence*. Training must allow gradual exposure to the high-stress environment to promote practice of skills under realistic conditions and build trainee confidence to perform.

The stress exposure training approach incorporates three stages or phases of training. The first stage is *Information Provision*, in which information is provided to the trainee regarding stress, stress symptoms, and likely stress effects in the performance setting. The second stage is *Skills Acquisition*, in which specific cognitive and behavioral skills are taught and practiced. These are called *high performance* skills, representing those skills required to maintain effective performance in the stress environment. The third stage is *Application and Practice*, the application and practice of these skills in a graduated manner under conditions that increasingly approximate the criterion environment.

In the following, we elaborate the stress exposure training approach by examining the specific activities that comprise each stage.

**Phase 1: Information Provision** Clausewitz (1976) wrote, “It is immensely important that no soldier, whatever his rank, should wait for war to expose him to those aspects of active service that amaze and confuse him when he first comes across them. If he has met them even once before, they will begin to be familiar to him” (p. 122). Phase 1 of stress exposure training includes two primary
components: a) indoctrination, or discussion of why stress training is important, and b) preparatory information on stress effects.

The first component of Phase 1 training is trainee indoctrination. The purpose of indoctrination is to increase trainee attention and training motivation. This is accomplished in several ways. First, trainees need to know the objectives of training and why stress training is important. This may be achieved by discussing operational incidents or case histories in which stress had a significant impact on performance. These “lessons learned” emphasize the rewards and costs of effective and ineffective performance in real-world stress environments. Indoctrination serves to ensure “user buy-in” – that is, the trainee should understand the purpose and value of stress training and how stress training can support mission accomplishment.

The second component of Phase 1 training is the provision of preparatory information. As we noted earlier, stress can lead to a number of adverse effects, including physiological effects such as a pounding heart and sweating, emotional effects such as anxiety or confusion, and cognitive effects such as attentional deficits and loss of focus. Research suggests that preparatory information regarding a potential threatening event can less negative reactions to that event. For example, Vineberg (1965) found that, in training soldiers for nuclear warfare, the communication of accurate information was critical in clarifying misconceptions, reducing fear of the unknown, and increasing a sense of personal control over these events. Unfortunately, this approach often runs counter to military practice, which is to give the individual the least amount of information necessary for a given situation. Nevertheless, a National Research Council study on enhancing military performance concluded that “stress is reduced by giving an individual as much knowledge and understanding as possible regarding future events” (Druckman and Swets, 1988: 21).

It is likely that preparatory information reduces negative reactions to stressful events in several different ways, by enhancing familiarity, predictability, and controllability. First, by providing a preview of the stress environment, preparatory information renders the task less novel and unfamiliar. Familiarity enhances self-efficacy, which has been shown to be a significant predictor of performance (Locke et al., 1984). Second, knowledge regarding an upcoming event increases predictability, which can decrease the attentional demands and distraction of having to monitor and interpret novel events in real-time (Cohen, 1978). Third, preparatory information may enhance the sense of behavioral or cognitive control over an aversive event by providing the individual with an instrumental means to respond to the stress. That is, information regarding the nature of an aversive event can provide us with information on how to respond in that setting.

A comprehensive preparatory information strategy should provide information on the nature of the stress environment and typical physiological, emotional, and cognitive reactions to stress, how stress is likely to affect performance, and how the individual may adapt to these changes. Accordingly, Driskell and Johnston (1998) defined three primary types of preparatory information that should be incorporated in the Information Provision phase of training. Sensory information is information regarding how the individual is likely to feel when under stress, including typical physiological and emotional responses to stress. When confronted with a threatening or novel situation, the individual is likely to experience a number of unpleasant or intrusive physical and emotional reactions such as increased heart rate, labored breathing, and feelings of fear or confusion. These are normal “fight or flight” stress reactions, but they present several problems. First, they are distracting and divert attention from the task. Second, people often tend to misinterpret or over interpret these “normal” stress reactions as catastrophic, leading to a spiral of arousal, distress, and loss of attention. Worchel and Yohai (1979) found that when individuals were able to label or identify physiological reactions (that is, they were able to attribute their physiological reactions to some reasonable cause), they were less distressed or aroused by those reactions. Therefore, it is likely that providing personnel with accurate information regarding typical stress effects and
stress reactions – on how the individual is likely to feel in a high-stress situation – will lessen the negative impact of these reactions in the operational task environment.

Procedural information describes the events that are likely to occur in the stress environment, including a description of the setting, the types of stressors that may be encountered, and performance effects the stressors may have. For example, procedural information for a task such as manning a checkpoint may include a description of the contextual environment in which this task may take place, the noise and other distractions that may be present, and how these factors may impact decision making. Janis (1951) observed a reduction in negative stress reactions among combat aircrews when descriptive information on air attacks was provided in advance.

Instrumental information describes what to do to counter the undesirable consequences of stress. That is, it is useful for the individual to know not only how he or she will feel when under stress and the events that are likely to occur, but also how to respond to counter these negative effects. For example, it may be valuable to know that as threatening events unfold in a particular task environment, there will be a significant increase in background noise that can be distracting and mask task-relevant information, but also what one can do to overcome the effects of these distractions. This type of information has instrumental value in that it provides the individual with a means to resolve the problems posed by the stress environment.

Inzana et al. (1996) tested the effectiveness of preparatory information, examining the performance of Naval personnel on a command-and control decision-making task under high stress conditions. The preparatory information intervention included sensory information (e.g., “Stressors such as high task load may cause you to feel distracted or hurried.”), procedural information (e.g., “These are normal reactions, but may lead you to misinterpret specific data fields.”), and instrumental information (e.g., “Try to match the pace of the task, but pay close attention to the information in those fields.”). Results indicated that the personnel who received preparatory information prior to performing under high stress conditions reported less anxiety, were more confident in their ability to perform the task, and made fewer performance errors than those who received no preparatory information.

Phase 2: Skills Acquisition The objective of the skills acquisition phase of stress exposure training is skill acquisition and rehearsal. The goal of training at this stage is to build high performance skills that are required to maintain effective performance under stress. A number of stress training strategies or techniques may be incorporated in this phase of training. These may include the training of general skills such as cognitive control or mental practice strategies to more task-specific training strategies such as decision making training. Johnston and Cannon-Bowers (1996) have noted that these strategies may include developing metacognitive, cognitive, psychomotor, and physiological control skills. Specific stress training techniques may include the following.

Cognitive control techniques Wachtel (1968) noted that when a person is under stress, attention is diverted inward to interpret novel or unfamiliar stress-related reactions, and less attention is devoted to external task-related stimuli. The term cognitive control subsumes a number of training approaches that attempt to train individuals to recognize task-irrelevant thoughts and emotions that degrade task performance and to replace them with task-focused cognitions. The primary emphasis of cognitive control techniques is to train the individual to regulate emotions (e.g., worry and frustration), regulate distracting thoughts (self-oriented cognitions), and to maintain task orientation. Singer et al. (1991) have proposed an attentional-training approach that attempts to train individuals to maintain attentional focus on task-relevant stimuli in the face of external distractions. This approach includes training that describes how attention may be distracted during task performance, followed by practice in performing the task under stress, focusing attention,
and refocusing attention after distraction. Empirical results indicated that this type of training, by focusing directly on enhancing attentional focus, could overcome the distraction and perceptual narrowing that occurs in stress environments.

**Physiological control techniques** Physiological control techniques attempt to provide the trainee with control over negative physiological reactions to stress. These types of approaches attempt to train the responses that are characteristic of effective performance: being calm, relaxed, and under control. Training may include relaxation training (awareness and control of muscle tension, breathing, etc.), biofeedback, and autogenic-feedback training, which has been used successfully in alleviating space motion sickness (Cowings and Toscano, 1982). All of these techniques have in common an effort to increase the extent to which the individual’s physiological reactions are under conscious control.

**Overlearning** The term *overlearning* refers to deliberate overtraining of a performance beyond the level of initial proficiency (Driskell, Willis and Copper, 1992). Researchers have noted that overlearning may be a useful stress training technique: Janis (1949) noted that “Drills of this type, when repeated so that the response is overlearned, tend to build up an automatic adaptive response” (p. 223). Tasks that are overlearned become more routinized or automatic, require less active attentional capacity, and are less subject to disruption by increased attentional demands. In that one effect of stress is to reduce or restrict attentional capacity, tasks that are overlearned should be more resistant to degradation. In fact, much military training attempts to reduce the impact of stress in combat through the use of repetitive drill, providing soldiers with a set of habitual responses that are less subject to degradation under stress.

**Mental practice** Mental practice refers to the cognitive rehearsal of a task in the absence of overt physical movement (Driskell, Copper and Moran, 1994). In a meta-analysis of research on the effects of mental practice, Driskell, Copper and Moran (1994) found that mental practice was an effective means for enhancing performance, although somewhat less effective than physical practice. Furthermore, mental practice may be a particularly effective technique for training complex cognitive tasks, for rehearsing tasks that are dangerous to train physically, or for training tasks such as emergency procedures where the opportunity for actual practice occurs very seldom.

**Time-sharing skills** Time-sharing, or multi-tasking, can be defined as the capacity to perform concurrent tasks or to interleave multiple tasks (Fischer and Mautone, 2005). High stress environments often involve an increase in task load, stemming from the imposition of additional tasks (e.g., a radar operator whose task suddenly expands from monitoring several targets to monitoring multiple targets while answering outside queries and requests for information) or may result from having to attend to novel or unfamiliar stimuli (e.g., a soldier may engage one target while scanning for additional threats). Heggestad et al. (2002) argue that timesharing is a skill that can be improved with practice. For example, Hirst et al. (1980) found when subjects were asked to read aloud prose while taking dictation, performance dropped dramatically. However, with substantial dual task practice – over 50 h – subjects could more readily read while taking dictation, achieving reading and comprehension rates similar to that of the single-task control subjects. Therefore, significant improvement in multi-tasking ability can be made when tasks are paired during training. However, time-sharing is considered a task-specific skill that must be practiced in the context of the real-world operational environment.
**Guided error training**  We generally try to train correct responses and avoid errors in training. However, there may be value in experiencing how things can go wrong or how errors can be made, especially when the criterion situation in one in which errors may abound. Lorenzet, Salas, and Tannenbaum (2005) have noted that errors may occur in training on the basis of several strategies: a) errors may be avoided in training, b) errors may be allowed in training but not specifically triggered, c) errors may be induced or evoked in training, or d) errors may be designed intentionally in training to guide skill development. In an empirical test of the guided error approach, Lorenzet et al. identified common errors that occurred on a training task, and then designed a training procedure that guided trainees through these errors and provided corrective feedback. Results indicated that those who received guided error training performed better and developed greater self-efficacy than those who received error-free training. Thus, allowing trainees to experience likely errors and receive error correction may be an effective approach to enhancing performance in a high stress, high error task environment.

**Decision-Making Training**  Formal, analytic decision making approaches require the decision maker to carry out an elaborate and exhaustive procedure characterized by a systematic, organized information search, thorough consideration of all available alternatives, evaluation of each alternative, and re-examination and review of data before making a decision. Although this procedure is often taught as the decision making ideal, some researchers have argued that under conditions of high demand or high time pressure, decision makers do not have the luxury to adopt a time-consuming analytic strategy. Moreover, encouraging the decision maker to adopt a structured, analytic decision making model could undermine behavior that may more adequately fit the requirements of the task situation (see Cannon-Bowers and Salas, 1998). Johnston, Driskell and Salas (1997) found that on a time-pressured, realistic military task, those who were trained to use a less analytic decision-making strategy performed more effectively than those who used a formal, analytic decision strategy. Thus, one goal of decision making training for stressful environments is to emphasize the use of simplifying heuristics to manage effort and accuracy, and to improve the capability of the decision maker to adapt decision making strategies to high demand conditions.

**Enhancing flexibility**  Hackman and Morris (1978) have noted that one of the few universally effective task strategies is flexibility or adaptability. Flexibility has been defined as the ability to adjust one’s behavior to suit changing task conditions, or as “the ability and willingness to respond in significantly different ways to correspondingly different situational requirements” (Zaccaro et al., 1991: 322). Pulakos et al. (2002) have identified several critical dimensions of adaptive performance, including flexibility in handling uncertain task conditions, interpersonal flexibility, and flexibility in problem solving.

Research indicates that stress can lead to a loss of flexibility or to greater problem-solving rigidity (Cohen, 1952). Rigidity refers to the tendency to approach a problem with a restricted attentional focus and expectancy that there is a single solution that does not vary. However, high-stress environments require flexibility to respond to novel and varied task contingencies. Certain training procedures can enhance flexible behavior. Gick and Holyoak (1987) argue that positive transfer (i.e., the extent to which training results transfer from the training setting to the real-world setting) is more likely when a variety of different examples were provided during training. Schmidt and Bjork (1992) refer to this as practice variability, noting that intentional variation during skills practice can enhance the transfer of training. Thus, presenting training material or training activities in various contexts, from different perspectives, and with diverse examples can result in more flexible use of a skill under novel and variable task conditions.
Team training  One of the more well-established findings in psychology is that as stress increases, the individual’s breadth of attention narrows (Easterbrook, 1959). Perhaps the earliest statement of this phenomenon was the assertion by William James (1890) that, under stress, the individual’s field of view is reduced from a broad perspective to a narrower, restricted focus. Driskell, Salas and Johnston (1999) extended this proposition to the group level of analysis, arguing that the narrowing of attention or “tunnel vision” that occurs under stress may result in a shift from a broader, team perspective to a narrower, individualistic focus. Results of an empirical test supported this assumption, indicating that stress results in a narrowing of team perspective. Under stress, team members were shown to be more likely to shift from a team-level to an individual-level task perspective, resulting in degraded team performance. Interventions that attempt to reinforce teamwork skills may be applicable for teams that perform in high stress environments.

Phase 3: Application and Practice  Helmus and Glenn (2005) cite a conversation between two Marines at Iwo-Jima, drawn from the book *Flags of Our Fathers*:

‘Did you see those Japanese firing at us?’ he screamed to the guy next to him. ‘No,’ the leatherneck answered, deadpan. ‘Did you shoot them?’ ‘Gee, no,’ Buchanan replied, ‘That didn’t occur to me. I’ve never been shot at before’ (Bradley and Powers, 2000: 156).

The classic *American Soldier* studies were conducted during the Second World War to examine battlefield performance (Stouffer et al., 1949). Military researchers asked combat veterans from the Italian and North African campaigns what type of training they lacked. The most common answer was that they lacked training under realistic battlefield conditions (Janis, 1949). Effective military performance requires that the skills learned in training be transferred to the operational setting. The novelty of performing even a well-learned task in a high-stress real-world environment can cause severe degradation in performance. Therefore, the final phase of stress training requires the application and practice of skills learned in training under conditions that approximate the operational environment.

Clearly, the adage “train as you fight” is a well-established military axiom, and the goal of “realistic training” is accepted by most military trainers. However, several specific issues are critical in implementing realistic stress training. The first questions that arise are: “How realistic should it be?” or “How can we simulate real-world conditions in a training environment?” Training fidelity refers to the extent to which the characteristics of the training environment are similar to the characteristics of the criterion setting. Given that the ultimate criterion of military training is combat, there are few who think that the characteristics of combat can be closely approximated outside of combat. This is likely the case, and some would argue that because the training environment cannot capture all that is relevant to a combat setting, it has limited value in preparing personnel for combat. However, it is not necessarily true that higher fidelity always leads to better training. In fact, Keinan and Friedland (1992) note that for complex, high-demand military tasks, training that incorporates no stress and training that incorporates constant high intensity stress are both likely to be counterproductive. Training that incorporates no stress or that does not involve the contextual factors that characterize the criterion setting does not provide the trainee with pre-exposure or skills practice in this operational environment. Training that incorporates stressors of very high intensity is likely to overload all but the most experienced trainees and may interfere with skill development and lead to loss of confidence.

Friedland and Keinan (1996) have found evidence to support the effectiveness of *phased training* as an approach to manage training for complex, high stress environments. Based on the assumption that a high degree of complexity in the training environment may interfere with initial skill acquisition, phased training is an approach to maximize training effectiveness by partitioning
training into separate phases: during initial training, trainees learn basic skills in a relatively low-fidelity or low-complexity environment; and latter stages of training incorporate greater degrees of complexity or realism.

Graduated exposure to real-world stressors in the application and practice phase of stress exposure training provides several advantages. First, it serves as a complement to the preparatory information provided in phase 1 of training. Whereas the goal of phase 1 is to provide knowledge regarding the stress environment, one goal of phase 3 is to allow pre-exposure to these conditions. This reduces anxiety and uncertainty regarding this environment and enhances a sense of individual control and increases confidence to perform in this setting. Second, graduated exposure to stress events in training allows the individual to become more familiar with relevant stressors without being overwhelmed, and is less likely to interfere with the acquisition and practice of task skills than would exposure to intense stress. Finally, allowing skills practice in a graduated manner across increasing levels of stress increases familiarity with the types of performance problems that can occur in this setting. Trainees can experience errors, receive guidance and feedback, develop work-arounds, and have the opportunity to bring performance back to baseline levels using the skills learned in phase 2 of training.

A second problem unique to implementing stress exposure training relates to training design. It is important to note that stress exposure training is a model for stress training rather than a specific training technique. The stress exposure training model describes three stages of training, each with a specific objective. However, the specific content of each stage will vary according to the specific task requirements. Both the type of stressors and the skills required for effective performance depend on the task to be trained. Therefore, stress training must be context-specific, and a careful needs analysis is required to define the specific tasks to be trained, determine the types of stress in the task environment, and develop training content.

Moreover, there is another factor that differentiates stress exposure training from traditional training, and that is that stress exposure training is event-based. In a traditional training design approach, a task analysis is performed to define the task and identify the characteristics of the work and of the worker required for successful performance. These identified knowledge, skills, abilities, and other attributes (KSAOs) form the basis for the training curriculum. Event-based training is unique in that the event itself is the curriculum (see Cannon-Bowers, Burns and Pruitt, 1998). An event is defined as a specific task procedure (e.g., execute emergency action plan) with corresponding performance conditions (e.g., organizational, environmental, social, and task demands). Events may be discrete and singular, or multiple events may be connected into a series representing a longer scenario. In event-based training, events are embedded into training to achieve desired training objectives and provide the opportunity for trainees to apply skills in an environment representative of real-world operational conditions.

Developing event-based training is a multi-step procedure (see Cannon-Bowers et al., 1998; Salas et al., 2005). The first step is the identification of training requirements, tasks, and competencies, based on a traditional needs/task analysis. This information is used to determine training objectives. The next step is the development of specific events (“trigger” events or scenarios) to be embedded into the training. These events are based on training objectives and may be derived from critical incident data or on input from subject matter experts. In brief, key events are defined to act as cues that trigger essential actions or behaviors, and provide the basis on which the trainee is instructed and evaluated. These events create opportunities for performance measurement, and therefore performance measures are established and trainee performance is observed, evaluated, and incorporated into feedback.

There are several advantages of the event-based approach for stress exposure training. First, events can be defined to represent real-word events and contextual demands. In fact, events that are
realistic, allow the trainee to respond in multiple ways, and that unfold over time can engage the trainee in a “real-world” scenario without actually requiring perfect fidelity. Second, in a complex task or training environment, not all behaviors have to be observed, just those pre-defined behaviors that are reactions to scripted events. Thus, instructors know a priori when “trigger” events occur and key behaviors are exhibited. Finally, training events can be varied so that they require different responses under different conditions, enhancing flexibility of response and adaptability. Events can be scripted to trigger errors so that trainees can experience likely sources of error under realistic conditions. Multiple events can allow a progression through graduated levels of intensity in a multi-event scenario.

In summary, stress exposure training provides a comprehensive model of stress training. It incorporates three stages. In Phase 1, trainees receive preparatory information regarding stress, stress effects, and stress reactions. In Phase 2, trainees acquire specific skills required to maintain effective performance in high-stress environments. In Phase 3, trainees have the opportunity to apply and practice these skills in an event-based scenario that approximates the criterion environment. Research indicates that this stress training approach can reduce negative reactions and enhance performance under stress (Saunders et al., 1996). In the following, we describe a laboratory application and a more applied real-world application of stress exposure training.

A Laboratory Application

Driskell, Salas and Johnston (2001) conducted an experimental research study to examine the extent to which stress training generalizes to novel stressors and to novel tasks. The problem these researchers addressed is this: Given that a primary goal of stress training is to provide practice under conditions similar to those likely to be encountered in the real-world setting, it is often difficult to anticipate the specific to-be-encountered events in training. In other words, on one hand, we have the general prescription that stress training should anticipate the conditions of the operational environment. On the other hand, we are faced with the realization that many real-world environments of interest are dynamic and emergent, and it is difficult to provide practice and training for potential scenarios that are themselves unpredictable or unanticipated.

Therefore, one question that has considerable applied as well as theoretical implications is the extent to which stress training is generalizable to novel stressors and to novel tasks. That is, if the design of a particular stress training intervention requires trainees is to practice Task A under time pressure, a critical question is whether the positive effects of this training intervention generalize to a task situation in which time pressure is not salient, but that involves a novel stressor such as noise? Moreover, if the design of a particular stress training intervention requires trainees is to practice Task A under time pressure, a related question is to what extent do the positive benefits gained in training generalize to a task setting in which trainees face not Task A (the training task), but a novel task, Task B? In brief, do the beneficial effects of stress training generalize to novel stressors and novel tasks, or does a unique stress training intervention have to be targeted for each type of stressor and each type of task that the trainee may face?

Driskell, Johnston and Salas (2001) designed a series of laboratory studies to address this question. Study 1 was designed to address the question of generalizability of stress training from stressor to stressor. Research participants performed a laboratory task over three trials: 1) performance was assessed pre-training, in which participants performed the task under either time pressure or noise, 2), performance was assessed post-training, in which participants who received “noise stress” training performed under noise stress, and participants who received “time pressure” training performed under time pressure, and 3) performance was assessed under novel stressor conditions, where the participants who received noise stress training now performed under time...
pressure, and the participants who received time pressure training now performed under noise stress.

Study 2 was similar, except that the goal was to examine the generalizability of stress training from one task to another. Study 2 also included three performance trials: 1) performance was assessed pre-training, in which participants performed either task A or task B under stress, 2) performance was assessed post-training, in which participants who received stress training and practice for task A then performed task A under stress, and participants who received stress training and practice for task B then performed task B under stress, and 3) performance was assessed under novel task conditions, where the participants who received stress training for task A now performed task B under stress, and the participants who received stress training for task B now performed task A under stress.

For each study, the stress training implemented consisted of a brief stress exposure training (SET) intervention. The training intervention consisted of three stages: a) preparatory information, b) skills training, and c) application and practice. In the preparatory information phase, participants were given a) descriptive information on the type of stressors that they would encounter in performing the task, b) sensory information on typical physical and emotional reactions they were likely to feel when under stress, and c) procedural information on how stress may impact task performance. For example, those who received SET-noise training were given information on the types of noise they would encounter and how it would be presented, they were told how noise can lead to frustration and distraction, and they were told that noise can lead to increased errors as task performers have to allocate attention to the noise and the task.

The goal of the second phase of training, skills training, was to teach skills to counter the negative effects of stress. A brief attentional training intervention (see Singer et al., 1991) was implemented that focused on three points: a) stress can be distracting b) to counter the distraction, individuals should selectively attend to task-relevant stimuli, and c) the key to effective performance is to ignore distracting stimuli and maintain focus on the task. In the third phase of training, participants applied these skills while performing the task. Participants first practiced the task under either noise stress or time pressure for 30 seconds. The experimenter then discussed with each participant whether they were able to apply the skills learned, and reemphasized the key points presented in training. Participants again practiced the task under stress for a 30-second period, after which the experimenter again discussed application of skills and key training points. Participants then performed the task for a 3-minute period, again followed by refresher training.

The results of both studies indicated that the improvement in performance realized from pre – to post-training and the reduction in subjective stress realized from pre – to post-training were sustained when participants performed under a novel stressor (Study 1) and performed a novel task (Study 2). These results indicate that, under certain conditions, the positive gains from stress exposure training can generalize to novel settings.

A Real-World Application

The Federal Law Enforcement Training Center (FLETC) provides training to law enforcement personnel from numerous federal, state, and local agencies. A law enforcement officer’s survival requires that he or she is able to quickly assess a situation and respond with appropriate actions in dynamic, life-threatening, time-pressured situations that are likely to be encountered in carrying out their duties. Accordingly, a research program has been initiated to examine the extent to which stress training can better prepare law enforcement officers to perform under highly stressful conditions. Initial results from the research program have been reported in a technical report entitled the Survival Scores Research Project (FLETC, 2004).
This research program has several goals. Law enforcement officers must perform in an environment that may transition from routine to critical within seconds. Violent and life-threatening events often take place in poorly lit settings, with multiple suspects and innocent bystanders at close range, and require critical decisions within seconds. Thus, one primary goal of this research program is to develop a scenario that reflects the challenges faced during law enforcement duty. In other words, is it possible to develop a realistic scenario that simulates the high-stress demands of a law enforcement encounter? A second goal of this research program is to incorporate this scenario into an effective training program to enhance performance under stress.

In pursuit of the first research goal, FLETC researchers developed a scenario designed to replicate real-world law enforcement situations. Law enforcement subject matter experts were interviewed to gather actual experiences reflecting high-risk encounters. A multiple-event scenario was developed that included a series of 7 events, including 1) call-in to establish radio communications, 2) non-emergency vehicle operation, 3) emergency vehicle operation, 4) vehicle spin-out, 5) entry into building to question suspect, 6) gun take-away and shoot-out, and 7) post-shooting interview. This fast-flowing (approximately 35 minute), realistic scenario incorporated environmental stressors (noise, time pressure, lethal threat), high task load, social stressors (the trainee’s partner was a confederate who performed scripted errors in the scenario), and critical task errors (e.g., a misfiring weapon).

All of the research participants previously received and completed basic training on these tasks, including emergency driving, shoot/no-shoot judgment situations, managing assault and resistance, and exchange of fire. However, none of the participants had completed exercises specifically designed to evoke the high stress demands of the real-world environment. Thus, one goal of this phase of the research program was to quantify the stressfulness of the research scenario and to examine the relationship between stress and trainee performance.

All performances were videotaped, and a battery of physiological and psychological measures were administered during the scenario to measure stress response. Trainee performance was also assessed via a series of performance measures, including threat recognition, latency to respond, weapons handling, tactical movement, and other measures. Results indicated that the scenario was perceived by trainees as highly stressful. Moreover, as stress demands increased in the scenario, there was a corresponding increase in physiological measures of heart rate, blood pressure, and cortisol levels. Significant decrements in performance were observed. For example, during the gun take-away and shoot-out event, weapons handling skills were seriously degraded as trainees were unable to perform complex motor skills, performed them in the wrong sequence, or performed the wrong function altogether. In many cases, decision-making ability was impaired, with some trainees observed pulling the trigger up to 10 times before initiating a reload of an empty weapon. While the research scenario was shown to be highly successful in evoking high stress, outside the generalization that as physiological measures increased, trainee performance declined, there was little empirical evidence linking physiological measures to successful trainee performance.

There are several important benefits of this initial research study. The first was the development of an event-based scenario, developed by experienced subject matter experts, representing critical law enforcement events. Second, this research scenario was shown to be a realistic and highly stressful simulation of these real-life incidents. Third, this research identified a number of performance deficiencies in a research population that had previously received comprehensive basic training on these tasks. These deficiencies included poor decision making, tunnel-vision or perceptual narrowing, memory deficits, use of improper procedures, and poor communications.

One further implication of this initial research was the establishment of the requirement to develop stress training interventions to offset the observed performance deficiencies. Current research efforts in the second phase of this research program are being devoted to developing event-
based stress training procedures, modeled on the stress exposure training paradigm, to optimize law enforcement officers’ performance in stressful encounters. In brief, this research program represents one of the most ambitious and comprehensive applied research efforts to examine stress effects and stress training in a real-world setting.

Summary

In conclusion, we return to the optimistic note with which we began this chapter: we know quite a bit about stress training. A substantial body of stress research has accumulated over the past decade that provides sound guidance for designing and implementing stress exposure training. Moreover, this work has expanded beyond the experimental laboratory to the field, which is the ultimate testing ground for applied research. Current research on stress exposure training approximates Berger’s (1988) concept of a theoretical research program, an integrated body of research that consists of theory development, experimental research to test and elaborate theory, and applied research that applies or extends theory to an identified real-world problem (see Driskell and King, forthcoming). Maintaining effective performance under high stress conditions is a daunting challenge. We ask our military personnel and law enforcement officers to face this threat. It is imperative that they have the preparation and training necessary to carry out these duties.

References


Chapter 15

Augmenting Multi-Cultural Collaboration

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1. Introduction

1.1 Operational Environment

In current military operations, the US Army is striving to adapt an unprecedented capability in war-fighting to counter insurgencies and establish stability necessary for the reconstruction of failed or failing states. Stability operations were recently established by Department of Defense Directive 3000.05 (2005) as a core US military mission, on a par with combat operations. A primary objective in counterinsurgency or stability operations, more broadly called irregular warfare, is to protect the public and gain their trust (U.S. Army Combined Arms Center, 2006). Military experts have proposed that this is best achieved by establishing or re-establishing security, basic services, and opportunities for growth (Chiarelli and Michaelis, 2005; Gray, 2006; Petraeus, 2006). These missions are more about winning the peace than winning the war (Chiarelli and Michaelis, 2005) and will require a different and much broader perspective than more traditional combat operations.

In counterinsurgency or stability operations, military efforts are necessary, but they must be complemented by actions that address the root causes of the instability (U.S. Army Combined Arms Center, 2006). The military may at times be asked to act as diplomats to support or even implement political, social, or economic programs. Although, these will remain primarily civilian functions, collaboration with military forces will be necessary especially early in an operation or in high threat environments. Due to the complexity, uncertainty, and unpredictability involved in irregular warfare, military and civilian subject matter experts will work together to understand the range of options available, to consider possible cross domain consequences and interdependencies, and to develop coordinated courses of action that stakeholders are committed to implementing.

It is anticipated that US military forces will regularly collaborate with multinational forces, other government agencies, nongovernmental organizations, intergovernmental organizations such as the United Nations, and local military, political and business leaders. Diversity can be an advantage because more expertise exists within the team and can be brought to bear on the problem, but it can also be a disadvantage in that collaboration and coordination can be difficult and time consuming. Interoperability among organizational processes and information systems will be a challenge, but, in addition, it is also likely that solutions acceptable to one organization or nation will not be acceptable across all stakeholders. For example, tightening restrictions on travel or early curfews may take insurgents off the street and reduce violence, but these actions may also hinder legitimate movement among the local population, interfering with the distribution of aid or the ability of people to go to work or school. These conditions may increase discontent and ultimately lead to the creation of more insurgents and more violence, achieving short-term success, but losing the battle for hearts and minds. Unity of effort as seen in shared and synchronized
objectives, actions, and messages among the domain experts and various stakeholders is necessary to conduct irregular warfare operations (U.S. Department of the Army, 2006).

These are wicked problems, in that not only is there disagreement about the solution but there may even be disagreement about how to define the problem (Roberts, 2000). Is the problem primarily political, social, economic, or military? Is it due to a breakdown in government and societal infrastructure, an inability to influence attitudes or use information effectively, or some other factor? Wicked problems are inherently stressful and ill-defined (Rittel and Webber, 1973; Buckingham Shum, 2003). They are dynamic, evolving and changing over time and the solutions may be many and varied. Wicked problems require team solutions. Contemporary theories of team effectiveness include the team task as one of the central variables in understanding the team (Beck and Pierce, 1996; Ilgen et al., 2005; Kozlowski and Ilgen, 2006). It is within the context of the task that the team can be understood. There are several task taxonomies that exist (e.g., Steiner, 1972), but McGrath’s Circumplex (1984) is especially well suited to organize research (see Figure 15.1) and understand team performance on wicked problems.

Figure 15.1 McGrath’s circumplex of group tasks

McGrath (1984) identified eight task types, these were created from four quadrants representing performance processes: Generate, Choose, Negotiate, and Execute (e.g., perform overt physical behaviors). Tasks that border one another in the circumplex are more similar than tasks further away on the circumplex. The Generate Quadrant is split into Task Type 1: Generate Plans, and Task Type 2: Generate Ideas. The tasks in this quadrant require the group to be creative. Answers are not right or wrong. Usually, the number of ideas or plans generated and the quality of the plans or ideas determine the success of the group.

The Choose Quadrant is made up of Task Type 3: Intellective, and Task Type 4: Decision-Making. Intellective tasks have a correct answer that is demonstrable. Solutions may be “Eureka”-type, in which the correct answer is not only demonstrably correct but also intuitively compelling, Fact-type, in which the correct answer has no intuitive appeal although it can be demonstrated, or Expert-type, in which the solution is based on the consensus of experts. The Decision-Making
tasks (Task Type 4) do not have a true, correct answer. Rather, groups are to select the preferred alternative based on peer consensus.

The Negotiate Quadrant contains task types in which the groups need to choose among alternatives and there is intra-group conflict. Task Type 5 includes tasks in which groups must resolve conflicts of viewpoints. A Choose Quadrant task performed by a multinational team may become a Task Type 5. Task Type 6 includes tasks in which groups must resolve conflicts of interest. An example of a Type 6 task is a social dilemma, in which each group member must decide whether to optimize group or individual outcomes knowing that if everyone chooses to optimize individual outcomes, the entire group will lose. Another example is the Prisoner’s Dilemma. In this task, group members are most highly rewarded if they are the only one taking a competitive approach and most highly punished if they are the only one taking a cooperative approach. However, group members are mildly rewarded for joint cooperative acts and mildly punished for joint competitive acts.

The Overt Physical Behavior Quadrant contains tasks in which the group members perform manual and psychomotor tasks. With Type 7 Tasks, the group performing the physical behaviors competes with other groups. In Type 8 Tasks, the group strives to meet a standard of excellence. Visualizing the task types on a circumplex, as McGrath did, is useful in identifying other similarities and differences among the tasks (see Figure 15.1). The tasks on the right side of the circumplex (Types 1, 8, 7, and 6) are tasks that involve action or behavioral tasks; those on the left (Task Types 2, 3, 4, and 5) are conceptual, intellectual tasks. In addition, tasks on the top of the wheel (Task Types 3, 2, 1, and 8) are cooperative tasks and those on the bottom (Task Types 4, 5, 6, and 7) are conflict tasks.

Collaborating to solve wicked problems, diverse subject matter experts will most likely perform all eight task types. It is possible, through selection and training, to create groups that are likely to succeed at one task type; however, creating a group that will be able to successfully complete all eight types in high threat environments is especially challenging. Task type should be considered in research to better understand collaboration among highly diverse team members solving wicked problems. In addition, a well-defined process to guide collaboration is needed.

1.2 Integrated Battle Command

The United States Joint Forces Command (JFCOM) is developing doctrine to guide military leaders to think more broadly about the operational environment (Joint Warfighting Center, 2006), to use a systems or effects-based approach that recognizes the interdependencies among problems and solutions and understands how problems across domains interact and why solutions in one domain invariably disrupt conditions in another domain. These cross domain interdependencies often make this a wicked problem.

JFCOM has teamed with the Defense Advanced Research Project Agency (DARPA) under the Integrated Battle Command program to conduct a series of experiments to help refine concepts (Allen, Corpac and Frisbie, 2006) and develop technologies to enhance the capability of military commanders and staffs to collaborate within an effects-based approach to operations (Corpac et al., 2006). The technologies are being designed to aid the understanding of and to visualize interdependencies among effects in the operational environment that occur as a consequence of command decisions. In addition, an option exploration component is being proposed that would allow commanders and staffs to conduct “what if” type evaluations of various courses of action. To explore these options requires not only valid models be developed or acquired for each of the effect domains, but also an ability for multiple models to interact to provide decision makers a more complete understanding of the possible interactions. This program is about understanding
possibilities, not prescribing a single approach. As mentioned earlier, wicked problems do not lend themselves to a single, correct answer. Rather, it is the ability of the command team to understand contingencies and the possible effects that are an important first step in the problem solving process.

1.3 Wicked Problems

The objectives of the Integrated Battle Command program are consistent with recommendations made by Rosenhead (1998), also cited in Ritchey (2005) of the London School of Economics for dealing with complex social problems. Rosenhead states that first and foremost teams must accommodate multiple alternative perspectives rather than prescribe a single solution. Accommodation can be achieved through transparent team interactions and graphical representations which, in turn, should foster ownership of the problem formulation. Rosenhead further suggests that solving wicked problems is facilitated by a focus on the relationships among discrete rather than continuous alternatives and a concentration on possible rather than single solutions. While technologies can aid the team in understanding the problem and the possible effects of solutions, the process for solving the wicked problem proposed by Rosenhead is essentially collaborative.

A similar strategy is described by Roberts (2000) in which she defines wicked problems based on the level of conflict present in the problem solving process and the extent to which power to define and solve the problems is centralized, decentralized and contested, and decentralized and not contested. If there is little or no conflict among the team regarding the nature of the problem or the solution, the problem is a simple or Type 1 problem. If there is conflict over the solution then the problem is a complex, Type 2 problem. If conflict exists over how the problem is to be defined and solved, then the problem is labeled as a wicked, Type 3 problem. Roberts suggests that if a wicked, Type 3 problem exists the best approach to problem definition and solution is determined by the distribution of power among team members with an authoritative approach being preferred when few stakeholders have the power to define the problem and propose the solution. If power is more dispersed among the stakeholders then competitive or collaborative strategies are used depending on the extent to which the power distribution is contested. If contested, competitive strategies may emerge which assume a zero-sum or win-lose distribution of outcomes. If, however, power is distributed and not contested, then collaborative strategies can be used. The collaborative strategy is based on the premise that a team can be more than the sum of its individual parts and that problem solving can be “win-win.” Using a collaborative strategy is especially important if, as is often the case, expertise is distributed among the team members. Implementing the solution requires commitment and coordination among experts.

Merely establishing a team and providing the opportunity for collaboration, however, will not insure that the stakeholders will collaborate effectively. Team members may all agree on an overarching goal, but disagree on the underlying problems and how they should be solved. Because of the nature of the problems, it is unlikely that the new technologies will unambiguously identify the correct or even a “best” approach. The team will need to collaborate to develop a shared understanding of the operational environment. An important aspect of any collaboration and especially collaboration among highly disparate experts is communication, the exchange and understanding of unique information. In a coalition it is assumed that each stakeholder will contribute their expertise to the problem solving process.

Research has shown, however, that when team members represent diverse positions, information exchange may be biased to promote one solution over another, or there may be a tendency for team members to ignore differences and focus on areas of similarity (Janis, 1972). To further complicate matters, these teams will not be hierarchically based. As defined by Roberts (2000), these are Type
3 problems and although the US Army or a sister service may lead the team, power and expertise will be distributed among the team members. Cooperation among team members will be based on team members’ willingness to participate based on their perception that participation will aid them in meeting their national or organizational objectives. Another complicating factor will be the organizational and cultural differences that exist among the team members. Culture affects how team members work together: how they assign roles and responsibilities, coordinate actions, support one another, and exchange information (Sutton and Pierce, 2003; Sutton et al., 2006). The US Army encountered both organizational and cultural barriers in establishing and maintaining a multi-cultural coalition in Bosnia Herzegovina (Pierce, 2002; Pierce and Dixon, 2006; Pierce, 2006). The insurgency has significantly complicated military operations in Iraq, but the challenges inherent in multicultural teamwork continue to limit the potential of coalition operations.

As stated in the introduction, multi-cultural collaboration is a major group dynamic force in the military today. In the remainder of this chapter, we will review the group dynamics literature to better understand how teams are formed of diverse subject matter experts and how they develop over time. We will also define processes that aid or hinder their effectiveness. Finally, based on our understanding of team processes within the context of wicked problems, we will propose collaborative concepts and technologies including consideration of cultural factors to improve coalition effectiveness.

2 Why and How Do Teams Form and Develop?

2.1 Social Exchange

Why would a subject matter expert collaborate with others in a group? Drawing on many different disciplines, Moreland (1987) identified several reasons why people join groups. From an evolutionary perspective, a key reason why these experts might collaborate is to ensure their very survival (Moreland, 1987; Levine and Moreland, 1998).

From a social exchange perspective, people join groups that will maximize their rewards and minimize their costs. Some rewards for collaborating with others may include an increased understanding of the “big picture” and access to information about the consequences of various group decisions and actions. The main reward for collaboration is the ability to meet individual goals. It is safe to assume that subject matter experts are likely to collaborate to accomplish group goals to the extent that their individual goals are likely to be met and collaboration is unlikely to be too costly. Costs may include time expended on unproductive group endeavors, conflict, and discomfort caused by unease in sharing sensitive material with other group members, who are currently considered friendly and safe, but may turn into foes sometime in the future.

Drawing from the attraction literature, Moreland predicts that people will be likely to join groups to the extent that they are strongly attracted to the group’s other members or to the group, itself (affective integration, Moreland, 1987). One of the factors that will affect individual attraction is similarity (Newcomb, 1961; Byrne, 1971). Unfortunately, in solving wicked problems, the subject matter experts comprising the groups are likely to be dissimilar not only on visible, demographic variables (e.g., ethnicity, nationality), but also on non-visible, functional dimensions (e.g., area of expertise), thus potentially decreasing affective integration (Mannix and Neale, 2005). One-way to encourage affective integration and improve performance on wicked problems is to use tools and strategies that highlight similarities among the collaborators.

In addition to similarity, proximity is another important factor that affects attraction (Newcomb, 1961). People are likely to join groups with members that share physical or social environments (environmental integration, Moreland, 1987). Collaborators who are experts in the same domain
share social environments; collaborators located in the same region share physical environments. Collaborators may be drawn to work with others who share social and physical environments rather than drawn to others who will best accomplish the task. If individuals are selected to participate on the team based on factors other than expertise, their influence on the team may be minimized and additional, non-productive conflict may result.

In interviews with US and British commanders and staffs at a multinational command exercise (Pierce, 2006), lack of expertise among team members was cited as one of the impediments to coalition operations. It was perceived that some nations did not send their best qualified staff officers to multinational assignments and often selected officers based on other reasons such as status, relationships, or simply availability rather than expertise. Understanding each member’s team participation objectives and the knowledge and capabilities that he or she brings to the coalition are essential first steps in establishing roles and responsibilities and developing team processes that promote effective interaction among team members. Excluding or marginalizing certain team members based on real or perceived weaknesses may increase workload and resentment among others and can decrease motivation, understanding, and commitment across the team.

2.2 Socialization

Moreland and Levine’s (1982) Model of Socialization provides a theoretical framework to explain how groups change over time. Groups and their members can progress through five stages of development. In the first stage, investigation, prospective group members perform reconnaissance in order to determine which groups will meet their needs. Naturally, this process will be driven by the reasons the prospective member has for joining the group. Awareness of even an erroneous reason as to why one joined a group can alter behavior. For example, Back (1951) randomly assigned participants to groups, but he told group members they were paired with one another for various reasons. These reasons affected the group members’ behavior. People who were led to believe they were paired with others due to similarities in personality had longer conversations than people in other groups; those who were led to believe they were paired with others who shared their goals and interest in the tasks spent very little of their time conversing about anything other than the tasks. They finished the tasks quickly and efficiently. Those who were led to believe that they were grouped together because it would be important for them to know one another acted in a more conservative manner than others: they focused on their own actions more than on the actions of other group members and were careful not to risk their status. Therefore, the primary purposes for group membership are likely to affect group processes. Knowing the reasons the collaborators perceive to be primary may help in predicting their behavior in the group. Also during the investigation stage, the group recruits members that it thinks will best fit its needs. If both the group and the member determine that group membership is desirable, the member will gain entry into the group, become more committed to the group, and enter the second stage, socialization.

During the socialization phase, the group will try to accommodate the new member and the new member will try to assimilate into the group. The new member will use a variety of social influence strategies to attempt to persuade the group to meet its needs. To assimilate the new member, groups offer formal and informal training. Moreland and Levine (1989, 2001) identified several factors (e.g., age, sex, newcomer’s status, self-esteem, task related knowledge and abilities, motivation) that may affect the socialization process. Two of these factors, tolerance for ambiguity and autonomy (including an internal locus of control), a sense of independence and self reliance, and an active rather than a passive orientation to the world, have also been identified as dimensions on which people from different cultures vary. Thus, those from cultures that value tolerance for ambiguity or uncertainty, such as Singapore and Sweden (Hofstede, 1989) and people from cultures with an
active orientation such as Taiwan, Philippines, and the United States (Kirkman and Shapiro, 2001) may become socialized more easily into a wide variety of groups. More important, prospective members who match other group members on these characteristics will integrate more easily into the group (Moreland and Levine, 1989). Using this framework, it is reasonable to assume that it may be more difficult for some multinational teams to assimilate its members than other teams. Better understanding of how culture influences team socialization is needed. If assimilation is successful, the group member will become more committed to the group and the group to its member. Acceptance will lead to the third stage, maintenance.

The full member and the group, from time to time, will engage in role negotiation to be sure that both the member’s and the group’s needs are being met. On occasion, divergence may occur, decreasing the commitment of both the group and its member, and leading to the fourth stage, resocialization. Once again, the group will try to accommodate the member’s needs. The marginal member will attempt to assimilate into the group. If this is unsuccessful, then commitment to the group will reach a nadir forcing the member to exit the group and enter the final stage, remembrance. In this final stage, the group will try to understand its relationship with the ex-member; the results from this process will become part of the group’s tradition. The ex-member will also try to understand what happened in his or her relationship with the group (reminiscence).

This framework will be most useful in explaining group formation and development among groups that have the power to add and expel its group members. This power lies on a continuum, ranging from groups that have complete discretion on one end of the continuum to groups in which members do not control who will join or remain in their group on the other end. Some business groups and military groups are comprised of people who are told to which team they belong and with whom they will work. For some of these groups, membership changes quickly, often, and without notice. In addition to fluctuations in group membership, some business and military groups may have a large number of members and those members may be distributed across distant geographical and physical locations. Group commitment in such groups is hypothesized to be lower in these circumstances and although we anticipate that military personnel will spend some of their time working with diverse subject matter experts in a distributed environment, the focus of this paper is on team processes that occur when they meet face-to-face. Readers are directed to read Shapiro, Von Glinow and Cheng’s (2005) recent volume to focus on issues of teamwork among distributed multinational teams.

While researchers have studied organization commitment within and amongst military groups, to include the commitment of nested group and minority group members (Heffner and Gade, 2003; Karrasch, 2003), empirical research is necessary to understand better the effects of group commitment on team collaboration and operational performance. The framework may also explain how interactions among team members will evolve. In a military coalition, group membership may be predetermined, but motivation to participate and affective commitment may vary greatly.

2.3 Group Identification

Fully socialized members will view themselves as group members, that is to say, their self-identity will include group membership. Social Identity Theory and Self Categorization Theory provide theoretical frameworks for understanding how and when people view themselves as individuals and group members.

Social Identity Theory (Tajfel, 1982) was created, in part, to explain results from the minimal group technique paradigm. In this paradigm, participants are randomly assigned to one of two groups. However, they are not allowed to meet or interact with anyone from their group; membership is anonymous. The group is in name only. Yet, when given the opportunity to distribute rewards,
participants consistently give less to out-group than in-group members (Tajfel et al., 1971). Later studies showed that in-group favoritism can be found whenever social categories are made salient (Oaks, Haslam, and Turner, 1994). Inter-group conflict can increase the salience of social categories, thereby increasing the in-group favoritism bias. Individuating information or the presence of a superordinate group identity (Gaertner, L. and Dovidio, 2000) is likely to make the social category less salient and reduce the bias toward in-group favoritism. For example, Cunningham (2005) recently found that among teams with a common in-group identity, the more ethnically diverse the teams were, the more satisfied the team members were with their co-workers. However, ethnic dissimilarity reduced satisfaction with co-workers among teams without a common in-group identity.

Tajfel (1982) explained the fact that merely categorizing people into groups led to in-group favoritism by hypothesizing that in order to understand the social environment, people categorize the environment into in-groups and out-groups. Membership in the in-groups and not in the out-groups then becomes part of one’s self or identity. Tajfel hypothesized that people seek out positive social identities. Believing one’s in-group is better than out-groups can help turn a social identity into a positive social identity. In-group favoritism and out-group degradation falls out of this belief.

Expanding on Tajfel’s work, Dimmock, Grover and Eklund (2005) examined three components of social identity: 1) the cognitive component, which includes knowledge of one’s group membership, 2) an evaluative component, which includes the value of the group membership to the individual, and 3) an affective component, which is the emotional significance of group membership. Through factor analyses of items designed to tap into each of the three components of social identity and a hierarchical regression analysis of survey responses completed by football fans, they found the affective and cognitive components loaded on a single factor together and were more important in predicting in-group bias than the evaluative component. The items comprising the affective/cognitive component scale of social identity could be modified and used to predict the subject matter experts who are most likely to fall into in-group biases.

Tajfel (1982) further theorized that at any moment each person lies somewhere on an interpersonal-intergroup continuum. At the interpersonal end of the continuum, people are less likely to see themselves in terms of social identities and more likely to see themselves as unique individuals. At the intergroup end of the continuum, people view their entire identity solely based on group membership.

Self Categorization Theory (Hogg, Turner and Davidson, 1990; Turner, 1991; Oakes, Haslam and Turner, 1994) contends that when people are at the interpersonal end of the continuum, they identify with their personal identity; they tend to focus on characteristics that make them different from other in-group members. However, when people are at the inter-group end of the continuum, they identify with their social identity; they self-stereotype in terms of group membership and perceive themselves in a depersonalized manner.

People have a different interpersonal-intergroup continuum for every group to which they belong. There are several different continuums that subject matter experts may be identifying with as they collaborate to solve wicked problems: the continuum concerning the group’s collaboration, the continuum for the nation to which he or she belongs, the continuum for the subject in which he or she is an expert, or on the continuum concerning his or her religious organization, racial group, sex, or familial group. Which group’s continuum will be used at any given time and where on the continuum will the subject matter expert lie? This is determined by social readiness and fit.

Social readiness is the extent to which a person defines himself or herself as a member of a particular social category. This is affected by the salience of the social category, the person’s goals, needs, and expectations regarding the relevance of membership in the social group and past
experience. Culture may also affect social readiness. Analyzing self descriptions of children as young as 3 years of age, Wang (2006) found Chinese American more than Euro-American children focused on social aspects of the self. They were more likely to fall on the intergroup end of the continuum. However, the Euro-American more than the Chinese–American children focused on the personal aspects of the self; they were more likely to be on the interpersonal end of the continuum. In addition to social readiness, fit determines where and on which continuum a person will lie.

Fit is determined by the meta-contrast principle: people will be organized into social categories such that the differences between people in the same social category are smaller than the differences between people in different social categories. In other words, people are organized into groups to make within group differences smaller than between group differences. Turner and Haslam (2001) explain:

…categorization is a dynamic, context-dependent process, determined by comparative relations within a given context. The meta-contrast principle indicates that, to predict categorization, the entire range of stimuli under consideration, rather than isolated stimulus characteristics, must be considered… For example, we might categorize an individual as ‘Australian’ to the extent that, in the current comparative context, the difference between individual Australians… are less than the differences between Australians and Americans. Alternatively, the salient category might be ‘English speaking’ in a context where the difference between various English-speaking groups (such as Americans and Australians) is less than the difference between English and non-English speakers. These ideas can be expressed in terms of a meta-contrast ratio, that is, the average perceived intercategory difference divided by the average perceived intracategory difference. The higher this ratio for some social category such as Australian, the more likely it is that individual Australians will be perceived in terms of their shared national identity (p. 35).

Because social category salience changes frequently, it will be difficult to make predictions a priori concerning fit and readiness of diverse subject matter experts as they collaborate in teams to solve wicked problems in dynamic, ever-changing and threatening environments. The fact that diversity exists in the team may not be as important to the development of a collective group identity as the ratio of in-group to out-group members.

In a recent review of the effects of diversity on teams, Mannix and Neale (2005) conclude that surface-level social category differences (e.g., ethnicity, gender, age) tend to have negative effects on team performance. However, underlying differences (e.g., personality, functional background, education) can lead to positive effects on team functioning. Van Knippenberg, De Dreu and Homan’s (2004) Categorization-Elaboration Model proposes many of the factors that moderate the relationship between diversity and performance (e.g., relational conflict, task motivation, elaboration of task relevant information and perspectives).

As similarities and differences among collaborators become evident, the group member’s perception of self will shift from membership in one group to another group to more of an individualistic orientation and then back to membership in a group as the context and situation changes. As these shifts occur, in-group members might become out-group members and then return to in-group members again.

Krauss and Chiu (1998) suggest that language is used to mark and maintain social identities. The actual language (e.g., English vs. German) spoken by people is one of the most salient markers used in social categorization and social identity. In a series of studies, it was found to be more important than the geographical region in which people lived or their cultural background (Taylor, Bassili and Aboud, 1973; Giles et al., 1976; Giles, Taylor and Bourhis, 1977). In addition, linguistic style can also provide cues as to social identities (Krauss and Chiu, 1998). For example, Hamilton et al. (1992) found people used fewer state verb phrases and more action verb phrases when explaining behaviors of in-group rather than out-group members. Because state verb phrases
are more abstract than action verb phrases, Maass and colleagues suggest that people linguistically code behaviors of out-group members within the out-group stereotype, and predict that this is related to group expectancies (Maas, Arcuri and Semin, 1989; Maass and Arcuri, 1992; Maas, Zabbini and Stahlber, 1995). Shifts in in-group and out-group status may be able to be detected using linguistic analysis. These shifts are important because people process information from and about out-group and in-group members differently. Extreme out-group members may not even be processed as human.

Using functional magnetic resonance imaging (fMRIs), Harris and Fiske (2005) examined the activation of the medial prefrontal cortex (mPFC), which is known to be associated with social cognition, as participants viewed pictures of people and objects. Activation was high when participants viewed people stereotyped to be high in either warmth or competence. However, when people viewed extreme out-group members (e.g., those low in both warmth and competence, such as addicts or the homeless), the mPFC area was not activated. Harris and Fiske conclude that extreme out-group members are de-humanized. Subject matter experts expected to collaborate with extreme out-group members may have an exceedingly difficult time gaining a collective in-group identity.

Linguistic analysis may be used to determine the extent to which each individual views each of the other team members as in-group or out-group members. A method that researchers have found useful in evaluating individuals and team interactions is the Linguistic Inquiry Word Count (LIWC; Pennebaker, Francis and Booth, 2001). The LIWC analyzes text on a word-by-word basis, categorizes each word using 72 linguistic dimensions (e.g., pronoun, present tense, cognitive process), and determines the relative frequency of each linguistic dimension. The words the LIWC categorize are function words, particles, or “junk” words; they are not meaning laden content words, but rather the words we use to hold the content together. Using the LIWC, Pennebaker and his colleagues have found linguistic analysis to predict personality. For example, Pennebaker and King (1999) found that the more people used first person singular pronouns, the higher they scored in neuroticism and the lower they scored in openness. Avoidance of tentative words and the use of social and positive emotion words were characteristics of extroverts.

LIWC has been found to predict deception (Dzindolet and Pierce, 2004; Dzindolet et al., 2005). For example, Newman et al. (2003) report that deceptive communications, compared with honest communications, contain less cognitively complex language (e.g., fewer exclusive words; perhaps due to the cognitive load of lying) and fewer first person singular pronouns (perhaps to allow people to distance themselves from the lie). LIWC can identify psychological and physical health. Rude, Gortner and Pennebaker (2004) report that the use of first person singular pronouns is related to depression; Pennebaker et al. (2004) report the use of non-I pronouns is related to testosterone level. LIWC can also be used to identify high performing groups. For example, Dzindolet et al. (2005) found the LIWC was useful in identifying groups who used more productive decision-making strategies. Examining correlations among word use and group performance across many different tasks, Dzindolet and Pierce (2006) concluded that the more groups used words with six or more letters and avoided prepositions, both indicators of more cognitively complex language, avoided expressing negative emotions and discussing social processes, the better the groups performed. However, task, group size, and communication medium greatly moderated the word use-group performance correlations.

Most importantly, LIWC can be used to understand social relationships (Pennebaker, Mehl and Niedergoffer, 2003). How people communicate with one another, independent of the content of what they are saying, offers us clues into their relationship. One particularly useful function word category is first person singular pronouns. Chung and Pennebaker (forthcoming) report that
among dyads, the lower status, more subordinate, dyad member uses significantly more first person
singular pronouns than the higher status, more dominant dyad member.

Both linguistic analysis and cultural awareness training could be used as intervention strategies. Linguistic analysis could be used to diagnose communication processes and to assess the extent to which the group has a collective identity to identify at-risk groups. Cultural awareness training may make nationality and culture less likely to be salient categories on which individuals base their in-group and out-group status.

2.4 Social Cognition and Perception

In the next section of this review, research findings relevant to social cognition and perception are reviewed. How collaborators are likely to explain the behavior of in-group and out-group members, and errors and biases they are likely to make in processing social information about in-group and out-group members are discussed.

Causal attributions To collaborate effectively, it is advantageous to be able to infer both in-group and out-group members’ thoughts and intentions. Knowing the extent to which an in-group member is committed to a group task or to a more individualistic goal aids in establishing trust and assessing team member contributions. How do people come to know others’ thoughts and intentions? People rely on what is observable: behavior. Attribution theorists (e.g., Heider, 1958; Jones and Davis, 1965; Kelley, 1972) hypothesize that people categorize the cause of behavior as either internal or external to the person performing the behavior. If the behavior is thought to be the result of a person’s thoughts, intentions, abilities, or personality, an internal attribution is made. If the behavior is thought to be the result of situational forces, an external attribution is made. According to Kelley’s Covariation Model (Kelley, 1972; Kelley and Michela, 1980), people make causal attributions by examining the relative likelihood of the behavior when the cause is present and absent. If the cause and behavior occur together more than the behavior occurs in the absence of the cause, that is, the cause and the behavior covary, people are likely to infer a causal relationship. People focus on three types of information to make an internal or external attribution: 1) Distinctiveness, 2) Consensus, and 3) Consistency.

Distinctiveness is the extent to which it is unusual for the person to exhibit the target behavior across a variety of contexts. Distinctive behaviors are attributed to external sources; low distinctiveness behaviors are attributed to internal forces. Consensus is the extent to which other people are exhibiting the behavior in the context. High consensus behaviors are attributed to external forces; low consensus behaviors are attributed to internal ones. Consistency is the extent to which the person exhibits the same behavior in the same context at a later time. If consistency is low, an attribution is not made; the behavior is thought to be a coincidence or an aberration. However, if consistency is high, then an attribution will be made.

Using Kelley’s Covariation Model, a person would probably make an accurate determination as to the cause of another’s behavior. However, the determination would require the use of cognitive resources. To determine why Karen argues with Bob, group members would need to search to determine how often Karen argues with other people (distinctiveness), how often other people argue with Bob (consensus), and whether Karen argues with Bob in the future (consistency). Rather than using these cognitive resources, people often make attribution errors.

Errors and biases in causal attributions People are biased toward making internal rather than external attributions; this is called the fundamental attribution error (Ross, 1977), and is hypothesized
to be due to the fact that dispositional characteristics are oftentimes more salient than situational characteristics (Krull and Dill, 1996; but see Robins, Spranca, and Mendelsohn, 1996).

The use of the fundamental attribution error is influenced by culture (Norenzayan and Nisbett, 2000). People from individualistic cultures (e.g., American) make more fundamental attribution errors than those from more collectivistic (e.g., Chinese) cultures (Miller, 1984; Triandis, 1990; Choi and Nisbett, 1998; Leung and Chan, 1999). This finding holds true even when confounding variables are controlled (Norenzayan and Nisbett, 2000). Norenzayan and Nisbett (2000) review research indicating that Americans more than Hindu Indians, Chinese, and Koreans make the fundamental attribution error. They suggest that the cultures who historically think more holistically rather than analytically are less likely to make fundamental attribution errors.

When explaining others’ behavior, people are likely to underestimate the effect of the situation and overestimate the effect of the person’s intentions, attitudes, abilities, or personality. However, when people are trying to understand their own behaviors, the bias is reversed; external attributions are more likely. To explain their own behavior, people are likely to overestimate the effect of the situation and underestimate the effect of personal attributes. This bias is called the actor-observer effect (Jones and Nisbett, 1972; Karasawa, 1995; Krueger, Ham and Linford, 1996).

The fundamental attribution error and actor-observer effect extend to groups (Doosje and Branscombe, 2003). People are more likely to explain in-group members’ behavior with external rather than internal causes and explain out-group members’ behavior with internal rather than external causes. For example, Jewish and German visitors to Ann Frank’s home rated the extent to which the German’s behavior toward the Jews during the Second World War was due to internal (aggressive nature of Germans) or external (historical context) causes. Jewish visitors were significantly more likely to explain the atrocities with internal causes than German visitors. In addition, German visitors were significantly more likely to explain German behavior with external causes than Jewish visitors.

In addition to the fundamental attribution error and the actor-observer effect, people make self-serving biases in their attributions. When faced with positive outcomes, people are more likely to make internal attributions; when faced with negative outcomes, people are more likely to make external attributions. Cultural differences in self-serving biases exist (Oettingen, 1995; Lee and Seligman, 1997). Specifically, people from individualistic cultures engage in the self-serving biases more than people from other cultures (Heine and Lehman, 1997; Kitayama et al., 1997; Heine et al., 1999). Van Boven et al. (2003; Study 3) found that American students more than Japanese students showed a self-serving bias by believing that they were less likely than others to fall into the trap of the fundamental attribution error.

The ultimate attribution error (Pettigrew, 1979) is the phenomenon that self-serving biases extend to in-groups. When making attributions for positive in-group behaviors, internal attributions are made; yet, external attributions are made to explain positive out-group behaviors. Similarly, to explain negative in-group behaviors, external attributions are made; yet, internal attributions are made to explain negative out-group behaviors. Therefore, the same behavior is likely to be explained differently based on whether or not the person performing the behavior is considered to be an in-group or out-group member by the perceiver. These explanations affect people’s expectations about future in-group and out-group behavior.

Processing social information Group membership affects how we process information about other people (Levine and Moreland, 1998). For example, Zarate and Sandoval (1995) found people process information about in-group members more quickly than information about out-group members, for example, participants sorted photographs of same-sex targets more quickly than they sorted opposite-sex targets on a number of different dimensions. Research suggests that
this phenomenon is due to an increase in speed of processing in-group information compared with neutral information rather than a decrease in speed of processing out-group information (Gaertner and McLaughlin, 1983). In addition, people remember information about their in-group members better than information about out-group members (Fiske, 1998). For example, Park and Rothbart (1982) found people recalled more information about same-sex than opposite-sex targets.

These processes occur without our awareness. Research using the Implicit Association Test finds evidence for implicit prejudice among people who do not even know they harbor biases against out-group members (Dovidio, Johnson and Howard, 1997). Implicit prejudice, when applied to people of different races, may lead to aversive racism. The aversive racist would never overtly perform racist behaviors; this would fly in the face of their self-concept of not being racist. In fact, the aversive racist even may appear to favor out-group members in many situations. However, when given justification, the aversive racist will more harshly treat the out-group than in-group members. For example, white college students gave more lenient sentences to black than white defendants in situations in which clear evidence against the defendant did not exist. However, in situations in which clear evidence did exist, the white college students gave longer sentences to the black than white defendant (Pfeifer and Ogloff, 1991). Therefore, in multinational teams, prejudice and discrimination toward other group members (based on another categorization, for example, age, sex, race, nationality) may not occur until certain team members make mistakes or fail.

Views toward out-group members can change with friendly contact between in-group and out-group members. For example, Henry and Harden (2006) found the more contact between Whites and Blacks in a sample from the United States and between Christians and Muslims in a sample from Lebanon, the less the participant reported negative feelings toward the out-group members (explicit prejudice). However, social contact reduced implicit prejudice only toward the Whites and Christians, the higher status groups.

One can easily see how complex the relationships among the diverse subject matter experts might be. Experts who see solving the wicked problems as the most salient category dimension are likely to view the other collaborators as in-group members. However, some of these collaborators may be more focused on other salient category dimensions (e.g., nationality), and view only collaborators who share their nationality as in-group members. Subject matter experts from other nationalities are viewed as out-group members and, at least initially, may be viewed negatively. However, as the subject matter experts from different nations work together to solve the wicked problems and contact increases, those with higher status will be viewed more positively by the collaborators with lower status. However, contact will not change the higher status nationality collaborators’ view of lower status nationality others. Within the same group of collaborators, great variations in who is considered an in-group and an out-group member and how positively out-group members are viewed will exist. To make matters more complicated, these relationships are predicted to change as category salience, readiness, fit, and contact with out-group members change.

Errors and biases in processing social information The false-consensus effect, the tendency for people to overestimate the extent to which others share our attitudes, opinions, and beliefs, is stronger among in-group members than out-group members (Karasawa, 2003). Therefore, members of the same group expect the other group members to agree with them to a far greater degree than the members actually do. This bias can lead to faulty information processing in at least three different ways.

First, expectations drive the information people seek. The tendency to seek out, and therefore find, evidence that confirms rather than disconfirms expectations is dubbed the confirmation bias (Frey and Schulz-Hardt, 2001). Making matters worse, people are especially likely to fall into the trap of the confirmation bias when they are personally invested in creating and finding solutions to
problems and when the potential solutions being examined are agreeable rather than threatening. For example, when faced with an agreeable solution, people are likely to ask, “Can I believe this?” whereas when faced with a threatening solution, they ask, “Must I believe this?” (Dawson, Gilovich and Regan, 2002). With these biases in place, it is likely that multi-cultural group members will overestimate the extent to which they agree with one another and may prematurely accept solutions that appear to be agreeable to all the stakeholders without fully examining the full range of consequences of executing the solution.

Second, expectations can lead group members to create confirmatory evidence. For example, if I expect a group member to be friendly and warm, then I am likely to treat the person in a friendly, warm manner. The group member is then likely to act friendly and warm to me, thus providing evidence that my expectation was correct. This phenomenon is called the self-fulfilling prophesy (Merton, 1948). Expecting the multi-cultural group members to agree with one another, group members may create an atmosphere in which all the group members appear to agree. Breakdowns in group processes may not occur until the execution stage, when differences in attitudes and beliefs become evident.

Third, evidence that matches one’s stereotypes or expectations are processed more quickly (Brewer, Dull and Lui, 1981), attended to longer (Ruscher and Fiske, 1990), and are better remembered, especially in complex environments (Fyock and Stangor, 1994). People often ignore information that is relevant but inconsistent with their stereotypes (Dijksterhuis and Knippenberg, 1996), unless the information is extreme or bizarre (Stangor and McMillan, 1992). Even if the inconsistent information is noticed, it is likely to be attributed externally, whereas internal attributions are made when faced with information that is consistent with expectations (BenAri, Schwarzwald and HorinerLevi, 1994).

Taken together, errors in information processing can lead to an illusion that group members agree with one another, when in fact they do not. Subject matter experts collaborating on wicked problems are likely to overestimate the extent to which other stakeholders hold similar values, opinions, and attitudes, especially when a collective group identity is salient and the stakeholders are perceived as in-group members. This may cause problems in coordination and execution of potential courses of action.

Even though group members overestimate the extent to which in-group members share their opinions, beliefs, and attitudes, people perceive in-groups to vary more than out-groups (illusion of out-group homogeneity; Park and Rothbart, 1982). For example, college students and elderly participants were asked to rate how varied college students and the elderly were on a number of personality traits and characteristics. Consistent with the hypotheses, college students rated other college students as highly varied and rated the elderly as similar. In addition, the elderly rated elderly targets as highly varied and rated college students as similar (Linville, Fischer and Salovey, 1989).

Therefore, when the subject matter experts collaborate to solve complex problems without well-defined problem spaces, it is likely that they will overestimate the extent to which out-group members are similar to one another. After a brief encounter with a few out-group members, the experts are likely to believe the traits and characteristics of this small sample of out-group members will be shared by most out-group members. Underestimating the wide range of knowledge, skills, abilities, and personalities of out-group members, experts are likely to find less than optimal solutions.

However, recent research indicates that under high threat and workload conditions, a bias in the opposite direction may emerge. Ackerman et al. (2006) asked Whites to view pictures of Blacks or Whites who held either angry or neutral facial expressions. In addition, some of the participants were distracted with other tasks as they viewed the photos. In a recognition task,
evidence for the out-group homogeneity bias was found for the neutral faces. However, under
the conditions in which cognitive resources were limited and participants were viewing photos of
angry faces, evidence for an out-group heterogeneity bias was found. Providing the subject matter
experts with useful information about their own and other team members’ culture-based values and
social interaction styles may help the collaborators avoid falling into some of the biases based on
nationality in-group and out-group status.

In summary, as diverse subject matter experts collaborate to solve wicked problems, the extent
to which they view the other collaborators as in-group or out-group members affects how they
explain the behaviors of the collaborators, the speed at which they process information about
the collaborators, the information they are likely to remember about the collaborators, and their
expectations about the collaborators’ opinions, attitudes, and actions. Technological solutions may
be developed to assess the collaborators’ view toward other group members or help members to
form a collective group identity. In addition, some technological tools will be used by the subject
matter experts to help them perform their tasks. As mentioned earlier in this paper, technologies
to aid subject matter experts’ understanding and visualization of the varied consequences of any
action are being developed. How will the collaborators view the automated tools? How will the
subject matter experts process information provided by the automation?

2.5 Automated Aids: The Ultimate Out-Group Members

Groups provided with technologies capable of organizing, synthesizing, and analyzing vast amounts
of information provided by subject matter experts into a narrow set of acceptable solutions from
which the group can select or modify have some unique challenges. The underlying assumption in
providing these automated aids to groups is that the groups will function better with the technology
than without it. Some researchers have found support that individuals perform better with automated
aids than without them (Corcoran, Dennett and Carpenter, 1972; Parasuraman, 1987; Thackray
and Touchstone, 1989; Dalal and Kasper, 1994). However, human-computer teams do not always
function optimally. Subject matter experts collaborating to solve wicked problems may have
available to them use of an automated aid, but this does not necessarily ensure better performance.
In fact, researchers identify two types of common errors in automation use (Parasuraman and
Riley, 1997).

Rational decision-makers will rely on an automated aid when doing so will maximize gains and/
or minimize losses. Failure to rely on an aid in this situation constitutes disuse (Parasuraman and
Riley, 1997). Disuse is defined as “underutilization of automation” (p. 233). Anecdotal evidence
supports disuse; Parasuraman and Riley (1997) described many real-world incidences in which
disastrous results occurred due to people ignoring automated warning signals. Further, laboratory
experiments have found disuse in paradigms in which the aid’s decisions are provided only after
the human operators have indicated their decision (Moes et al., 1999; Dzindolet et al., 2002). For
example, Moes et al. (1999) found the majority of college students (67 per cent) chose to ignore
the decisions of an automated aid even after being provided with feedback that their automated aid
made half as many errors as they did during 200 prior trials.

When ignoring an automated aid will maximize gains and/or minimize losses, rational subject
matter experts will ignore the aid and rely on their decisions. Relying on the automated aid in this
circumstance would constitute misuse (Parasuraman and Riley, 1997). Misuse has been found
among operators performing monitoring functions (Parasuraman, Molloy and Singh, 1993; Singh,
Molloy and Parasuraman, 1997) and among those provided with automated decisions aids (Layton,
Smith and McCoy, 1994; Mosier and Skitka, 1996; Dzindolet et al., 2001).
One strategy used to optimize human-computer performance has been to call on system designers to create automated aids that are increasingly more reliable. More reliable decision aids are assumed to increase human-computer team performance. As with human teams, however, increasing the reliability of one team member’s performance does not necessarily affect the team’s performance. Using a signal detection analysis, Sorkin and Woods (1985) revealed that optimizing an automated aid’s performance does not always optimize the human-computer team’s performance on a monitoring task. Specifically, they found that using a response criterion that yielded the best performance for the automated aid (i.e., highest detection rates and fewest false alarms) did not yield the best performance for the human-automated team. Although “synergy” can be found in human-computer teams (e.g., Dalal and Kasper, 1994), it is not likely to be gained by optimizing human-alone or computer-alone performances. The interaction between the automated aid and human operators must be considered.

Subject matter experts may initially expect automated aids to perform superior to their human group members. For example, Pomranky, Dzindolet and Peterson (2001) and Dzindolet et al. (2002) found college students predicted an automated decision aid would make fewer errors on a target detection task than other human participants. However, after working with superior, but imperfect, aids, participants preferred to seek out information from human rather than automated aids (Dzindolet, Pierce, and Beck, 2006). Linguistic analysis of the participants’ descriptions of their human and automated aids revealed that the participants had much less cognitively complex schemas about their automated than human aid (Dzindolet and Pierce, 2006). Without an understanding of why the automated aid might err, the participants overreact to errors made by an automated aid.

Providing an automated decision aid to a group of people, rather than to one human operator, further complicates the picture. Will group members uniformly misuse or disuse the automated aid? Will some members misuse the aid and others disuse it? Research examining the effect of an automated aid on group performance is scant. However, extrapolating from research on information processing, one can confidently predict that group members, faced with the same information provided by an automated aid, will notice, interpret, and analyze the information differently, based on prior experience and expectations. It is possible, and maybe even probable, that several stakeholders endorsing contradicting courses of action will find support for their solution using information provided by the automated aid. It is erroneous to assume that providing group members with an automated aid will necessarily increase the group’s performance.

### 3 Team Processes and Team Performance

#### 3.1 Mental Models

As teams perform various tasks, they form conceptualizations of the task requirements, the knowledge, skills, and abilities of the other group members, and the relationships among the team members and the task within a temporal context (Cannon-Bowers, Salas, and Converse, 1993). A team’s mental model can be examined for accuracy and for sharedness (that is, the extent to which members of the same team have the same team mental model). Several reviews of the team and group literature suggest that team mental models are important in understanding team effectiveness (Kerr and Tindale, 2004; Kozlowski and Ilgen, 2006). In a recent study, Edwards et al. (2006) examined the relationship between shared mental models and team performance. High and low ability members were paired into homogeneous and heterogeneous dyads and performed several tasks over a 10-day period. Results indicated that the relationship between team ability and performance was mediated by the shared mental model’s accuracy. Similarity of the shared mental
models was not as important as accuracy in affecting performance. Measuring shared team mental models is challenging (Kozlowski and Ilgen, 2006). However, determining the extent to which the diverse subject matter experts’ shared mental models are accurate may be beneficial in supporting the team’s success. An awareness of one’s own and another culture’s cognitive biases and social-interaction expectancies may help team members build more accurate team models. Providing team members with such training may help to improve team performance among multinational teams.

3.2 Social Facilitation

For diverse subject matter experts to collaborate to solve wicked problems, they will perform some tasks alone and some with the group. To perform a task in a group, one must perform the task in the presence of other group members. A rich literature in social psychology identifies how performing tasks in the presence of others affects performance. The mere presence of others affects the way people perform tasks. In a classic study, Allport (1920) counted the number of associative words people generated alone and in the presence of others. The results indicated that people generated far more words when in the presence of others than when alone. He dubbed this effect social facilitation. Since then, other researchers have found that sometimes the presence of others hurts performance (e.g., Platania and Moran, 2001). Zajonc (1965) created the Drive Theory of Social Facilitation to explain these apparently contradictory findings. According to Zajonc, the presence of others increases arousal. The increased arousal increases the likelihood that dominant responses will be emitted. If the dominant responses are correct (e.g., with well practiced or simple tasks), the presence of others will improve performance. However, if the dominant responses are wrong (e.g., with new, novel, complex tasks), the presence of others will impair performance.

Zajonc hypothesized that merely the presence of others increased arousal. Since then, other researchers have suggested that other factors that may account for the increased arousal due to the presence of others. For example, according to evaluation apprehension, group members become anxious because they fear they will be evaluated negatively by the other group members (Cottrell, 1972). Baron’s (1986) distraction-conflict theory proposes that the presence of others causes people to divide their attention between the task they are performing and attending to the other people who are present. This causes arousal. In addition, Baron hypothesizes that the distractions caused by the presence of others may lead to cognitive overload, thereby, restricting attention to only the most important facets of the task. There is no evidence to suggest that this effect will vary across cultures, but this may be an area for investigation. In the interim, however, we will assume that the effect will be maintained cross culturally.

Extrapolating these findings, diverse team members will probably generate more and better solutions to wicked problems if they work alone rather than in the presence of other team members. However, this is probably not practical. Each group member does not have enough information to make an acceptable solution; collaboration is essential. Assuming the task must be performed in a group, members should set norms and rules that try to reduce evaluation apprehension and distraction. Osborn’s (1957) brainstorming rules explicitly state that group members should not criticize ideas generated by other group members, and research has found that brainstorming groups following Osborn’s rules generate more and better ideas than groups not following his rules (e.g., Meadow, Parnes and Reese, 1959). However, Nemeth et al. (2004) found that groups encouraged to criticize group members’ ideas and openly debate generated more ideas than groups not provided with these instructions and about the same number of ideas as those provided with Osborn’s rules. A better understanding of how to facilitate collaborative debate among diverse team members is required.
3.3 Sharing Knowledge

One reason why collaboration is essential in generating solutions to wicked problems is that the problem space is too complex and large for any one individual to completely know. Thus, collaborating with experts in domains other than one’s own, one can expand one’s knowledge base. As a group, the experts’ information can be combined and compiled; the solution can be created from this expanded knowledge base. For this to occur, however, group members must share their unique pieces of information. Ideally, group members share areas of their unique expertise, information the other group members do not know. However, in a series of studies, Stasser and his colleagues have found that this is not the case (Stasser and Titus, 1985, 2003; Stasser, Taylor and Hanna, 1989; Stasser, 1992). In fact, group members tend to spend the majority of their time discussing information the group members have in common. Rather than basing their decision on a knowledge base that is equivalent to the union of the group members’ knowledge, they base their decision on a knowledge base that is equivalent to the intersect of the group members’ knowledge. In highly disparate teams, this knowledge base is likely to be small and biased.

In addition, information that is salient and negative is more likely to be shared in group discussions (Wittenbaum, Hollingshead and Botero, 2004). Thus, left to free, open discussions, subject matter experts solving wicked problems are likely to overly focus on information that is shared, salient, and negative. This bias is likely to negatively affect the group’s decision making. Linguistic analysis may be useful in determining the extent to which group members are focused on shared and unshared information alerting team members to their biases.

From the above discussion, it might appear that groups homogenous with respect to knowledge or perspective may be less affected by group interaction than heterogeneous groups. However, this is not the case.

3.4 Group Polarization

Group members who agree with one another prior to a group discussion become more extreme in their attitudes and beliefs at the end of the group’s discussion. This finding is named group polarization (Fraser, Gouge and Billig, 1971; Knox and Safford, 1976; Myers and Lamm, 1976). If individuals promote a slightly risky course of action, they are likely to endorse a more risky course of action after discussing their position with other like-minded individuals. Similarly, if individually, group members hold slightly conservative views, they are likely to become even more conservative after talking with like-minded group members. Given that people are attracted to similar others (Newcomb, 1961), for example, like-minded others, group polarization is likely to occur.

3.5 Group Conflict and Trust

Decision-making will be optimized when there is an ideal amount of conflict in a group. Groups with an ideal level of conflict are likely to be cohesive. Several meta-analyses of the relationship between group cohesion and performance have been performed. Beale et al. (2003) found that three measures of cohesiveness (task commitment, group pride, and attraction among group members) were related to team performance. Mullen and Cooper (1994) suggest that the relationship is bi-directional. They found that successful team performance increased group cohesion. Gulley, Devine, and Whitney (1995) found that cohesion was related to group performance, especially if the task was interdependent.
If there is too little conflict in the team, groupthink can occur (Janis, 1972, 1982: 1996). When the group’s overriding emphasis is to get along with one another and reach consensus, the group can overlook important pieces of information as they make decisions. Janis outlined some symptoms of groupthink, which include an illusion of invulnerability concerning the group’s ability to make immoral or unwise decisions, conformity pressure and self-censorship, an illusion of unanimity, and the presence of mind guards. These mind guards are group members who “protect” the group from information inconsistent with the group’s decision. Groupthink has been implicated in Kennedy’s administration’s decision to invade the Bay of Pigs (Aronson, Wilson and Akert, 2005), NASAs decision to launch the Challenger (Esser and Lindoerfer, 1989), and the Bush administration’s decision to invade Iraq (Franzoi, 2006).

Fortunately, researchers have identified several procedures that eliminate groupthink (McCauley, 1989; Schafer and Crichlow, 1996). Groups with impartial leaders who are open to a variety of ideas are less likely to suffer from groupthink. In addition, groupthink can be minimized if members encourage the criticizing of ideas, seek opinions of those outside the group, and assign certain members of the group to play the role of devil’s advocate. In addition, allowing group members to state their opinions anonymously can reduce conformity pressure and self-censorship. Finally, creating subgroups can decrease groupthink. Linguistic analyses may be used to determine if the diverse subject matter experts are experiencing groupthink as they solve wicked problems.

The lack of group conflict can lead to groupthink, however, too much conflict can also lead to lower commitment to group goals and poor decision making. Social psychologists have identified three broad sources of conflict: 1) Personal Conflicts, 2) Substantive Conflicts, and 3) Procedural Conflicts (Panteli and Sockalingam, 2004). Personal conflicts occur when reciprocity of attraction among group members is low, in other words, group members do not like one another (Alicke et al., 1992; Morrill, 1995). Given that similarity leads to interpersonal attraction (Newcomb, 1961), personality conflicts are more likely to occur among diverse rather than homogenous groups (Rosenbaum, 1986; Moreland, Levine and Wingert, 1996; Riordan and Shore, 1997). Jehn (1995) examined work groups in a real world setting and found that relationship (or personal) conflicts were related to dissatisfaction among group members, but they were not related to performance.

Substantive conflicts occur when group members disagree about issues concerning the tasks the group is to perform. People with different perspectives of, expectations about, and prior experience with a problem are more likely to have substantive conflicts than more homogeneous groups. Jehn (1995) found substantive conflict hurt team performance for routine tasks but was beneficial to performance on novel tasks. Substantive conflicts expose group members to different perspectives, which can lead group members to consider a wider range of issues or facts ultimately improving group performance. However, De Dreu and Weingart’s (2003) meta-analysis found an overall negative relationship between substantive conflict and performance. Examining real-world teams, Lovelace, Shapiro and Weingart (2001) found that functional diversity did lead to more substantive disagreements, but that the disagreements hurt performance only if the communications were contentious and team members did not feel free to express task-related doubts. Ilgen et al. (2005) suggest that teams perform well if they unemotionally debate in an atmosphere of trust, feel free to express divergent opinions, and can resist the tendency to compromise or reach consensus too early.

Procedural conflicts surround the roles group members believe others should play and how conflict should be resolved. Formal rules, for example, bylaws or Robert’s Rules of Order, help group members to avoid procedural conflicts by stating up front the manner in which conflict should be handled in the group (Forsyth, 1999). To the extent that group members from different cultures hold different expectations about how to appropriately handle interdependence and
resolve conflict, culturally diverse groups will experience more procedural conflict than more homogeneous groups.

How well group members manage the three types of conflict affects trust, knowledge sharing, and performance. Panteli and Sockalingam (2004) created a model to understand how group conflict and trust change over time. They suggest that initially group members exhibit calculus-based trust (CBT) in one another, which is fragile. At this level of trust, group members trust one another and act in a trustworthy manner only to gain the rewards from working with one another and to avoid punishments associated with not working together. However, if procedural conflicts are managed well such that group members know what to expect from one another, then trust increases, increasing knowledge sharing and the likelihood that substantive conflicts may lead to more diverse and better solutions rather than to group withdrawal and diminished trust. If substantive conflicts are managed well and the group succeeds, trust will increase, knowledge sharing will increase, which will lead to less personal conflict and an increase in commitment to the group. Eventually, trust and knowledge sharing grow such that trust changes from CBT to knowledge-based trust (KBT), which is less fragile and more enduring. As long as conflict is continually managed well, group members are likely to share even more knowledge with one another leading to even higher levels of trust, group commitment and, ultimately, good performance. Some groups will even reach identification-based trust (IBT), though this is very rare. With IBT, group members can nearly take one another’s places, have shared identities, and have strong inter-relationships to the point that synergy is realized.

3.6 Negotiation

To try to manage conflict well, group members often negotiate with one another and with out-group members. Three types of negotiation strategies are: 1) Concession Making (or Yielding), 2) Contending, and 3) Problem Solving (or Mutual Gains Bargaining).

Concession making occurs when group members lower their demands and accept less. In the long term, occasional yielding can increase trust from other group members. However, concession making should not be done too early in the negotiations. It is appropriate only after a win-win solution is not found (Pruitt, 1998).

Contending involves trying to persuade others to yield or concede. Group members can influence and persuade in-group and out-group members in a number of ways. Informational influence occurs when new information or a novel interpretation or perspective presented by a group member changes the thoughts, feelings, or behaviors of other group members (Deutsch and Gerard, 1955). Exposure to decisions reached by an automated aid may influence group members through informational influence. Trying to persuade others to yield, group members may try to present knowledge or information that supports their point of view.

Cialdini (2001) reviewed many types of social influence tactics that operate through normative influence, which occurs when group members change their judgments and views toward those of the other group members in order to have other group members like them, to hold the majority opinion, or to avoid conflict (Goethals and Zanna, 1979). Cialdini explains that people are more likely to be influenced by people they like and by people in authority. In addition, people are likely to be influenced by the fact that a large number of people hold a certain belief or perform a certain behavior. People are swayed by social proof (Cialdini). Using normative influence to convince others to concede, group members may try to appear credible exerting power and status or likeability. In addition, they may make efforts to convince others that they hold the majority opinion in attempts to persuade. Although contending may lead to short term victories, constant contending in long-term relationships decreases trust and group commitment (Pruitt, 1998).
Like concession, if it occurs too quickly, opportunities to find win-win solutions may not be fully explored. Linguistic analysis may be useful in assessing the extent to which diverse subject matter experts are engaging in contending and concession-making behaviors disproportionately, potentially decreasing commitment and productivity.

Ideally, negotiation strategies involve problem solving, generating solutions that satisfy the goals of all involved. Tactics that lead to problem solving involve log-rolling, in which each group member is given their highest priority issues but must concede on all others, expanding the pie, that is, finding additional resources to accommodate all parties, compensating the loser, and cutting the loser’s costs (Pruitt, 1998). The Dual Concern Model (Pruitt and Carnevale, 1993) conceptualizes the three strategies (and inaction or avoidance) as a 2 (other-concern) X 2 (self-concern) design. Concession making involves a high concern for others and low self-concern; contending involves a low concern for others and high self-concern. Avoidance of conflict occurs with low concern for self and others. Problem solving represents high concern for self and others (Pruitt, 1998).

Of course, self-serving biases and other errors in information processing can lead members of the group to believe that they showed more concern for others than other group members, and paradoxically, that they are better negotiators than most other people (Pruitt, 1998). In addition, Wicklund (1989) has found that people overestimate their contribution to group products. Specifically, they are likely to overestimate their ownership of ideas discussed in a group. For this reason, more than one group member may take credit for creating or finding a particular solution during a group discussion.

3.7 Group Motivation

When working in a group, the responsibility for the group’s product is diffused among the group members. Therefore, group members may not be as motivated to extend as much effort as when working alone. This phenomenon has been dubbed social loafing (cf., 1979) or free riding (Kerr and Bruun, 1983). One theory which has been successful in accounting for much of the findings in the social loafing literature is Shepperd’s Expectancy-Value Theory (1993, 1998). According to this theory, motivation is predicted from a function of three factors: expectancy, instrumentality, and outcome value.

The first factor, expectancy, is the extent to which members feel that their efforts are necessary for the group to succeed. When members feel their contributions are dispensable, or when one’s individual contribution is unidentifiable or not evaluated, one is likely to work less hard (Harkins and Petty, 1982; Kerr and Bruun, 1983; Williams and Karau, 1991). Team efficacy, the group’s perception that it will be able to accomplish its task, and group potency, the group’s perception that it is effective, may affect expectancy. A recent meta-analysis revealed that team efficacy does lead to improved performance, especially when the task is interdependent (Gully et al., 2002).

Instrumentality, the extent to which members feel that the group’s successful performance will lead to a positive overall outcome, is also predicted to affect effort. Members who feel the outcome is not contingent on the group’s performance are less likely to work hard. Thus, effort should be decreased among members who feel their group’s performance is irrelevant. In one study, Shepperd (1998) varied instrumentality. Half the participants were told that the seven groups with the highest number of ideas generated (out of ten groups) would earn a reward. Other participants were told that the members of the four groups with the highest number of ideas generated (out of 40 groups) would have their names entered into a lottery. One name would be drawn and that person would earn a reward. Thus, in the former condition, members had a 7 in 10 chance of attaining the reward; in the latter condition, there was only a 1 in 200 chance of attaining the reward. In addition to the optimistic bias (participants estimated their chance of winning to be about 1 in 4),
he found that performance suffered when instrumentality was lowered. If the subject matter experts collaborating on wicked problems determine that the overall outcome is not contingent on their group collaboration (either because they estimate other groups are more able to do the task or that this group is dispensable), then the subject matter experts will put little effort into the task.

Finally, the value of the outcome is predicted to affect motivation. Outcome value is the difference between the importance of the outcome and the costs associated with working hard. Increasing the costs or minimizing the importance of the reward will lead members to put forth less effort. More effort will be extended toward tasks that lead to valuable outcomes without requiring much cost. Costs vary with the number of other tasks one must perform, fatigue, and intrinsic interest of the task. Importance is predicted to be affected by the rewards of successful task completion and the penalties of task failure. Group goal setting (relative to “Do Your Best” instructions and supervisor-set goals) has been found to be related to improved group performance. Recent research performed by Wegge and Haslam (2005) indicates that avoiding failure mediates the relationship between group goal setting and performance on an idea generating task. Thus, group goal setting may affect performance through effort.

4 Putting it All Together

One of the greatest challenges that the diverse subject matter experts collaborating to solve wicked problems will face is competing goal sets. Although the members are likely to be highly motivated to solve aspects of the wicked problem, their primary allegiance is likely to be to their unit or nation. Although there is much research that focuses on competing goals in small groups (e.g., the research using the Prisoner’s Dilemma and resource dilemma paradigms), research needs to be done examining competing goal sets in this complex context.

The review of the group literature within the context of wicked problems has made clear some of the potential problems the diverse subject matter experts will face as they develop into a team, form a collective group identity and collaborate. Understanding the underlying dynamics of how teams form, develop, and make decisions is a first step to improving team performance. This information can be used in the development of team member selection and training programs, to influence the design of teamwork processes, and to derive requirements for collaborative systems.

5 Technologies to Augment Collaboration

For a diverse team to work together well it is necessary that they understand the mission, are committed to the team, understand each others’ roles and responsibilities, and leverage expertise. For the team to maintain an accurate mental model and perform well the team members must communicate effectively. However, as discussed in this chapter, team members will likely have different agendas and different perspectives on the way in which to approach and then solve the problem at hand.

As discussed earlier, DARPA and JFCOM have begun a program of research to develop and evaluate technologies to aid organizationally and nationally diverse, often distributed team members understand the possible and combined effects of actions in irregular warfare. The Army Research Laboratory (ARL) Human Research and Engineering Directorate (HRED), working with its academic and industry colleagues, is leading a research program to develop tools to augment collaboration among these teams. It is our contention that even with the use of technologies to better understand the possible implications and interdependencies of actions, teams will require additional collaborative support to insure effective teamwork. The goal of the program is to develop tools
that maximize collaboration amongst diverse people from different organizations and cultures. We propose to augment team performance by providing opportunities for team members to learn about their own and other’s culturally-based biases that may affect information exchange and teamwork and by identifying ineffectual collaboration, in real-time, during the mission planning and execution process and to identify potential interventions.

Currently, two technologies are in development to promote cultural understanding and improve collaborative decision-making among culturally diverse team members. These two technologies, Globesmart® Commander (GS Commander) and Globesmart® Soldier (GS Soldier) are based on the assumption that culture can influence interaction and decision-making and that team interactions can be improved by better understanding your own and other’s cultural biases. The cultural awareness tool, GS Commander (2006) is an instructional tool designed to provide diverse teams with information and skills they need to adapt to cultural influences on teamwork at the operational level (Sutton et al., 2006). GS Commander includes a self-assessment survey and nine training modules. The goal of GS Commander is for users to develop an understanding of how culture influences social interactions and decision-making in diverse, multinational teams. It allows users to compare their own social profiles on the six dimensions of the survey to the profiles of national averages for representative North Atlantic Treaty Organization nations. The six dimensions reflect culturally-based values or social interaction styles identified in culture research (e.g., Hofstede, 1989; Triandis, 1990; Schwartz, 1992; Trompenaars and Hampdon-Turner, 1998). The survey and the survey algorithm were developed by Aperian Global, with the subject matter expertise of Dr David Matsumoto (Matsumoto and LeRoux, 1999; Matsumoto and Juang, 2004). Table 15.1 shows the six dimensions assessed within the GS Commander survey.

### Table 15.1 The six Globesmart® Commander dimensions self-assessment survey

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Practical Implications</th>
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<tbody>
<tr>
<td>1. Independence/Interdependence:</td>
<td>Shapes a preference for individual initiative and action or for a more group-oriented approach emphasizing the interests of the team as a whole.</td>
</tr>
<tr>
<td>2. Egalitarianism/Status:</td>
<td>Shapes a preference for mutual consultation in decision-making or for greater deference to rank and hierarchy.</td>
</tr>
<tr>
<td>3. Risk/Restraint:</td>
<td>Shapes a preference for rapid action and risk-taking or for more cautious and calculated actions based on ample information.</td>
</tr>
<tr>
<td>4. Direct/Indirect:</td>
<td>Shapes a preference for open and explicit communication, or for careful attention paid to context or to implicit meanings in a given message.</td>
</tr>
<tr>
<td>5. Task/Relationship:</td>
<td>Shapes a preference for immediate attention to getting the job done or for establishing strong and trusting personal relationships first.</td>
</tr>
<tr>
<td>6. Short-term/Long-term:</td>
<td>Shapes a preference for making choices based upon a narrow time horizon or for considering the impact that choices will have over a longer span of time.</td>
</tr>
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</table>

Following completion of the self-assessment survey, GS Commander users are presented with modules that explain each of the six dimensions, how to identify the social interactions profiles of others and, through scenario-based perspective-taking and style-switching exercises, how to choose the best interaction approach to take with individuals of each profile.

The GS Soldier tool is currently under development and focuses on cultural understanding in the context of tactical operations that require social interactions with the local Iraqi population. In
the “Witnesses to History” section, the tool will present historical information through the use of interactive timelines that allow users to compare events that occurred at a particular time in history, from the 1940s to present, from the viewpoint of both the American and Iraqi cultures. GS Soldier will also provide information about Iraqi core values, non-verbal gestures and body language, name structures, demographics, land and people, history, and language and communication. It will include a module on key spoken and written phrases and allow users with recording and playback devices to practice pronouncing these phrases. Finally, GS Soldier will include interactive branching scenarios focused on the importance of cultural understanding in decision-making in the context of conducting foot patrols and home searches.

In addition to understanding culturally-based biases, we propose that explicit feedback on how the team is operating can change team performance. The communication among team members is one of the richest sources of data about the team’s performance and their mental processes (Beck and Pierce, 1996; Cannon-Bowers, Salas, and Converse, 1993; Fleishman and Zaccaro, 1992; McGlynn et al., 1999; Smith-Jentsch, Mathieu, and Kaiger, 2005). However, the use of communication data to predict team performance has been limited by the labor intensive and time consuming processes involved in both capturing and analyzing the data. Machine learning technologies have strong potential to be used for analyzing written communication among team members. Technologies for analyzing the semantics and syntactical properties of language can be combined to provide tools that can characterize the quality and content of information being conveyed in these communication streams (Foltz, 2005). Using the verbal content of written communication, such a toolset can be used to improve ad hoc team formation and functioning and has the potential for providing rapid assessment of individual and team performance in real time, including measures of situation awareness, consensus, knowledge gaps, information sharing, and workload, as well as predictions of future performance based on analyses of the current context. Other information can be extracted and analyzed in a post hoc manner.

Latent Semantic Analysis (LSA) is a machine learning algorithm that interprets the meaning of words and text (Landauer, Foltz, and Laham, 1998) by comparing it to a known corpus of information that provides the context for the text. LSA is not merely keyword searching and matching. Rather, LSA uses a fully automatic mathematical technique to extract and infer the contextual meaning of words in large collections of natural discourse. LSA algorithms are trained on a large corpora of domain- and task-specific information, which allows the algorithms to accurately identify like concepts between team members. LSA has been applied to a wide range of domains, including cross-language information retrieval systems, automatic essay scoring systems, as well as in systems for monitoring and providing feedback based on written team communications.

Studies employing this technology with US military officers and cadets have shown that they make measurably higher quality contributions using the technology than when discussing the same issues face-to-face (LaVoi et al., forthcoming). ARL HRED is using LSA-based tools to monitor written communication streams from individuals and teams. The tools could be used to help assess the phase of the group’s development, shifts in in-group and out-group status of various members, collective group identity, reliance on automated aids, evaluation apprehension, group polarization, and groupthink. The tools support ongoing collaboration by identifying the quality of the team performance and by analyzing such performance measures as convergence of contributions, consensus and trust among team members, degree of topic-related discussion, contending and concession-making behaviors, and identification of critical incidents. The output of the performance measures are then used with visualization tools to provide military personnel with summaries of the performance of teams in order to enhance overall situation awareness. More systematic validation research is necessary to understand the extent to which LSA algorithms may be used in place of self-report surveys and assessments of team trust, conflict, consensus,
and performance. In the future, the output from such a toolset could be further used for tracking teams’ behaviors and cognitive states, identifying critical incidents, determining when appropriate feedback needs to be given, generating automated after action reviews, and adapting interfaces to provide relevant data to teams.

6 Conclusions and Recommendations

In this chapter we have described a class of problems our military forces are facing. These problems are wicked problems in that there are multiple ways to define and solve the problem and solutions in one domain may have significant effects in other domains. To be effective, decision-makers must consider these interdependencies and develop solutions that can achieve their objectives across domains. This complexity requires new technologies that support understanding and visualization of possible effects. However, the ability of teams to use the power of these new technologies will be directly related to their ability to collaborate. A number of factors from the group dynamics literature that influence how well the team will form and perform have been reviewed. Cultural understanding and feedback have been proposed to facilitate team interaction and performance. Opportunities to evaluate these systems are being sought at research laboratories across the military.

References


Matsumoto, D. and LeRoux, J. (1999), *The Intercultural Adjustment Potential Scale-55 (ICAPS-55)* (Culture and Emotion Research Laboratory, Department of Psychology, San Francisco State University), 1600 Holloway Avenue, San Francisco, CA 94132.


Augmenting Multi-Cultural Collaboration


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Chapter 16

Individual Differences in Stress Reaction

James L. Szalma

Introduction

Research in individual differences in performance has a long history, dating to the emergence of psychology and psychometrics itself (e.g., Cattell, Galton; see Boring, 1950). However, there has been a disconnect between this tradition and that of experimental psychology (Cronbach, 1957). As the origins of human factors and human performance research were in applications of experimental psychology, the disconnect manifested in relatively limited scope of individual differences research in human factors and ergonomics. At the same time, modern emphasis on human-centered design raises questions regarding how the characteristics of the human interact with those of the interface/task to influence system performance and operator well-being. In this chapter I hope to demonstrate that a synthesis of Cronbach’s two disciplines (a rapprochement?) is possible and of great importance for understanding performance under stress, and that an integrated framework, based on cognitive science approaches, already exists and can be applied to human factors research and design. I also discuss the implications of an individual differences approach for theories of stress and performance and summarize empirical studies applying this perspective to the evaluation of factors that influence performance, workload, and stress response in cognitive and perceptual tasks. Finally, future directions for application of an individual differences perspective to human factors research on performance under stress are discussed.

Group and individual differences: Different perspectives on the same problem

Experimental and human factors psychologists have traditionally treated variation in behavior across participants as error variance or “nuisance” variables (e.g., Kirk, 1995). However, the individual differences perspective views the “nuisance” as a central focus of interest, the “error” as meaningful variance to be partitioned (Karwowski and Cuevas, 2003). Neither approach, by itself, is adequate to fully understand human performance in complex task environments, an observation that is hardly new (Cronbach, 1957). However, the integration of these complementary approaches has emerged as an important issue for current and future efforts in human factors research and practice. The transition from solid state, inflexible interfaces to virtual, “soft” and flexible computer-based interfaces permits the adaptation of the display, and to some extent controls, to the needs and preferences of the individual user or operator. At the same time, increasing numbers of technologically savvy users have come to expect their devices and computer-based tools to be adaptable to their needs and preferences, and such a cultural shift will most certainly extend into work environments across multiple domains, including some military applications.

Human factors researchers and practitioners have been quite successful at identifying task and display characteristics that influence human performance (Wickens and Hollands, 2000), and applying them to interface design (e.g., Karwowski, 2006; Sears and Jacko, forthcoming). However, across many domains a common observation is that of individual differences in performance
and behavioral response among groups of users or participants. Indeed, it is often the case in psychological research that “error” variance accounts for more variability than the manipulated or observed variables. It is unlikely that this substantial variability is entirely random, and systematic examination of person characteristics can contribute to understanding a larger portion of the variability in human-technology interaction and system performance. Such advances can then be applied to both interface and training design. For instance, an individual differences perspective can be applied to the design of adaptable displays that conform to user needs and preferences, and to training regimens to fit an individual’s learning style and strengths/weaknesses with respect to skill sets (including stress training, cf. Driskell et al., this volume).

Ultimately the emphasis on group differences (or, more formally, differences in task and environmental characteristics that affect performance of individuals exposed to those conditions) versus an emphasis on individual differences provides different vistas onto the same phenomenon, human performance. They share similar overarching goals, to understand the factors that control or influence performance and apply this understanding to real-world problems in system design and performance. Note that although these “two disciplines of psychology” discussed by Cronbach (1957) have different perspectives on the analysis of human behavior, this distinction is often mislabeled or misunderstood as being one of nomothetic vs. idiographic research. Researchers can and have effectively applied idiographic methodologies to the study of individual differences, but in applied experimental psychology and human factors it is more often a nomothetic approach. It may seem a contradiction to examine how individuals differ from one another using an approach that seeks to identify universal lawful relations. However, one goal for individual differences research is to investigate the characteristics that individuals share that result in common behavioral response, and to identify which characteristics are associated with differences in response. A second goal is to determine how these correlations with performance are moderated by task and environmental variables. From this perspective, the characteristics of the person are as important as the characteristics of the task the person is engaged in and the interface he/she is using. This approach rests upon the adoption of a trait perspective, which proposes a finite number of characteristics that humans share that determine their unique individuality via how the traits are expressed and by the profile of the traits (for an extensive treatment of the trait concept see Matthews, Deary and Whiteman, 2003). Note that this perspective is not limited to the affective traits to be reviewed in this chapter, but also extends to cognitive and psychomotor capacities. Further, such capabilities need not be assumed to be “innate.” For the purposes of individual differences in performance research, cognitive and psychomotor skills may be considered to be “traits” if they are sufficiently stable over extended periods of time. From this perspective the study of individual differences is also not restricted to stable traits. Transient states also play a role in processes of self-regulation and adaptation relevant for performance (e.g., see Matthews et al., 2002; Matthews and Zeidner, 2004).

The individual differences perspective in human factors and performance research

Many psychologists have argued that the proper unit of analysis for human performance, and particularly for stress research, is the interaction between the human and his/her social and physical environment (Lazarus and Folkman, 1984; Bandura, 1986, 1997; Carver and Scheier, 1998). This line of thinking has manifested in several forms, including the transactional perspective (Lazarus and Folkman, 1984; Lazarus, 1991, 1999; Scherer, 1999; Matthews, 2001), reciprocal determinism (Bandura, 1986), and the ecological approach to psychology—the perception-action cycle (Gibson, 1979; see also Flach et al., 1995; Hancock, 1997). In human factors this unit becomes the “system” composed of the human and the technology he/she is using. A fuller understanding
of human performance and human-technology interaction depends on understanding not only the characteristics of each component separately (human and interface) but the characteristics of the cycle of the interaction between them as it unfolds over time. Understanding these dynamics will facilitate design of systems that support performance as well as improvements in interface design and operator training. Further, a more complete model of the dynamics of the transaction can be applied to development of mitigation strategies for dealing with the negative effects of high workload and stress. Adopting an individual differences perspective permits identification of the “person” part of the transaction, and can contribute toward a more detailed examination of the person-environment interaction as the fundamental unit of analysis in theory, research, and design.

The problem: Need for theoretical integration and empirical coordination

There is a voluminous literature regarding how the characteristics of tasks, displays, and controls influence performance (e.g., Sanders and McCormick, 1993; Proctor and Van Zandt, 1994; Wickens and Hollands, 2000; Wickens et al., 2003). There is also a large literature on stress and performance (Hockey, 1983; Driskell and Salas, 1995; Hancock and Desmond, 2001; see also Conway, Szalma and Hancock, 2007; Hancock, Ross and Szalma, 2007). With respect to individual differences research, there is a substantial literature linking traits to performance on perceptual and cognitive tasks (e.g., Eysenck and Eysenck, 1985; Eysenck, 1992; Smith and Jones, 1992; Matthews et al., 2000; Matthews, Deary and Whiteman, 2003). There is also a rather large literature on personality traits and performance in work settings, but these tend to focus on organizational issues of personnel selection, job design, and job performance (e.g., see Barrick, Mount and Judge, 2001) rather than on specific cognitive tasks and human-technology interaction. In addition, most of this research does not derive general theories of the role of personality in performance and information processing applicable beyond a limited area of study (see Matthews, Deary and Whiteman, 2003, for a more in depth treatment of this issue). That is, these research traditions are not well linked conceptually or empirically, perhaps in part because researchers have tended to stay within their “niche” areas, not extending far beyond to incorporate findings from other research domains. For instance, there are substantial literatures on working memory capacity, cognitive style (operationalized as holistic/analytic processing), cognitive style (operationalized as field dependent/independent), spatial ability, attentional control, desire for control, cognitive failure, the need for cognition, and emotional stability (anxiety, neuroticism), to name but a few. However, these exist as distinct, relatively uncoordinated research areas, so that theories (and measures derived from them) in one domain are not often integrated with those of others, limiting progress in both theory and research (noteworthy exceptions are Extraversion and Neuroticism/Trait Anxiety; see Matthews, Deary and Whiteman, 2003; Matthews and Zeidner, 2004). Further complicating efforts at integration is the lack of consensus regarding the structure and processing of the cognitive, affective, and motivational subsystems (but see Dai and Sternberg, 2004), making it rather difficult to derive the general principles necessary for human factors applications. Indeed, the number of “basic” personality traits and the degree of their independence from one another is controversial (e.g., Eysenck, 1991; Block, 1995). Thus, the field is replete with “mini” theories that are difficult to integrate for purposes of application to real-world problems such performing stressful tasks under conditions of high workload. Such integration is crucial, however, for the design of interfaces as well as for improvement in the performance and well-being of human operators. If the individual differences in affective and cognitive traits and states are not incorporated into theories of human performance and principles of interface design, we are in essence neglecting half of the equation.
central to human factors and ergonomics, and conducting a very curious kind of “human-centered”
design that neglects human personality, emotion, and motivation.

An additional challenge for individual differences research is one shared by other areas of
behavioral science, particularly in the study of stress and performance. Specifically, it has proven
difficult to systematically investigate the combined, interactive relationships of multiple traits
(or stressors) with human performance and adaptation to task demands. Individual differences
researchers usually focus on a single characteristic, as in stress research in which empirical
investigations are often restricted to single stressors. However, real people cannot be summarized
by a single characteristic, just as real environments do not consist of unitary stressors, and how these
specific characteristics of the person and of the environment affect performance may depend to a
large extent on the other characteristics of the individual. When a trait is “expressed” in a particular
setting, other traits may be activated as well, producing complex interactions among multiple traits
and multiple environmental events. Added to this is the problem of determining which relations
among traits are multiplicative (e.g., emotional stability and extraversion; attentional control and
anxiety?) and which may be additive (e.g., anxiety and spatial ability?). Hence, there is a need
for more studies of the joint effects of two or more traits on task performance, workload, and
stress, a daunting endeavor because of the complexity that results from combination of only two
characteristics (cf. Hancock and Szalma, Chapter 1, this volume). An example will be presented
later in this chapter that illustrates this complexity.

The solution: Theory integration at multiple levels of analysis

Meeting these challenges requires a comprehensive theoretical framework that incorporates
the person and task characteristics, the mechanisms by which they interact and determine
performance, and how these transactions can be shaped by changing the structure of the
environment. A theoretical framework that articulates these mechanisms can then be integrated
with current models of workload, stress, and performance. Fortunately such a framework exists
that integrates trait theories with theories of cognition, emotion, and motivation using a cognitive
science perspective to explain self-regulation and adaptation. The cognitive-adaptive framework
presented by Matthews (1997a, 1999; Matthews and Zeidner, 2004) conceptualizes traits and
transient states as composed of multiple self-regulatory processes at multiple levels of analysis
(from the molecular genetic to higher level knowledge structures) and function (i.e., cognition,
motivation, and emotion). With respect to level of analysis, Matthews (1999) included three
levels of explanation, in terms of neurological/physiological mechanisms, cognitive architecture
(information processing mechanisms), and knowledge structures (goals, strategy choice, appraisal
and coping). Thus, the framework integrates processing oriented explanations (e.g., connectionist
networks; see Matthews and Harley, 1993) of trait-performance relationships as well as content-
oriented explanation (goals, interests, etc). The mechanisms by which these systems interact to
support self-regulation were identified by Matthews and his colleagues as an “adaptive triangle,” as
shown in Figure 16.1 (Matthews, 1997b, 1999; Matthews and Zeidner, 2004). The three vertices of
the triangle represent skills, self knowledge, and action (real-world adaptive behavior). Personality
traits are represented in this model in terms of the characteristics of skills and self knowledge at
multiple levels of analysis. Thus, in contrast to arousal theory (e.g., Eysenck, 1967) which posited
a central arousal mechanism to explain variation in personality, the cognitive adaptive framework
conceptualizes traits as distributed across multiple components of self-regulatory mechanisms.
Although much research remains to be done to explore the dynamics of the interactions among
the different components (e.g., traits, information processing, cognitive states, task demands,
and environmental conditions), at different levels of analysis, the cognitive-adaptive framework
provides the integration needed to guide systematic research to fully exploit the potential of the individual differences perspective for human factors research and practice.

From the cognitive-adaptive perspective, traits can be treated in a way analogous to Hockey and Hamilton’s (1983) conception of the cognitive states associated with different sources of stress. They described the “broad band” approach to stress research, in which one systematically investigates the effect of a specific stressor (e.g., noise) on multiple psychological systems (arousal, working memory, selective attention, visual search, etc). As Hockey and Hamilton (1983) noted, adopting such a “broad band” approach permits the establishment of cognitive patternings associated with specific stressors. Thus, one can identify the differences in cognitive patternings (cognitive states across multiple stressors). This approach can be extended to investigation of individual differences in performance. That is, just as different stressors (noise, heat, etc) produce different cognitive patternings; different traits may be associated with distinct cognitive patternings (Matthews, 1992, 1999). An application of this approach to extraversion by Matthews (1992) is shown in Table 16.1. The cognitive patterning of neuroticism/anxiety is more difficult to establish, because the effect of neuroticism on different components of the cognitive architecture, and therefore performance, depends in large part not only on the level of threat posed by the environment (including task demands; see Table 16.1) but also the task motivation associated with the person-task interaction. In essence, it depends on the coping strategy selected, which is itself dependent upon the available resources for coping.
Table 16.1 The cognitive patterning of extraversion and anxiety/neuroticism

<table>
<thead>
<tr>
<th></th>
<th>Vigilance</th>
<th>Selectivity</th>
<th>Speed</th>
<th>Accuracy</th>
<th>STM</th>
<th>LTM</th>
<th>Attentional Resource Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>−1</td>
<td>0</td>
<td>+</td>
<td>−1</td>
<td>+</td>
<td>−</td>
<td>+1</td>
</tr>
<tr>
<td>A/N</td>
<td>#</td>
<td>+2</td>
<td>*</td>
<td>*</td>
<td>−</td>
<td>−3</td>
<td>−</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Response criterion</th>
<th>Reflective problem solving</th>
<th>Semantic Memory Retrieval</th>
<th>General Intelligence</th>
<th>Affect</th>
<th>Self efficacy</th>
<th>Coping style</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>−</td>
<td>−</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>Task</td>
</tr>
<tr>
<td>A/N</td>
<td>*</td>
<td>−4</td>
<td>−3</td>
<td>0</td>
<td>−</td>
<td>−</td>
<td>Emotion</td>
</tr>
</tbody>
</table>

Note: E = Extraversion; A/N = Anxiety/Neuroticism; STM = Short term memory; LTM = Long term memory; 1arousal-dependent effects; 2for negative or threat stimuli; 3memory process can be enhanced for unhappy events or threat information; 4effects occur only for more difficult or complex problems (see Eysenck and Eysenck, 1985, p. 299); 5results vary depending on task factors (e.g., threat vs. non-threat stimuli, task difficulty) and person factors (e.g., amount of effort expended; see Eysenck, 1992; Eysenck and Calvo, 1992); # results vary across studies. After Matthews (1992, 1999) and Matthews et al. (2000).

Note that the cognitive-adaptive framework can help address the “it depends” problem in human performance research by specifying the cognitive, motivational, and emotional components that influence how an individual responds to different patterns of environmental demand. From this perspective it is not which traits are associated with adaptation and performance, but how trait profiles influence adaptation across different environmental conditions. The former approach is one of selection (i.e., which individuals are “best” at performing a particular task), but the latter can be applied to interface and training design by identifying task and environmental factors that offer the best motivational and affective “affordances” for effective adaptation. What is needed for application of the cognitive-adaptive framework to the human factors issues surrounding performance under stress is further integration of that perspective with models such as the maximal adaptability model of Hancock and Warm (1989) and the compensatory control model described by Hockey (1997). This will require systematic empirical research aimed at articulating the mechanisms underlying the cognitive processes involved in task performance (e.g., more precise description of mental resources and quantification of the basic dimensions of information processing and task performance; see Hancock and Szalma, Chapter 1, this volume; Hancock and Szalma, 2007; Szalma and Hancock, forthcoming).

Specific applications of individual differences

Approach to performance under stress

In the following sections applications of individual differences analysis of performance of stressful tasks is reviewed and results interpreted in terms of the cognitive-adaptive, maximal adaptability and compensatory control models. The tasks involved in most of these studies required selective, divided, or sustained attention for signal detection and discrimination. In addition, a study is reviewed that examined the relation of personality traits to shooting performance in a law enforcement field.
Individual Differences in Stress Reaction

training exercise. These studies represent efforts to examine the interactions between operator and task characteristics on performance, workload, and stress.

Figure 16.2 The Maximal Adaptability Model

*Note:* The adaptation is manifested in the plateau at the apex of the extended inverted-U which describes the zones of stable response to environmental demands (stressors). Failures in adaptation that occur when the input stress exceeds adaptive capacity are illustrated as declines in response capacity at multiple levels of function ranging from basal states and comfort zones to physiological adaptation. Note that the vertical line labeled “Center point” indicates that adaptation is symmetrical with respect to under- and over-stimulation, with the balance point residing within the normative zone.

*Source:* Adapted from Hancock and Warm (1989).

Role of disposition in attention: Pessimism, optimism, and extraversion

Maximal adaptability Model  One of the key insights of the maximal adaptability model of Hancock and Warm (1989; see Figure 16.2) is that in many instances the tasks themselves pose the most proximal form of stress, and that decomposition of task characteristics to base axes of space and time can, in principle, permit prediction of physiological and behavioral adaptation to stress (see Hancock and Szalma, Chapter 1, this volume). The two base axes defined by Hancock and Warm (1989) were that of information structure and information rate. Information structure, a spatial dimension, refers to the organization of task elements. Information rate represents the temporal dimension of tasks. According to the model, the spatial and temporal properties of task contribute to the level of adaptive function by the individual. Thus, if the task and the environmental
characteristics (e.g., noise) could be accurately quantified, the adaptive state of the individual could be expressed as a vector combining these factors (see Figure 16.3).

Figure 16.3 The Maximal Adaptability Model with Task Dimensions Included

Note: The stress/environmental base axis in Figure 16.2 has been decomposed into two separate component dimensions of environmental demands (tasks), information rate and information structure. These dimensions, if quantified, can be combined with other environmental inputs into a vector representation that indicates adaptive capacity.

Source: Hancock and Warm (1989).

Changes in spatial and temporal demand: A group differences analysis

A limitation of the Hancock and Warm (1989) model is that the two task dimensions have not been quantified, nor have their relation to one another been adequately explored. Understanding the nature of such interaction is a necessary first step toward realizing the vector representation Hancock and Warm (1989) proposed. Hence, Ross et al. (2003) examined the joint effect of intermittent bursts of 85 dB white noise and manipulations of temporal and spatial processing on performance. In that study, they manipulated the relative dominance of spatial and temporal task properties, and also employed a third condition in which these two properties were combined. Based on the maximal adaptability model it was hypothesized that if the spatial and temporal dimensions share a common mechanism, combining these demands into a task should impose greater demand and task-induced stress on the observer, resulting in poorer performance and higher perceived workload and stress. Ross and her colleagues did not find evidence supporting this contention, suggesting that the two dimensions may not share common perceptual mechanisms. However, the tasks they used were relatively easy and may not have been sufficiently demanding to produce the expected differences.
Individual Differences in Stress Reaction

An individual difference analysis of the data from the Ross et al. (2003) study was conducted by Thropp et al. (2003) on the influence of dispositional optimism/pessimism on performance and self reports of stress state. Optimism/pessimism is known to affect performance and stress response. Individuals higher in pessimism tend to perform more poorly across a variety of domains, such as competitive swimming (Seligman et al., 1990), insurance sales performance (Seligman and Schulman, 1986), and even presidential candidates (Zullow, 1995). Optimism/pessimism may exert its effect in part by influencing general expectancies regarding performance and affective responses to performance success and failure (see Chang, 2002). Individuals high in pessimism tend to appraise events more negatively than those low in pessimism and adopt maladaptive coping strategies (Scheier and Carver, 1987; Szalma, 2002a). Attention is then redirected toward the self and managing the negative affect associated with pessimistic appraisals of the task. In contrast, the more positive expectations of individuals high in optimism may be associated with greater attention toward task-based processes, thereby improving performance and reducing stress symptoms. Note that these patterns are similar to those associated with Neuroticism (e.g., see Matthews, Deary and Whiteman, 2003).

Based on previous research, and the maximal adaptability model, it was expected that dispositional pessimism might be related to early “failures” of adaptation, i.e., subjective comfort (see Figure 16.2), manifested in increased levels of stress associated with tasks that imposed greater spatial-temporal demand. Note that in this and the other experiments described here, optimism/pessimism was measured using the optimism/pessimism (OPI), developed by Dember and his colleagues (Dember et al., 1989). Several studies using the OPI have indicated that optimism and pessimism are not polar opposites, but are partially independent dimensions (cf. Watson and Tellegen, 1985), with correlations of approximately $r = -0.5$ (Hummer et al., 1992; for a review see Dember, 2002). Thus, separate scores for optimism and pessimism are computed when that scale is applied.1

Consistent with expectation, Thropp et al. (2003) reported that pessimism predicted increased stress symptoms, evaluated along the dimensions of Task Engagement and Distress (Matthews et al., 2002), but these effects were restricted to tasks with spatial uncertainty. Pessimism also predicted greater use of emotion-focused coping, consistent with previous research (e.g., Scheier and Carver, 1987; Szalma, 2002b), but only in tasks with spatial uncertainty. For distress, optimism predicted lower post-task distress for tasks requiring either a spatial or temporal discrimination, although these effects were nullified when the pre-task state was accounted for in the regression model. Indeed, consistent with previous work (Szalma, 2002b), optimism predicted lower pre-task distress and higher pre-task engagement, while pessimism predicted higher pre-task distress and lower pre-task engagement. For a task requiring a temporal discrimination of the same stimulus, these effects were not observed. Pessimism and optimism were unrelated to performance, however. This may be due to the task-noise combination being of insufficient intensity to overwhelm the cognitive resources of individuals high in pessimism. However, the pattern of results suggests that the cognitive state of individuals high in pessimism differs somewhat from that of individuals low on that trait, although the emergence of such differences depends in part on the nature of the task demands (i.e., spatial uncertainty). Taken together, Thropp et al. (2003) interpreted these results to mean that pessimistic individuals disengage from the task in an attempt to cope (using emotion-

1 The OPI correlates well with other measures of optimism/pessimism (e.g., the Life Orientation Test (LOT); Scheier and Carver, 1987) when treated as one-dimensional. Careful reading of Scheier and Carver (1987), however, reveals that factor analysis of the LOT, which treats optimism-pessimism as a single dimension, also breaks down into two factors.
focused coping) with the greater demand associated with spatial uncertainty. This interpretation accords with the avoidance tendencies of individuals high in Neuroticism (e.g., Matthews, Deary and Whiteman, 2003; Matthews and Zeidner, 2004). Note that pessimism and optimism were related to different cognitive states. Specifically, pessimism was associated with decreased task engagement and optimism with lower levels of distress.

There have been inconsistencies across studies, however. Optimism is generally associated with greater positive affect, and would therefore be expected to be associated with greater task engagement. Indeed, evidence for such a link has been observed (e.g., Szalma, 2002b). However, Ross, Szalma, and Hancock (2004) reported that higher levels of dispositional optimism predicted decreased task engagement, but only for tasks requiring spatial discriminations (but no spatial uncertainty). Note that this was the case even after pre-task engagement measured prior to performing the task was accounted for in the regression model. In addition, the association of pessimism with stress in tasks with spatial uncertainty did not extend to a case in which there was no spatial uncertainty but a spatial discrimination was required. In sum, the relation between optimism/pessimism and performance, workload, and stress is not a simple one, and depends on the task characteristics (in this case the kind of perceptual discrimination required and the presence or absence of spatial uncertainty) and pre-task cognitive state of the individual.

**Extraversion**

Based on previous research on extraversion (see Matthews et al., 2003 for a recent review), it was expected that this trait might also be linked to performance, perceived workload, and stress associated with signal detection tasks, and that the relationship between this trait and the outcome variables might be moderated by the demands of the task (spatial/temporal) and the presence of an external source of stress (85dBA white noise). Thus, in the experiment described above, extraversion was measured using the adjective marker scale of the big five factors derived by Goldberg (1992). Thus, Thropp, Szalma, Ross and Hancock (2004) reported that extraversion was related to the performance and workload associated with perceptual discrimination of spatial and temporal stimulus properties. Specifically, higher levels of extraversion predicted more lenient responding, but only in a condition in which the individual was exposed to 85dBA intermittent white noise and was required to discriminate stimulus duration. Individuals high in extraversion but who performed the same task under ambient noise conditions (60dBA) achieved response bias levels similar to those lower in extraversion. Stated another way, white noise had the effect of inducing greater conservatism in responding, but only among those low in extraversion (see Figure 16.4). In addition, these effects were not observed in tasks with greater spatial demand. Across all conditions, however, higher extraversion predicted lower perceived workload, particularly perceived temporal demand.

The association of extraversion with response bias was consistent with the general finding that extraversion is associated with greater leniency in responding (Matthews, Deary and Whiteman, 2003), but these results also indicate that environmental stressors (e.g., noise) and the temporal and spatial characteristics of the task can influence the relation between extraversion and behavioral response. One possibility is that introverted individuals were more likely to find the noise distracting and, in combination with higher time pressure (i.e., perceived temporal demand) relative to extraverted individuals, may have had to make judgments faster and adopt a more lenient criterion than they do under quiet conditions. Given the impulsivity associated with extraversion (Eysenck and Eysenck, 1985), it may be that choosing the conservative criterion is more characteristic of the relatively non-impulsive introverts. However, research on the effects of stress and personality on signal detection theory measures have not produced consistent results.
A potential mechanism to explain differences in perceived temporal demand as a function of extraversion is shown in Figure 16.5. Hancock and Weaver (2005) noted that the attentional narrowing phenomenon that occurs under stressful conditions, which has been traditionally considered a narrowing in spatial attention (Easterbrook, 1959; Cornsweet, 1969; Hancock and Dirkin, 1983; Dirkin and Hancock, 1984, 1985) also extends to the temporal dimension. They further argued that these two dimensions share a common narrowing mechanism, by which the locus of attention to various cues changes as stress increases. Thus, to the extent that the stressed individual directs attention to external events time will slow down. By contrast, an internal locus of attention is likely to induce a subjective experience of time moving faster. One might therefore expect that traits that are associated with individual differences in attention (in this case, internal vs. external locus) would also predict the form of temporal distortion that occurs. Extraversion is one such variable (see Matthews, 1992; Matthews et al., 2000, 2003). Extraverts tend to over-estimate duration when performing tasks with stimuli that are low to medium in complexity (Eysenck, 1959; Zakay, Lomranz and Kazinz, 1984; but see also van den Van den Broek, Bradshaw and Szabadi, 1992). These effects may be due to the need for extraverted individuals for stimulation when the environment is relatively unstimulating (Zakay, Lomranz and Kazinz, 1984). If true, extraverts would be expected to have a greater tendency to orient their attention to external events relative to introverts. Based on the Hancock and Weaver (2005) model (Figure 16.5), extraverts would be expected to experience attentional narrowing along the temporal dimension that would manifest as a subjective experience of time “slowing down.” Thus, when attention narrows under stress, individuals higher in extraversion would be more likely to exclude internal cues and drive attention toward external events. By contrast, individuals low in extraversion (introverts) would more likely exclude external cues and direct attention to internal events. If this is the case, then
extraverts should feel a relative slowing down of time and experience less temporal demand, while individuals lower on that trait will feel time speeding up and therefore experience higher temporal demand (see Figure 16.6).

**Role of disposition in sustained attention: Pessimism and vigilance**

Empirical research on sustained attention originated in studies examining performance decrements among military personnel engaged in monitoring RADAR displays (see Warm, 1984), but vigilance remains a crucial aspect of modern military and civilian operations. Although the problem of sustained attention is not new to the military (e.g., observers in “crow’s nests” of sailing ships), the problem has been exacerbated by the proliferation of automated systems that relegate the human operator to the role of system monitor. It has also been well established that there are individual differences in performance associated with vigilance (see Davies and Parasuraman, 1982; Berch and Kanter, 1984; Davies, 1985). However, among the several traits that are associated with performance, it is unclear how task conditions influence these trait-performance relations or whether and how traits themselves jointly influence performance. Indeed, Berch and Kanter (1984) noted this problem over 20 years ago.

One potential skill that may differentiate good “vigilators” from poor ones is the capacity to cope with the stress and high workload associated with sustained attention. Research has indicated that vigilance tasks impose substantial workload (Warm, Dember and Hancock, 1996), and that operators find these tasks to be stressful (Warm, 1993; Szalma et al., 2004; Warm, Matthews, and Finnomore, this volume). However, individuals who engage in more task or problem-focused
Individual Differences in Stress Reaction

Individual Differences in Stress Reaction (Lazarus, 1991; Lazarus and Folkman, 1984; Matthews and Campbell, 1998) may be able to sustain their attentional capacity longer. Pessimism and optimism may therefore influence the performance, perceived workload, and stress associated with vigilance by influencing task appraisal and coping processes. Thus, Helton et al. (1999) reported that individuals high in pessimism exhibited a steeper vigilance decrement than more optimistic individuals. They also reported that pessimists reported higher levels of stress symptoms. Although efforts to replicate these performance results have been mixed (e.g., Szalma, 2002b; Ganey et al., 2003; Helton et al., 2005; Szalma et al., 2006), other experiments have demonstrated that pessimism is indeed associated with higher levels of stress and less adaptive coping in vigilance (Szalma, 2002b; Ganey et al., 2003; Szalma et al., 2006). One possible reason for these inconsistencies is that the task used in the Helton et al. (1999) experiment was very demanding, employing a very high event rate and a difficult visual discrimination. By contrast, the tasks used by Ganey et al. (2003) and Szalma (2002b), while demanding and of longer duration, involved easier perceptual discriminations. Further, Helton et al. (2005) found a significant relation of optimism to performance only in a low signal salience condition. It is likely that performance differences related to dispositional pessimism and optimism emerge only when the task is sufficiently demanding that substantial coping resources are required, such that the tendencies for pessimists to engage in more maladaptive forms of coping result in the diversion of cognitive resources away from task performance and toward managing negative emotions and dealing with task-irrelevant interference (see Matthews and Campbell, 1998; Matthews et al., 1999, 2002). Note that it is precisely at this point of stress level that theories such as the maximal adaptability model would predict performance failure (Hancock and Warm, 1989; see also Hancock and Szalma, Chapter 1, this volume; Szalma and Hancock, 2005). Further, the
diversion of effort away from task demands, although not a problem for relatively undemanding
tasks, diverts much needed resources and effort when tasks are demanding (cf. Hockey, 1997).
This interpretation of the research on the relation between pessimism/optimism and performance,
workload, and stress of vigilance is consistent with the general finding that traits are more strongly
associated with effective adaptation when environmental demands (i.e., stress) are high (Matthews,

**Pessimism and display format** Although the evidence described above reveals that those high in
pessimism experience stress when engaged in vigilance, these effects are not uniform across all
task characteristics. We have already noted that task difficulty and demand (e.g., event rate) may
influence whether pessimism is related to performance. It is also the case, however, that display
characteristics moderate the relationship between pessimism and task stress. Thus, Szalma (2002a)
examined the effect of using different formats of configural displays on the performance, workload,
and stress associated with vigilance. Configural displays exploit emergent features (or, in the case
of object displays, actual features) by semantically mapping system dynamics to easily perceivable
display dynamics, thereby enhancing the salience of changes in the display. These displays can
improve performance (see Bennett and Flach, 1992) and may also serve as possible approaches to
designing for stress mitigation (Hancock and Szalma, 2003a). Szalma (2002a) reported that a group
differences analysis yielded the expected performance enhancement with using configural and
object displays and in the case of object displays, this performance enhancement was associated
with a reduction in perceived workload. Although pre-post vigil changes in stress state were
consistent with previous research, Szalma (2002a) reported that there were no significant effects of
display or discrimination type on the stress or coping responses of observers.

However, an individual differences analysis revealed effects of display and pessimism on stress
and coping response. Szalma (2002b) reported no significant association between performance
and optimism or pessimism, but pessimism significantly predicted perceived workload, changes
in pre-post task stress and in choice of coping strategy. Further, the prediction of workload by
pessimism was restricted to the task requiring the more demanding discrimination (i.e., when the
configurality of the display did not aid performance). Among the subscales of the TLX, it was the
perceived performance and frustration scales that showed significant relationships to pessimism,
but only with the more difficult discrimination task. Note that these dimensions of workload reflect
appraisals of the self (i.e., how the individual perceives his/her response to task demands) rather
than appraisals of task demand (e.g., mental demand), consistent with the finding that individuals
who are high in Neuroticism (pessimism is correlated with Neuroticism; see Richardson, 1999)
tend to engage in more negative thinking regarding their own performance (Matthews, Deary and
Whiteman, 2003). With respect to stress, pessimism predicted higher levels of pre-task stress and
optimism predicted the opposite trend: lower levels of pre-task stress. Although pessimism and
optimism also predicted higher and lower post-task stress, respectively, these associations were not
statistically significant with the pre-task states were accounted for in the regression models. These
results suggest that the influence of pessimism and optimism effects on stress response to sustained
attention may be mediated by their pre-task affective state rather than by any strategic differences
in how these individuals process task-related information. However, the relations among these
variables are likely dependent upon task parameters, as Helton et al. (1999) reported significant
pre-post differences in stress state as a function of pessimism.

**Optimism, pessimism, and feedback** Another variable that moderates the relation between
pessimism and stress response in vigilance is the form in which knowledge of results (KR) is provided
in training for vigilance. Szalma et al. (2006) examined the effect on performance, workload, and
Figure 16.7a Pre-post task distress as a function of pessimism and feedback condition

Figure 16.7b Pre-post task distress as a function of pessimism and feedback condition

Note to 16.7a and 16.7b: Dotted line with arrow represents the region of significant differences between the regression lines. NKR = no feedback provided; FAKR = feedback provided regarding false alarms.

Source: Szalma et al., 2006.
stress of providing feedback regarding correct detections, false alarms, misses, or all three forms of KR to observers. In that study, a configural object display was used, and Szalma and his colleagues reported that, at the level of group differences, KR enhanced performance when all three forms of feedback were provided. The individual differences analysis revealed that pessimism did not significantly predict performance, perhaps due to the facilitating effect of an object display on signal salience (Szalma, 2002a). However, pessimism was associated with pre-post task increases in distress and pre-post task decreases in task engagement, but these predictive relationships depended on the form of feedback provided. Thus, false alarm KR reduced the Distress associated with vigilance (presumably by providing information regarding the accuracy of responses), but this benefit was restricted to individuals low in pessimism (see Figure 16.7a). For individuals higher on that trait, false alarm KR did not reduce pre-post task distress. Similarly, false alarm KR also served to increase task-engagement (which reflects motivational and energetic aspects of stress state; see Matthews et al., 2002), but only for individuals low in pessimism (see Figure 16.7b). Pre-post task worry was related to optimism but only weakly to pessimism. However, the relationship between worry and optimism was restricted to the miss-KR training condition. Thus, provision of miss-KR served to reduce pre-post task worry, but only for individuals relatively high in optimism. Note that optimism and pessimism were associated with the stress effects of “negative” feedback (i.e., feedback regarding errors) rather than “positive” feedback (i.e., feedback regarding correct detections). This suggests that pessimists and optimists are differentially sensitive to the valence of feedback in terms of stress response (cf. Gray, 1982; see also Matthews and Gilliland, 1999), although they are able to retain sufficient resources to devote the effort necessary for task performance regardless of their level on these traits.

The role of disposition in shooting performance and time perception

In addition to laboratory studies on attention and monitoring, we have also conducted research on the personality traits associated with performance on firearms training tasks completed under time pressure as part of mandatory field exercises for law enforcement officers (Szalma, Oron-Gilad, and Hancock, 2005; Oron-Gilad et al., 2007; Szalma et al., 2007). No significant association between the five traits and performance in shooting tasks were observed, a finding one would hope to observe in professional police officers. There was also no association of the traits to prospective time estimation of the duration of the more demanding tasks. Consistent with the maximal adaptability model (Hancock and Warm, 1989), there was evidence of a subjective cost to performance in the form of increased perceived workload for more demanding of the tasks, and an increase in stress symptoms pre-post training session (Oron-Gilad et al., 2007). However, these effects varied as a function of officers’ personality traits (Szalma et al., 2005, 2007). Specifically, individuals high in Conscientiousness reported greater temporal demand, and individuals higher in emotional stability (neuroticism) reported higher perceived performance ratings. Intellect, which corresponds to the “openness to experience” domain of the Big Five (Goldberg, 1992), also predicted higher ratings of task demand (mental and temporal) as well as effort. However, this relationship was observed only for the most difficult of the shooting tasks performed. Such results accord with studies reviewed above indicating that traits are more likely to be associated with stress response only when the demands of the task are sufficiently high to force the individual to allocate compensatory effort and leave fewer resources available for on-going self-regulatory processes. With respect to stress and coping, Agreeableness was associated with higher post-task engagement, consistent with the generally energetic approach to tasks and compliance associated with individuals high on that trait (Matthews, Deary and Whiteman, 2003). Higher post-task engagement was associated with higher levels of Intellect. Individuals high on this trait tend to
Figure 16.8a Duration judgment ratio (estimated time/clock time) as a function of emotional stability at three levels of extraversion for a challenging firearms task.

Figure 16.8b Post-task distress as a function of emotional stability at three levels of extraversion.

*Source:* Szalma et al., 2007.
enjoy challenging activities, and this may have made them more engaged in the tasks. Indeed, individuals high in Intellect also reported greater use of task-focused coping skills, consistent with greater engagement in the task.

Joint effects of traits  The results described above indicated that traits may affect the workload, stress, and coping with demanding firearms tasks. However, the examination of each trait separately masked more complex interactions with respect to performance and stress state. Indeed, previous research has demonstrated that traits can have joint or “interactive” effects on worker performance evaluations. For instance, Burke and Witt (2002) reported that Intellect “interacts” with Extraversion, Emotional Stability, and Agreeableness in predicting supervisor performance ratings of financial service employees. Similarly, Extraversion and Emotional Stability are known to interact in influencing variables associated with stress such as depression and anxiety (The “neurotic introvert;” Eysenck and Eysenck, 1985), and the influence of the capacity to control one’s attention on performing attentional demanding tasks depends on one’s level of trait anxiety (Derryberry and Reed, 2002). In the police field study, analysis of joint trait effects revealed that shooting performance and time perception were indeed related to officer traits (Szalma et al., 2007). Thus, extraversion and emotional stability jointly predicted time perception ratings of officers after a demanding shooting task (see Figure 16.8a), such that at low levels of emotional stability individuals high in extraversion judged the task to be significantly longer than those low on extraversion. At higher levels of emotional stability no substantial differences in duration judgment as a function of extraversion were observed. These results were consistent with the hypothesis, based on Hancock and Weaver (2005), that an individual whose attention is externally directed (e.g., extraverts) is more likely to experience a “slowing down” of time. Interestingly, a similar interaction was observed for post-task distress (see Figure 16.8b). That is, among individuals low in emotional stability, those high in extraversion reported greater post-task distress than their cohorts low in extraversion. No such differences were observed at higher levels of emotional stability.

By far the most important variable with respect to interactive effects was Intellect. Recall that no significant associations were observed between shooting accuracy and individual traits. However, there was a joint prediction by Intellect and Conscientiousness, such that higher levels of Intellect were associated with higher shooting accuracy, but only for individuals high in Conscientiousness (see Figure 16.9a). No such relation was observed for individuals low in Conscientiousness. Note that these effects were restricted to the most difficult task performed by the officers in the training session, consistent with the other findings reviewed in this chapter. Finally, Intellect and Conscientiousness also jointly predicted post task distress, such that at the end of the training session individuals high in conscientiousness reported greater levels of distress, but only for those low in Intellect (see Figure 16.9b). Again, this may indicate that something about those high in Intellect (e.g., perhaps the use of more adaptive coping strategies) serves to protect them from stress symptoms if they are also high in Conscientiousness (and therefore more likely to have allocated substantial effort to task performance).

Intellect and Emotional stability jointly affected time perception on one of the more difficult tasks (see Figure 16.10a). Thus, low emotional stability was associated with greater distortions of time (overestimation), but only for individuals low in Intellect. The same variables jointly predicted pre-task (i.e., pre-training session) Worry, with lower emotional stability associated with greater worry regarding the imminent training activities (Figure 16.10b). However, this pattern of results emerged only in individuals who were low in Intellect. No such differences were observed at higher levels of Intellect, suggesting that high levels on this trait may serve as a “protective factor” for stress states.

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2 The term “interaction” will be used here for convenience and simplicity of discussion. However, it should be remembered that the joint “effect” of measured traits cannot be interpreted in the way that interactions are considered in factorial designs in which participants are assigned at random to experimental conditions.
Figure 16.9a Shooting accuracy on a challenging firearms task as a function of intellect at three levels of conscientiousness

Figure 16.9b Post-task distress as a function of intellect at three levels of conscientiousness

Source: Szalma et al., 2007.
Figure 16.10a Duration judgment ratio (estimated time/clock time) as a function of intellect at three levels of emotional stability for a challenging firearms task

Figure 16.10b Pre-task worry as function of intellect at three levels of emotional stability

Source: Szalma et al., 2007.
**Figure 16.11a** The maximal adaptability model incorporating hypothesized adaptive function of individuals low in emotional stability (a similar pattern would be expected for trait anxiety and pessimism)

The vertical line labeled “center point” illustrates the asymmetry in the model introduced by consideration of traits.

**Figure 16.11b** Representation of the maximal adaptability model shown in (A) focusing on the hyperstress region

Note that the thin curves are represent “normative” patterns of adaptation, and the thicker curves represent hypothesized adaptive patterns for individuals low in emotional stability (or high in trait anxiety or pessimism). Low emotional stability would be expected to shift the thresholds of failure (the “shoulders” of the functions) lower, such that for these individuals adaptive failure occurs at lower levels of environmental demand. However, the degree of shift is not equivalent for each level of adaptation. Thus, one might expect that the normative and comfort zones to narrow to a greater degree than the zone of psychological (i.e. performance) adaptation.
Incorporation of individual differences into stress theory

As we have noted elsewhere (Szalma and Hancock, forthcoming), because individual differences are a source of influence on adaptation to stress and the allocation of effort and compensatory mechanisms, the maximal adaptability model (Hancock and Warm, 1989) and the compensatory control model (Hockey, 1997) should be extended to include individual differences as an input or component. For the Hancock and Warm (1989) model, it is likely that individual differences will exert their effects in determining the width of the “plateau” of adaptive function and/or the slope of the decline in adaptive response when the threshold or “shoulder” of failure occurs (Szalma and Hancock, forthcoming). For instance, it is likely that individuals lower in emotional stability will reach the thresholds for psychological comfort and, if task demand is sufficiently high, quality of performance earlier than those higher on that trait. Alternatively, an individual who uses adaptive coping strategies may have a tolerance threshold much higher than an individual who uses maladaptive coping (e.g., avoidant coping). An implication of this possibility is that it may be possible to train “expert stress copers” and to adapt such training to the needs of the individual learner, based on his/her affective traits. Figures 16.11a and 16.11b show a possible application of the Hancock and Warm (1989) model to emotional stability (trait anxiety and pessimism would likely show similar patterns to emotional stability).

With respect to the compensatory control model (Hockey, 1997), there are several points at which traits may exert an influence. First, traits may influence both the level and the allocation of effort toward task performance. For instance, individuals low in emotional stability or high in pessimism may prematurely or wrongly conclude that allocating effort to performance will not be useful to achieve success and therefore “give up” and abandon the task. Even in cases where effort is maintained, traits such as pessimism may reduce the efficiency of the effort or action monitors. Thus, as pessimism is associated with maladaptive coping strategies in domains where time pressure is an element (e.g., Helton et al., 1999, cf. Matthews and Zeidner, 2004), it is possible that individuals high on that trait will devote substantial effort to regulating their emotions or avoiding the stress, reducing the amount of resources available to deal with the high task demands. This pattern of responding suggests that improving task skill, including stress coping skills (e.g., see Driskell, Salas, Johnston, and Wollert, this volume), represents a potentially useful approach to mitigating the stress related to performance failures for individuals with traits that are associated with maladaptive responses (Matthews, 1999). The effectiveness of task skills likely manifested in the shooting performance observed in the police field study. Even police officers with lower levels of emotional stability still performed as well as their cohort higher on that trait when the task was a simple one with which they were very familiar. Similarly, the effects of trait on performance, workload, and stress response in laboratory experiments are generally observed only when tasks are relatively difficult. Because the difficulty of a task for any individual is influenced by skill level, stressors are more likely to impair performance of a vulnerable individual (e.g., high anxiety, pessimism in task environments with high time pressure) who lacks adequate skills to cope effectively with the stress. Stated another way, even an anxious, pessimistic person can perform well if he/she is trained so that many elements of task performance require more automatic rather than controlled processing (Schneider and Shiffrin, 1977).

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3 Note that “low emotional stability” (alternatively, “high neuroticism”) is a relative term. All the officers were in the “normal” range of the emotional stability spectrum, showing no evidence (based on the measure used) of clinical depression or anxiety.
Barriers to theory integration

Ultimately, the ability to integrate theories of personality, stress, and performance will depend on the degree to which the latter can be meaningfully quantified. Specifically, for an individual differences perspective to fully contribute to stress research concepts such as “resources” must be refined. This is a problem in general for stress research (for recent discussions see Hancock and Szalma, 2007; Szalma and Hancock, forthcoming), and ultimately is closely related to the problem of quantifying human information processing (McBride and Schmorrow, 2005). Although there have been substantial efforts to link personality theory with cognitive science and cognitive neuroscience (e.g., see Matthews, 1997a; Ackerman, Kyllonen and Roberts, 1999; Ackerman and Kanfer, 2004; Matthews and Zeidner, 2004), these have yet to be fully integrated into the dominant energetic models of stress and performance discussed in this and other chapters of this volume. For instance, if the base axes of the Hancock and Warm model, which reflect spatial and temporal task elements, could be adequately defined and quantified, investigation of trait-task interactions using the cognitive adaptive framework could be accomplished more precisely with resultant benefits to both theory and practice. Although quantification of these axes is a difficult undertaking, novel approaches to quantifying human information processing are emerging (McBride and Schmorrow, 2005; in particular, see Hancock, Szalma and Oron-Gilad, 2005; Szalma and Hancock, 2005). Integration of these lines of research is crucial if a more complete and accurate model of human performance under stress is to be achieved.

The way forward: Cognitive-adaptive framework, stress, and performance

The cognitive-adaptive model represents integration of theories of personality, emotion, and cognitive science, making it extremely useful for application to the study of human performance under stress. The identification of “trait-cognitive” patternings is a promising approach to understanding how traits influence performance, and corresponds to the “broad band” approach to stress research advocated by Hockey and Hamilton (1983). A successful application that may serve as a guide for future work is the cognitive patterning of extraversion. This was summarized by Matthews (1992, 1997b), who noted that extraverts show superior divided attention, resistance to distraction, and working memory capacity, but are less skilled at sustained attention, or engaging in reflective problem solving. However, the application of this approach to individual differences research has been the exception rather than the rule. Much of individual differences research in human factors and ergonomics focuses on very specific traits (e.g., need for cognition, cognitive failure) applied to a limited number of performance settings. Even at the level of broad traits, most relevant research for understanding performance under stress and the application of human factors principles to mitigate stress, have focused on extraversion and neuroticism. Conscientiousness, Agreeableness, and Openness to Experience have been relatively neglected (Matthews, Deary and Whiteman, 2003). In contrast with the broad band approach advocated by Matthews (1992), the narrow band approach has been applied more often in individual differences research. In this approach, the influence of several traits on one kind of task or information processing is evaluated. Such research is useful in summarizing how trait profiles may be related to a single task, exemplified in the effects of individual differences on vigilance performance (Davies and Parasuraman, 1982; Berch and Kanter, 1984; Davies, 1985). However, this approach renders it more difficult to clearly establish the links between the traits and the cognitive states associated with task performance. In addition, the “profile” established in the narrow band approach is most often distributed across different studies, making theory driven evaluation of the relationship between trait profiles and task performance within a single study relatively difficult, a limitation Berch and Kanter (1984) themselves noted. The assertion here is not that the narrow band approach
be completely abandoned, or that the study of very specific traits (e.g., field dependence) should cease. Rather, individual differences research should be organized around a common framework that, when combined with empirical research using the broad band approach, would organize the empirical literature and improve theories of information processing, stress, and performance.

**Stress theory and the cognitive-adaptive framework**

Although the maximal adaptability model and the compensatory control model are presented and used in stress research, they are actually models of how humans perform activities (i.e., behave) and adapt to change. “Stress,” as environmental demand, physiological and psychological response, and the transaction between these, is not a discrete state. It is instead a continuous stream of cyclic activity. That is, internal and external demands are always present and fluctuate in intensity, and humans continuously adapt to these at multiple levels of transaction (Matthews, 2001). Hence, stress research should move away from discrete, static approaches (e.g., “exposure vs. non-exposure” to a stressor) and consider change in adaptation over time. This is hardly a new idea. For instance, treating human behavior as a “continuous stream” and focusing on change in the flow of behavior was advocated by Atkinson and Birch (1978) with respect to motivation research, and in stress theory by Lazarus and Folkman (1984). Indeed, Lazarus and Folkman (1984) explicitly noted the importance of time in understanding human-environment transactions in their characterization of cognitive appraisals as “largely evaluative, focused on meaning or significance, and [taking] place continuously in waking life” (p. 31, emphasis added). Taking this perspective, future research should increase its focus on the changes in cognitive state as a function of changes in stress exposure during a performance session (e.g., increases or decrease in noise, time pressure) or changes in task demand (e.g., workload transitions; see Huey and Wickens, 1993; and see also Cox-Fuenzalida, Swickert and Hittner, 2004) or task difficulty. This would address the question of how cognitive state and adaptation change when the “stress” fluctuates from one level to another. The need for such an approach has been recognized, with workload transitions being a noteworthy example. Further, changes in cognitive performance and in stress over time have been investigated in experimental paradigms such as vigilance and adaptive automation. Indeed, with the burgeoning field of neuroergonomics the potential for more fine-grained analysis of change in stress state over time is growing rapidly (Hancock and Szalma, 2003b, 2007).

What is needed is an extension of this mindset to the inclusion of an individual differences analysis of the person-environment transaction at multiple levels of analysis.

Increased understanding of phenomena as complex as performance under high workload and stress will be facilitated by theories that integrate the models of the cognitive, emotional, and motivational processes with models of stress and performance. Many psychological theories have common constructs (e.g., resources, adaptation, arousal, attention), but they organize them differently within their respective theoretical structures (e.g., resources in Hockey’s model vs. in the Hancock and Warm model). In addition, many theories use different terms to describe similar processes (e.g., selective/divided attention vs. working memory vs. short term memory), and the same terms to describe different processes (e.g., knowledge, value, valence, resources, stress). Although these theories are not necessarily in fundamental opposition to one another (e.g., they share common assumptions regarding adaptation and the importance of cognitive resources), this “buzzing confusion” must end if we are to move beyond incremental advances. Individual differences research cannot resolve many of these definitional problems, but analysis of the differences in human characteristics that influence the transaction between environmental characteristics and human cognition, emotion, and motivation can contribute to further elucidation of these elusive constructs by specifying how human characteristics interact with those of the task to influence performance outcomes, particularly when employed in tandem with a neuroergonomics approach (Hancock and Szalma, 2007).
Figure 16.12a The maximal adaptability model incorporating hypothesized adaptive function of individuals high in extraversion

The vertical line labeled “center point” illustrates the asymmetry in the model introduced by consideration of traits.

Figure 16.12b Representation of the maximal adaptability model shown in (A) focusing on the hypostress region

Note that the thin curves represent “normative” patterns of adaptation, and the thicker curves represent hypothesized adaptive patterns for individuals high in extraversion. High extraversion would be expected to shift the thresholds of failure (the “shoulders” of the functions) such that for these individuals adaptive failure occurs at less extreme levels of hypostress or under stimulation. However, the degree of shift is not equivalent for each level of adaptation. Thus, one might expect that the normative and comfort zones to narrow to a greater degree than the zone of psychological (i.e. performance) adaptation.
An example: Extraversion

To demonstrate potential ways of integrating the cognitive-adaptive framework to stress theory, we consider Extraversion and Anxiety because these traits have been studied more extensively than others (Matthews, Deary and Whiteman, 2003). Recall that the cognitive patterning of extraversion consists of faster responding, less accuracy, larger working memory capacity and more attentional resources, and better divided attention (Matthews, 1992, 1999). This permits them to maintain performance levels (adaptive plateau) in the presence of noxious or distracting stimuli with fewer resources devoted to the supervisory controller for maintaining performance levels (i.e., less compensatory effort required). Further, as they have larger working memory and resource capacities they can tolerate higher levels of demand than those low in extraversion. These would have the effect of shifting the edges of adaptation failures of comfort and performance further out (i.e., at higher levels of stress; see Figure 16.12a). Although extraverts and introverts may have similar skill levels for a cognitive task, and therefore shift to the higher level control loop (i.e., automaticity levels, cf. Hockey, 1997), the strategic decisions made by the supervisory controller, which can select from multiple options to deal with the increased demand, will likely differ as a function of traits and the nature of the environmental demands. For high stress (overload) conditions the extraverts would have the advantage because the effort “budget” is larger and therefore more effort can be allocated without additional cost to functional state. In addition, the efficiency of the controller and the effort monitor are likely to be higher for extraverts and those low in Neuroticism/Anxiety, the former due to larger resource capacities and the latter due to fewer resources allocated to managing negative affective states.

However, a different scenario emerges if the environmental demands are characterized by hypostress (underload) where there is minimal task or time pressure and, in some cases, reflective problem solving may be required. In these circumstances, individuals lower in extraversion have the advantage, because the amount of working memory/resource capacity available for task performance is functionally increased by the increase in time allowed for information processing. Extraverts, however, might be more prone to boredom for lack of stimulation, and therefore have to devote efforts to compensate for the unpleasant state such environments induce in them. Thus, for hypostress the shoulder of failure occurs at less extreme levels of hypostress for those high in extraversion and earlier for those high in that trait (see Figure 16.12b). Note that this introduces an asymmetry in the maximal adaptability model (see Figure 16.12a), as a function of the trait and associated cognitive patterning. In addition, the size of the adaptive “zones” will be different as a function of trait differences. Thus, in overarousing situations, low extraversion would likely be associated with a smaller difference (relative to extraverts) between the thresholds of the normative and comfort zones. The reverse pattern would be expected for the hypostress region. In other words, the size of the normative, comfort, and psychological zones of adaptability likely vary as a function of traits, and, in the case of extraversion (and also Neuroticism/Anxiety; see Figures 16.11a and 16.11b) be asymmetric around the center of the comfort zone. Whether such differences extend to the physiological threshold will likely depend on the physiological system in question. In general, one would expect that the magnitude of the effect of individual differences in affective traits on adaptation would decline as one moved to either extreme of stress level. Similarly, points of task load that will overwhelm the resource capacity of the supervisory controller for most individuals, regardless of trait. In addition, as the evidence reviewed in this chapter suggests, at low levels of task demand traits are not likely to exert as strong an influence. Note that low demand does not necessarily mean that the individual is in the hypostress region. Low demand can lead to hypostress if that state is aversive to the individual (e.g., boredom), but it does not deterministically
lead to such a state. It depends on the appraisals of the demands (Lazarus and Folkman, 1984), which itself is influenced by cognitive and affective traits.

The above considerations suggest that if the task is relatively difficult (e.g., a difficult perceptual discrimination under conditions of low signal salience such as camouflaged objects), individuals high in extraversion might find sustained attention tasks more stressful and report higher levels of workload. Introverts, who are better adapted for such environments, would have more capacity to devote to the monitoring task, because extraverts would have to devote resources to managing the aversive situation (i.e., devote more compensatory effort and be higher in “strain” levels). The evidence that exists for both long duration and short duration detection tasks does not uniformly support the above hypothesis (e.g., Rose et al., 2002; Thropp et al., 2004), but to completely test this conception requires systematic manipulation of task demands that push the individual closer to the thresholds of adaptive failure (increases the strain on the supervisory control loop). From the cognitive-adaptive framework perspective, the task demand must be manipulated so that the tasks vary in the skills required and the effect of task parameters on knowledge structures (i.e., motivational and emotional states; self-efficacy, etc). Further, changes in adaptation should be examined as a function of time. Although performance may be preserved regardless of an individual’s trait characteristics, failures in subjective comfort (perceived workload and stress) may emerge earlier for individuals low extraversion (and perhaps low in emotional stability as well) for tasks that impose multiple demands or are performed in the context of time pressure. Similarly, individuals high in extraversion may reach the threshold of failure in subjective comfort earlier for tasks associated with hypostress (e.g., vigilance).

Note that this example has focused on Extraversion. The same logic can be applied to Neuroticism/Anxiety or to any other trait (e.g., pessimism/optimism). The situation is further complicated when one considers interactions among these traits. Thus, the actual form of the extended-inverted U would be a resultant of combinations of functions (vectors) based on trait profiles. These are important issues for further research, because although the analyses are complex, this complexity is what exists in real-world stressful environments. However, to fully exploit this approach by applying it to traits such as pessimism, Conscientiousness, Agreeableness, or Openness to experience (Intellect), the cognitive patterning of these traits needs to be empirically established as it has been for Extraversion (Matthews, 1992, 1999).

Applications to human factors and ergonomics

Design principles and guidelines

The cognitive-adaptive framework provides a strong foundation for theory and research on which to empirically investigate individual differences in human performance, but there has been limited application of theory and research on trait-performance relationships to problems in human factors and ergonomics (i.e., interface and training design principles and guidelines). What has been investigated are often very specific traits for very specific domains, making derivation of general theory and design guidelines difficult. In real world environments individuals perform tasks requiring multiple cognitive processes that need to be well supported by interface and training design in order to ensure protection of performance in stressful circumstances. Hence, what is needed is integration of the cognitive perspective on personality with the design principles of human

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4 I am reminded of one of Hancock’s aphorisms with respect to psychology: “There are the hard sciences, and then there are the difficult sciences.” The problem of individual differences in performance certainly provides evidence supporting that statement!
factors and task taxonomies that can be derived from human factors and ergonomic methodologies (e.g., cognitive task analysis). That this has been relatively neglected is understandable, given the theoretical difficulties and empirical inconsistencies that have historically plagued individual differences research. However, we are presented with real-world problems here and now, and it is time to take what theory and research we have and derive general guidelines or principles for design, so that those creating human-machine interfaces can design displays that take different “trait-cognitive” patterns into account. Establishing such patterns can also be applied to the design of training regimens, for instance by placing extra emphasis on those aspects of task performance or environmental conditions in which individuals with specific trait-cognitive patterns are most vulnerable. Note that these suggestions do not replace current practices in training and interface design, but rather augment and extend them to account for differences across the individuals who are the ultimate “customers” for interface design.

Applying the theories discussed here, it is clear that interfaces and training should be designed to facilitate effective (i.e., adaptive) responses and protect performance when problems occur in environments to which the person is not dispositionally well adapted. For instance, because individuals low in Trait Anxiety and high in Extraversion tend to respond well to fast paced environments, they should receive additional training in coping with low demand environments (the moments of boredom), while those (relatively) high in Neuroticism and/or low in Extraversion might benefit from stress training for the time pressured environments (moments of terror). Such an intervention should not replace existing training procedures, and it is not the case that those high in Extraversion and low in Neuroticism/Trait Anxiety do not need training for stressful conditions. Rather, it may be that additional or more intensive training should be employed for conditions to which individual trainees may not be dispositionally well-adapted.

In regard to display design, individuals high in Extraversion/low in Neuroticism/Trait Anxiety should have displays that adapt to their state as a function of changing demands. Using adaptive automation as an example (see Parasuraman and Hancock, Chapter 3, this volume), during the “moments of boredom” extraverts might need tasks that engage them so as not to strain their limited resources on coping with the relatively aversive underload. By contrast, those low in Extraversion and/or high in Neuroticism/Trait Anxiety may need higher levels of automation (see Oron-Gilad et al., 2005) and displays with easily perceivable elements (Hancock and Szalma, 2003a) when task demands increase dramatically over short time epochs (moments of terror). Note that it is not the case that one set of trait profiles is “good” and others “bad,” for task performance, a typical bias among practitioners who use measures of affective traits primarily as a selection or job placement tool. Rather, different profiles are associated with better adaptive responses in different environments (see Matthews, 1997b, 1999; Matthews, Deary and Whiteman, 2003). One implication of this is that it may be advisable to create teams with diversity in trait profiles so that team members can aid one another as operational conditions change. For instance, it may be useful to include both optimists and pessimists on a team so that their different strengths and capacities can complement one another (Dember, 2002).

Future research

Taken together, the results of the field and laboratory studies reveal that whether affective traits influence performance, workload, and stress depend in part on the characteristics of the tasks themselves as well as the profile of operator traits. Thus, the finding of relatively weak correlations between traits and performance (e.g., Barrick and Mount, 1991; Barrick, Mount and Judge, 2001) may be due to masking by 1) variability in task and environmental characteristics across studies, and 2) complex interactions among traits, cognitive states, and the characteristics of the environment,
especially the task structure itself. Further exacerbating the latter problem is the relatively limited number of studies examining the interactions among multiple traits and task characteristics. Hence, an area clearly in need of further research is in examination of “joint” or “interactive” effects of multiple traits on information processing and performance. Even under uncontrolled conditions of a field study such effects emerge, and they should be examined systematically in the laboratory to determine which information processing capacities are influenced by joint trait interactions (e.g., working memory capacity, attentional control, spatial or verbal processing skills, etc). Further, the effect of different levels of task demand, and the nature of those demands, needs to be evaluated with respect to combinations of traits.

Conclusions

In this chapter the case for an individual differences approach to understanding performance under stress was presented, with examples of studies conducted both in the laboratory and in the field. The problems are complex, which makes developing a comprehensive theoretical model difficult. A framework exists, however, that can be integrated with established stress theory. Theoretical integration can point the way toward systematic research to enhance our understanding of the multiple factors that control performance and how to exploit them to the benefit of those who operate under highly stressful conditions. This chapter illustrates an initial attempt at such integration.

Pursuing integrative research of the nature described above will yield positive results, but it will take the efforts of many and does not represent a “magic bullet” solution. It might therefore be tempting for some individuals to revert to applications of individual differences research to the personnel selection approach by simply assigning individuals to tasks and environments to which they are best suited. This can be useful to some degree, but there are reasons for avoiding over reliance. First, in some domains there are limitations in “human capital,” (e.g., the armed forces) and selection based on affective traits may not be practical. Second, even in domains where selection is possible and is currently standard practice (e.g., law enforcement), it is difficult to assign individuals to environments to which they are best adapted because the environments change frequently. These changing circumstances should be incorporated into the design and operation of tasks and interfaces, and consideration of affective traits and their relation to performance can facilitate these efforts. Finally, in many real-world situations the environment does not monolithically support adaptation for individuals with particular trait profiles. For instance, based on the evidence, it seems reasonable to assume that in a combat situation the low Neuroticism/Anxiety combined with Extraversion would generally perform better at the cognitively demanding tasks required of leaders in those situations. However, due to heightened awareness for threat, individuals high in Anxiety and low in Extraversion might be more attuned to changes in the environment during a routine patrol, potentially facilitating their capacity to detect IEDs. Note that the implication here is not that stable extraverts are poor at detecting threat or that neurotic introverts are poor decision makers in combat. Rather, it is argued that because individuals with different traits are differentially well-adapted to different environments, we should exploit those differences through training and interface design. If we are to prevail in the cognitively dominant World War IV (Scales, 2006), it is crucial that we utilize all our psychological tools ranging from the perceptual and cognitive to the personality traits of military personnel to interface and training design. Considering individual differences affords an avenue toward making such design a force multiplier that maximizes performance and survivability of our military and homeland security personnel.
References


Warm, J.S., ed. (1984), *Sustained Attention in Human Performance* (Chichester, United Kingdom: Wiley.


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Chapter 17

Stress and Performance: Experiences from Iraq

LTC J.L. Merlo, CPT Michael A. Szalma and P.A. Hancock

This chapter is dedicated to those who gave up their freedom so that others may have theirs.

Introduction

The technological advances in warfare have changed many of the tactics, techniques and procedures that have historically been used to win the nation’s wars. However, the ability to mitigate the effects of combat stress on the warrior has not evolved as rapidly. Daily news from the home front, often accessed real time via Internet connectivity and international cell phone calls now add new levels of stress to the soldier who is forced to have proxies handle his or her stateside affairs. All the while they are readily cognizant of the fact that nothing is certain in their new, if temporary surroundings. This chapter attempts to explain the effects of these stresses, new and old, from the soldier’s perspective. In so doing, we consider such effects on both active duty soldiers and the citizen soldier.

Imagine standing for hours under 120º Fahrenheit heat, controlling an access point on a road or intersection as vehicles without license plates or identification of any kind rapidly approach. Split-second decisions must be made as to whether or not to engage these vehicles with lethal force. A decision that is too conservative or too stringent in the identification of friend or foe can leave the soldier with the option of being judged by twelve or carried by six. The criterion to make some of these life and death decisions are often regulated by the rules of engagement (ROE), but these guidelines must be applied under a dynamic context, shaped and molded by the stress of ever changing circumstances. Maintaining vigilance under such demanding conditions is a daunting challenge indeed, as the mind drifts towards anything that relieves the immediate stress at hand.

While many of the challenges and stressors of the current theater of operations are not new, many have a new face and must be identified, understood and confronted to ensure the success of today’s warrior. The ultimate price of war is constantly revealing itself even for those studying the war. The dining facility at West Point, where all 4,000 plus cadets eat simultaneously, is a usually boisterous gathering as one might imagine since these are essentially college students chatting with one another about the day’s activities. However, the fear, remorse and sorrow that accompanies a death announcement of a brother or sister at arms creates a deafening silence and somber mood to finish a hurried lunch. The impact is much greater as individual cadets realize that any one of the names announced could have been sitting alongside of them at these very same dining tables just 6 months before. The stress of war is not confined just to the theater of conflict.
Stress in Garrison: Notification and Preparation

The first consideration with respect to practical soldier stress comes from the anticipation associated with potential deployment. For example, rapid deployment units rotate through varying levels of alert status, including degrees of readiness that would potentially have them in the air and traveling to some hostile area of the world less than 18 hours from initial notification. The rest of the Army is usually given a greater notice that they will be deployed. Notification that a deployment is forthcoming used to be a relatively infrequent event. However, it is becoming an annual event for many soldiers in today’s forces. The current operational tempo of active Army divisions is a year deployment followed by one year stabilization and then another year long deployment.

Prior to the current War on Terrorism, soldiers from the Reserve Component (Reserves and National Guard) were called upon to supplement active duty forces during a relatively brief period of time, usually during a crisis. Since the War on Terror, however, the Reserve Component has been used much more often and in increasing roles of responsibility such as US border security (Steele, 2006). In late 2004 and early 2005 approximately 40 per cent of soldiers in the Iraq Theater were Reservists or National Guardsmen. This represents a fundamental change in status for soldiers of the Reserve Component. As a result of this shift, the nature and level of stress on Reservists and National Guardsmen has also changed. Such sources of stress felt by these soldiers include: the attitude of active component toward the reserves; family stabilization; employment and reemployment; and reintegration into daily military life and on the job training.

When a unit is given the luxury of advance notice (either reserve or active), the flurry of activity in preparation of deployment often makes the deployment itself a break from the stress of this preparation. The preparation (usually at least a 6 month process) includes everything from marksmanship training, immunizations, updating wills and powers of attorney, to month long deployments to training centers. Training center rotations can be in the form of mission rehearsal exercises, or opportunities to learn how to use new equipment, to conducting live fire exercises and performing tactical operation center exercises.

Good leaders often try to protect what little time there is for family especially during this pre-deployment training. For example, one brigade commander in the First Cavalry Division stopped his unit during the middle of their mission rehearsal exercise and redeployed them from Fort Polk back to Fort Hood. The soldiers were allowed almost 48 hours back at Fort Hood with their families and then redeployed back to Fort Polk to continue training. The significance of this short break was to allow the soldiers to enjoy Thanksgiving with their families since they were virtually guaranteed to miss the next one because of the impending deployment. There is a precarious balance that a commander faces as he prepares his soldiers for deployment. The balance between getting all of the training done that is necessary and required and not seemingly starting the deployment 6 months early. The commander struggles over the potential of not having his forces ready; juxtaposed with having them worn out before they ever get to the site of the conflict.

With well over half of the force married, the pending separation for newly married couples, parents away from young children, absence from significant others, etc. creates a phenomenal amount of stress for the soldier and the family alike. Many soldiers remark that the separation from loved ones is the hardest part of the deployment. A year long deployment essentially guarantees the missing of every holiday, birthday, and anniversary. This separation from family, coupled with the significant time difference of distant deployments, makes communication difficult even when it is technologically feasible.

The US Army is becoming battle hardened. The number of soldiers experiencing multiple deployments to Iraq or Afghanistan is steadily increasing. While young soldiers might find their first deployment adventurous, exciting, and welcome, their feelings are somewhat different facing
another deployment after a brief time back in the United States. The soldier’s family and loved ones often show less acceptance of the episodes of repeated deployment. While there is more understanding of what the deployment will entail, the understanding of the negative consequences (missing events, injury, and death) are also evident and thus affect the relationship.

Both active component and reserve component families must cope with the frequent separation of their loved ones. However, this separation is perceived differently by the two groups. Reservists and their families are traditionally used to being separated for 2−4 weeks a year for annual training. Active duty soldiers, however, are used to longer and more frequent separations due to training requirements. Although the separation is still difficult for both types of soldiers, the active soldiers have more experience of and to a degree greater insulation from the stresses of separation. This additional stressor to reservists is a result of the increased operations tempo of the War on Terror. With increased call-ups, reservists are now being informed that they should expect to be deployed for durations of at least 12−18 months every 5−6 years. This naturally leads to increased stress levels in the family, especially just prior to the first deployment. Unlike active duty families that have access to military installation resources as well as to each other, reserve families are often left with little military sponsored help. Although each reserve unit does have a family readiness group, the individuals comprising this group often live great distances away from each other. It is not uncommon for reserve soldiers to drive one to two hours to perform weekend reserve duty. This lessens the number and degree of support meetings of reserve families in comparison with active duty families.

A stressor that active duty soldiers do not have to endure is the effect of a deployment on civilian employment. In the past, employers have not often been too adversely affected by reserve military duty. They see their employees leave for only 2 weeks a year. Weekend duty often has no impact on the employer’s operations. However, when a reservist deploys in the current circumstances, the employer feels the impact. This increases the stress felt by the reservist because not only is he/she leaving the family, but also leaving his/her work place. Concerns such as “What will happen to my project?” are often expressed. Despite federal law ensuring subsequent re-employment, most reservists still have concerns about the availability of their job upon their return. Although law protects the job, it does not guarantee that the employer will follow the law. In addition, the law states that the employer must provide an equivalent job, not necessarily the same job. Another concern regarding re-employment is the prospects of career progression. Again, the law and reality do not necessarily coincide. “Will I get promoted when I get back?” This is especially of concern to reservists with 10 or more years to serve in the military since they can now expect to be deployed at least two more times. “Will I get promoted if my boss knows I will be deployed two more times?” Of course, this stress resulting from actual and anticipated effects on employment is even greater for self-employed reservists. Unless his/her company is large enough to have a manager to run the business during an absence, a deployment often results in the shut down of the business. This in turn affects all other employees of that business for whom the reservist may well feel responsible. Thus, the impacts of foreign conflicts are felt even beyond the immediate families of those individuals involved.

Another stressor not felt by active component soldiers is a probable decrease in salary. Although some reservists make more income through military deployment (especially with the tax free status when involved in hostile fire zones), many actually experience a significant loss in income. Many employers do continue to compensate for this loss in pay during the deployment, thus alleviating some concerns. However, the majority of employers do not provide this extra pay. As a result, the family income can be significantly reduced. As financial problems add stress to any situation, the effects of financial hardship on the reservist and his/her family are even greater. Although the Soldiers’ and Sailors’ Civil Relief Act does provide some protection and assistance,
it does not adequately solve all problems for the deploying reservist in financial matters. As a result, each situation must be independently addressed, thus adding stress to the chain of command who themselves are attempting to maximize the number of soldiers that are deployed in order to accomplish the mission.

Related to the stress of leaving civilian employment is the stress of entering active duty. Although many reservists have served on active duty, it may have been a number of years previous to the deployment. While reserve soldiers still perform military duty, their approach is often more easy-going than their active counterparts. Suddenly being on active duty, possibly for the first time, adds another item to the list of things that need to be adapted to. Not only are the regimens of daily military life thrust upon the individual, the idea that “this will be over in two weeks” no longer applies. Most of those with prior active duty experience readjust quickly and without excessive stress. However, many of those individuals that have never served on active duty often find it overwhelming, especially in the early stages. Although the vast majority of these soldiers integrate with little problem, some experience a large, residual amount of stress. This may be due to family separation, the prospects of going to war, the discipline of military duty, and the relative privations of military life all for the first time. Although all soldiers, both active and reserve, must also undergo these same transitions, those with prior experience have an easier time adjusting than those reservists without that experience. Indeed, it is one of the principles of stress research that those with prior experience of any stress are better able to deal with the effects of such stress (and see Hancock, 1986).

Similarly, getting to know one’s military job can also be a source of stress. A reservist may be one of the best postal workers in his or her Zip code with a vast amount of knowledge and experience in postal duties. However, as a reservist (especially those without active duty experience) the experience and knowledge of the military job is very rarely as high. An individual who has driven a tank only 2 weeks out of the last 5 years has much less experience than active duty soldiers with only 3 months of service in a unit. This relative level of inexperience can result in a feeling of inadequacy and self-doubt. This stress coupled with the notion that in 30−90 days “we will be in a war zone doing this job” causes a high degree of stress. This is exacerbated when a reserve unit is activated to perform a totally different mission than the one for which they have traditionally trained, a topic we cover in greater detail later in this chapter.

One difference between the two components that gives reservists an edge over their active duty counterparts is peer familiarity. Active duty soldiers are often rotated between different units (and installations) every two to four years. Reservists, however, are often in the same unit for five to 10 years (if not longer). Although they do not interact with each other on a day-to-day basis, reservists do have long-term work relationships that increase the sense of belonging. This provides some inoculation against the stress and feeling of being uprooted. However, this very same phenomenon can actually be a detriment to individual reservists. Since the War on Terror has increased the need and utilization for reserve soldiers, many activated units are called upon to conduct missions for which they simply do not have enough manpower. As a result, the concept of “cross-leveling” has been applied to mobilizing reserve units. If a unit does not have enough soldiers of a certain rank and/or job, another unit (often from a different state and region of the country) is required to send some of its soldiers. These soldiers now must attempt to integrate into a unit comprised of people that have known each other for many years. This increases the stress of the “cross-leveled” soldier as well as the chain of command that must work to fully integrate all of these “new” soldiers. This is especially true for those “cross-leveled” soldiers that are sent to theater in less than 2 weeks after being mobilized.

While there are many positives to be gained from the familiarity that the chain of command has for members of its command, there are negative impacts as well. Taking disciplinary actions
for regulation infractions can sometimes be problematic for leaders that have worked closely with the same subordinates for long periods of time. Additionally, social structures in civilian life might be quite different from the military rank structure in the Guard or Reserve unit. Civilian bosses can become subordinates in the Guard and Reserve and vice versa. These various circumstances mean that individuals in the deployed force are often each facing their own particular spectrum of stresses and thus single strategy answers are unlikely to be effective. However, if the anticipation of events provides an initial source of disturbance, it is the actual deployment that sees the most significant changes and the greatest sources of acute stress.

The Long Ride Over

Deployment overseas most often occurs on charter aircraft and more often than not these respective arrivals and departures are not as precise as normal commercial air travel. Understandably, the loading of an aircraft with weapons and other military equipment makes packing, passenger manifesting, and customs declaration arduous tasks. Aircraft are often used as available, causing soldiers to wait an entire day only to be turned away with orders to return in a short period of time that could extend from hours to days. The difficult task of saying goodbye to family and friends starts all over again. It seldom becomes easier.

Travel over different time zones and transfer from civilian aircraft, to military aircraft, to ground convoy, makes for a long trip indeed. Food during transit is most often a military ration that is consumed in make-shift temporary facilities. The flow into theater becomes even harder as security becomes more and more important as the deployment destination is approached. During the movement to theater, sleep is often shortened by many disruptions. The soldier’s circadian rhythms are desynchronized by the geographical time change. Sleep during transit is difficult due to transports being full with little to no empty space. Temporary billeting at transition points are usually crowded and in the form of open bay barracks, placing soldiers in gymnasium type facilities with room enough to walk between endless rows of bunk beds. Due to the different shifts of guards, dining times and personnel movements, the lights in such a temporary facility are often left on at all times, with no ability to dim or darken specific areas. The noise from nearby soldiers snoring, to vehicle movement, to personnel moving in and out, make quality sleep difficult, and sometimes impossible to achieve. Consequently, the soldier is often stressed and somewhat disoriented even before reaching the combat theater. From the notification, to the preparation, the difficult farewells and the arduous transit; the fatigue of war has started early to take its toll on the body and mind. The soldier is highly susceptible to disease at this early stage in the deployment. As the body struggles to adapt to the time change, the sleep deprivation, and the close quarters living, sniffles, coughs and dysentery become common place.

The Intermediate Staging Base

Occasionally, units will wait for some period of time in an intermediate staging base (ISB). These bases are usually temporary facilities similar to the temporary facilities in transit holding areas. These temporary bases are only used until a unit can move forward to their ultimate deployment location. In Iraq and Afghanistan these ultimate locations are military camps and forward operating bases (FOBs). FOBs are similar to fire bases in Vietnam. However technology has made the current day FOBs infinitely more modernized and sophisticated. Units will operate out of these camps and FOBs, when they move forward into the operational theater, but until that time they reside in the ISB. The anxiety builds in the ISB as soldiers wonder what awaits them in their ultimate area
of operation. Units monitor as much traffic and information coming from their area of operation as they can in an effort to review their plans and inform their troops. Often units will send small advance forces or representatives (ADVON) to increase their connectivity to the activities occurring forward. This contact with one’s own soldiers forward both increases and decreases the pressures and stressors of the unit. There is relief in knowing that aspects of preparation were right on target and will serve the soldiers well. This is juxtaposed with new information about upcoming missions or enemy tactics that were not as well prepared for during home station preparation.

Relief in Place/Transfer of Authority

The time in the intermediate staging base eventually ends. More often than not, there is actually a sense of relief when the troops begin to move forward. Cramped conditions, endless waiting and planning, give way to action as the movement into the area of operation begins. For many of the wide eyed younger troops it is their first taste of battle, for experienced leaders it is the first opportunity to see how their subordinates, equipment and planning will react in battle situations. If a unit is being replaced then a relief in place is conducted. There is not usually a one-to-one transfer of jobs as would take place in the civilian realm. Rather, there is more of a transfer of authority where the new unit understands the requirements and missions of the old unit and assumes responsibility for these requirements and missions in a way that fits their commander’s guidance. When conditions are ideal, this transfer of authority takes place with a procedure called “left and right seat rides”. This metaphor relates to the new unit sitting in the passenger’s seat and then sitting in the driver’s seat as they quickly learn about the area of operation, its people and the nature of the varying missions.

When the relief in place or the transfer of authority is proceeding, the number of soldiers on the ground is almost twice the numbers that are usually present. While this would seem advantageous, it is actually a very difficult time tactically and logistically. The FOB’s are usually the appropriate size for the unit that is occupying it. Doubling the numbers in a FOB makes sleeping, feeding, waste removal, storage, parking, and all ancillary functions difficult. This places considerable strain on the existing logistical systems and the people who have to run them. It is a precarious balance to keep redeploying units from interfering with deploying units and vice versa, all while continuing to conduct military requirements and missions for the area of operation. Transfer and relief are hard enough on their own but we need also recall that such actions take place in the presence of the cumulative effects of stress discussed in the preceding paragraphs. The travel, close quarters, time zone differences and workload have all played a huge part in each soldier’s life and most will have exhibited the full blown symptoms of ailments such as respiratory infections, dysentery and sleep deprivation. Unfortunately, the cognitive and physical requirements of impending tasks seldom allow a soldier to take proper care to remedy his or her health concerns. There is seldom time for proper recovery during the fast paced transitions that occur during this initial time in the area of operation.

Groundhog Day

The day to day activities and lives of soldiers in conflict areas such as Bosnia and related military operations have been compared with the popular movie Groundhog Day, in which the main character wakes up every day (it happens to be Groundhog Day) and repeats the day before, with the only changes being the ones that he makes. This is also pretty much the case in parts of Afghanistan and Iraq, however the nature of the combat actions in parts of Iraq have made many
of the operations change in scope very rapidly and often. The operational tempo of the battle is a double edged sword. The days seem to go faster the busier one is kept, but the fast pace can not be held indefinitely. Soldiers require downtime. They need time to write home, watch a movie, listen to music, or do something familiar that allows their mind to leave the combat theater and seek normalcy. Such epochs of recovery are essential if the day to day level of stress is not to accumulate to the level of a breaking point. These summated effects to a “shoulder of inflection” (or breaking point) have been modeled in general stress theory by Hancock and Warm (1989).

The nature of the mission in Iraq has many soldiers performing jobs that are not part of their typical military occupational specialty. For example, many of the heavy artillery units are performing duties that are more consistent with military police or infantry units. While these units have received additional training to conduct these operations, they are by no means as trained to do these “new” tasks as they are their traditional duties. One heavy artillery battalion became tasked to secure convoys originating in Baghdad, but traversing throughout all of Iraq. Equipped with armored HUMMWVs, the battalion size unit traversed over 1 million miles in escorts for a 1-year period, but fired zero artillery rounds. These newly acquired roles and responsibilities may well go beyond the purview of traditional Army activities. For example, one of the tasks that is unique in nature to most conventional forces is the training and advising of indigenous forces. In

Figure 17.1 CPT James Wayne, the Brigade Surgeon for 3rd Brigade, 1st Cavalry Division, administers medical care to Iraqi children in a good will medical visit to a rural village south of Baghdad

Photo by SGT John Queen, U.S. Army.
Iraq particularly, this service infrastructure building responsibility is especially evident and is one to which we next give particular emphasis.

**Stressors Unique to Military Advisers of Indigenous Forces**

An example of active duty and reservists being reclassified into military roles with which many have had no prior experience at all is the job of military adviser. Not since Vietnam has a large group of soldiers been called upon to train, teach, and mentor foreign soldiers. It must be noted that due to the fluid nature of the war in Iraq, as well as the continued maturation of the theater of operations, the stressors and experiences related herein may be different in magnitude than those felt by others serving in similar roles but in different locations and time periods. Some of the stressors felt by the reservists called upon to be advisers to the New Iraqi Army were similar to those already mentioned above. Therefore, this section is dedicated particularly to those stressors that are either unique or at much higher intensity levels than those that were felt by reservists and active duty deployed for more conventional types of duty.

One of the biggest stressors felt by the soldiers is the magnitude of the situation they were about to enter. In some cases, there are only eight to ten soldiers paired with 750 Iraqi infantry soldiers, who may or may not have completed basic training. This ratio of over 75 Iraqis to 1 American adviser is an initial source of great stress. However, as an inoculation against this, the respective, actual experience of two of the authors was that adviser teams (once they were in theater, not prior) quickly became cohesive. As the deployment continued, this uneasiness vastly abated as the individual advisers came to understand their Iraqi counterparts. By the 4th or 5th month, most advisers were extremely comfortable being alone with literally hundreds of Iraqi soldiers. At this point, a new stressor emerged that was not greatly anticipated prior to deployment. After the first few months, especially if the unit had seen enemy contact, the adviser often became attached to a select few numbers of Iraqis, often one or two. The new stressor was the knowledge that the adviser could not become too close to these individuals. The problem of infiltration remained a concern. Each adviser had to come to grips on his (females were not advisers to Iraqi infantry) own terms with the fact that he must perhaps be prepared to fight his counterpart in self-defense. Although to date we have not heard of any such cases, the adviser must be mentally prepared for such a possibility.

The stress of being alone with armed Iraqis took on a different aspect not felt by other reservists or active duty soldiers. A large number of advisers worked independently from higher headquarters, often separated from American and Coalition Forces. As a result, each adviser team had to deal with the stress that their own security depended on the Iraqis. A full elaboration concerning the nature of internal security measures employed by adviser teams is not appropriate here. However, the idea that one’s outer security measures comprised of people that may be your enemy adds to combat stress. A second stressor encountered by the adviser teams was a lack of adequate interpreters. There are numerous examples of adviser teams operating without even one interpreter. When present, the number of interpreters at any one time for eight to ten men was often only one or two at best. This means that six to eight advisers operated without an interpreter at any one given time. Despite this lack of resources, the adviser was still expected to teach and mentor his counterparts. Often, an Iraqi with a smattering of English understanding was used to varying effect. Not being able to communicate effectively became a serious source of frustration. Even when an interpreter was available, the translation was not necessarily accurate. This led to even more frustration, both on the part of the American adviser and the Iraqi trainees.

A third stressor, which in reality encompasses many different, but related stressors, resulted from cultural differences. American advisers were not used to dealing with people that often took
three-hour breaks during the middle of the day and that stopped working late in the afternoon. The concept of “work until mission complete” is part of the American work ethic, but not necessarily a part of the Iraqi culture. This can lead to great frustration on the American side, especially when schedules have to be met in order for operations to be synchronized. Similarly, the subject of leave also proves to be a source of frustration to advisers. Many Iraqis take seven to ten days of leave every month to visit their families, usually after being paid. To the advisers, this means that one-fourth to one-third less training time can be used to prepare the Iraqis for combat operations. Endowed with the idea that the advisers were the exit strategy of the United States, this delay in preparing their Iraqi units became a frustration to each adviser team. An added frustration resulted from the pay system of the Iraqi Army. The Iraqis pay their soldiers in cash every month. Despite all best intentions and efforts at the adviser level, the potential for and actual occasions of stealing and corruption is a great source of frustration to the adviser teams. Knowing that this was happening from the top to bottom, yet seeing no progress to fix the problem, aggravated most adviser teams.

The sense of a lack of progress was not limited to the Iraqi pay system. A common complaint among advisers was that the Iraqis were slow to adopt changes suggested, or even demanded, by their American advisers. This frustrated advisers extremely, since they would be forced to repeat the same information time after time over the course of the entire deployment. This was true even if the consequences of not implementing change resulted in catastrophic failure. For example, all American soldiers understand the concept and basis for trigger discipline – not putting the finger on the trigger until actually preparing to shoot. Many Iraqi units did not fully comprehend this concept, resulting in unnecessary deaths of Iraqi soldiers due to negligent discharges of weapons. This is certainly one area in which advanced human factors and ergonomics can well provide needed help (and see Hancock et al., 2006). This concept of being frustrated at the rate of progress of indigenous forces is not unique to the Iraq conflict. Lieutenant Colonel John L. Cook (1987), once an adviser to the South Vietnamese Army of the Republic of Vietnam (ARVN), states:

> For years the army had subjected him [the advisor] to an unbending philosophy of ‘do it now,’ and ‘do something, even if it’s wrong.’ As a result of his training and his experience in the army, the advisor often tried to push the Vietnamese too far too fast – in the same manner he has pushed an infantry company, if he’d ever had one – thinking that the war could be won during his relatively short tour in the combat zone. Often the unsuccessful advisor failed to understand why the Vietnamese did not feel as he did, unable to realize that long after he had returned to the safety and comfort of the United States, they would still be fighting their enemy, just as they had for the past twenty years.

Similar to his Vietnam-era predecessors, the adviser to the Iraqis found that: “this inability turned to frustration, and the frustration deteriorated into distrust and hatred for the very people he had been sent to advise” (Cook, 1987). Although not true of all adviser teams, many individual advisers took on negative attitudes about their Iraqi counterparts and the mission as a whole. This often manifested itself after six to eight months of being in the advisory role.

Another cultural difference that is a source of friction for the adviser teams was the priority for equipment within the Iraqi chain of command. To the Iraqi officers, having a particular asset, such as a vehicle, furniture, office/living space, or even a weapon, is a sign of prestige. Thus, the advisers constantly noted that an officer in the chain of command would often take vehicles and weapons that were meant for squads that were conducting missions. Worse, due to the importance of friendship and social ties to the Iraqis, many such assets were transferred from one Iraqi officer to another in a totally different unit. Although these redistributions of assets did not directly affect the adviser, it was a source of stress to the Iraqi counterparts that was felt at some level by the adviser who was powerless to stop it.
Surprisingly, one of the greatest stressors to the adviser teams did not come from the Iraqis they were training or even the enemy. It came from the American side. As a result of being called upon to do missions that most individuals had no prior experience of, the adviser chain of command learned as it operated. This lack of understanding translated into policies and actions that made little sense to those advisers at the lowest levels. This was exacerbated by the presence of two distinct chains of command: the Iraqi and the American. In several instances, the senior American adviser thought of himself as the commander of the Iraqis and the advisers. Thus, he would order his American advisers to ensure that the subordinate Iraqi units conducted a mission. This same senior advisor might have trouble in convincing his senior Iraqi counterpart to order his Iraqi subordinates to conduct the mission. This left the subordinate advisers with a mission that their Iraqis knew nothing about. Whether or not the mission was conducted often depended on the personality and agreeableness of the Iraqi chain of command.

In addition, the adviser teams were not adequately supported logistically due to the organizational structure set up by higher headquarters. This was the greatest single stressor for the advisers in Iraq. The concept was very simple: each adviser group was to be supported by the nearest US unit. But often this did not reflect reality. Due to the nature of the theater of conflict, the support structure was not firmly established, especially during the first six to eight months of the deployment. The
active duty units tasked with supporting the adviser teams were unaware of the task! Once made aware, the logisticians had to learn how to support these small teams that were not technically attached to their unit. This was especially true while the adviser teams were overseeing the Iraqi basic training, as the Iraqis had not been assigned an area of operations controlled by an American unit. Not being assigned to an area controlled by an American unit meant that there was no one responsible to support the adviser teams. This lack of support ranged from a lack of ammunition, food, and maintenance parts. This caused a great deal of stress to the advisers, especially since they knew exactly where and who the nearest American unit was but could not elicit response from it.

A related stressor included access to adequate mess facilities. Some adviser teams were located on base-camps that had Coalition and Iraqi components. These adviser teams were able to eat in mess facilities run by American contractors, or at least overseen by Americans. Other advisers were not so lucky. Almost an entire Iraqi division and their American advisers operated out of a base with no American forces. Consequently, the food facilities did not accord with American standards (this facility in question was later shut down by American health inspectors). This added to the stress of the advisers, and their Iraqi counterparts. As a result, the advisers would ask for food parcels from their families, thus causing stress on home families in both an emotional sense (“Why isn’t my loved one being fed properly?”) and in a financial sense (sending packages to Iraq can become quite costly).

Another stressor, already alluded to, was the presence of multiple chains of command. Advisers have their own internal chain of command: battalion adviser, brigade adviser, division adviser. The Iraqis have a parallel chain of command. Once assigned to an area of operations, the advisers and the Iraqis have to report to the Coalition chain of command. As the Coalition chain of command, usually an American combat team, did not interface with Iraqis on a day-to-day basis, they did not understand the difficulties in arraying and deploying Iraqi combat troops. As a result, the American advisers were caught in the middle, attempting to accomplish the mission assigned by the Coalition headquarters while still training and mentoring their Iraqi counterparts, who could not yet perform at the expected level. Many of the problems discussed above have been addressed and many rectified as the theater has matured and stronger support channels have been established. However, most of the stressors associated with training indigenous forces remain. Language, culture and other associated differences often make working with other militaries a very stressful and extremely hazardous challenge.

**Environmental Stressors**

If being shot at in combat is not stress enough, many of the present conflict locations bring their own unique, environmental issues. This has been documented on many occasions throughout history, including the Second World War. The Army Research Branch’s psychological report, *The American Soldier: Combat and Its Aftermath, Volume II* also noted that the environmental stressors took its toll on soldiers, particularly combat soldiers (see Stouffer et al., 1949: 76–95). Iraq is no exception. For example, the summer time heat in Iraq usually exceeded 100º Fahrenheit. Soldiers wearing full body armor, knee and elbow pads and enclosed inside armored vehicles quickly dehydrate if fluids are not forced upon them. Heat stress and dehydration obviously present a strong physiological challenge but even sub-clinical changes in core body temperature can have strong deleterious effects upon perceptual and decision-making capacities (and see Hancock and Hoffman, 1997; Hancock and Vasmatzidis, 1999). The air conditioning of combat vehicles has become an operational necessity. It is virtually impossible to remain combat effective in a vehicle that is completely enclosed when temperatures exceed 80 °F, much less 100 °F. Temperatures seldom drop below 80 °F degrees in the summer, even at night. In Iraq, the sand and dust is like a
fine talcum powder and finds its way into food, electronic devices, and anywhere that you do not want it.

The heat and intense sun in Iraq make simple everyday tasks arduous. A soldier must always be protected from the sun’s harmful ultraviolet rays as sunburn has obvious debilitating effects. While the majority of a soldier’s skin is covered by the uniform and other protective gear, parts of the face still require protection, i.e. the nose, cheeks, etc. Protective eyewear, usually part of the uniform in most commands, requires a darkened lens in the middle of the day to see through the glare and bright light. The ballistic lens in issued eyewear provides excellent protection from flying debris, however, this configuration allows little air to pass between the skin around the eye socket, meaning that sweat can pool and occlude the lens and make the area around the eyes uncomfortable. Cultural sensitivity in certain regions means that the soldier is required to remove their darkened eyewear during conversation. This light/dark transition can itself induce a temporary visual degradation, which can be deleterious to some mission objectives.

The soldiers’ clothing is likely to stay wet most of the day due to excessive sweating. While this is tolerable during the day, this uniform becomes very uncomfortable when the evening temperatures dip and the lowered temperature causes the soldier to become uncomfortably cold. The simple task of carrying notepaper or index cards becomes impossible unless they are covered in plastic. Paper products become useless as the sweat penetrates pockets in which they are carried. Plastic coating or plastic bags are one remedy, but it creates a barrier between the body and the clothing that does not allow the transfer of air through the clothing, thus lengthening the drying process. Sweat also plagues soldiers as gloves, boots, socks and helmet liner all become saturated. Sweat from the face is a constant source of irritation to the eyes and causes an ungloved hand to become slippery, especially against smooth metal surfaces, like weapons and tracked vehicles. Skin lesions seldom have the opportunity to dry completely and often heal at a much slower rate than normal. The amount of clothing needed early in the morning changes as the sun comes up. While this might seem trivial, the time to shed clothing is not always available due to mission requirements, and excessive sweating usually occurs before the removal of excess clothing is permitted.

The soldier’s normal uniform is not enough protection from kinetic insult (more simply bullets and shrapnel), therefore an outer protection is also worn. The new Interceptor Body Armor (IBA) system consists of an Outer Tactical Vest (OTV) with a yoke and collar assembly, throat and groin protectors, and two ballistic plates called Small Arms Protective Inserts (SAPI) that fit into pockets on the front and back of the OTV. The use of improvised explosive devices (IED) during the recent conflicts has resulted in the need for more protection in the side or deltoid (shoulder/upper arm) and Axillary (armpit/under arm) protection. The Deltoid and Axillary Protector (DAP), was later added and consists of two interchangeable modular components, the deltoid (upper arm) Protector and the Axillary (under arm) Protector. The deltoid Protector attaches at the shoulder of the OTV and is secured around the wearer’s arm with a strap. The Axillary Protector is worn under the OTV and is attached to the underside of the shoulder portion of the OTV and to the interior adjustment strap on the lower side of the OTV. While the IBA is absolutely essential in the protection of the individual soldier, it is heavy (21.7 lbs for a medium size) and reduces airflow to the body, thus the uniform underneath stays drenched from sweat.

The amount of water that the soldier consumes during such periods of extreme heat exposure is substantially greater than normal consumption rates. Standard heat/work indices put almost everyday in Iraq into the highest heat category, advising three times the manpower to perform even the most routine task. Of course, this is not possible. A soldier on a routine foot patrol would need to carry a minimum of 2 quarts of water at 2.1 lbs a quart. The soldiers’ load quickly becomes an issue (IBA, water, weapon, ammunition, communication gear, batteries, special equipment, etc.) while these challenges are not new, they continue to plague the foot soldier more today than ever.
before. Lastly, getting a soldier to carry the water is only half the battle for leaders as soldiers still have to be reminded to drink. Cooler water seems to be more appealing than water that is the same temperature of the surroundings. This adds another logistical challenge as potable ice is not readily available in austere conditions and the storage of ice is even more limited. Drinking water is often times heavily chlorinated to ensure that it is potable, resulting in a pungent taste. Beverage powders have been issued as an alternative to drinking the water straight but do not serve as an alternative to drinking plain water. Soldiers in extreme climates could possibly require more sleep but definitely need quality sleep over time. However, quality sleep is hard to obtain. Evening temperatures often never get lower than 80 °F and sleeping in the day (as a soldier on reverse cycle is required to do) is almost impossible if mechanical cooling means are not available.

One of the number one antagonists of electronics and their portable power sources is heat. Battery life is significantly shortened when the cells are exposed to heat or cold extremes. The ambient temperature of a weapon left in the exposed sun can quickly exceed 120 °F which makes it inaccessible to the ungloved hand. Armored HUMMWVs, tracked vehicles and even SUVs can not be closed up without some sort of air flow to the soldiers inside. In Iraq, the temperatures inside armor-kitted HMMWVs have been reported to reach 150 °F. Soldiers were forced to open windows resulting in them being either injured or killed by grenades, small arms fire, and shrapnel entering through open windows. The Army has contracted for Red Dot air conditioners, which are capable of lowering the temperature inside the HMMWV cab by as much as 40 °F, making a huge difference in the soldier being able to perform his duties while remaining under the protection of the armor.

Computer screens and other displays have to have sufficient contrast and luminance adjustments to make them readable under extreme light conditions. All electronic equipment has to be constantly maintained to remove dust and survey any damage done by excess heat. Vehicle batteries, filters, and fluids all have to be constantly maintained to ensure they are performing in the grueling conditions. Special equipment like vapor tracers and metal detectors all are susceptible to the heat. Concessions must be made to make extra batteries available and equipment rest periods part of the mission planning. Military working and specially trained dogs are an integral part of the missions performed daily. The dogs require more rest and water than normal and the dogs’ duty day must be adjusted even more than the soldiers, as a panting dog (a dog’s perspiration mechanism) is less effective in detecting prescribed scents. The dogs already prescribed uniform of a fur coat is often times also covered in an OTV specially made for canines. Additionally, a dog’s pad (foot) can easily be burned by hot black asphalt, requiring a mat or special shade requirement for where the dog must tread.

The extreme heat causes other forms of environmental interference. Dry soil and sand are flying through the air leaving at a minimum a powdery coat of dust on even the most protected equipment. The heat is especially troublesome when there are large civilian gatherings. Crowd control and care become harder as the heat increases the needs of the groups logistically and heat elevates the temper of the crowds (Bell and Baron, 1976). A peaceful gathering can turn violent if the heat sways the temper of the crowd. Tropical climates cause the need for water, both for consumption and irrigation to increase, putting stress on utility infrastructure, which is usually lacking after conflict. During the summer season, natural lakes and ponds tend to dry up, leaving these usually abundant sources void of water, causing a migration to the cities, and further exacerbating the problem. There are many tactics, techniques and procedures that are allowing soldiers to successfully mitigate the heat and its debilitating effects. The following represent some such techniques and recent innovations:
Red Dot air-conditioners have been installed in the majority of up-armored vehicles and continued ways of making all types of vehicles more tolerable in the heat are being explored. Often soldiers at remote sites are able to rotate through the vehicle allowing them to lower their body temperature during a break and extend their overall ability to maintain vigilance and hydration during a “shift”.

- Clothing, especially undergarments are being issued that “wick away” water and moisture and allow air to travel between the skin and the clothing. This not only helps in the evaporation process making the soldier cooler, it also helps the soldier stay more comfortable as the sun sets and the temperature becomes uncomfortably cool.
- Protective eyewear has been issued that is both ballistically protective as well as protective against ultra violet rays. Brands like Wiley X™ are providing eye-saving protection and have simple additives like anti-fog and securing lanyards.
- Hydration systems like the Camelbak™ are providing a superior drinking platform that provides a good volume of insulated storage and the hands free ability to consume water is popular among soldiers.
- Shade systems of all sorts are being erected in areas where a static defense might be located or continued presence is dictated. Even the smallest amount of shade lowers the temperature tremendously and provides cover from the direct exposure to the sun making equipment handling easier and protecting the skin.

Additional Battlefield Stressors

The specific environments that the military operate in create conditions that make normal routine dampening of everyday vibration almost impossible. For example, paved roads are often not available to military vehicles as they typically move over uneven terrain, or stay off the “beaten path” so as not to interfere with civilian movements. Tracked vehicles are substantially heavier than most normal road vehicles and cause extensive damage on poorly constructed roads as well as rutting on dirt roads, especially in damp conditions. When ruts are formed in muddy roadways and then dried in the sun, the resulting “washboard” like road surface would destroy most civilian vehicle’s shock-absorbers, struts, and allied suspension systems. Since the military must be able to operate in such harsh environmental conditions continuously, even the wheeled vehicles that the military use are required to have heavy duty springs, shocks and suspensions systems. This is a trade-off however, as the dampening systems do not remove the type of WBV that a normal civilian would do. Thus, a paradox exists, in that the vehicles are routinely operated in an environment that is laden with vibration-inducing, and yet the nature of the suspension does not dampen these effects. Such WBV has significant deleterious effects upon operator performance (Conway, Szalma and Hancock, 2007).

Military vehicles are not built primarily for comfort as their seat padding exemplifies. Most military vehicles are equipped with radios and many now have some sort of hardened display and/or land navigation screen mounted so that the vehicle commander can access the screen. These screens are almost impossible to read during periods of WBV and usually require the driver to stop to enable reading or precision data entry. Some of the more basic map reading skills (i.e., when not much information is required) can be performed as long as manipulation of the screen, extensive reading and/or data entry is not required. Many of the weapon systems that the military use produce large amounts of recoil upon firing and the effect on WBV is substantial. Vibrations created by the firing of a round from a tank or howitzer often creates momentary disorientation and requires postural adjustments as the soldier is physically jostled. Targets often have to be re-acquired and
engagement decisions reestablished. There are also effects associated with WBV in relation to smaller caliber weapons as we discuss below.

Certain combinations of WBV factors are more disruptive than others. For example, in most cases the higher the intensity of vibration the more disruptive it is to tasks such as display reading. Writing is also difficult when extensive WBV occurs, resulting in many personnel actually writing notes on the forward windscreen with an alcohol pen whilst steadying themselves with their non-writing hand. Sometimes this bracing is achieved with an elbow if the non-writing hand is being used to hold a radio handset. Extensive WBV can make even the simplest task extremely difficult. The WBV that is present when a vehicle is in motion requires the gunner to pay special attention. If the weapon is mounted to the vehicle, the body is usually tightly pushed into the weapon contact points (butt stock assembly), so the body is stabilized by the weapon’s platform. When WBV is transferred from the vehicle (even during vehicle idling there is low intensity/high frequency WBV), the gunner’s body absorbs most of it. The vibrations are conducted through the vehicle frame to the mechanical assembly holding the weapon, and into the weapon itself. Attaching the weapons to the vehicle frame helps the gunner keep control during high intensity vibrations. However, most of the assembly mounts that hold weapons have physical limitations as far as deflection and elevation. While these limitations are not a problem at the usual engagement ranges, the close nature of combat in urban environments make traditional mounts sometimes inadequate. These limitations result in the manual carrying of an individual weapon in certain tactical situations. This configuration makes the physical dampening of WBV effects particularly difficult and in some situations virtually impossible.

Many of the weapons and sensors that are mounted on top of vehicles provide a great deal of magnification. Simple geometry shows that much of the WBV are magnified as the sight moves with the viewer due to WBV. Inside track vehicles many of the viewing sensors have built in gyroscopic stabilizers. These systems are not usually found in wheeled vehicles and are not available in binoculars and weapon sights/systems that most of the soldiers have available for use. While these stabilizers help in target acquisition and identification by stabilizing the far scene, the gunner is still plagued by WBV effects transmitted from the vehicle. Usually a gunner physically pushes his body (brow or even the eye socket) into the sight that he is using (most sights have some sort of brow pad to cushion the part of the face that touches the sight). The gunner is required to force his body into the sight aperture so that the WBV resulting from the vehicle’s movement or the recoil created by the firing does not cause the gunner to lose his sight picture. While pressed into the sight aperture, similar to the butt stock weld discussed above, much of the WBV conducted from the vehicle’s frame is transferred to the sight aperture mechanism and into the head of the gunner. Often the WBV being transferred into the head of the gunner are at a minimum uncomfortable and along with all of the other stressors like heat and visual fatigue, they each challenge the gunner’s vigilance and readiness to respond. As a result, gunners often exhibit symptoms ranging from severe headaches to extreme fatigue.

One of the many antagonists of electronics and their delicate parts is vibration. Many systems require huge dampening devices to prevent the vibration shock from destroying them. Radio and computer mounts use rubberized spring-like mechanisms at the mounting points to dampen the vibrations at the mounting point. Equipment is either securely mounted or tied down to prevent shifting and movement resulting from the vibration. The technological move from transistors and solenoids to solid state circuits has greatly reduced the mechanical failures related to vibrations, but most of the off-the-shelf products require some degree of hardening or at least some type of protective outer shell or case to protect them from the extremes noted. The soldier’s normal uniform is not enough protection from kinetic rounds, therefore an outer protection is also worn, called the Interceptor Body Armor (IBA). While the IBA is absolutely essential in the protection
of the individual soldier, it is heavy (21.7 lbs for a medium size) and bulky. Soldiers often wear knee pads and elbow pads as part of their protective ensemble. These provide some degree of protection from WBV as the joints are often the point of contact for the conduction of vibration from the source to the individual. However, the protective gear is physically hardened with either Kevlar™ or hard plastic making it subject to further conduct vibrations as well. There are existing and emerging tactics, techniques and procedures that are allowing soldiers to successfully mitigate debilitating WBV effects. These include:

- The gyroscopic stabilized sights that are available on many of the sophisticated weapons are absolutely essential in dampening the effects of high intensity WBV on viewing targets. Work must still be done to improve the relationship between the gunner’s eye and the aperture of the sight and many of the displays and remote displays of some systems are being to address these challenges.
- Foam padding on metal floors of vehicles has greatly reduced the transmission of WBV to the feet of the soldier standing in them and the transmission of rattles and high pitches created when metal objects strike other metal objects due to excessive WBV.
- Laser emitters on individual weapon sights (red dot sights, PEQ-4s, and so on) are eliminating or reducing the need for a tight cheek to stock weld that allow the conduction of WBV from the weapon to the individual and vice versa. These sights are greatly enabling the soldier to get good sight pictures while in non-standard positions (like bracing due to intense WBV).
- Because of the rubber mounting shocks that many of the displays have to be mounted on for protection, the movement of these displays due to WBV makes them unreadable. While not readily used in the field, advances have been made in the stabilization of screens and displays and advances in this area are being well received.
- The use of quality knee and elbow pads has lessened the effects of some types of WBV on the joints. However, the WBV is still present and could be still causing performance decrements that are not as readily sensed.

Stressors from Combat Operations

Soldiers serving in Iraq are stressed by many of the same things that have plagued military personnel throughout time. Attacks are quite frequent, and in the present conflicts this means incoming mortar rounds. Snipers and small ambushes act as skirmishers, then run before decisive engagement is feasible. Improvised Explosive Devices (IED) are presently the number one killer of American soldiers in Iraq. Suicide bombers and vehicle-borne explosives also produce mass casualties. The fear associated with each of these situations can be intense and does not differ much from the fear from the similar dangers of sudden death and injury associated with previous conflicts across recorded history. As a number of Vietnam veterans who have served in Iraq (usually as members of the reserve component) have related, the stress of Iraq is very much the same as the stress of Vietnam.

Is there a difference between Iraq’s stressors and the stressors of other conflicts? One difference may not be in the tactics employed by the enemy, but in the retaliation. In prior conflicts, American soldiers were often able to return fire and “get pay back” or “vent” at least in the direction of the enemy. Thus, much anger and vengeful emotions could be released. In Iraq, this is frequently not the case. If a convoy is hit by an IED, most times the insurgent conducting the attack is able to escape undetected. Similarly, suicide bombers kill and maim many victims, yet their death leaves no one at which to return fire. This build-up of intense emotion without adequate release potentially leads to a great deal of conflict-induced stress and can leave some soldiers looking for a fight. This
is especially true in individuals with jobs that do not routinely put them in a position to attack the enemy. For example, a transportation soldier, whose job it is to run supplies and equipment from one end of Iraq to another, may be part of convoys hit by many IEDs. However, as a transportation soldier, he/she will probably never partake in an assault against insurgent strongholds. This individual may never have the chance to directly engage the enemy that may have killed many friends. The stress and psychological consequences of this remain to be determined.

Many World War II veterans speak of destroying possible enemy positions before they were given a chance to engage US forces. Massive artillery preparatory salvos usually preceded a well-planned assault. Taking such preventive measures is often not possible in Iraq, especially in built-up, urban areas and densely populated terrain. Anticipating and expecting to be hit provides an enormous source of stress to the soldier. Over time, this becomes a psychological fatigue that is accompanied by the physical fatigue associated with wearing 50+ pounds in 110+ degree heat in an arid environment. Thus, the physical stressors only intensify the psychological stressors. As noted in the first chapter of this text by Hancock and Szalma, the problem of stressor interactions is a crucial one, but one that has yet to receive even cursory attention.

The Casualties of War

In many of the conflicts currently facing the United States and its allies, the enemy does not place the same amount of effort in reducing collateral damage as does the Coalition Forces. Coalition Forces often place themselves at greater risk in an effort to protect non-combatants and to ensure that many of the tactics and procedures that the old regimes followed are not being repeated by the new fledgling governments. The ground placed IED and the vehicle borne IED detonate most often as area weapons, killing and maiming innocent bystanders. Soldiers left to deal with the victims of the destruction have to deal with the aftermath and with limited resources as their guard can never be dropped. The enemy can strike again in an effort to affect first responders and create more destruction and confusion. The enemy’s lack of sophisticated weaponry has also led to the launching of extremely inaccurate mortar and rocket fire. These inaccurate fires from makeshift launchers add to the overall stress of the environment as a lucky shot from an enemy indirect fire system brings even the relative safety of the FOB debatable.

These inequities of action create a frustration that pile onto the already-existing mountain of combat stressors. Differences in FOBs (some are quite nice while others are lacking basic amenities), who leaves the safety of FOB regularly and who does not, all become sources of comparison creating friction among soldiers. These comparisons are also communicated to the families back home as some lucky soldiers might have better access to the Internet and communicate more often than other soldiers who are on some remote FOB and do not have the same level of connectivity. These inequities have always been a source of frustration in every war, however, such inequities have not always been as visible as they are to soldiers and their families today. Soldiers compare everything from sleeping arrangements, dining facilities, to Internet access, and any shortfall is noted and resented.

In the efforts to address these and like issues, technology has been a double-edged sword. Effectively applied human-centric technology has been and will continue to be invaluable. Implements of war like ceramic body armor and armored vehicles have saved countless lives. However, the precarious balances between comfort, efficiency, and survivability versus lethality or even perceived lethality has to be constantly assessed. American soldiers will give up survivability to remain lethal and preserve the ability to achieve assigned missions. Soldiers have to be ordered to wear earplugs to protect their hearing because of the difficulty the attenuation causes in their ability to hear radio traffic, civilian conversation and their immediate surroundings. Soldiers must
be ordered to stay down inside their vehicles (even in the absence of manning their vehicle mounted weapons) in order to stay safe from the effects of seldom detected IED blasts.

Soldiers often “battle the new technology.” When new systems are developed, the old systems are not always able to be integrated. Difference in connectivity, equipment types by units, operator training, etc. all create conditions where soldiers are often required to perform operations such as data entry, twice. These troublesome technology fledglings are often dubbed “swivel seat operations” as a soldier is forced to enter the same or related information into two separate technology platforms. While this is somewhat expected across services, this often occurs because of the differences between headquarters at all levels of the chain of command. The tactical operations center at any level versus the tactical operating units or the proverbial “point of the spear” are in constant aggravation of one another as each struggles to “help” versus hinder the other’s progress and information requirements. Again, the centrality of human factors and ergonomic requirements are emphasized by these everyday issues of usability and integration.

Stressors from the Home Front

American soldiers throughout history have had to deal with separation from family members and the American way of life. This represents a large factor in the stress felt by soldiers abroad. Young soldiers are often separated from their parents for the first time. Meanwhile, older soldiers are separated from newborns, young children, and spouses. Knowing that their families are worried about their safety places extreme stress on soldiers in various ways. While in a combat environment, soldiers routinely perform hazardous jobs. Clinicians testify to the importance of talking about this stressful period of time. Who better to tell than family? This is the initial impulse of each soldier. Before confiding in their loved ones, however, soldiers make a choice. “Do I tell the family this, or not?” “Will he or she understand, or possibly worry about me, if I tell him/her this?” These are the questions that go through the soldier’s mind. Not wanting to burden the family with actual knowledge of the dangers faced, soldiers will often remain silent about their conduct. This adds to the feelings of being “different”, which only intensifies upon redeployment to home station, where most of the population cannot relate to the experiences of the returning soldier.

In addition to financial problems that inevitably arise during the course of a year-long stay, soldiers also worry about the physical well-being of their family. Some soldiers have parents or spouses that are battling cancer or other terminal illnesses. Although some are sent home early to deal with these situations, not all are given this opportunity. A prime example of soldiers being concerned about their families’ safety stems from Hurricane Katrina. This storm hit the Gulf Coast while several National Guard and Reserves units from these afflicted states were serving in Iraq. Although some soldiers were allowed to return home, not all were able to. For those not allowed to return home, an inordinate amount of stress followed, as they had little to no contact with their families during this period (most local communication assets being destroyed by the storm).

Another stressor that is often joked about in the military, but is of real importance, is marital infidelity. Soldiers depart for a year or more. Many of these soldiers are informed by friends or other family members of the activities of spouses and significant others. Even for those who have little doubt as to the faithfulness of their spouses, the thought does enter their minds from time to time. A confirmation bias may also ensue if the soldier becomes suspicious for whatever reason. That is, the soldier may start to interpret phone conversations, e-mails, and letters in a different light once suspicion is aroused. This may in turn cause them to treat the spouse, who may have no thoughts of infidelity, in a more hostile or aggressive manner. This may lead to unnecessary strife between individuals already strained by separation and anxiety.
During deployment, soldiers will face stress from home many different reasons, some of which are described above. Redeployment back to the home also adds stress to the soldier. “Will my young toddler recognize me?” “Has my spouse gotten used to being without me?” “Have I changed?” These are all common concerns to the redeploying soldier. If wounded, the soldier has even more obvious concerns about re-integration with the family (and employment if in the reserve component). This stress can be addressed by proper planning and with adequate time, however. Planning on a period of adjustment for all parties concerned, with a high degree of communication, is often sufficient to alleviate much of the stress resulting from redeployment. As a result of the dynamic nature of the battlefield, soldiers only receive estimates of when they will redeploy. When 1st Armored Division conducted their relief in place and transfer of authority with 1st Cavalry Division, the decision was made to extend them and move them into a different area of operation. This actually required some of the soldiers that had already moved back to home station in the deployment sequence to return to theater within days of arriving home. While families are notified that soldiers are scheduled to return, they are constantly reminded that dates are never definitive.

The Resilience of Soldiers

Through all of the aforementioned stressors, soldiers not only persevere, they often excel. Soldiers on the streets of Afghanistan and Iraq are ambassadors of good will. They enable schools to be refurbished and rebuilt. They reclaim neighborhoods and provide the conditions for neighborhood councils and infrastructure regeneration. Soldiers set the conditions for free elections to occur and for people to enjoy freedoms never previously experienced. They work long days with no vacation and complaining often seems more of a pastime than the airing of actual heartfelt grievances. While usually busy and desiring rest when not, soldiers are afforded many opportunities to seek normalcy. Weight rooms and exercise areas are one of the first “extras” established by most military units. Morale, welfare and recreation activities such as visits from the celebrities and satellite television areas are always big hits with the soldiers and allow a great chance for them to leave their worries behind for a couple of hours. Video movie rentals, music and mail voluntarily consume most soldier’s free time. Many soldiers are afforded the opportunity to take college courses on-line when time permits.

Soldiers put pictures from home, artwork from children and anything else that reminds them of home around their work or resting place. Pictures of loved ones in their helmet, one foot patches of grass nurtured outside their tents, or videos of a child’s first step are some of the glimpses of normalcy and reminders of better times and places. The stories of heroism and fantastic soldier deeds are endless. Most go unpublishized and those that are reported are soon forgotten. News media revel in shocking, disturbing, and upsetting stories that prove ratings winners. They rarely give equal time to positive and inspiring stories from the area of conflict, the latter appear to have relatively little appeal. However, generative actions like the school supplies and clothing drives initiated and executed by soldiers will affect generations to come. One story of particular note is of a Mississippi National Guard soldier who worked in a prosthetic clinic as a civilian. After performing his unit duties as a military policeman in Baghdad, he would spend his free time building a prosthetic clinic for Iraqi civilians. His workplace back in Mississippi sent supplies and he recruited other volunteers to help. When he left Baghdad, over eighty prosthetics had been fitted and he left a working clinic set up in the Iraqi Convention Center.

Every soldier may reach their breaking point at some time. Tears are shed alone, over the phone or in the comfort of others, perhaps during a memorial ceremony. Every soldier expresses his or her dealings with stress in their own individual manner. The Army goes to great lengths to identify those soldiers who are having problems dealing with the excessive, conflict-related
stresses. Every soldier deployed to a combat theater is required to complete a Post-Deployment Health Reassessment (PDHRA). The assessments are conducted immediately upon return to home station and then after 6 months elapse from return. The assessments look for symptoms from conditions like Post Traumatic Stress Disorder and similar ailments. These PDHRAs are just one indicator of how the Army has identified the importance of helping soldiers deal with stress in the post-deployment phase.

There is no greater acute source of stress than the threat of sudden death or injury. Thus, operation in conflict-laden areas is always a high-stress enterprise. Soldiers must deal with these issues and many adverse local conditions that attend each of the specific environments of the many regions of deployment to which the soldier is directed. These proximal sources of stress are augmented by concerns generated at distal (home-base) areas where the soldier’s absence is felt by family, friends, and colleagues. A nation at war pays a high price not simply in terms of its financial status but in damage to its human capital. The fact that so many young men and women are able to tolerate and even function effectively in such adverse conditions is a testament to their resilience and their professionalism. But we cannot push this capacity beyond the “inflexion point of failure” (and see Hancock and Warm, 1989). In the same way that each individual has their breaking point, so each organization can, if stretched too far, fail in the same manner. Although we will then be tempted to blame individuals for such catastrophic breakdown, it will in reality be a social failure. It will be wise not to stress our military forces to this point.

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