Chapter 16

Upper Extremity Intervention in Cerebral Palsy: A Neurodevelopmental Approach

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CHAPTER OUTLINE

CEREBRAL PALSY
THE NEURODEVELOPMENTAL TREATMENT APPROACH AND PEDIATRIC THERAPY
ROLE OF PERFORMANCE COMPONENTS ON OCCUPATIONAL PERFORMANCE
THE RELATIONSHIP OF POSTURE TO UPPER EXTREMITY FUNCTION
Postural Control in Typically Developing Children
Postural Control and Anticipatory Control in Children with Cerebral Palsy
SENSATION AND ANTICIPATORY CONTROL IN HAND FUNCTION
KINESIOLOGIC ASPECTS OF TRUNK AND ARM FUNCTION
Typical Trunk and Upper Limb Interactions
Base of Support and Upper Limb Function
BIOMECHANICAL INTERACTIONS OF THE UPPER LIMB IN CEREBRAL PALSY
Contrasts between Hypotonia and Hypertonia
TREATMENT APPROACHES: CONCEPTS OF INHIBITION AND FACILITATION
Inhibitory Techniques
Facilitation Techniques
Combining Inhibition and Facilitation

THE ASSESSMENT PROCESS
Physical Status of the Individual
TREATMENT PLANNING
THE INTERVENTION PROCESS
Neurodevelopmental Treatment and Hand Function
Efficacy of Neurodevelopmental Treatment
SUMMARY
CASE STUDY ONE: A CHILD WITH CEREBRAL PALSY
CASE STUDY TWO: A CHILD WITH LOW TONE

Therapists who treat children with developmental delays, movement disorders, and tone abnormalities such as those seen in cerebral palsy (CP) face significant challenges in their efforts to provide efficacious interventions. Muscle tone and spasticity are impairments seen in CP resulting from central nervous system (CNS) damage that cannot be permanently changed by means other than medication and surgery. However, therapists can maintain and improve performance in children with CP through their interventions and the use of assistive technology. Clinicians can influence client factors and modify environments that affect the manifestation of muscle tone, its power, and the degree to which it interferes with participation in occupation, thus adding to the potential for client participation. This chapter discusses the therapeutic management of children with CP, focusing on the use of neurodevelopmental treatment (NDT) as an intervention.
CEREBRAL PALSY

Cerebral palsy is a general term that describes a non-progressive group of posture and movement disorders diagnosed within the first 2 to 3 years of life (Koman, Smith, & Shilt, 2004). The apparent causes of CP come from a variety of sources, including maternal infection, prematurity, multiple births, hypoxia associated with birth trauma, and maternal bleeding from premature placental separation, to mention a few (Nelson & Grether, 1999). Although the insult to the CNS is believed to be static, impairments seen with CP include musculoskeletal concerns, muscle weakness, spasticity, vision problems, cognitive limitations, and seizures. Secondary conditions related to the various primary impairments continue to evolve across the life span and include muscle tightness and contracture, joint abnormalities such as dysplasia and dislocation, growth problems, pain, social isolation, and diminished ability to participate in the community through occupations such as education, work, and leisure. Evidence suggests that loss of function seen in typical aging is accelerated in CP, and that the secondary conditions associated with CP become more common and more severe with age (Andersson & Mattsson, 2001; Cathels & Reddihough, 1993; Murphy, Molnar, & Lankasky, 2000; Turk et al., 1997).

The incidence of CP over the last 20 years, currently estimated at 2 to 4 per 1000 children, appears to be increasing. This change may result from many factors, including improved documentation of the diagnosis in countries around the world, improved care of premature and sick infants, or other unknown factors (Nelson & Grether, 1999).

The movement disorders associated with CP include spasticity, dyskinesia or dystonia, hypotonia, and ataxia. Spasticity is the most frequently occurring disorder and a mixture of various movement disorders are common. The accepted distributions of movement impairment include hemiplegia, diplegia, and quadriplegia (Dabney, Lipton, & Miller, 1997).

Although improved care has resulted in typical life spans for persons with less significant involvement, those with severe quadriplegia and associated conditions may die earlier (Hutton & Pharoah, 2002; Strauss & Shavelle, 1998). Strauss, Cable, and Shavelle (1999) carried out an epidemiologic review of a large database targeting causes of death in CP. Their findings found elevated death rates from cancer and heart disease occurring at relatively young ages. Although this study awaits replication and support from clinical studies, the findings are provocative to say the least.

THE NEURODEVELOPMENTAL TREATMENT APPROACH AND PEDIATRIC THERAPY

The intervention approach discussed in this chapter is the neurodevelopmental treatment approach, or NDT, originally called the Bobath approach. This paradigm hypothesizes that abnormal tone and impairments of movement and posture result from lesions in the CNS and limit the development of function. Intervention is aimed at minimizing these impairments and improving functional outcomes as a result of problem-solving among the clinician, client, and family to develop new movement strategies and management of postural tone. The original approach was developed by Berta and Karel Bobath, a physiotherapist and physician, respectively, who evolved the paradigm between late 1940 and 1990. Currently the instructors who teach the technique and the national Neurodevelopmental Treatment Association (NDTA) continue to expand and update the treatment approach.

When Mrs. Bobath first began to practice as a physical therapist, therapeutic interventions for neuromuscular diagnoses were based on the stretching and strengthening regimens used with the impairments left after polio. Unhappy with the results of such treatments, Mrs. Bobath documented observations from her assessment and treatment of adults with paralysis after stroke and children with CP. Dr. Bobath supported her ideas with information from the neurophysiologic scientists of the day, including the hierarchic perspective of the CNS, the cephalad to caudal/proximal to distal nature of human development, and the concept that postural control evolved from primitive reflexes (Howle, 2004). The Bobaths’ early work focused on altering muscle tone and reflexes to enable the development of more normal movements and followed the normal developmental sequence in treatment. The importance of the postural reflex mechanism was highlighted and primitive reflexes were seen as a first step in the development of higher-level, skilled movements. The persistence of these reflexes in conditions such as CP originally was believed to block more skilled movement, hence the concept of reflex-inhibiting postures (RIPs), which were used to facilitate higher level movements (Bobath, 1955).

Over time, Mrs. Bobath’s approach changed as she documented her observations about the results of her treatment. Although the concept of reflex inhibition, even today, is seen by some as the substance of NDT, Mrs. Bobath actually discarded this focus by 1964, moving on to the idea of “handling” or moving the
child so as to generate active movement responses. The treatment approach continued to focus on development of movement skills based on the normal developmental sequence until the lack of carryover outside of individual sessions became apparent. The Bobaths (1984) then acknowledged the importance of linking treatment to the performance of functional tasks in other settings, thus underscoring the importance of motor learning on the part of the client.

Motor learning is defined as

“a set of processes associated with practice or experience leading to relatively permanent changes in the capability for producing skilled action.” (Shumway-Cook & Woollacutt, 2001, p. 27).

Shumway-Cook and Woollacutt distinguish between motor learning and performance, citing changes in motor performance as being temporary, whereas permanent changes in skilled action result from true motor learning. Clearly for children with CNS dysfunction to change their occupational performance outside of therapy intervention sessions, true motor learning must take place. Current NDT treatment recognizes the importance of motor learning to skilled performance, and the necessity of practicing client-designated activities in treatment for changes in performance to occur.

Although the Bobaths themselves did not incorporate motor performance into their theory, the Neurodevelopmental Treatment Association Theory Committee, consisting of multidisciplinary NDT instructors in the United States, began updating the theoretic paradigm in the early 1990s to incorporate current concepts with applicability to treatment of persons with neurologic deficits. It was at this time that theories such as dynamic systems theory and motor learning were formally integrated into the theoretic basis for the treatment approach (Howle, 2004). One of the challenges for clinicians is the constant need to keep their knowledge current with changes in knowledge generated by science, a challenge the NTDA has taken seriously, as evidenced by the work of the NDTA Theory Committee.

## ROLE OF PERFORMANCE COMPONENTS ON OCCUPATIONAL PERFORMANCE

Aspects of performance that therapists analyze when planning treatment for children with CP are components such as postural control, strength, muscle tone, spasticity, range of motion, and the performance of the activity or occupation designated as the goal of intervention. Current studies provide a much clearer picture of the role such impairments and movement disorders have on performance skills. For example, Gordon and Duff (1999b) studied the relationship between finger-tip force regulation in grasp, spasticity, stereognosis, two-point discrimination, manual dexterity, and perception of pressure sensitivity. Their work demonstrated a clear relationship among tactile perception, anticipatory control (activation of sensory and muscular systems for a specified activity based on prior learning and experience) (Shumway-Cook & Woollacutt, 2001) and task performance; however, it also suggested that the role of the other impairments in performance was dependent on the aspects of the activity being performed. They noted that spasticity appeared to affect the adjustment of grip to object weight and to the length of time between grasping and actually lifting an object, but it did not have a relationship to anticipatory control.

The NDT approach emphasizes the importance of postural control and anticipatory postural control, both performance skills in the Occupational Therapy Practice Framework (The American Occupational Therapy Association [AOTA], 2002), to the outcomes of therapy intervention, or areas of occupation. The next section of this chapter discusses postural control and its impact on upper limb function.

## THE RELATIONSHIP OF POSTURE TO UPPER EXTREMITY FUNCTION

One of the Bobaths’ contributions to management of neuromuscular conditions was their understanding that spasticity was not just an individual muscle phenomenon, but actually affected posture and control of upright position in space, a concept not previously acknowledged. The emphasis on the postural reflex mechanism as central to changes in other aspects of motor performance was a principal factor in the Bobath treatment approach, which underscored their belief in the hierarchic, maturational principles of motor development. The Bobaths believed that more distal skills (e.g., reach, the ability to stand) could not develop until postural control of head and trunk occurred, defined as the postural regulation of the body’s position in space for purposes of stability and orientation (Shumway-Cook & Woollacutt, 2001). Therapists trained in the NDT approach through the 1980s focused on altering postural tone passively, then on facilitating active control in the head and trunk and finally on development of control in the upper and lower limbs. At the present time, NDT theory
locates intervention for impairments such as postural control within the desired occupational performance outcome rather than as the primary treatment outcome.

**Postural Control in Typically Developing Children**

In typically developing children, postural control evolves from the development of antigravity movement, postural adjustment reactions, somatosensory input, and experience, and is defined as maintenance of body position in space (Nichols, 2001). *Postural sway*, a component of postural control defined as “the movement of the center of gravity within the base of support in any upright position” refers to the constant movement of the body when upright and occurs in a developmental sequence that matures around 13 years of age (Nichols, 2001, p. 275). Another aspect of posture, *anticipatory postural control*, defined as activation of sensory and muscular systems for a specified activity based on prior learning and experience, helps to provide efficient adjustments of the body to support use of the limbs for various activities (Shumway-Cook & Woollacott, 2001).

All motor activities require some degree of postural control, although those requirements vary depending on the activity and the environment in which it is performed. Bertenthal and Von Hofsten (1998) related postural control to hand function, specifying that postural control is a necessary requirement for the development of grasp and manipulation, and integration of vision into hand function.

This constellation of postural control components was not well delineated during the Bobaths’ time; however, the current premise that postural control and its elements are necessary for successful motor performance supports some of the Bobaths’ ideas about the interaction of the trunk and upper limbs. For example, Bertenthal and Von Hofsten (1998) discussed the importance of postural elements to both visual skill and upper limb performance in tasks such as reach and grasp, noting that

“...reaching for distal objects is necessarily a dynamic process demanding mutual and reciprocal processing of the relevant perceptions and actions” (p. 519).

Stapley, Pozzo, and Grishin (1998) studied the interaction of anticipatory postural control and reach in typical subjects. Their work suggested that the use of anticipatory postural adjustments plays a role in activation of upper limb movement from a fixed base of support before reach, as well as stabilizing the body during reach.

**Postural Control and Anticipatory Control in Children with Cerebral Palsy**

In contrast to typical children and adults, children with CP have difficulties with postural control and anticipatory postural adjustments, as evidenced in a number of studies. Liao and co-workers (2003) found significantly worse postural control in sitting as demonstrated on parameters of static and dynamic sway indices in children with spastic CP when compared with typically developing children. Roncesvalles, Woollacott, and Burtner (2002) found that children with CP did not demonstrate increased muscle response to changes in platform perturbations, although typical children did. They hypothesized this difference in ability to demonstrate recovery of balance resulted from insufficient contraction of agonist postural muscles.

Studies of anticipatory postural control demonstrate differences in children with CP as well. Van der Heide and co-workers (2004) found that children with CP after prematurity have difficulty adapting or grading postural adjustments to a variety of task-specific circumstances. Not unexpectedly, these difficulties were worse in children with diplegia or quadriplegia than in children with hemiplegia. A top-down sequence of activation of postural muscles, particularly in the neck extensors, was seen in their sample of children with CP, which varied from the muscle activation sequence seen in typical children. They noted that the gestational age of the child was related to postural adjustment problems; the shorter the gestation, the greater the impact on postural adjustment.

There are different theories about the interaction of postural control and sensation and the role of anticipatory postural control in upper limb function, including the Dynamic Systems Approach and Neuronal Group Selection Theory. Howle (2004) contrasted and compared some of these theories as they relate to NDT. Although these theories present different perspectives on the topic of postural control and upper limb function, there is no question these elements of performance are an important factor to be considered in movement intervention, regardless of the theoretic perspective.

**Sensation and Anticipatory Control in Hand Function**

The Bobaths saw movement and sensation as complex, interdependent aspects of human performance (Howle, 2004). They hypothesized that lack of movement
control affected the ability to perceive and process sensation. Although the sequencing of sensation and movement proposed by the Bobaths may be open to question, there is no argument that persons with CNS lesions do have sensory impairments that affect their motor performance. Problems with sensory perception and sensory processing affect performance in a number of ways, including inability to detect and identify incoming sensory information; difficulty interpreting single sensory or multisensory input; problems with modulation of sensory inputs to match changes in task and environmental demands; and inability to match sensory information with experience, memory and specific tasks (Eliasson, Gordon, & Forssberg, 1995; Gordon & Duff, 1999a; Gordon & Duff, 1999b; Lesny et al., 1993; Yekutiel, Jariwala, & Stretch, 1994). Impaired development of anticipatory control during hand function also results from impaired sensation. Eliasson and Gordon (2000) described anticipatory control in object manipulation as “internal representations or sensorimotor memories of the object gained during previous manipulatory experience” (p. 233).

Researchers have carried out extensive studies over recent years in an attempt to isolate the role of sensation in prehensile and release functions in typical adults and children (Forssberg et al., 1991; Kinoshita et al., 1992; Eliasson, Johansson, & Westling, 1992). This series of studies was followed by a body of research looking at issues of vision, tactile sensation, spasticity, and force generation in grasp and release. Comparisons of these parameters in grasp and release between children with CP and typical children also were performed (Duff & Gordon, 2003; Eliasson & Gordon, 2000; Eliasson et al., 2003; Gordon, Charles, & Duff, 1999; Gordon & Duff, 1999a; Gordon & Forssberg, 1995). This work has established that the grasp and release of children with CP is impaired by deficits in tactile perception and processing, difficulty with graded control resulting from balanced interactions between muscle agonists and antagonists, and temporal control of movement events (Eliasson & Gordon, 2000). Temporal issues were cited again in the work of Gordon and co-workers (2003), who found that release of objects that varied in weight required more time in children with CP than in typical children, especially when accuracy and speed were necessary.

This discussion underscores the notion that motor behaviors, sensory perception, and sensory processing are inextricably linked, and that experience and practice with various motor behaviors helps to build performance and anticipatory control in children with CP. This is true for all aspects of motor performance, including postural control, hand function, gait, and speech.

**KINESIOLOGIC ASPECTS OF TRUNK AND ARM FUNCTION**

The problems with postural control and upper limb function seen in children with CP affect all aspects of occupational performance. It is for this reason that evaluation of posture, postural adjustments, and their interactions with the upper limb particularly should be part of a therapeutic assessment, as well as the status of body structures.

**TYPICAL TRUNK AND UPPER LIMB INTERACTIONS**

The axial skeleton is the base upon which the limbs are supported and from which they operate. The alignment of the spine, pelvis, and ribs influences how both the upper and lower limbs rest in space and how their movements are used in the performance of various activities. Remember that many of the muscles controlling the upper and lower limbs are the spine, rib cage, and pelvis, and that the shoulder girdle moves over the rib cage. The anatomical connections between these musculoskeletal units are why mobility and stability of the entire trunk are so important to movement of the limbs (Neumann, 2002).

The pelvis provides support for the spine. Because the lumbar spine interacts specifically with the pelvis in virtually all movement sequences (e.g., forward flexion, extension, rotation, lateral flexion), motor or joint impairments in one or the other structure affect movements in both areas. Similarly, movements in any region of the spine result in movements within the entire spine, with the degree of the resulting motion decreasing distally from the originating movement. Therefore, disruption of motion in one region of the spine affects the entire spine, and by association, the position of the head in space (Neumann, 2002).

In children with CP, both structures and movements of the axial skeleton often are impaired, affecting both posture and limb function. Such limitations in the biomechanical interactions of the pelvis and spine are concerns for therapy intervention in the child with CP.

The shoulder girdle is comprised of the scapulae, clavicles, sternum, and glenohumeral joints. Just as with the spine and pelvis, dysfunction at any one joint of the complex affects movement at all of the other joints. The shoulder, elbow, and forearm place and sustain the wrist and hand in space for function.
Arranging hair on the back of the head, clipping toenails, bathing, and dressing are all examples of activities that require the hand to be moved to a distance away from the body. In typical movements, certain shoulder complex functions are aided by actions of the spine. For instance, rotation and flexion of the lumbar, thoracic, and cervical spine extends the range of reach for items high on a shelf or under a bed.

The rotary movements of the shoulder and forearm are particularly important to skilled dexterous movements within and between the hands, both at and away from midline. Removing post earrings, for example, requires the palms of the hands to be facing each other on one side of the body, an action that would not be easily performed without humeral and forearm rotation.

Finally, the complexity of wrist and hand movements is significant and remarkable for the highly complementary nature of the interactions among various structures. Consider playing the piano and the configuration of the wrist and fingers. During an octave stretch, the wrist may be flexed to provide additional range of movement in abduction and extension at the fingers. When a chord is played, the wrist is extended to provide power, stability, and control for the flexed fingers. Knowledge of these kinds of interactions assists the therapist to both understand and treat limitations in occupational performance that involve the hands.

Awareness of the complex structures in the hand is critical as well, including the carpal, metacarpal, phalangeal joints, and arches.

**Base of Support and Upper Limb Function**

Another biomechanical aspect of upper limb performance is the base of support generated for upper limb function, basically the foundation of the head, trunk, and limbs. Shumway-Cook and Woollacutt (2001) define base of support as

“the area of the object in contact with the support surface”

(p. 164).

A wide base of support, such as the feet widely separated in standing, provides stability for motor functions, whereas a narrow base of support in sitting and standing is more conducive to body mobility. One also needs to consider the nature of the supporting surface; some properties of various surfaces enhance contact with body structures, such as beanbag chairs. Age, the nature of the activity, and the environment are other factors that affect the base of support incorporated by the individual.

In movement disorders such as CP, base of support is affected by the movement disorder itself, structural issues such as hip dislocation, and elements related to the movement disorder such as limited postural control. Age, task constraints, and the physical environment mentioned previously should be considered when carrying out assessments of performance in which base of support is an issue. Interventions used to develop more skilled action in NDT are designed to take into consideration base of support and its impact on the individual’s ability to perform upper limb functions.

**BIOMECHANICAL INTERACTIONS OF THE UPPER LIMB IN CEREBRAL PALSY**

Depending on muscle tone and distribution of motor impairment in the individual with CP, there are commonly fluctuations in movement control that affect position of the spine and pelvis and postural adjustment responses (Liao et al., 2003; Van der Heide et al., 2004). These difficulties can be increased by tightness in the soft tissue structures of the lower limbs, such as the hamstrings and hip flexors (Reid, 1996). Such problems in the axial structures influence purposeful movements in the upper limbs of children with CP. Posterior tilt of the pelvis and flexion of the lumbar spine increase thoracic flexion and compromise actions in the shoulder girdle and shoulder.

As discussed, changes in any aspect of shoulder girdle function influence the entire shoulder girdle complex (Neumann, 2002). Scapulohumeral rhythm is commonly affected by increased thoracic flexion, causing the scapula to rotate upward sooner in the interaction of the two structures and sometimes limiting the range of overhead action. Movements in the frontal plane, such as humeral flexion and horizontal adduction, seem to be difficult for children with CP, resulting in the increased presence of humeral abduction and sometimes humeral extension. External rotation of the humerus is affected by both increased thoracic flexion and the resulting scapular abduction, which biomechanically aligns the humerus into an internally rotated posture. This configuration is most often seen in children with spasticity; those who have dyskinesia or dystonia may seek to control extraneous movement in their upper limbs by holding their upper limbs against their bodies in a practice called “fixing” or stabilizing the upper limb (Nichols, 2001). This practice volitionally can limit their humeral motions initially; however, if the practice persists, actual soft tissue limitations can occur.
Movement of the body and limbs as a unit is a characteristic seen in CP (Hadders-Algra et al., 1999). Isolation of movement in the various segments of the upper and lower limb is missing, causing a lack of disassociation between the movement elements between and within each limb. For instance, the motions used in the shoulder girdle and humerus affect movement components seen in the forearm and wrist. Humeral abduction and internal rotation facilitate overuse of forearm pronation and limit active supination needed for efficient hand use, a common problem in children with spastic CP. Active elbow and wrist extension is often restricted by spasticity in the elbow and wrist flexors, over time causing muscle tightness and contracture. The predominance of flexion at the elbow and wrist also affects the development of active intrinsic muscle function in the hand, resulting in the use of tenodesis interaction between the wrist and fingers and the use of extrinsic finger flexors and extensors to control the digits. Types of grasp available, especially for children with more severe impairments, are limited to more primitive grasp sequences and lack of both power and precisionprehensile. Deformities of the web space of the thumb and hypermobility in the metacarpophalangeal (MCP) and distal interphalangeal joints of the thumb are common.

These atypical interactions in the upper limb of children with CP result in significant activity and occupational limitations. Some authors hypothesize that the movement alterations are actually an adaptive function rather than true movement impairments (Steenbergen, Hulstijn, & Dortmans, 2000). Whatever the cause of the movement limitations, the manipulative function needed to manage such items as clothing fasteners, the ability to write, and use scissors, is often either impaired or missing. Clinicians should assess the child's postural control and upper limb function as a whole to design interventions that enhance all aspects of performance.

**Contrasts between Hypotonia and Hypertonia**

The discussion to this point has addressed postural control, anticipatory postural control, the relationship of posture to upper limb function, and aspects of atypical motor performance in children. Most of the discussion has related to the child with spasticity and increased tone. Muscle tone refers to the resistance a muscle offers when lengthened (Shumway-Cook & Woollacott, 2001). This resistance is a result of both neural factors (e.g., spasticity) and biomechanical factors (e.g., fibrosis, atrophy, changes in contractile properties of some muscle fibers).

Children with hypertonia have increased stiffness or tone in their muscles, whereas children with hypotonia have decreased resistance to lengthening and laxity of both muscle and other soft tissue structures around the joints. It is not uncommon to find children with hypotonia in the trunk and hypertonia in the limbs, or those with fluctuating tone, as well as children with generalized hypotonia. The intervention approaches to these variations in muscle tone differ in that children with hypotonia use end range movements (activities carried out by motions at the end of the available joint range) and often have increased range of motion in contrast to the limited active and passive mobility seen with hypertonia. Children with underlying low tone often use stabilizing or fixing of a body part (Nichols, 2001) to create stability, as well as a wide base of support in upright positions to create postural stability. Body movements are characterized by straight plane actions without a rotary component and limitations in strength and endurance are common. In the upper limb and hand, lack of graded, efficient movements restrict refined functions such as precision grasp, interdigital interaction, and isolated digital control used in complex manipulative sequences. The intervention procedures differ somewhat, although the emphasis on postural control as a necessary element of performance remains unchanged.

**Treatment Approaches: Concepts of Inhibition and Facilitation**

Three concepts underscore therapeutic handling (facilitating active movement by using a hands-on approach) in the NDT treatment approach, key points of control, inhibition, and facilitation. Key points of control refers to specific hand placement by the therapist during handling that allows direct influence or control over the area and indirect control over other body structures or functions proximal or distal to the key point. These sources of control are used to either inhibit or facilitate movement sequences and postural control. Proximal key points include the pelvis, shoulder girdle, and trunk, whereas distal key points are areas such as the elbow and ankle. Inhibition is defined as

> “the reduction of specific underlying impairments that interfere with function” (Howle, 2004, p. 261).

In treatment, therapists use inhibition to limit the ungraded force produced by spasticity, to balance unequal power between antagonists and agonists, or to
limit those movements that impair smooth coordinated action. Facilitation consists of

“strategies employed in therapeutic handling that make a posture or movement more likely to occur” (Howle, 2004, p. 260).

It is used to activate, grade and change various movements, and should affect the direction, force and availability of various movements.

Specific techniques are used for inhibition and facilitation (Box 16-1). These are discussed next.

**Inhibitory Techniques**

Inhibition is the primary tool used to manage abnormal posture and tone. Specific “hands-on” inhibitory techniques such as vibration, use of mobile surfaces, location, position of structures within the treatment environment, and use of various sensory stimuli and speed of movement can all be used to minimize impairments.

**Vibration** in NDT consists of placing the hand on a body area and vibrating or oscillating the location gently and consistently. Use of mechanical vibrators is discouraged because of the noise and difficulty grading the intensity of the vibration. This technique is best used when a more global movement or gross motor activity is being performed so as not to interfere with performance. It is particularly useful when managing trunk tone for vocalization or extending the range of movement in the trunk or a limb. As with all inhibitory techniques, one should withdraw the technique during activity performance.

**Prolonged stretch** through weight bearing in both upper and lower limbs is an inhibitory technique used to elongate soft tissue structures and minimize flexion or extension synergies in the limbs. It can be used to increase range of movement and decrease tone in children with spasticity, or in children with hypotonia or athetosis who have decreased range caused by fixing body parts to limit extraneous motion.

**Therapist guidance of movement** has applicability for both inhibition and facilitation. For inhibition, the therapist uses key points of control to limit ungraded force in one muscle group while facilitating active movement in the agonist or antagonist. It can be particularly helpful in the case of hemiplegia, in which asymmetries exist, or in the cases of diplegia and quadriplegia, in which symmetry of limb posture and lack of dissociation of movement is a problem. In these circumstances, the therapist can inhibit asymmetry by directing activities that are bilateral or symmetric in nature, or by inhibiting symmetry of posture by using treatment activities that require the limbs to be used reciprocally.

**Use of mobile surfaces** has both inhibitory and facilitatory applications. Children who have increased trunk extensor tone accompanied by lower limb extension can be positioned on a mobile surface and the gentle rocking movements of the surface used to inhibit tone and relax the child. Over time, passively applied movement on a mobile surface is shifted to the facilitation of the child’s ability to use his or her own active motion to manage tone increases.

**Inhibition through activity** is when the therapist teaches the child or individual how to manage atypical movements or increases in stiffness through specific movement sequences. For example, in the child who has increased tone in the flexors of the upper limb that limits dressing or bathing, upper limb weight bearing against a wall or the floor can help inhibit the flexion posture, or bending from the waist and shaking the arms in space can help reduce the stiffness. Whenever possible, clients should be taught to use their own movement over time for health promotion and increased participation.

**Facilitation Techniques**

The use of key points of control combined with therapist guided movement plays a big role in facilitation. Remember that key points of control are body areas from which the therapist facilitates or inhibits movement. In facilitation, the goal might be to assist the client to open a cupboard door using a more involved upper limb while the unimpaired limb holds and then places an item into the cupboard. The therapist could use either the shoulder or elbow as a key point of control to facilitate placement of the impaired arm on the door handle, a task that the client cannot do without prompts.
In this same example, *tapping* could be used along the muscle belly of the elbow extensors to activate the movement necessary to extend the arm to the door handle. Tapping can be used alternatively with *tactile cues*, which are a firm touch on the body part to indicate that it needs to move. Tactile cues are a less invasive form of facilitation, so moving back and forth between the two techniques is one way to withdraw input as the client is more able to perform the desired activity with less assistance.

*Deep pressure and joint approximation* are facilitation techniques to activate cocontraction around the joints. The use of these techniques works best on low-toned persons, but those with high tone often demonstrate underlying low tone when their high tone is altered. Sequencing deep pressure and joint approximation after tone inhibition is a common practice to facilitate better control and muscle activation.

*Weight-bearing on both upper and lower limbs* has properties of facilitation, as well as inhibition, depending on how it is applied. Static weight-bearing, especially for extended periods of time, can be achieved by “locking” or hanging on the joints. However, if weight-bearing is accompanied by *weight-shifting* (volitional or assisted movement of body weight) and active movement sequences, it can facilitate active movements in various muscle groups. *Weight-shifting* refers to movement of body weight through momentum of a body part (Shumway-Cook & Woollacott, 2001). Active weight shift occurs in all volitional movement transitions and is an important therapeutic tool in persons with movement impairments resulting from neuromuscular disorders. In the upper limb, humeral flexion, elbow extension and possible wrist and finger extension can be facilitated by weight-shifting over weight-bearing positions.

*Vestibular input* can be used to facilitate postural control. Combinations of sensory-integrative techniques can be incorporated, using swings or platforms (Blanche, Botticelli, & Hallway, 1995). If the child is not capable of sitting independently or sustaining posture on such equipment, the therapist can sit on the device with the child in his or her lap. A more desirable option is to incorporate meaningful activities such as dance with repeating rotary turns into the treatment whenever possible.

*Environmental modifications* include arrangement of physical, sensory, and even social aspects of the environment to facilitate action. Pediatric therapists are particularly good at such modifications. Arranging the room so that items are placed strategically so as to encourage active movement, use of surfaces that challenge the abilities of the child, and use of materials in occupations that are meaningful to the child are all ways to facilitate skilled action and successful performance. These same kinds of modifications can apply to specific aspects of hand function as well. For instance, using checkers instead of pennies to facilitate elements of a precision prehension can ensure success for the child and build the motor and sensory aspects of activity demands.

*Sensory modifications* can be helpful too. Music that is invigorating or calming can be used, singing, use of high contrast, complex or simple visual backgrounds are some ways to alter the sensory environment. Use of social facilitation is another technique that has been enhanced by inclusive practices in the classroom (Kellegrew, 1996). Peer engagement and support can serve to motivate and facilitate children in ways that parents or therapists cannot achieve. Children’s desire to be like their peers is a powerful force in facilitating performance, especially in the achievement of activities and occupations that the child wishes to perform to be with friends.

**COMBINING INHIBITION AND FACILITATION**

In almost any treatment session with children who have CP, it is necessary to combine aspects of inhibition and facilitation. This requires considerable skill on the part of the clinician, especially in the case of active children. By altering movements through the use of facilitation or inhibition, the clinician causes the client to change or adapt. This requires the clinician to quickly alter hands-on input to continue to enhance the improvement in the child. Ultimately the goal is to be able to withdraw both kinds of techniques so that the child can demonstrate motor learning and carryover of the skills learned in therapy.

**THE ASSESSMENT PROCESS**

Assessment of the child with cerebral palsy can be complex. Multiple aspects of performance should be analyzed, including physical and sensory status, developmental status, postural control, and quality of movement elements. The challenge for the clinician is how to sort through these aspects of the client to see which appear to be most critical to occupational performance. Distribution and degree of movement impairment also can be a guide. Children with mild hemiplegia, for instance, may not need extensive physical assessment but based on research findings (Gordon & Duff, 1999b) need assessment of tactile function. Developmental and occupational assessments are appropriate. A child with severe quadriplegia is more likely to need physical status assessment (e.g., strength, range of motion, spasticity) and less likely to need a full developmental evaluation.
Various assessments are discussed next, including standardized tools whenever possible.

**Physical Status of the Individual**

Range of motion and muscle strength are assessed using standard goniometry and manual muscle testing. Argument existed for some years about whether accurate evaluation of strength was possible in children with muscle tone impairments, however, the existing literature on functional gain after strengthening programs makes this a relevant area to assess (Damiano, Vaughan, & Abel, 1995; Darrah et al., 1999; Dodd, Taylor, & Damiano, 2002).

Muscle tone is assessed through the use of tools that are somewhat subjective, including the Ashworth Scale (Bohannon & Smith, 1987). The Tardieu Scale’s use is evolving; however, it requires more time and expertise to achieve accurate results (Mackey et al., 2004). These two scales assess increased tone but are not particularly helpful with hypotonia. Existing tools to measure decreased tone directly do not exist.

Assessment of sensation is a time-consuming process that often is not carried out in children with CP in spite of a body of research indicating tactile discrimination deficits in children with CP, particularly hemiplegia and quadriplegia (Duff & Gordon, 2003; Eliasson & Gordon, 2000; Eliasson, Gordon, & Forssberg, 1995; Gordon et al., 2003; Gordon, Charles, & Duff, 1999; Gordon & Duff, 1999). Gordon and Duff (1999b) and Lesny and co-workers (1993) used a variety of measures in their work that are recommended for clinical practice, including tests of two-point discrimination, stereognosis, and deep pressure.

NDT emphasizes quality of movement. Existing tools that assess quality of movement are limited. Examples are the Gross Motor Performance Measure (Boyce et al., 1995; Gowland et al., 1995; Thomas et al., 2001), the Toddler and Infant Motor Evaluation (TIME) (Miller & Roid, 1993; Rahlin, Rheault, & Cech, 2003), and the Movement Assessment of Infants (Hallan et al., 1993; Harris et al., 1984).

The limitations in standardized tools that assess movement and posture are a concern for the NDT treatment approach because the treatment emphasis is on developing posture and movement. Researchers have options available to them, but these are too expensive and complex for the clinic. Nichols (2001) suggested using indirect observation during assessment of motor milestones, which is the best option available in the clinic at present.

The success of any therapeutic intervention is dependent on the therapist’s ability to analyze aspects of performance and change over time. When one is planning interventions that use an NDT treatment approach, remember that the approach addresses posture and movement in the context of occupational performance. This means that occupational performance needs to be assessed. Pediatric therapists have a host of tools available to them in this realm, some of which have a developmental or skill focus. The reader should see Asher (1996) for a complete listing.

**Treatment Planning**

Planning appropriate interventions and documenting outcomes are aspects of service provision that require careful attention. Setting appropriate goals is the cornerstone of treatment planning. As noted in the OT Practice Framework, the occupations selected as outcomes of intervention should be meaningful and purposeful to the client and family; and successful outcomes are more likely when occupations are incorporated into daily routines (AOTA, 2002). These premises hold true for NDT intervention just as they do for other treatment approaches.

Use of activity analysis and the principle of partial participation are useful tools to help build specific skills over time (Vogtle & Snell, 2004). Refer to Table 16-1 in Case Study 1 for one example of activity analysis that is useful when planning NDT intervention. Sensory and motor elements are delineated to assist the clinician in organizing treatment and incorporating strengths of the client. Partial participation, which enables clients to complete steps of an activity that they are able to do with the remaining steps completed by a caregiver, can be planned satisfactorily through the use of this kind of activity analysis (Vogtle & Snell, 2004). Breaking an activity into steps also helps the clinician evaluate treatment outcomes in a more systematic manner.

Another aspect of treatment planning that benefits from activity analysis and partial participation is the integration of accommodations into interventions. By breaking an activity into steps and sorting out which of those the client can do, modifications to promote successful performance can be easily identified and used in treatment. This has the extra benefit of giving the clinician the opportunity to see if suggested modifications really work before asking families and educators to make them.

Tables 16-2 and 16-4 in the Case Studies later in the chapter give illustrations of how a clinician could use an activity analysis to plan treatment. The tables include columns for activity steps, movement components, and facilitation techniques. Organizing treatment into this kind of table can help the clinician develop a plan for intervention that includes aspects of facilitation and inhibition.
THE INTERVENTION PROCESS

Once assessment is complete and goals are established by the family, child, and clinician, it is time to consider how to provide treatment. The use of NDT techniques means that the therapist needs to combine the client factors to be addressed (e.g., tone, weakness, range of motion, postural control issues) with performance skills and activity demands of the goal while learning and practicing identified activities or occupations. The nature of the occupation selected as a goal in conjunction with client factors dictates the degree of postural control integrated into the intervention.

If the goal activity is focused on hand function, then the level of postural control and adjustment factored into the session depends on the planes in which the hand function takes place and future postural control goals. For instance, tying shoes occurs at some distance from the body. Potentially there should be either more work on posture involved in this kind of activity than if the goal was handwriting, or the therapist should develop postural supports necessary to allow the hands to be free for the act of shoe-tying.

The base of support required by an activity during intervention depends on the movement transitions needed during performance, and on the degree of body stability required by activity demands when adjusted by client factors. For instance, a child with significant quadriplegia may not be likely to use isolated trunk control, so a wider base of support might be chosen during hand function activities to contribute to the child’s stability. A less involved child who is mobile and has elements of active trunk control would be more likely to benefit from working on a narrower base of support. Base of support can be graded over time as progress is seen. It is also important to remember if the child is in supportive seating during the day, the practice part of sessions needs to take place in the same configuration.

Base of support can affect the degree of weight shifting used in treatment. Large weight shifts obviously are important to movement transitions; however, lesser degrees of weight shifting can play an important role in upper extremity treatment. Sitting at a table and cutting with scissors, for instance, usually incorporates subtler weight shifts. If the child reaches for items set back from the edge of the table, an anterior weight shift occurs. Similarly, reaching for items off to the side results in a lateral weight shift. Using subtle weight shifts assisted by key points of control when working on table top activities and development of fine motor skills can extend reach and assist with hand placement, as well as inhibiting extensor tone in the trunk.

Weight shifts can assist in inhibition of tone and facilitate active trunk and upper limb function. Other facilitation and inhibition techniques can be applied during treatment of hand function as well. Gentle vibration or oscillation on the trunk or limbs helps to manage upper limb tone and use of the shoulder or elbow as key points of control facilitates active movements in the wrist and hand. Preparatory activities using upper limb weight bearing prepare the hand for more active hand function by inhibiting tone and improving mobility of wrist and finger flexors. These activities can take place with the child in sitting or standing, not just in quadruped, positions in which upper limb weight bearing often takes place in typical children.

NEURODEVELOPMENTAL TREATMENT AND HAND FUNCTION

There are children in whom the primary intervention focus needs to be within the hand. Examples are children with quadriplegic involvement in which the most important goal is isolated index finger function to access a computer or augmentative communication device; a child with hemiplegic impairment who wants to be able to hold a piece of paper in the impaired hand so that cutting can be accomplished; or a young person who wants to be able to manipulate a joystick to drive a power chair.

In these kinds of examples, direct treatment of the hand is necessary. Most of the inhibition and facilitation techniques described earlier can be applied directly to the hand. Vibration or oscillation at the wrist or from the web space of the thumb minimizes tone in the fingers; these techniques can be used as preparation before performance or used during activities. Weight bearing on the hand is a well-known NDT technique for soft tissue stretch and tone management that is underused in reciprocal hand interactions such as hand-to-hand clapping games with another person, in which hand contact is extended for the purpose of stretch, deep pressure, or tone management. The degree of wrist and finger extension involved in the activity can be graded by the therapist depending on the desired outcomes and the tolerance of the child.

Key points of control in the hand include the wrist, longitudinal arch of the hand, MCP joint of the index finger, thenar eminence, and web space of the thumb. Obviously the use of key points of control has to be carefully managed in such a small area as the hand, which is when careful grading of activities comes into play. For example, when isolated control of the index finger is desired, the therapist may choose to use the MCP joint as a key point of control. Activities that might be used to facilitate sensorimotor experiences in
This situation include pushing keys on a piano, computer, or toy, pressing stickers onto a surface, making fingerprints in play dough, extending the digit for placement, removal of a ring, and so forth. Those activities that entail pressure (e.g., play dough, pressing keys, stickers) are situations in which weight shifts across the pad of the digit provide alternating deep pressure inputs into the interphalangeal (IP) joints, as well as the MCP joint, a facilitatory technique.

The mobility of the carpals and metacarpals of the hand contribute to the arch structures of the hand, wrist flexion and extension, and radial to ulnar side interactions within the hand. All of these elements also play a role in grasp and manipulation between and within the hands. Hypertonic CP commonly results in a predominance of wrist and finger flexion combined with ulnar deviation at the wrist—resulting in ulnar prehensions. Maintaining mobility in the structures of the hand mentioned earlier while facilitating active movement and the ability to participate in chosen occupations are focal concerns of NDT treatment.

Although the prevailing muscle tone in the hand is increased with generalized hypertonia, hypermobility in the IP joints of the fingers and thumbs is common, as well as in the MCP and carpometacarpal joint of the thumb. This combination of increased mobility and fluctuating tone in the spastic hand presents challenges for the therapist and the need to alternate strategies of inhibition and facilitation frequently when working within the hand.

Activity demands should be considered as part of treatment as well. AOTA (2002) defines these demands as

“... objects, space, social demands, sequencing or timing, required actions, and required underlying body functions and body structure needed to carry out the activity.” (p. 624).

Specific aspects of any activity are items that should be considered in treatment, and amended or modified when necessary to enable the client to have success in performing the occupation. Nowhere is this more important than when working within the hand. For example, it is common for therapists to choose the smallest possible items to develop skills such as tip-to-tip prehension. Larger items offer the child better control and incorporate the same movement sequences used in precision prehension; as skill is gained, the therapist can then move on to include small objects in therapy.

Practicing occupations during treatment has been emphasized in this chapter. There is a body of research supporting the efficacy of activity practice in children with cerebral palsy (Duff & Gordon, 2003; Taub et al., 2004) and the importance of activity context on practice outcomes (Volman, Wijnroks, & Vermeer, 2002).

It is critical that the therapist spend significant time having the client practice designated goals during the session. The therapist can use inhibition and facilitation in this process, but needs to withdraw such assistance as the session moves on, remembering that ultimately the child is expected to do the task without such assistance.

**Efficacy of Neurodevelopmental Treatment**

Judgment about the efficacy of therapeutic interventions should be based on careful examination of published studies, either through systematic review or meta-analysis. Such methods are limited by the limited availability of high-quality studies. Two recent systematic reviews of NDT intervention have been carried out (Brown & Burns, 2001; Butler & Darrah, 2001). Butler and Darrah (2001) incorporated articles back to 1973, whereas Brown and Burns (2001) included those published since 1975. There were 21 studies in the review by Butler and Darrah (2001) and 17 articles in the review by Brown and Burns (2001). Both reviews classified articles as one of five levels of evidence. Brown and Burns (2001) used the Quality Assessment of Randomized Clinical Trials scale created by Jaded and co-workers (1996) to assign levels of evidence, whereas Butler and Darrah (2001) used a system developed by the American Academy of Cerebral Palsy and Developmental Medicine (Butler & Darrah, 2001). Another unique feature of their review is their incorporation of dimensions of disability reflective of the National Center for Medical Rehabilitation Research (NCMRR) model of disablement (Shumway-Cook & Woollacott, 2001) as one judgment of outcome.

Both reviews cited numerous problems in attempting systematic study of NDT. Problems included heterogeneity of the target population, lack of randomization, inadequate blinding of subjects, a wide range of subject ages, use of a variety of clinical and standardized outcome measures, small sample size and limited follow-up, interventions that included other methods besides NDT, a range of duration and intensity of treatments, and inconsistency of significance across studies. Both studies concluded that the efficacy of NDT could not be decided on the basis of the studies reviewed, although Butler and Darrah noted that studies published in the last 14 years had more statistically significant results. In addition, both noted that newer interventions based on more current theories of motor learning and skill development exist and appear to be generating more conclusive evidence (Butler & Darrah, 2001). Butler and Darrah cited the lack of association to any of the NCMRR dimensions to which the various studies were compared. These
same authors suggest that the use of NDT as a control intervention in studies comparing it to another treatment would contribute to the body of existing evidence about treatment efficacy for children with CP.

Since these two systematic reviews were published, other publications about efficacy of NDT have been published (Trahan & Malouin, 2002; Tsorlakis et al., 2004). Trahan and Malouin’s research was a pilot study analyzing the outcomes of an intermittent intensive NDT intervention. Tsorlakis and co-workers (2004) research was a carefully designed randomized clinical trial comparing outcomes between two different durations of NDT treatment that attempted to avoid design problems of earlier studies. Duration of intervention has become a focus of studies because of the development of constraint-induced therapy that provides intensive duration of therapy over a relatively short term (Taub et al., 2004).

### SUMMARY

This chapter has described the neurodevelopmental treatment approach to pediatric intervention, and its history, evolution, and current perspective. As reiterated throughout the chapter, NDT is an intervention focused on improving postural control and active movement skills. The therapist bears the responsibility for integrating this kind of approach into function and practice of function. Carryover of movement changes into function does not occur naturally, as once proposed by the Bobaths. Although the efficacy of NDT has yet to be demonstrated convincingly, more recent studies are supportive and suggest that the shift to integration of NDT with functional outcomes has merit in the treatment of upper limb function in children with CP.

### CASE STUDY 1

**A Child with Cerebral Palsy**

Seven-year-old Jodie, who had spastic CP of quadriplegic distribution, used a head-activated switch to work on the computer, which meant scanning the keyboard rather than being able to use direct selection of desired keys. Her school therapists, teachers, and family wanted to explore the possibility of hand activation of Jodie’s computer access switch with the eventual goal of direct selection on an alternative keyboard, which would be faster and more productive. Although computer use in the context of the school environment was the initial occupational goal, success meant she would be able to access her home computer with less assistance than she presently required.

### TASK ASSESSMENT AND GOALS

Activity analysis of the process of pushing a switch (Table 16-1) and physical assessment of Jodie’s ability to push a switch with her hand were carried out, along with an assessment of performance components, activity demands, and client factors in the OT Practice Framework (AOTA, 2002) and of performance components in Uniform Terminology III (AOTA, 1994). Jodie demonstrated challenges in motor and process aspects of performance skills. She maintained her head in an upright position for long periods of time and used it to move her eyes when tracking items. Efforts at arm and hand movement affected movements of her head and trunk, resulting in dynamic tone changes throughout her body manifested by increased extension in her torso, head, and neck, and by bilateral rigid extension at the elbows and in the lower limbs. A consistent lean to the left was noted, a trend made worse by her attempts to use her hands. She could lift her arms actively by flexing and elevating her shoulders to about 80 degrees but movement toward or away from the midline to place her hands was difficult. There were soft tissue restrictions in her shoulders, limiting the end range of humeral flexion and abduction.

Jodie’s hands were most often fisted and wrists stiffly extended. A right hand preference was noted. Jodie reached for offered items directly in front of her body but was unable to grasp an object volitionally or bring her hands to her mouth. When a toy was placed in her hand, she would hold it indefinitely using increased flexor tone in the fingers of her hands but was unable to do anything with it; there was no volitional release of objects and efforts to do so resulted in head shaking in an effort to release items from her hand. There was no isolation of movement between limbs or within either limb.

Jodie could place her hand on a 5" × 7" switch placed in front of her with difficulty, but could not consistently depress and release the switch to use it for computer access, nor could she remove her hand from the switch once it was placed there.

The movement components she needed to activate the switch for various aspects of the activity are noted in
Table 16-1  Activity analysis of activating/deactivating a switch for computer use

<table>
<thead>
<tr>
<th>Step of Activity</th>
<th>Visual Component</th>
<th>Auditory Component</th>
<th>Movement Components*</th>
<th>Tactile Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moves arm to switch</td>
<td>Locates switch</td>
<td></td>
<td>Lifts right arm toward the switch using humeral flexion and horizontal abduction. Elbow extension</td>
<td>Kinesthetic feedback from the limb moving</td>
</tr>
<tr>
<td>Places hand on switch</td>
<td>Sees switch and uses vision to guide placement of hand on switch</td>
<td></td>
<td>Humeral extension activated to bring hand to switch</td>
<td>Jodie feels the switch under her fisted hand</td>
</tr>
<tr>
<td>Presses switch to activate</td>
<td>Sees scanning array activate when switch is pressed</td>
<td>Hears click as switch is activated</td>
<td>Humeral extension is used to push the switch</td>
<td>Jodie feels the pressure of the switch on her hand increase as she pushes</td>
</tr>
<tr>
<td>Releases pressure on the switch</td>
<td>Uses vision to guide her hand lifting to release switch pressure</td>
<td>Hears click as pressure is released and switch deactivated</td>
<td>Humeral flexion is used to lift her hand off the switch</td>
<td>Feels absence of sensation as her hand clears the switch</td>
</tr>
<tr>
<td>Moves arm and rests hand on the surface away from the switch</td>
<td>Sees hand lift off of switch and targets where hand is to rest</td>
<td></td>
<td>Moves arm away from the switch using humeral flexion and horizontal adduction; humeral extension is used to lower arm to the table surface</td>
<td>Feels table surface under her hand and arm when she rests them on the table</td>
</tr>
</tbody>
</table>

*Because the client has stiffly extended elbows, which become stiffer with efforts at movement, the choice made is to focus on humeral movements to move her hand. Use of wrist flexion and extension also would be helpful; however, these movements are not absolutely necessary to activate the switch.

Table 16-2. The use of these movements for activating the switch were felt to be appropriate because Jodie’s volitional control of her elbow, wrist, and hand movements was minimal, and the switch could be successfully activated using these movements. In addition to movements to activate and release the switch, she needed to be able to organize and sequence these movements with enough speed to push the switch in a timely fashion when visually cued to do so by the scanning sequence. Thus anticipatory control in her arm (remember that anticipatory control was defined as activation of sensory and muscular systems for a specified activity based on prior learning and experience), postural control and adjustment of her head, and active isolated movements of her right upper limb were other aspects of performance needed for motor control and learning so that she could initiate, sustain, and terminate movements of the shoulder in sequence to perform the activity.

TREATMENT PLAN
The organization of the treatment plan for Jodie is detailed in this section and based on a school year with weekly sessions. The treatment plan incorporates both environmental and client factors, as well as practice of the skill being developed during sessions and at home outside of the therapy setting at school.

THERAPY GOALS
The goals found in Box 16-2 include long-term goals and benchmarks as seen in an individualized educational plan (IEP) write-up. Benchmarks were chosen that support the
use of Jodie’s right upper extremity for single switch activation working from her wheelchair. Although Jodie does have significant limitations in postural control, note that postural elements are woven into the treatment but are not identified as long-term goals.

**THERAPY ENVIRONMENT**

The therapist chose to intervene with Jodie in her classroom. The first-grade classroom was broken up into areas, meaning that there were times when floor space was available for therapy with Jodie out of her wheelchair. The therapist brought a therapy bolster to use during sessions. Being in the classroom meant that the same physical set-up of the switch and computer was available for practice in a real-life situation in which the therapist could observe Jodie’s progress. Classmates were present, as was the case during spelling class, and could be available to provide encouragement if approved to do so by the classroom teacher.

**HANDS-ON TREATMENT**

The therapist used four premises upon which to base her treatment. First, tone increases seen in Jodie when she attempts to use her upper limbs will be altered through the use of work on a mobile surface (the bolster), facilitation of forward and lateral weight shifts when reaching for her switch, and use of periodic rapid oscillations to the upper limbs. Second, use of facilitatory tapping and active-assisted hand placement on the switch will be used to help Jodie activate shoulder movements for hand placement, switch depression, and switch release (see Table 16-2). Third, practice of the task will be used to ensure changes in motor performance, motor learning of the skill being developed, and switch activation for computer use. Fourth, tactile enhancement and reinforcement will be used to ensure that Jodie knows when her hand is and is not on the switch to help build anticipatory control mechanisms needed for successful task accomplishment.

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### Table 16-2 Facilitation and inhibition techniques to be used in Jodie’s treatment

<table>
<thead>
<tr>
<th>Step of Activity</th>
<th>Movement Component</th>
<th>Facilitation/Inhibition Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moves arm to switch</td>
<td>Lifts right arm toward the switch using humeral flexion and horizontal abduction. Elbow extension</td>
<td><strong>Tapping</strong> under the humerus to facilitate shoulder flexion and elbow extension; <strong>tapping</strong> on the medial border of the arm to facilitate horizontal abduction; <strong>forward then lateral weight shift of torso across the pelvis</strong> to facilitate arm movement in a sagittal then lateral plane</td>
</tr>
<tr>
<td>Places hand on switch</td>
<td>Humeral extension activated to bring hand to switch</td>
<td><strong>Sweep tap</strong> across volar surface of the humerus; <strong>posterior weight shift of torso across the pelvis</strong> to facilitate arm movement toward the switch</td>
</tr>
<tr>
<td>Presses switch to activate</td>
<td>Humeral extension is used to push the switch</td>
<td><strong>Active assist</strong> from head of humerus or on the forearm to facilitate pressure on hand to activate switch; <strong>lateral weight shift of torso across the pelvis</strong> to facilitate switch activation</td>
</tr>
<tr>
<td>Releases pressure on the switch</td>
<td>Humeral flexion is used to lift her hand off the switch</td>
<td><strong>Tapping</strong> under the humerus to facilitate shoulder flexion and elbow extension; <strong>tapping</strong> on the medial border of the arm to facilitate horizontal abduction; <strong>forward weight shift of torso across the pelvis</strong> to facilitate arm movement in a sagittal plane</td>
</tr>
<tr>
<td>Moves arm and rests hand on the surface away from the switch</td>
<td>Moves arm away from the switch using humeral flexion and horizontal adduction; humeral extension is used to lower arm to the table surface</td>
<td><strong>Tapping</strong> under the humerus to facilitate shoulder flexion and elbow extension; <strong>tapping</strong> on the lateral border of the arm to facilitate horizontal adduction; <strong>forward then medial weight shift of torso across the pelvis</strong> to facilitate arm movement in a sagittal then lateral plane</td>
</tr>
</tbody>
</table>
TREATMENT IMPLEMENTATION

In this section, sequencing within therapy sessions is described, incorporating the physical environment, therapy equipment, therapeutic facilitation, and practice components.

Tone Management and Preparation for Activity

Jodie was removed from her wheelchair for the first 15 to 20 minutes of each 40-minute session. This enabled the therapist to use weight shifts and techniques to modify the dynamic muscle tone Jodie demonstrated whenever she tried to use her upper limbs and gave her practice in use of appropriate postural components. A bolster was used because it enabled the therapist to use two planes of motion: anterior/posterior movements and lateral movements. Jodie was placed on the bolster, either on the far end or straddling it, to enable the therapist to use the movement of the bolster when addressing Jodie’s muscle tone during activities and to facilitate her active weight shifts while providing a wide base of support. These bolster motions were activated by the therapist’s use of her own lateral weight shifts and anterior or posterior body movements.

At the same time, rapid oscillations of Jodie’s upper limbs were used to help loosen her stiff arms in preparation for developing the active shoulder movements needed to activate the switch (Figure 16-1). At this point, the therapist had Jodie lean onto her upper limbs positioned on the bolster to help inhibit tone and increase range in her hands as preparation for switch activation.

Forward weight shifts accompanied the upper extremity weight bearing, passively accomplished at first by the therapist leaning forward into Jodie’s torso and moving her forward. The therapist facilitated the weight shift in this manner for the first few times, and then used decreasing assistance as Jodie exhibited the ability to activate a weight shift on her own.

Switch Activation

This skill was practiced first with Jodie still on the bolster. Using the bolster allowed the therapist to facilitate weight shifts and shoulder movements and inhibit hyperextension of the trunk during efforts at movement. An adjustable height table under which the bolster was slid helped to support the switch. The switch position at first was put further back on the table than needed to require an exaggerated forward weight shift to counterbalance the extensor thrust that occurred when Jodie tried to move. Remember at this point that Jodie’s arms were resting on the table surface at midline so she would not have to move her shoulder high or far laterally to place her hand on the switch. The switch surface could be enhanced with a number of different materials (e.g., carpet samples, various fabrics) to heighten differences between the table and switch surfaces.

When Jodie was asked to activate the switch, a series of short taps under her humerus were used to activate humeral flexion (Figure 16-2), then laterally to bring the humerus to the switch, which was placed slightly off to the side (Figure 16-3). Active assistance in placing her hand was also used alternatively to help Jodie develop a sense of what was needed to get to the switch; however, this only occurred on alternate attempts rather than each time she tried to touch the switch.
Placing her hand on the switch and activating the switch were skills that were separated on the goal list but not in treatment. At this early point in learning to activate the switch, the switch was attached to a device such as a radio or fan, items that do not require a great deal of accuracy for successful activation. Once Jodie had her hand on the switch, a tap on either the volar surface of the humerus or the forearm was used to facilitate activation. An assisted weight shift posteriorly helped with switch activation as well, but it needed to be carefully carried out so that Jodie was not pulled backward. Active assistance was used to press the switch, using the same careful guidelines described earlier. A latch switch was used to limit the amount of time the device is active, requiring Jodie to lift her hand from the switch, then depress it again to restart the device.

Releasing the switch was facilitated by incorporating the same techniques used to facilitate placing Jodie’s hand on the switch only in reverse order. Release of objects is a more challenging task for children with CP, as indicated by research in children with hemiplegia (Eliasson & Gordon, 2000; Gordon et al., 2003). Such studies have shown that the temporal aspect of release is a particular problem, which was the case for Jodie when releasing the switch.

SEQUENCING THE PLAN
The idea was to move Jodie forward in her treatment plan as expeditiously as possible. To do this, she needed to practice outside of her therapy sessions. Ideally this would occur in both home and school settings, depending on the family and time in the classroom. Another way to manage more practice would be to increase the frequency and duration of treatment sessions. Although this program was developed around the traditional weekly model of therapy frequency, research has demonstrated that massed or intensive practice such as is used in constraint-induced paradigms and other research has better outcomes for children with CP (Duff & Gordon, 2003; Taub et al., 2004).

Another critical issue was communication between the therapist and teacher. This assisted in documenting goals and assuring that teacher, aide, and therapist were all using similar techniques and the same equipment. If progress was not seen in a short period of time (2 to 3 weeks), then it would be necessary to re-evaluate the plan and adjust intervention.

OUTCOME
It was soon apparent that the switch needed to be stabilized on the surface; therefore a slightly inclined easel surface with Dycem under the switch and easel were used to provide stability. Masking tape was used on both home and school table surfaces to mark where the easel went to be sure that the location of the switch was consistent over time.
Jodie made rapid progress at placing her hand on the switch. Accurate depression and release of the switch voluntarily in a timely fashion took another 2 to 3 months to achieve with frequent dialogue among teachers, therapist, and family. Jodie was motivated, which helped, and had persistent encouragement from her classmates. Her switch activation accuracy initially deteriorated throughout the day as fatigue set in, so the family limited her home practice to weekends. At the end of 3 months, Jodie could accurately complete a 10-word spelling assignment using hand-activation of her switch in 30 minutes. Fatigue was becoming less of a factor, so her teacher began to add short assignments later in the day.

Two-and-a-half-year-old Lily has quadriplegic involvement with low muscle tone and aimless movements of her limbs. She can hold her head up and sit for short periods of time (3 to 5 minutes) when placed in supported sitting but spends much of her day playing in prone or supine, or propped in her infant seat. She can grasp objects with either hand but does not use both hands together. Most of her activity consists of mouthing objects and then dropping them after briefly holding onto them. Her mother reports her as being an irritable child who screams when new stimuli come into the environment. The family would like her to be able to play by herself for longer periods of time and use both hands to play, to sit up longer so they can play with her, to hold her cup and drink from it, and for her to be less irritable. Box 16-3 contains examples of goals for Lily. The goals of using her hands to hold a cup will be used for demonstration purposes. Specifically the goal will be for Lily to sit supported in her high chair and lift her cup and drink when it is placed on a surface in front of her. Table 16-3 shows an activity analysis of this goal, which is used to plan the intervention.

**PREPARATORY ACTIVITIES**

The intervention was scheduled for Lily’s usual afternoon snack time to locate the intervention in her usual daily pattern of activities. Doing so offered demonstration time and consistent feedback to the mother about Lily’s performance and gave the therapist the opportunity to re-evaluate Lily’s skills each week. Table 16-4 illustrates the steps of the activity and the techniques to be incorporated into the intervention session. Because Lily was anticipating the cup, she tended to be less tolerant of extensive prefeeding activity, so preparatory work was limited to 5 to 10 minutes. The therapist sat on a chair or sofa. Lily was positioned on the therapist’s knees; she could either face the therapist or face her mother with her back to the therapist. Facing the therapist meant her base of support was wider because she was straddling the therapist’s legs; while facing her mother she was not straddling and the base of support was narrower. Lily was supported at the shoulders and the therapist gently bounced her using plantar flexion and return from plantar flexion of her own feet to provide bounces that were timed asymmetrically so as not to be predictable. Firm downward pressure was applied at the shoulders, with the therapist’s thumbs positioned over the heads of each humerus and the fingers supporting the scapulae (Figure 16-4). Sound production by Lily was encouraged to activate abdominal contraction at the same time. This activity was sustained for 1 to 2 minutes, and then the therapist’s hand position was shifted.

**BOX 16-3 **

**Long-Term and Short-Term Goals for Lily**

1. Lily will lift the cup from the surface to her mouth
   a. Lily will place both hands on the cup when it is placed on the surface in front of her.
   b. Lily will lift an almost empty cup off of the surface briefly.
2. Lily will hold the cup when it is placed at her mouth to take a drink.
   a. Lily will place both hands on the cup while mother provides over hand assistance.
   b. Lily will spontaneously place her hands on the cup held at her mouth for a few second.
   c. Lily will hold an almost empty cup at her mouth with minimal assistance from her mother.
3. Lily will put the cup back on the surface after she has drunk from it.
   a. Lily will maintain her hands on the cup with maximal assistance from her mother as her mother returns it to the surface.
   b. Lily will hold the cup briefly when she is finished drinking and then place it.
4. Lily will lift the cup to her mouth, drink from it, and return the cup to the surface.

**CASE STUDY 2
A CHILD WITH LOW TONE**
to Lily’s abdomen and lumbar spine. The hand on the lumbar spine was for support, whereas the hand on the abdomen was used to apply firm downward pressure to continue activation of the abdominals.

A movement transition to produce coactivation of trunk extensors and flexors followed. Lily was weight shifted toward the arm of the chair with the key point of control at the pelvis. The goal here was for Lily to put both hands onto the chair arm, producing a bilateral upper limb weight-bearing activity (Figure 16-5). The pelvis was maintained in a straight plane position while the trunk rotated over it, a position requiring cocontraction of abdominals and trunk extensors. This activity was carried out briefly, and then Lily was facilitated to turn to face her mother with the therapist’s hands moved back to the abdominals and lumbar spine and downward pressure applied on the abdominals to activate a forward weight shift. Her mother facilitated bilateral shoulder flexion by holding her hands out to Lily. She did not pick up her daughter until Lily reached out with both arms. The

<table>
<thead>
<tr>
<th>Step of Activity</th>
<th>Visual Component</th>
<th>Auditory Component</th>
<th>Movement Components</th>
<th>Tactile Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cup is placed on surface; child’s arms activate at the sight of the cup</td>
<td>Sees cup approaching and set on surface</td>
<td>Person handing the cup may make statement; cup makes sound as it touches the table</td>
<td>Arms move toward the cup; possible components: humeral abduction moves to humeral adduction; elbows extend and hands open</td>
<td>Kinesthetic feedback from the limb moving</td>
</tr>
<tr>
<td>Takes cup</td>
<td>Sees the cup held at midline</td>
<td>Parent may make statement</td>
<td>Hands grasp cup; humeri are adducted, elbows midway between flexion and extension and forearm midposition, fingers flexing</td>
<td>Lily feels the cup on her hands; weight of the liquid gives proprioceptive feedback</td>
</tr>
<tr>
<td>Raises cup to her mouth</td>
<td>Sees the cup moving toward her face</td>
<td>Humeral movement is flexion; elbows move into flexion; fingers flexed</td>
<td>Feels cup touch her mouth; feels weight of cup on hands and through shoulders</td>
<td></td>
</tr>
<tr>
<td>Drinks from cup</td>
<td>May look at others in the room</td>
<td>Humeral and elbow flexion used to lift the cup to pour liquid into the mouth</td>
<td>Feels weight of the cup in her hands, and liquid in the mouth and throat</td>
<td></td>
</tr>
<tr>
<td>Brings cup back to surface and releases it</td>
<td>May look at cup as she moves it away from her mouth</td>
<td>Hears cup when it hits the table</td>
<td>Humeri and elbows extend</td>
<td>Feels cup hit the surface and absence of tactile feedback on her hands</td>
</tr>
</tbody>
</table>
movement transitions described provided limited vestibular input. More consistent use of rotary movements during transitions provides the kind of vestibular input children achieve themselves through active movements.

**ACTIVITY PRACTICE OF DRINKING FROM THE CUP**

Lily was placed in her child-sized chair. The therapist sat behind the high chair and placed her hands on Lily’s shoulders. The thumbs were placed along the proximal aspect of the humerus and the fingers rested on the abdomen. Her mother held a half-filled cup in front of Lily but did not place it on the tray. The therapist used pressure on the lateral border of the humeri to bring Lily’s hands together and then slipped her hands up over the proximal part of her arms to help Lily clap her hands several times. Her mother then placed the cup on the tray, tapping it to get Lily’s attention and asking her to take the cup. A subtle forward weight shift for the reach was facilitated using the shoulders as a key point of control. Her mother cued her verbally again and the therapist waited briefly to see if Lily reached for the cup, then helped place her hands on it. Firm pressure on the shoulders was attempted to sustain Lily’s hands on the cup. When unsuccessful, the therapist slid her hands down over Lily’s hands (Figure 16-6). Once Lily sustained her grasp of the cup, tapping under the arms to facilitate forward flexion; posterior weight shift used to facilitate arms to lift.

**OUTCOMES**

Lily actively resisted the movement transition sequence. After attempting to use it before giving Lily her cup, the therapist chose to discontinue this aspect of the inter-

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**Table 16-4 Facilitation and inhibition techniques to be used in Lily’s treatment**

<table>
<thead>
<tr>
<th>Step of Activity</th>
<th>Movement Components</th>
<th>Facilitation/Inhibition Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cup is placed on surface; child’s arms activate at the sight of the cup</td>
<td>Arms move toward the cup; possible components: humeral abduction moves to humeral adduction; elbows extend and hands open</td>
<td>Deep pressure on the abdominals to facilitate trunk and humeral movements toward midline; humeri as key point of control to bring hands together passively then as cue to do so actively; Hands clapped together to give sensory cue to open hands and deep pressure feedback to palms of hands.</td>
</tr>
<tr>
<td>Takes cup</td>
<td>Hands grasp cup; humeri are adducted, elbows midway between flexion and extension and forearm midposition, fingers flexing</td>
<td>Anterior weight shift to assist in reaching for and grasping the cup; hands brought to the cup and deep pressure on hands over the cup used to give sensory feedback; approximation through the trunk to facilitate co-contraction of abdominals and extensors</td>
</tr>
<tr>
<td>Raises cup to her mouth</td>
<td>Humeral movement is flexion; elbows move into flexion; fingers flexed</td>
<td>Shoulders used as a key point of control to sustain hands on the cup; ulnar side fingers used to tap under the arms to facilitate forward flexion; posterior weight shift used to facilitate arms to lift.</td>
</tr>
<tr>
<td>Drinks from cup</td>
<td>Humeral and elbow flexion used to lift the cup to pour liquid into the mouth</td>
<td>Posterior weight shift to facilitate neck flexors and abdominals to hold with head and trunk extended while drinking; shoulders continue as key point of control for entire upper limb</td>
</tr>
<tr>
<td>Brings cup back to surface and lets it drop</td>
<td>Humeri and elbows extend</td>
<td>Anterior weight shift to assist in reach of arms to the tray; gentle vibration to facilitate fingers letting go of the cup.</td>
</tr>
</tbody>
</table>
Lily was able to reach and grasp with two hands successfully in several weeks. Her ability to keep two hands on the cup while bringing it to her mouth took another month. Lily still refuses to grasp the cup on occasion when irritable.

**Figure 16-4** Lily is positioned on the therapist's knees facing the therapist. She is supported at the shoulders and the therapist is gently bouncing her, using her own feet to provide the bounces. Firm downward pressure is applied at the shoulders, with the therapists' thumbs positioned over the heads of each humerus and the fingers supporting the scapulae.

**Figure 16-5** A movement transition to produce coactivation of trunk extensors and flexors is illustrated here. Lily's weight is shifted toward the arm of the chair with the therapist's key point of control at the pelvis. The pelvis rotates slightly and one side lifts with the weight shift while the trunk rotates over it. At the same time, Lily moves her hand to the arm of the rocking chair to support herself, producing a weight-bearing activity in conjunction with a movement transition.

**Figure 16-6** In this figure, the child is having difficulty sustaining her grasp on the surface of the cup. To cue her, the therapist places her hands over Lily's and applies gentle pressure over Lily's wrists and hands to support the cup and give her sensory feedback about the task. As Lily becomes more proficient, the therapist can slide her hands back up the forearms to guide the movement while Lily maintains her grip on the cup independently.
REFERENCES


