KEY TERMS
augmented intervention
evidence-based practice
functional training
impairment training
neuromuscular retraining

OBJECTIVES
After reading this chapter the student or therapist will be able to:
1. Appreciate the complexity of motor responses, and discuss methods used to influence body systems and their effects on functional behaviors.
2. Outline the differences in recovery related to healing, compensation, substitution, habituation, and adaptation.
3. Analyze the similarities and differences among impairment training of specific body systems, functional training, augmented feedback training, and learning-based sensorimotor retraining.
4. Select appropriate intervention strategies to optimize desired outcomes.
5. Analyze variables that may both positively and negatively affect complex motor responses and a patient’s ability to participate in functional activities.
6. Identify procedures and sequences required to attain the most successful therapeutic outcome that best meets the needs and goals of the client and the family.
7. Consider the contribution of the client, the client’s support systems, research evidence, neurophysiology, and the best practice standards available to optimize outcomes.

Before discussing therapeutic intervention procedures, the therapist must identify the learning environment within which the client will perform. As discussed in Chapter 1, that environment is made up of the therapist and the client, all internal body control mechanisms of the client, and the external restraints and demands of the world. Although this text focuses on relearning functional movement, the reader must always consider all aspects of the client including how other organs or body systems will be affected by or will affect the therapeutic outcome both during rehabilitation and in relation to long-term quality of life. An examination and evaluation (see Chapter 8) are performed before intervention to establish movement diagnoses. These examinations lead to movement diagnoses that must link to functional limitations or restrictions in activities and their causations (body system problems). Movement diagnoses and the degree and extent of the system or subsystem dysfunction or impairments determine prognosis of the outcomes on the basis of the client’s potential for functional improvement. Factors such as motivation, family support, financial support, and cultural biases must be considered as part of the prognosis.1 This process guides the selection of intervention strategies. Although it could be assumed that some of these impairments would be directly correlated to the central nervous system (CNS) trauma experienced by the client, it must also be determined whether some or most of these impairments have developed over a lifetime as a result of small traumas and adjustments to life. This insidious cause of impairments needs to be differentiated from acute causation of activity limitations because goal setting and expectations related to prognosis and recovery can be different.

Both the American Occupational Therapy Association (AOTA) and the American Physical Therapy Association (APTA) have developed guides to practice that help to direct therapists entering the professions and should help to guide practice throughout their working lives.2,3 APTA, through the initiation of the California Physical Therapy Association, has been collecting and classifying evidence-based articles through the Hooked on Evidence project.4 Through the use of current evidence-based practice; sensorimotor processing, motor control, motor learning, and neuroplasticity theories (see Chapter 4); and body systems models, the therapist must determine the flexibility or inherent motor control the client demonstrates while executing functional activities and participating in life. This chapter or other chapters in the book cannot establish for the reader the exact treatment sequence that should be used for every patient, but an example of a decision-making pathway has been given in Box 9-1. Functional goals must be established that lead to the client’s ability to participate in life within his or her environment and whenever possible lead to or maintain the quality of life desired by the client. Similarly, the therapist must differentiate whether the observed motor problems are based on acute or longstanding impairments before establishing timelines for prognosis.

Before beginning any intervention, the therapist must determine the treatment strategies that will be used to help the client attain the desired functional outcomes. The specific environment used by the therapist to optimize patient performance will depend on the functional level and amount of motor control exhibited by the patient. The following
Client’s base of support under the normal center of gravity. This augmented intervention is being done in a treadmill training. In the early phases, a therapist or assistant might be the early phase of partial body-weight supported interventions from the above categories. An example of this for additional detail):

**Functional training:** Practice of a functional skill that is meaningful, goal directed, and task oriented. Patient will experience errors and self-correct as the program becomes more automatic and integrated. An example would be gait training on a tile surface, rugs, inclined surfaces, compliant surfaces such as grass, and so on to practice ambulation.

**Body system or impairment training:** Treatment focus is on correcting a body system problem during an activity (e.g., pure muscle strengthening, stretching, sensory training, endurance training).

**Augmented feedback training:** Patient needs external feedback (auditory, visual, kinesthetic) and control over the motor program running the target task. This will limit the response patterns (e.g., reducing degrees of freedom, reduction or enhancement of tone) for successful performance of the desired movement (e.g., handling techniques, body-supported treadmill training, constraint-induced training).

**Learning-based sensorimotor retraining:** Treatment focus is placed on improving sensory discrimination dysfunction as a consequence of somatosensory, premotor, and motor cortical disorganization resulting from trauma, degeneration, or overuse.

Clients with CNS damage often benefit from combining interventions from the above categories. An example of this might be the early phase of partial body-weight supported treadmill training. In the early phases, a therapist or assistant is guiding the client’s leg during swing and stance phases while the body harness supports a portion of the client’s total weight (augmented feedback) to assist the postural system in running appropriate programs to maintain balance and decrease the power needed to generate a more normal gait pattern. This augmented intervention is being done in a functional pattern within an environment that perturbs the client’s base of support under the normal center of gravity.

Thus, this perturbation moves each foot reciprocally backwards and the body forward, triggering a stepping reaction. In the case of an individual after a cerebrovascular accident (CVA), one leg will still respond normally, thus helping to trigger a between-limb reciprocal stepping action of the involved leg. In the case of bilateral involvement, both legs may need placement, requiring two people to assist. The activity may be classified as impairment training, with the focus on appropriate power production or cardiovascular fitness, leading to functional training to trigger normal motor programs necessary for gait. Simultaneously, augmented training done by a therapist includes manual assistance in the direction, rate, and placement of the involved leg throughout the gait cycle. In this previous example, therapists need to make sure they are aware of the patient’s center of gravity and do not move the foot before it should be at “push off” during the gait cycle. This activity would not be considered functional training until the client could reciprocally move both legs during the gait pattern without the need of the harness for postural support and the therapist to guide the movement.

When selecting from a variety of treatment interventions (neuromuscular retraining, functional training, impairment training, and augmented feedback training), it is important for the therapist to consider that each one is based on different strategies and rationales that contribute to the expected outcome. All interventions should address the needs of the patient and must consider any emotional and cognitive restraints. Although these intervention methods can be used simultaneously or in various combinations, the clinician needs to consider which aspect of the intervention falls into which treatment classification. Although various treatment outcomes can be measured, if classification of each treatment variable is not identified, the determination of how and why the outcomes were influenced by the intervention becomes confusing and difficult to distinguish. Without understanding the interactions of intervention methods and the outcome, treatment effectiveness and future clinical decision making remain unpredictable, and unique practice
patterns and pathways are hard to identify with consistency. A master clinician who is effective with all patients but does not know how and why the decisions are made along the intervention pathway cannot leave a legacy of effectiveness that will ever lead to efficacy. Although not all graduates or inexperienced clinicians may have the innate aptitude or potential to become master clinicians, if professionals understand the verbal, spatial, cognitive, fine and gross motor, and emotional sensitivity variables that play a role in the evolution toward mastery, educational experiences might be able to nurture future colleagues along this pathway and help those with mastership potential reach that level of function earlier in their professional careers.

The reader must also remember that intervention encompasses multiple interactive environments where intervention decisions are often made moment by moment during any treatment period. The challenge to the educated clinical professional is to determine what is being done, why it is working, how to continue its effectiveness, and how to determine the progress of the successful intervention. The clinician must also determine how to empower the client (emotionally, cognitively, and motorically) to take over the intervention with inherent, automatic mechanisms that lead to fluid, flexible, functional outcomes independent of both the therapist and the environment within which the activity is occurring. It is not until clinicians can determine effective treatment outcomes from various interventions that efficacy within a research laboratory can be studied without speculation and hypothesis formation based on speculation. Effectiveness is the first way to determine evidence-based practice. Once effectiveness has been established through case studies and larger controlled studies within the clinical environment, researchers can begin to tease out separate variables and establish efficacy as part of evidence to justify clinical decision making.

HISTORY OF DEVELOPMENT OF INTERVENTIONS FOR NEUROLOGICAL DISABILITIES

In the mid 1900s the interventions by physical therapists (PTs) and occupational therapists (OTs) were separate. Generally, PTs worked on gross motor activities with specific emphasis on the lower extremities and the trunk, whereas OTs worked on the upper extremities and fine motor activities. Both professions focused on daily living skills, with those involving the arms falling within the domain of the OT and those involving the legs falling within the domain of the PT. Activities that required gross motor skills such as sitting, coming to stand, walking, walking with assistive devices, and running fell within the purview of the PT, whereas grooming, hygiene, and eating were the responsibility of the OT. Today, this approach is considered ridiculous owing to our understanding of motor learning, neuropsychology, and motor programming and control. In the past it was also accepted that the PT worked on specific system problems such as weakness, inflexibility, lack of coordination, and voluntary control, whereas the OT worked on functional activities integrated within the environment (such as dressing) and the patient’s emotional needs and desires (occupational expectations). According to the terminology of the mid to late twentieth century, PTs were trained to identify and correct impairments that caused functional limitations, whereas OTs were trained in activity analysis and treatment that identified and optimized the functional activities that resulted from the impairments. Few clinicians seemed to focus on the sequential or interactive aspect of lack of function with specific impairments. Thus after the onset of a stroke the PT would strengthen and evaluate range of motion (ROM) of the leg and trunk, whereas the OT would encourage the patient to try to functionally use the arm. The PT would be preparing the patient to transfer out of bed and get into and out of a chair and then helping the patient walk, whereas the OT would be preparing the patient to use the arm in functional activities such as grooming or eating. Both therapists hoped the patient would accept responsibility for continued improvement through practice. What both professions discovered was that the patient generally did not regain normal motor control. He or she might be able to walk and might be able to move the shoulder, but the movement strategies were generally stereotypical, were abnormal in patterns, and took tremendous effort by and energy from the patient to perform. Over time, clients lost the motivation to even try, and thus what had been gained through therapy may have been lost from lack of practice once they got home. There was also minimal recovery of functional hand use, often because of the tremendous effort a patient had to use to move the shoulder to place the hand somewhere. Once that effort had been used the tightness and increased tone in the hand prevented functional use. Although functionally independent skills as measured on the Functional Independence Measure were achieved, normal movement patterns and normal motor control were rarely restored, and quality of life was clearly affected for the patient and family.

During the decade or two before the 1960s, some talented and intelligent clinicians began to question the traditional intervention strategies used by the OT and PT. These pioneers in neurological rehabilitation set the stage for the development of new concepts that allowed basic science to infiltrate the clinical arena. The intervention strategies of Jean Ayres, Berta Bobath, Signe Brunnstrom, Margaret Johnstone, Susanne Klein-Vogelbach, Margaret Knott, Dorothy Voss, Margaret Rood, and others became popular. Colleagues observed these master clinicians and could easily see that the “new” interventions were much more effective and provided better outcomes than previous interventions. Each approach focused on multisensory inputs introduced to the client in controlled and identified sequences. These sequences were based on the inherent nature of synergistic patterns and motor patterns observed in humans and lower-order animals or a combination of the two. Each method focused on the individual client, the specific clinical problems, and the availability of alternative treatment approaches within an established framework. Some of these approaches focused on specific neurological medical diagnoses. The treatment emphasis was then on specific patients and their related movement disorders. Children with cerebral palsy and head injuries and adults with hemiplegia were the three most frequently identified medical diagnostic categories. In 1968 at Northwestern University a large conference was held and laid the foundation for the first STEP conference (Northwestern University Special Therapeutic Exercise Project [NUSTEP]). Most of these master clinicians, along with research scientists of the day, came together to try to (1) identify the commonalities...
and differences between these approaches, and (2) integrate and use the neuroscience of the day to explain why these approaches worked. \(^{34}\) Since the 1970s, substantial clinical attention has also been paid to children with learning and language difficulties. \(^{5,13,35}\) Now these concepts and treatment procedures have been applied across the age spectrum for all types of medically diagnosed neurological problems seen in the clinical setting (refer to Section II of this text). This expansion of the use of any of the methods for any pathological condition manifested by insults from disease, injury, or degeneration of the brain seems to be a natural evolution given the structure and function of the CNS and commonalities in system problems and activity limitations that take the individual away from participating in life.

Fortunately, most dogmatism no longer persists with respect to territorial boundaries identified by clinicians using some specific intervention methods. A conference in 1990 \(^{36}\) played a significant role in challenging the relevance of these territorial boundaries and stressed the adoption of a systems model when looking at impairments, activity limitations, and participation in life interactions. \(^{37}\) As the boundaries for interventions began blurring, intervention approaches such as proprioceptive neuromuscular facilitation (PNF) were then integrated into the care of clients with orthopedic problems and patients with neurological impairments. Today, few universities within the United States teach separate sections or units on specific approaches, but rather teach students to identify problems, when they are occurring in functional programs, and what bodily systems might be the cause of those activity limitations.

For example, assume that a client with hemiplegia exhibited signs of a hypertonic upper-extremity pattern of shoulder adduction, internal rotation, elbow flexion, and forearm pronation with wrist and finger flexion. Brunnstrom's \(^{8}\) would have identified that pattern as the stronger of her two upper-extremity synergies. Michels, \(^{21}\) although using an explanation similar to Brunnstrom's to describe the pattern, would have elaborated and described additional upper-extremity synergy patterns. Bobath would have asserted that the client was stuck in a mass-movement pattern resulting from abnormal postural reflex activity. \(^{30}\) Although the conceptualization of the problem certainly determined treatment protocols, the pattern all three clinicians would have worked toward was shoulder abduction, external rotation, elbow extension, forearm supination, and wrist and finger extension. The rationale for the use of this pattern within an intervention period would vary according to the philosophical approach. One clinician might describe the pattern as a reflex-inhibiting position (Bobath). \(^{31}\) Another would describe the pattern as the weakest component of the various synergies (Brunnstrom), \(^{8}\) whereas still another might identify the pattern as producing an extreme stretch and rotational element that inhibited the spastic pattern (Rood). \(^{25}\)

How those master clinicians sequenced treatment from the original hypertonic pattern to the opposite pattern and then to the goal-directed functional pattern would vary. Some would facilitate push-pull patterns in the supine and side-lying positions and rolling. Others would look at propping patterns in sitting clients or at weight-bearing patterns of clients in the prone position, over a ball or bolster, or in partial kneeling. All have the potential of improving the functional pattern of the upper extremity and modifying the hypertonic pattern. One method may have been better than the others given a particular patient, but in truth improved patient performance may have stemmed not from the method itself, but rather from the preferential CNS biases of the client and the variability of application skills among the clinicians themselves. That is, when a therapist intentionally uses specific augmented feedback to modulate the motor system's response to an environment but does not identify the other external feedback present within that environment (e.g., lighting, sound, touch, environmental constraints), therapeutic results will vary. Because of variance, efficacy of intervention is often questionable, although the effectiveness of that therapist may be easily recognized.

Because of the overlap of treatment methods and the infiltration of therapeutic management into all avenues of neurological dysfunction, various multisensory models were developed during the early 1980s. \(^{13,38-41}\) These have continued to evolve into acceptable methods in today's clinical arena. Although these models attempted to integrate existing techniques, in reality they have created a new set of holistic treatment approaches. In July 2005 the III STEP conference \(^{42}\) was held in Utah to again bring current theories and evidence-based practice into today's clinical environment. The history of the three STEP conferences demonstrates the evolution of evidence-based practice from the first conference, where basic science was the only evidence to justify treatment, to the second conference, where evidence in motor learning and motor control began to bring efficacy to intervention. By the time the third conference was held, the research in neuro/movement science regarding true efficacy within practice and the reliability and validity of our examination tools set the stage for standards in practice. \(^{43}\) Where the next conference will take the professions and how soon that will occur is up to colleagues in the future. No proceedings from that third conference were published, but over the preceding years articles covering most of the presentations had been published in the Journal of Physical Therapy. The ultimate goal would be to develop one all-encompassing methodology that allows the clinician the freedom to use any method that is appropriate for the needs and individual learning styles of the client as well as to tap the unique individual differences of the clinician. Although intervention today is based on an integrated model, the influence of third-party payers, the need for efficacy of practice, and time constraints often factor into the therapist's choice of intervention. Visionary and entrepreneurial practice ideas that have the potential to be effective will always be a challenge to future therapists. Those ideas generally originate within the clinical environment and not the research laboratory. For that reason, clinicians need to communicate ideas to the researcher, and then those researchers can develop research studies that test the established efficacy or refute that effectiveness. Few researchers are master clinicians, and few clinicians are master researchers; thus collaboration is needed as the professions move forward in establishing evidence-based practice.

Today's therapists have replaced many of the existing philosophical approaches with patient-centered therapeutic intervention. Patient performance, available evidence, and the expertise of the clinician often play a key role in the specific decision regarding an intervention. When confronted with an abnormal upper-extremity pattern, today's...
therapist may choose to work on improving the movement pattern using a functional activity. Control of the combination of movement responses and modulation over specific central pattern generators or learned behavior programs will allow the patient opportunities to experience functional movement that is task oriented and environmentally specific. With goal-directed practice of the functional activity, neuroplastic changes, motor learning, and carryover can be achieved. With a better scientific basis for understanding the function of the human nervous system, how the motor system learns and is controlled, and how other body systems, both internal and external to the CNS, modulate response patterns, today’s clinicians have many additional options for selection of intervention strategies. Whether a patient would initially benefit best from neuromuscular retraining, functional retraining, or a more traditional augmented or contrived treatment environment is up to the clinician and is based on the specific needs identified during the examination and evaluation process.

No matter what treatment method is selected by a clinician, all intervention should focus on the active learning process of the client. The client should never be a passive participant, even if the level of consciousness is considered vegetative, nor should the client be asked to perform an activity when the system problems only create distortion or demonstrate total lack of control of the desired movement. With all interventions requiring an active motor response, whether to change a body system impairment such as by increasing or reducing the rate of a motor response, modulate the tonal state of the central pattern generators and learned motor behaviors, or influence a functional response during an activity, the client’s CNS is being asked to process and respond to the external world. That response needs to become procedural and controlled by the patient without any augmentation to be measured as functionally independent. In time, the ultimate goal is for the client to self-regulate and orchestrate modulation over this adaptable and dynamic integrated sensorimotor system in all functional activities and in all external environments.

A problem-oriented approach to the treatment of any impairment or activity limitation implies that flexibility and neural adaptation are key elements in recovery. However, adaptation should not be random, disjointed, or non-goal oriented. It should be based on methods that provide the best combination of available treatment alternatives to meet the specific needs of the individual. Development of a clinical knowledge bank enables the therapist to match treatment alternatives with the patient’s impairments, activity limitations, objectives for improved function, and desired quality of life. A professionally educated therapist no longer bases treatment on identified approaches, although specific aspects of those approaches may be treatment tools that will meet the client’s needs and assist him or her in regaining functional control of movement. Treatment is based on an interaction among basic science, applied science, the therapist’s skills, and the client’s desired outcomes.

In most cases, multiple intervention strategies must be included, but the therapist needs to be able to identify why those selected treatments will lead to system improvement as well as documenting those findings using reliable standardized and acceptable clinical methods and terminology. These intervention strategies must be dynamic yet also understandable and repeatable. As new scientific theories are discovered, new information must be integrated to continue to modify treatment approaches.

**INTERVENTION STRATEGIES**

**Functional Training**

Functional training is a method of retraining the motor system using repetitive practice of functional tasks in an attempt to reestablish the patient’s ability to perform activities of daily living (ADLs) and participate in specific life activities such as golfing, fly-fishing, basketball, or bridge. This method of training is a common and popular intervention strategy used by clinicians owing to the fact that it is a relatively simple and straightforward approach to improving deficits in function. A system problem such as weakness in the quadriceps muscle of the leg can be treated by muscle strengthening in a functional pattern that can be easily measured. Because of its inherent simplicity, functional training is sometimes misused or abused by clinicians. Most patients with neurological deficits have multiple subsystem problems within multiple areas, which forces the CNS to use alternative movement patterns in order to try to accomplish the functional task presented. If the therapist accesses a motor plan such as transfers but allows the patient to use programs that are inefficient, inappropriate, or stereotypical, then the activity itself is often beyond the patient’s ability.

The patient may learn something, but it will not be the normal program for transfers. This activity often leads to additional problems for the client.

In Chapter 8 the steps involved in the examination process are explained in detail. The intricate relationship of body system problems, impairments, and functional limitations that decrease participation in the rehabilitation process are discussed. Functional training can be implemented once the clinician has identified the client’s activity limitations. The clinician must first answer the questions “What can the client do?” “What limitations does the client have when engaging in functional activities?” “Are there motor programs that are being used to substitute for normal motor function?” and “Can the therapist use functional training to improve body system problems within the context of the functional skill?” Once the therapist has an understanding of the reasons for any activity limitation and can alleviate substitution and compensation for the deficit, functional tasks should be identified and practiced.

**The Effect of Functional Training on Task Performance and Participation**

The main focus of functional training is the correction of activity limitations that prevent an individual from participating in life. However, through repetitive practice of functional tasks and gross motor patterns, many of the client’s impairments can also be affected. For example, if a therapist practices sit-to-stand transfers with a client in a variety of environments and performs multiple repetitions of each type of transfer, not only can learning be reinforced, but the client can also gain strength in the synergistic patterns of the lower extremities that work against gravity to concentrically lift the client off of the support surface and eccentrically lower him or her down. Weight bearing through the feet in a variety of degrees of ankle dorsiflexion during transfer training...
will effectively place the ankles in functional positions. The act of standing also helps the trunk and neck extensors to engage in postural control. Varying the speed of the activity during the treatment can stimulate cerebellar adaptation to the movement task. Moving from one position to another with the head in a variety of positions stimulates the vestibular apparatus and may assist in habituating a hypersensitive vestibular system, allowing the client to change body positions without symptoms of dizziness, resulting in a higher quality of life. Repetitive practice also affects the vasomotor system and may assist in habituating postural hypotensive responses.

A good example of the misuse of functional training is the “hag-and-drag” method of gait training in the parallel bars. This method finds the therapist literally dragging the client through the length of the parallel bars in an attempt to elicit some sort of movement response from the client. The therapist then labels this procedure “gait training.” Clearly, this approach will result in the client eventually learning dysfunctional, inefficient motor programs. Before long, as the client learns to run these dysfunctional programs procedurally, the clinician will realize that he or she has created a bigger problem, and a considerable amount of time and resources may be required to undo the damage that was created by limiting the available movement strategies, limiting the variability within practice, and ultimately restricting the plasticity of the nervous system. Similarly, forcing the axial trunk musculature to compensate for lack of motor control within the elbow and wrist will result in dysfunctional upper-extremity movement patterns.

Functional training is the best method of intervention when the client can run normal programs that have some limitation such as poor ROM or inadequate muscle power from disuse. In that way, functional training will run normal programming until fatigue sets in, which may be after only one or two repetitions. Increasing the repetitions and/or the power necessary to run the programs will lead to functional improvement. In using functional training, accurate standardized measurement tools that clearly illustrate change will quickly tell the therapist whether the change is in the direction of more functional control or additional limitation.

An intervention approach in the early 1990s that evolved as an offshoot of functional training was labeled clinical pathways. These pathways were established by health care institutions to improve consistency of management of patients who met specific medical diagnostic criteria. It has been proven that the implementation of these pathways reduces variability in clinical practice and improves patient outcomes. Health care practitioners also became aware that some individuals do not fall into these pathways and that some individuals do not fall into these pathways and need to be treated according to the specific clinical problems that the patients were presenting.

Selection of Functional Training Strategies

What is the “ideal” procedure for effectively and efficiently using functional training as a treatment intervention? First, it is suggested that the clinician identify and select procedures that will use the client’s strengths to regain lost function and correct system limitations—“What can the client do?” The clinician is also advised to avoid activities that may be too difficult and elicit compensatory strategies that may result in the development of abnormal, stereotypical movement and potentially create additional impairments. An example of this is using transfer training when the patient is unable to keep the program within the limits that define it as a transfer. What instead happens is that the patient would begin to fall. Once in that situation, the patient is then working on approaches to prevent from falling, not activities that allow the patient to safely transfer. The therapist’s decision regarding what functional patterns or activities to practice, and in what order, will depend on several factors. The therapist must choose functional activities that are necessary for the client to perform independently or manage with less help before being discharged home. For PTs, safe transfers and ambulation are generally the focus of functional training. For OTs, independent bathing, dressing, and feeding are major foci. Yet both PTs and OTs also need to be sensitive to the activities that the patient or the patient’s family want to improve to enhance the quality of life for everyone involved in the person’s case. The ability to get in and out of a car might be the most important activity for the client to learn because he or she needs to make frequent trips to the physician’s office and the primary caregiver has cardiac problems and is unable to assist the patient in transferring without placing his or her own cardiac system at extreme risk.

It is suggested that the clinician modify or “shrink” the environment to allow normal motor programs to run. An example of this might be to limit the ROM an individual is allowed while performing a rolling pattern. The therapist may opt to start this movement with the patient in a side-lying position. The amount of patient movement may be even further limited by the therapist stabilizing the patient’s hips by using the therapist’s one leg in kneeling position against the patient’s posterior pelvis and the therapist’s other leg in half-kneeling position with the top leg of the patient over the therapist’s half-kneeling leg. In this way the individual’s body can be totally controlled by the therapist; the patient can be encouraged to roll the upper part of his trunk both backward with the arm reaching back and then forward with the arm coming across the body toward a weight-bearing pattern on the hand. The therapist can change the rate of movement and also use his or her knees to control the range that the patient is allowed. The environment can be progressively “enlarged” to allow the client to perform the activity in a functional context. Although this narrowing of the functional environment would be considered a contrived environment and must not be recorded as functional as defined in a functional or activities-based examination, it may allow the nervous system the opportunity to control and modify the motor programs within the limitations of its plasticity at the moment. Therefore this therapeutic technique could be used within a functional training environment or may fall into an augmented treatment approach category, given an individual who has neurological problems that prevent normal movement.

The goal of therapy is to move toward functional training as quickly as the client’s motor system can control the movement. As learning and repetition assist the CNS in widening the response pattern during a functional activity, the client’s ability to respond to variance within the environment will enlarge and assist in gaining greater independence.
An example of this application of functional training might be asking a client to perform a stand-to-sit transfer. The client is first guided down to sitting onto a large gym ball, a high-low table, or a stool that allows the client to sit only one fourth to one half of the way down before returning to stand. As the client develops increased strength and balance and improved control over abnormal limb synergies and tone in this pattern, then a smaller gym ball or a lower point on a high-low table can be used. Finally, the client is asked to sit down onto a ball/mat or chair that results in the patient sitting with the hips and knees at 90 degrees. Once the client can sit down and return to a vertical position, the next task will be to sit down, relax, and then stand up. Once that activity is done easily, the client will be functionally able to stand to sit and to reverse the movement pattern to sit to stand.

Although many clinicians understand the importance of carrying out motor tasks within an appropriate biomechanical, musculoskeletal, and sensorimotor window in which the client has the ability to perform procedures functionally, it may be argued that in many cases this particular type of treatment strategy is simply not possible in a real-world situation. For example, given the current health care environment, if the client is given a limited number of visits to achieve the desired outcome, the clinician may conclude that there is no choice but to “allow as many degrees of freedom as possible” or, in other words, to “force the window open” no matter the abnormal movement patterns used or the limitations in independent functional control that they may produce.

In summary, the clinician should first identify and emphasize the client’s strengths (“What can the client do?”) and use those strengths to efficiently and effectively achieve functional change. Next, the clinician must prioritize what systems or activities the client truly needs to change. The choice of what activities to emphasize during therapeutic training always poses a dilemma to therapists. Although it may be ideal for the client to eventually be able to ambulate independently on all surfaces without any assistance or reach for any object in and from any spatial position, it may be more important initially for the client to be able to safely transfer from the bed to the wheelchair, sit independently while someone assists with dressing, or walk and transfer onto and off of the commode independently at home. One should keep in mind that although several skills may be learned by training them simultaneously, it may make more sense to concentrate on the safe performance of one or two necessary functional tasks rather than having the client end up being able to perform multiple tasks that require considerable outside assistance for safety. The need to work functionally on additional activities may also be an opportunity for the clinician to request additional therapy visits for the client, arguing that there is a reasonable expectation that more intervention would result in a greater increase in function and a greater decrease in the risk for potential injury than if the intervention were not continued. The use of valid and reliable functional outcome measures becomes critically important in case management. These tools objectively measure the effect of the intervention, help predict the potential risks if the therapy is not continued, and ultimately aid in the justification to continue therapeutic intervention.

### CASE STUDY 9-1 ■ FUNCTIONAL TRAINING: AMBULATION

Teaching a client to ambulate can be approached in many ways. Assume that the objective for a particular session is ambulation. First, the client may be asked to ambulate in the parallel bars using the upper extremities to assist in forward progression of the movement to decrease fear and to assist in maintaining balance. Once the patient can perform this ambulatory activity, the therapist might decide to progress the patient’s ambulation by introducing a walker, which has four points of support. Ambulating with the walker will again increase power production in the legs and create an environment of safety for the client. Once walking with the walker can be performed at various speeds and distances, the therapist may advance the activity to using two canes, then one cane depending on the client’s balance, coordination, and need. While the patient is practicing ambulating with cane(s), he may also be walking on a treadmill to increase endurance, velocity of gait, and power. Once the patient can ambulate safely with a cane, the therapist may decide to transition to walking without any assistive devices. Again the patient may first be asked to walk on a treadmill while holding on with his arms until he feels safe walking and no longer needs an assistive device. The therapist could transition to ramps, obstacles, uneven ground, and so on. All these activities would require the individual to begin with functional control over the program for ambulation. All the activities are focused on regaining independence in the functional activity of walking, using repetitive practice. These therapeutic devices assist the patient in successfully practicing the entire gait cycle on both legs. In time, the patient is asked to continue walking without the need of the assistive devices and will continue to practice that activity as functional movement or is considered functionally independent with the use of an assistive device. The therapist must also remember that when introducing an assistive device, that device itself will usually limit the environments within which a patient can ambulate independently.

### Conclusion

One important variable that has clearly been identified with respect to functional training is “task specificity.” Although it is important that a patient be independent in as many ADLs as possible, often the therapist, the patient, and the family need to prioritize which activities are most important to the quality of life of the patient. If walking into the mountains to do “birdwatching” is one important goal to the patient, then creating an environment that would closely resemble the environment of that activity is crucial. Similarly, practice within that environment is a key to successful carryover (see Chapter 4). If the patient wants to walk into the mountains and the family expects the patient to walk into his or her old job, a therapist must accept that motivation will drive behavior and task specificity will drive learning. Carryover into any other functional activity such as walking into the office building in order to go back to work may not be the motivating factor that will guide that individual’s desire to perform that motor task. Whether the patient ever goes back to work is not the variable that should be used as
part of the motivational environment for task-specific gait training geared to walking in the mountains and is not a decision for which the therapist is responsible. Therapists need to allow the patient to tell them what will be the most important task and the specificity of that task to optimize motor learning and functional recovery.

**Body System and Impairment Training**

As mentioned in Chapter 8, the therapeutic examination results in the identification of activity limitations and possible body system and subsystem impairments that are causing the functional movement disorders. Impairment training is another intervention strategy that involves the correction of impairments with the expectation that improving these impairments will result in a corresponding improvement in function. For example, when a client has the inability to stand up without assistance (activity limitation) and the clinician determines the cause to be lower-extremity weakness, an appropriate approach may be to strengthen the lower extremities (impairment training). Numerous studies have shown the effectiveness of impairment training in improving the functional performance of individuals with neurological conditions such as cerebral palsy, stroke, multiple sclerosis, Parkinson disease, and other neuromuscular diagnoses. The strengthening intervention selected should reflect the task and the environment within which the impairment was identified. The clinician should attempt to create a training situation so that the client may be able to run the necessary motor programs with all the required subsystems in place. For example, training sit to stand with weakness in the hip and knee extensors is much less likely to automatically result in the improvement of sit-to-stand function if the therapist begins the activity in sitting where generation of extension is most difficult, than if the strengthening training was performed with repetition of practice starting in standing and going to sit and back again to stand. By decreasing the degrees of freedom of the eccentric control of the hips and knees when going from stand to sit, the functional training activity has turned into specific impairment training. The therapist can ask the patient to eccentrically lengthen the extensors only in a limited range and then concentrically contract back to standing. As the power increases, the degrees of freedom can also be enlarged until the patient is able to complete the task of stand to sit while simultaneously regaining the sit to stand pattern. In pure impairment training a patient might also be asked to straighten the knee when sitting or to extend the hip when prone. These three exercises have the potential of training impaired strength, but only the first example forces the training within a functional pattern. Similarly, the therapist could train the sit-to-stand pattern using various seat heights that encompass many of the components that force the use of normal movement synergies and postural control, using the environment in which that activity is typically performed, versus performance of strengthening exercises against resistance in an open chain exercise program.

The decision to treat the impairments causing the activity limitations or to correct the functional problems themselves is influenced by myriad factors. It would appear that for certain tasks to be completed the client must possess the “threshold amount” of basic movement components required for the task. Task specificity within this limited environment will result in more meaningful changes in function. Impairment training can be a very effective treatment approach. It can lead to functional gains after an improvement in a specific body system problem. This can lead to improved participation in not only normal functional activities but also activities that should lead to a better quality of life.

Often, clients with neurological trauma or disease cannot begin therapy with functional or impairment training because of the degree and extent of impairments within the entire CNS. Therapists must then choose augmented therapeutic interventions that externally guide the clients’ learning through hands-on and environmentally controlled techniques such as a body-weight–supported treadmill training (BWSTT). It is cautioned that the therapist should not consider these interventions as functionally independent until the individual’s success is based on internal self-regulation of movement. The clinician must continually strive to transfer control to the client by widening the window of independence and limiting the manual or verbal guidance used during therapy.

**Augmented Therapeutic Intervention**

As discussed in the previous section, some treatment alternatives require little if any hands-on therapeutic manipulation of the client during the activity. For example, the patient practices transfers on and off many support surfaces with standby guarding only. Thus the client self-corrections or uses inherent feedback mechanisms to self-correct error to refine the motor skill. This ultimate empowerment of the client allows each individual to adapt and succeed at self-identified and self-motivated objectives first with augmented intervention and finally without any assistance. Often, allowing the client to try to succeed without assistance enables the therapist to evaluate what components of the task the client can control and what components are not within the client’s current capabilities, especially if normal, fluid, efficient, and effortless movement is the desired outcome. In some cases the therapist may use hands-on skills or augmented aids such as BWSTT, which would substitute for many aspects of the environment and allow the client to succeed at the task—but the control and feedback during the activity would be considered augmented feedback and fall into that classification.

These augmented techniques make up a large component of the therapist’s specific interventions tool box. The difference between augmented and functional training might be the need for the therapist or piece of equipment to be part of the client’s external environment for the client to succeed at the task. For example, in BWSTT a harness is used to take away the demand of gravity on the limbs during gait and the demand of the postural trunk and hip muscles for stability. Before the therapist or the patient can consider the movement as independent, those aspects must be removed from the environment. In the previous example, the individual needs to transition from maximal body weight support during ambulation to not needing any external support during ambulation. The client must assume total ownership of the functional responses. Then and only then has independence been achieved. At that time, functional retraining can be used with the intent of enlarging the environmental parameters to allow for maximal independence. Figure 9-1 illustrates this concept of functional versus contrived
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intervention, which must be constantly considered throughout any treatment session. Augmented techniques are often the early choices for treatment of patients who have neurological insults. It cannot be emphasized enough that once the client has the ability to perform without augmented methods and does so in functional, efficient ways, those augmented techniques need to be selectively eliminated.

Once a clinician has chosen to augment the clinical environment, the client needs to learn efficient motor behaviors within the limitations of that environment. The client influences the therapist’s decision-making strategies by selecting inefficient or ineffective motor responses to a given task demand. If the response is effortless, efficient, and noninjurious to any part of the body and meets the client’s expectations and goals, then the therapist knows the strategies selected were effective even if the therapist augmented the intervention. If the movement itself is available to the client, then there is a high probability that the client will be able to regain that movement control, regardless of the need for early augmentation to achieve the skill. If the response does not meet the desired goal for any reason, then the therapist must determine why. Often, it is because the therapist did not identify the correct body system problems. Many correct solutions may answer the question. Which solution is best may be more client than approach dependent. Yet if flexibility means that the therapist selects any component of any method that helps the client reach an objective, then the therapist is confronted with hundreds—if not thousands—of various treatment choices. If the treatment procedures used introduce information to the client through sensory systems, then from a neurological perspective a limited number of input systems or modalities are available. The myriad treatment procedures are transformed into neurochemical and electrophysiological responses that must travel along a limited number of pathways in the nervous system. Thus, many different treatment procedures may produce similar types of neurotransmission. The temporal and spatial sequencing or timing of the input will vary according to the technique and the specific application. The clinician has little basis for decision making without a comprehensive understanding of the neurophysiological mechanisms of (1) the various techniques introduced to modify input, (2) where that

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Contrived versus functional therapeutics. (Modified from the original work of Jan Davis, OTR, San Jose State University.)
information will be processed and how that might affect motor output, (3) prior learning and the ability for new learning, and (4) the client’s willingness and motivation to adapt. The reader is referred to Chapter 1 (Figure 1-1); Chapter 4 on motor control, motor learning, and neuroplasticity; and Chapter 5 for a discussion on motivation.

The number of available contrived or augmented feedback techniques is almost infinite. This section presents an overview of a classification system that can be used to help the reader develop a greater understanding of why certain responses occur and why the selection of certain techniques is appropriate and should positively affect the desired motor responses. This section focuses on intervention strategies that have been accepted, have been used within the traditional Western health care model, and are efficacious. Some alternative approaches to intervention that are not necessarily classified as traditional within this chapter are introduced in Chapter 39. There are other classification systems a clinician might use when analyzing movement problems seen in patients with neurological dysfunction. For example, a therapist may see in a patient a problem primarily with tone, such as hypertonicity, hypotonicity, rigidity, dystonia, flaccidity, intentional and nonintentional tremors, ataxia, and combinations of or fluctuations in the total movement strategies. Given this specific classification schema, one still uses the available treatment strategies or uses an input modality that may modify the specific tone problem that was causing the movement dysfunction.

The primary goal of this section is to help the reader develop a classification system based on the primary input modality used when introducing an augmented treatment technique to facilitate a sensory system and provide feedback to the CNS in order to help a client learn or relearn motor control. The reader has been provided with an in-depth reference to the specific neurophysiological approaches in the past also discussed in Chapter 1, and only a brief overview has been included within this chapter. In-depth discussion of some basic treatment strategies, explanations of less familiar techniques, and current approaches gaining popularity within the clinical area of movement analysis are found within the body of this section.

When the primary input system for a technique is identified, at no time do we suggest that it is the only input system affected. For example, when a proprioceptive technique is introduced, tactile cutaneous receptors are also simultaneously firing. If there is a “noise” component (such as with vibration or tapping with the fingers), then auditory input has been triggered as well. There is evidence that a given sensory modality may “cross over” or fuse with a completely different modality, helping in the synthesis of motor responses. In addition, there is evidence that the principles of neuroplasticity are applicable across modalities (e.g., auditory, visual, vestibular, somatosensory). Sometimes responses occur in a modality that does not appear to be related. For example, olfaction may improve tactile sensitivity of the hand. This concept is called cross-modal training or stimulation. Yet a classification schema based on a primary modality promotes logical problem solving because the therapist can select from available treatment procedures that theoretically provide similar information to the CNS and help in the organization of appropriate motor responses. The motor system and its various motor programmers adapt to the environment to achieve functional motor output toward a goal. Both external and internal feedback are critical for adaptation and change. External feedback in this chapter is considered a mechanism to help the client’s CNS optimally learn and adapt. Obviously, as the patient learns, internal feedback will allow the person to run feed-forward motor programs without the need for external feedback for control. External feedback will, it is hoped, be used only when the outside surrounding needs the feed-forward program to change to adapt to a new environment (refer to the Chapter 4 section on motor learning). Therapists must realize that even if the primary goal may be to facilitate or dampen a motor system response, diverging pathways may also connect with endocrine, immune, and autonomic systems. According to motor control theory, the clinical picture is a consensus of all interacting body systems (see Chapter 4). Research tools are not yet available to measure those systems interacting simultaneously, although functional magnetic resonance imaging (fMRI) studies are beginning to help researchers and clinicians identify what happens to the nervous system with input from the environment and how that information is processed. Efficacy using reliable and valid measurement tools must then be based on outcomes, with an understanding of the best available scientific knowledge as a rationale for why the outcome is present.

This classification system is based on identified input, observed responses, current research on the function of the CNS, and the various systems involved in the control and modification of responses. An understanding of normal processing of input and its effect on the motor systems helps the clinician evaluate and use the intact systems as part of treatment. Research with fMRI is now allowing greater insight into specific brain regions that are being used during various cognitive and motor activities. Yet the specific interactive nature of multisensory input, memory, motivation, and motor function is still unknown. When the response to certain stimuli does not help the client select or adapt a desired motor response, then the classification schema for augmented input provides the clinician with flexibility to select additional options. This can be done by spatially summatiting input, such as increasing the rate of the quick stretch or increasing the time between inputs to give the system ample time to respond.

Many factors can influence motor behavior, such as the methods of instruction, the resting condition of the nervous system, synaptic connections, cerebellar or basal ganglia or cortical processing, retrieval from past learning, motor output systems, or internal influences and neuroendocrine balance. Figure 9-2 illustrates and simplifies this total system. Its clinical implications become clearer if the therapist retains a visual image of the client’s total nervous system, including afferent input, intersystem processing, efferent response, and the multiple interactions on one another. At any moment in time, multiple stimuli are admitted into a client’s input system. Before that information reaches a level of primary processing, it will cross at least one if not many synaptic junctions. At that time the information may be inhibited, excited, changed or distorted, or allowed to continue without modification. If the information is at the first synapse, the patient will have no sensation. If it is inhibited at the thalamus, again the patient will not perceive sensation,
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but that does not mean other areas of the brain will not be sent that information, because sensory information is also sent to a variety of areas after that initial synapse. Research studies have found that sensory input information may even affect gait and other movement patterns even if the patient has no perception of the input. If the input is changed, then the processing of the input will vary from the one normally anticipated. The end product after multiple system interactions will be close to, will be farther away from, or will seem to have no effect on the desired motor pattern. Furthermore, sensory processing can take place at many segments of the nervous system. Although the CNS is not hierarchical, with one level in total control over another, certain systems are biased to affect various motor responses. At the spinal level the response may be phasic and synergistic. Brain stem mechanisms may evoke flexor or extensor biases, depending on various motor systems and their modulation. Cerebellar, basal ganglia, thalamic, and cortical responses may be more adaptive and purposeful. Thus the therapist must try to discern where the input or the feedback is being affective or short circuited.

Remembering input as a possible option for intervention will always allow the therapist to differentiate the same five alternatives—no response, facilitating (heightening), inhibiting (dampening), distorting, or normal processing. These alternatives can occur anywhere in the system at synaptic junctions. Finally, motor output is programmed and a response is observed. If the response is considered normal, the clinician assumes that the system is intact with regard to the use and processing of the inputs. If the response is distorted or absent, little is known other than there is a lack of the normal processing somewhere in the CNS or an insufficient amount of input was used. One way to differentiate motor problems from problems with other systems is to use other functional activities that have programs similar to the body system program identified as impaired. If a program, such as posture, demonstrates deficiencies in one functional pattern, then the therapist must determine if it is also deficient in other patterns. If the postural motor problem affects all motor performance, then the therapist had determined that a motor program deficit exists and will have to determine how to correct that problem. If, on the other hand, the program runs smoothly and effortlessly when certain demands are taken away, such as resistance from gravity, position in space, need for quick responses, and so forth, then it may be that the problem is within another subsystem such as cognition, perception, the biomechanical system, or the cardio-pulmonary system or is a power-production problem that can be corrected by slowly increasing the demand on the postural system through repetitive practice using various additional input interventions. Differentially screening motor impairments as pure CNS motor problems (muscle recruitment, firing rate, balance) versus problems with another system (perception of vertical) becomes critical in a managed-care system that funds only a certain number of treatment sessions. Internal influences also need to be considered because they affect each aspect of the system. Once normal processing has been identified, understanding of deficit systems and potential problems can be analyzed more easily. To reiterate, this requires awareness of the totality of the individual—that is, the client’s personal preference of stimuli and the uniqueness of processing and internal influences.
A systems model requires simultaneous processing of multiple areas, with interactions being relayed in all directions. A client’s CNS and peripheral nervous system (PNS) are doing just that, and the therapist must develop a sensitivity toward the client as a whole while interacting with specific components (see Chapters 1, 4, 5, 6, and 39 for additional information). With input from the client and family, it is the therapist’s responsibility to select methods most efficacious and effective for each client’s needs in relation to that person’s specific neurological problems. (See all clinical chapters in Section II.) This viewpoint, based on a variety of questions, leads to a problem-oriented approach to intervention. Because the output or response pattern is based on alpha motor neuron discharge and thus extrafusal muscle contraction, the first question is posed: what can be done to alter the state of the alpha motor neuronal pool or motor generators? Second, what input systems are available, either directly or indirectly, that will alter the state of the motor pool? Third, which techniques use these various input systems as their primary modes of entry into the CNS? Fourth, what internal mechanisms need modification or adaptation to produce a desired behavior response from the client? Fifth, which input systems are available to alter the internal mechanism and what outcomes are expected? Sixth, what combination of input stimuli will provide the best internal homeostatic environment for the client to learn and rehearse a more optimal response pattern? For example, assume that a client with a residual hemiplegia resulting from an anterior cerebral artery problem has a hypertonic lower extremity that produces the pattern of extension, adduction, internal rotation of the hip, extension of the knee, and plantarflexion inversion of the foot. The answers to the first two questions are based on the knowledge that the proprioceptive and exteroceptive systems can drastically affect spinal central pattern generators and that these input systems are intact at spinal, brain stem, cerebellum, andthalamic levels and may even project to the cortex.

Appropriate selection of specific techniques—such as prolonged stretch using the tendon organ to modulate the hypertonic pattern, quick stretch or light touch to the antagonistic muscle, or any other treatment modality within the classification schema—will provide viable treatment alternatives. Awareness that a client’s response pattern is an inherent synergistic pattern and that it is further elicited by pressure to the ball of the foot leads to a better understanding of the clinical problem. Knowing that the client is unable to combine the alternative patterns, such as hip flexion with knee extension needed for the late stage of swing phase through the early aspects of stance phase during gait, the therapist can use the other inherent processes to elicit these and other patterns. BWSTT is an example of an augmented treatment intervention in which the clinician assists the patient to place the leg and foot with each step while the apparatus controls balance and posture to provide an experience of normal gait while requiring the patient to have only the strength to manage partial body weight. 142-149 Finally, techniques such as combining standing and walking with the application of quick stretch, vibration, or rotation, or having the client reach for a target or follow a visual stimulus while walking, provide a variety of combinations of therapeutic procedures to help the client learn or relearn normal response patterns. Furthermore, combining techniques gives the clinician a choice of various procedures and promotes a learning environment that is flexible, changing, and interesting. The therapist must, again, make the transition from applying contrived therapeutic procedures during functional tasks to allowing the client to practice the task without the therapist interceding and without external feedback. 140 In that way the client uses inherent feedback to self-correct feed-forward motor programming and then to continue running the appropriate movement strategies. This self-correction leads to independence, adaptability, and long-term learning (see Figure 9-2).

To avoid confusion about which peripheral sensory nerve fiber coming from the surface of the body or extremities is being discussed, the two primary methods of classifications (Gasser-Erlanger and Lloyd), along with a description of the functional component, have been included in Table 9-1 for easy referral. The other sensory systems will be presented separately to help the reader establish an appropriate classification scheme. The primary sensory input systems presented include proprioception, exteroception, vestibular, vision, auditory, taste, and smell. These sensory inputs have the potential to influence CNS structures including the thalamus, sensory and motor cortices, the cerebellum, the reticular formation, and the basal ganglia and thus to affect the descending fibers under their control.

**Proprioceptive System Integration of Stretch, Joint, and Tendon Receptors**

Proprioception as an input system has a direct effect on program generators at the spinal level. 141 Because of its importance in motor learning and motor adaptation to new or changing environments, however, proprioception also has significant connections to the cortical and cerebellar neural networks. Its divergent pathways have synapses within the brain stem, diencephalon, and spinal system. Proprioceptive input can potentially influence multiple levels of CNS function, and all those levels can potentially modulate the intensity or importance of that information through many different mechanisms. 141, 142 Proprioceptors are found in three peripheral anatomical locations: the stretch receptors, the tendon, and the joint. The afferent receptors responsible for relaying sensory information through those sites are discussed in the following subsections.

**Muscle Stretch Receptors**

**Stretch.** Stretch, quick stretch, and maintained stretch are all sensory input systems that use the stretch receptors in the muscles and heighten the motor pool. 143-145 Stretch simultaneously heightens both the muscle response to that stretch and potentially heightens the sensitivity of the agonistic synergy. It will also lower the excitation of the antagonistic muscle and those muscles that are part of the antagonistic synergy. Stretch information will be sent to higher centers for sensory integration and perception. The cerebellum uses this incoming feedback to maintain and/or regulate motor nuclei in the brain stem that will influence the state of the alpha and gamma motor neurons. This allows for cerebellar feed-forward regulation (refer to Chapter 21). There are many ways to apply stretch to the muscles. The therapist can use (1) the hands and their respective muscle power to apply a stretch, (2) a manual weight system of some sort that maintains the stretch through the range, (3) a suspension system such as used in Pilates exercises (see
B fibers: large myelinated fibers with a high conduction rate

A alpha

Large, fast fibers of alpha motor system (large cells of anterior horn to extrafusal motor fibers)

Muscle spindle; primary afferent endings (primary stretch or low threshold stretch; Ia tonic fibers respond to length, Ia phasic fibers respond to rate)

Tendon organ for contraction; respond to tendon stretch or tension

Muscle spindle; secondary afferent endings; tonic receptors responding to length

Exteroceptive afferent endings from skin and joints; respond to light or low threshold stretch

Bare nerve endings; joint receptors, mechanoreception of soft tissues; exteroceptors for pain, touch, and cold (low threshold)

A beta

II

Gamma motor system (small cells of anterior horn to intrafusal motor fibers)

Chapter 39), (4) the patient’s own body weight against gravity, (5) a complex robotic system that computerizes the amount of stretch depending on the individual’s specific data (see Chapter 38), or many other creative ways to apply stretch to muscle fibers within the belly of the muscle tissue. As stated previously, stretch can also be applied to the antagonist muscle or muscle synergy in order to dampen agonist function. Thus stretch can be used to enhance tone in the agonist or to decrease tone of the agonist through the antagonist. The therapist should always remember that even though a response may not look obvious, as long as the peripheral nerves and motor neurons within the spinal system are intact, these approaches will change the state of the motor pool.

Table 9-2 lists a variety of treatment procedures believed to use proprioceptive input from the muscles as a primary mode of sensory stimulation. The varying intensity, amount of tension, or rate of the stimuli, in addition to the original length of the muscle before application of the stimulus, will determine its firing. Remember, afferent information is projecting to many areas above the spinal system, and the result will be regulation or modulation, ultimately affecting activity.141

**Resistance and Strengthening.** Resistance is often used to facilitate intrafusal and extrafusal muscle contraction. Resistance can be applied manually, mechanically, and by the use of gravity. Resistance recruits more motor units in the target muscles. Although resistance can contract both in an isometric and an isotonic fashion, most contractions consist of a mixture of the two. Certain muscle groups, such as the flexors, benefit from isometric exercise, as well as isotonic exercise in both eccentric and concentric modes. Under normal circumstances, the flexors are used for repetitive or rhythmical activities. The extensors, on the other hand, usually remain contracted in an effort to act against the forces of gravity. Therefore the extensor groups benefit best from isometric and eccentric resistance.146

When resistance is applied to a voluntary muscle, spindle afferent fibers and tendon organs fire in proportion to the magnitude of the resistance. Resistance is more facilitative to an isometrically contracted muscle than in an isotonic contraction.35 As isometric resistance is increased or continued, more motor units are recruited, thereby increasing the strength of extrafusal contraction.26 Eccentric isotonic contraction refers to the lengthening of muscle fibers with resistance added to the distal segment, as in lowering the arms while holding a heavy weight. Eccentric contraction uses less metabolic output and promotes strength gains in less time.26 However, all types of muscle contraction will promote increased strength. Resistance is an important clinical treatment and has been used and will continue to be used by clinicians within multiple treatment philosophies over the next millennium.5,19,25,28,77,147-153 The complexity of neural adaptation after resistive exercises may lead to a different training environment depending on age, athletic status, and specific body system deficits.154 Combining resistive training with guided imagery or other types of adjunct interactions has conflicting results.154-156 Yet there are still questions regarding optimal resistive training and

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**TABLE 9-1 CLASSIFICATIONS OF PERIPHERAL NERVES ACCORDING TO SIZE**

<table>
<thead>
<tr>
<th>GASSER-ERLANGER</th>
<th>LLOYD</th>
<th>MOTOR (FUNCTIONAL COMPONENT)</th>
<th>SENSORY (FUNCTIONAL COMPONENT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A fibers: large myelinated fibers with a high conduction rate</td>
<td>A alpha</td>
<td>Ia</td>
<td>Large, fast fibers of alpha motor system (large cells of anterior horn to extrafusal motor fibers)</td>
</tr>
<tr>
<td></td>
<td>Ib</td>
<td></td>
<td>Tendon organ for contraction; respond to tendon stretch or tension</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td></td>
<td>Muscle spindle; secondary afferent endings; tonic receptors responding to length</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td></td>
<td>Exteroceptive afferent endings from skin and joints; respond to light or low threshold stretch</td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td></td>
<td>Bare nerve endings; joint receptors, mechanoreception of soft tissues; exteroceptors for pain, touch, and cold (low threshold)</td>
</tr>
<tr>
<td>B fibers: medium-sized myelinated fibers with a fairly rapid conduction rate</td>
<td>B beta</td>
<td></td>
<td>Preganglionic fibers of autonomic system (effective on glands and smooth muscle; motor branch of alpha); unknown function</td>
</tr>
<tr>
<td>C fibers: small, poorly myelinated or unmyelinated fibers having slowest conduction rate; augmentation and recruiting occur within the nervous system after stimulation of these fibers has ceased</td>
<td>C gamma 1 and 2</td>
<td>II</td>
<td>Gamma motor system (small cells of anterior horn to intrafusal motor fibers)</td>
</tr>
<tr>
<td></td>
<td>A delta</td>
<td>III</td>
<td></td>
</tr>
</tbody>
</table>
whether one resistive technique is better than another. Research certainly has shown that resistance training does enhance functional abilities across age groups, but again the specifics regarding resistive training techniques are often not identified. The terms resistive training, weight training, and strength training are often used synonymously, and thus specifics are yet to be identified in the research. How all these uses of resistive exercises will play out in the future is up to future researchers in the field of movement science. Very costly high-technology tools have been added to aid in resistive training (see the discussion of Pilates in Chapter 39 and robotics in Chapter 38). Given the needs of individuals after neurological insults, cost becomes a major factor, and finding creative and cost-efficient ways to apply resistance may become a common research question in the future.

Tapping.

Three types of tapping techniques are commonly used by therapists. Tapping of the tendon is a fairly nondiscriminatory stimulus. Physicians use this technique to determine the degree of stretch sensitivity of a muscle. A normal response would be a brisk muscle contraction. Because of the magnitude of the stimulus and the direct effect on the alpha motor neuron, this technique is not highly effective in teaching a client to control or grade muscle contraction. Instead, tapping of the muscle belly, a lower-intensity stimulus, is more satisfactory. Reverse tapping is a less frequently described technique, but it can be used. The extremity is positioned so gravity promotes the stretch, instead of the therapist manually tapping or actively inducing muscle stretch. Once the muscle responds, the therapist taps or passively moves the extremity to help the muscle obtain a shortened range. An example of reverse tapping would be tapping the triceps muscle when the client is bearing weight on the extended elbow and actively trying to achieve full elbow extension. Gravity quickly stretches the triceps. Timing of this technique is important. If the therapist taps the elbow toward extension when the flexors’ motor neurons are sensitive, then those flexor muscles may respond to the stretch and contract, taking the arm farther into flexion. If the timing follows the quick stretch to the extensor, then the flexors will be dampened and active extension more likely a motor response.

Positioning (Range).

The concept of submaximal and maximal range of muscles is highly significant to clinical application. Bessou and colleagues monitored the neuronal firing of muscle spindles at different ranges of motion. Upper motor neuron lesions can alter the sensitivity of the spindle afferent reflex arc fibers by not using presynaptic inhibition to normally dampen incoming afferent activity. Therefore ROM should be carefully assessed on an individual basis, particularly in a patient with an upper motor neuron lesion, to determine the maximal or submaximal range for an individual. Therapists always need to determine whether the difference between optimal range and functional ROM is different. If a patient will never need to use full ROM, then spending long periods of time trying to stretch a shoulder or hip may not be the best decision with regard to intervention. As well as the ROM itself, therapists need to carefully evaluate excessive range resulting from hypermobility and hypotonicity. In those situations, external support of the affected joint or limb needs to be considered in all functional positions in order to prevent complications such as pain.

### Table 9-2: Proprioceptive Stretch Receptors

<table>
<thead>
<tr>
<th>RECEPTOR</th>
<th>STIMULUS</th>
<th>NATURE OF RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ia tonic</td>
<td>Length</td>
<td>Monosynaptic and polysynaptic facilitation of agonist</td>
</tr>
<tr>
<td>Ia phasic</td>
<td>Rate of change in length</td>
<td>Polysynaptic inhibition of antagonist and antagonistic synergy</td>
</tr>
<tr>
<td>Polysynaptic facilitation of agonistic synergy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input to cerebellum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input to opposite parietal lobe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific parietal lobe responses open for question</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>Length</td>
<td>Monosynaptic facilitation of agonist</td>
</tr>
<tr>
<td>Polysynaptic facilitation of specific muscle groups, depending on muscle function of tissue where II fibers originate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmittal of information to higher centers</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

POSSIBLE TREATMENT ALTERNATIVES

1. Resistance
2. Quick stretch to agonist
3. Tapping: tendon and/or muscle belly
4. Reverse tapping: gravity stretches; tapping agonist into shortened range
5. Positioning (range)
6. Electrical stimulation
7. Pressure or sustained stretch
8. Stretch pressure
9. Stretch release
10. Vibration: facilitatory frequency for small vibrator, relaxation for total body vibration
11. Gravity as a prolonged stretch
12. Active motion
Electrical Stimulation. For an in-depth discussion of the use of electrical stimulation both as an evaluation and a treatment modality, see Chapter 16 and Chapter 33. Electrical stimulation has the potential to be an excellent muscle spindle facilitatory technique, especially if additional therapeutic tools, such as resistance, are included. Electrical stimulation delivered to create muscle contraction is beneficial, but electrical stimulation as a sensory stimulus is less effective as a learning tool because there are no sensory receptors for electrical currents and thus they are not represented as a unique stimulus in the somatosensory cortex. Functional electrical stimulation (FES) is a technique that applies electrical stimulation during functional movement. Chapter 16 discusses this technique with traumatic spinal cord injury, but the application has gone beyond those individuals diagnosed with spinal injury. Individuals poststroke have also been studied using FES. The results were inconsistent. Some studies showed there was no difference in the stroke groups during or directly after intervention but that the long-term effect remained with those individuals who received FES, whereas those who did not regressed in function. Studies have shown that FES training increased walking ability and speed during and after the training. Studies that have looked at other neurological problems have also used FES and certainly are showing that this type of intervention may become a standard of practice in the future. Combined modulation of voluntary movement, proprioceptive sensory feedback, and electrical stimulation might play an important role in improving impaired sensorimotor integration by power-assisted FES therapy. The use of FES over acupressure points has been shown to significantly reduce pain.

Stretch Pressure. The muscle belly is the stimulus focus of stretch pressure. The therapist slowly applies pressure to the muscle belly. It is used to decrease or release tone in the target muscle, allowing for the (temporary) recovery of voluntary movement. Generally this type of stimulus is applied and maintained for a period of time (e.g., 5 to 10 seconds). It is not a quick stimulus and may be used as the tendon organ to dampen tone. This type of pressure technique is also used in a variety of complementary approaches (see Chapter 39).

Stretch Release. This technique is performed by placing the fingertips over the belly of larger muscles and spreading the fingers in an effort to stretch the skin and the underlying muscle. The stretch is done firmly enough to temporarily deform the soft tissue so the cutaneous receptors and Ia afferent fibers may produce facilitation of the target muscle. It is easy to determine quickly whether the response is efficacious by just feeling and looking at the response of the patient.

Manual Pressure. Manual pressure can be facilitatory when it is applied as a brisk stretch or friction-like massage over muscle bellies. The speed and duration at which the manual pressure is applied determine the extent of recruitment from receptors. Paired with volitional efforts, manual pressure can lead to motor function, and with repetition, motor learning.

Vibration. There are two types of vibratory methods used therapeutically. The first deals with the use of a handheld vibrator to facilitate Ia receptors to enhance agonistic muscle contraction in hypotonic muscles or to facilitate Ia receptors of antagonistic muscle fibers to inhibit hypertonic agonists. Currently the use of vibration to facilitate Ia responses within specific muscle function has been used to show how proprioception can be used to alter upright standing. The second type of vibratory method is a total-body vibration to facilitate postural tone and balance and is applied through the feet in a standing position. Some researchers found that at cessation of the input the contractibility of the muscle was enhanced for approximately 3 minutes. The discrepancy in the research may reflect the way the individual is using the input, both from a direct effect on the motor generator and from supraspinal modulation over the importance of the input, which may affect the overall learning and plasticity of the CNS. To facilitate hypotonic muscle, the muscle belly is first put on stretch, and then vibratory stimuli are applied. To inhibit a hypertonic muscle, the antagonistic muscle could be vibrated. The use of vibration can be enhanced by combining it with additional modalities such as resistance, position, and visually directed movement. Vibration also stimulates cutaneous receptors, specifically the Pacinian corpuscles, and thus can also be classified as an exteroceptive modality. Because of its ability to decrease hypersensitive tactile receptors through supraspinal regulation, local vibration is considered an inhibitory technique (it is also discussed later in the section on exteroceptor-maintained stimulus). Therapists have reported that vibration over acupressure points can modulate localized pain syndromes. It seems to trigger A delta exteroceptive fibers, which in turn dampen the effect of C fibers. (See Chapter 32 for more information on the treatment of pain.)

Farber summarized the use of vibration and clearly identified precautions that must be taken. Frequencies greater than 200 Hz can be damaging to the skin. We have found frequencies greater than 150 Hz to cause discomfort and even pain. Therefore it is recommended that vibrators registering 100 to 125 Hz be used. Most battery-operated hand vibrators function at 50 to 90 Hz. Frequencies less than 75 Hz are thought to have an inhibitory effect on normal muscle, although a study showed that some muscle groups, especially the lateral gastrocnemius, do respond positively to frequencies of 40 to 60 Hz. Another researcher studying vibration found similar results that frequencies of 50 Hz generated more neuromuscular facilitation than lower frequencies (30 Hz) when studying improvements in upper body resistance exercise performance. Cutaneous pressure is also known to cause inhibition, so if it is combined with a vibration technique that is being used to augment a muscle contraction, it can only serve to cancel the desired effects.

Amplitude or amount of displacement must also be considered when vibration is analyzed as a modality. It has been reported that high amplitude causes adverse effects, especially in clients with cerebellar dysfunction. Vibration is not recommended for infants because their nervous system is not yet fully myelinated and the vibration might cause too much stimulation. The reader is also cautioned about using...
vibration over areas that have been immobilized because of the underlying vascular tissue potential for clotting. Vibration on or near these blood vessels could dislodge a clot, causing an embolism. Vibration also needs to be used cautiously over skin that has lost its elasticity and is thin (e.g., that in older persons) because the friction itself from the vibration can cause tearing. The therapist must always keep in mind the environment and the functionality of an intervention procedure. The use of vibration may assist the client in contractions and somatosensory awareness, but it is an unnatural way to facilitate either system and thus needs to be removed as part of an intervention as soon as the patient demonstrates some sensory awareness and/or volitional control over a movement component.

Within the last decade the use of vibration of specific muscle groups of the neck has been studied in order to determine its effect on upright standing and the interaction with and without eyes open.\(^{179,180}\) These studies showed that by vibrating specific muscle groups, those muscles would actively contract and change the position of the head in space but that with eyes open the effect was minimized in relation to global postural control. A similar study examined the effect of vibration on various muscles within the lower extremities and how that affected various postural responses.\(^{191,193}\) These researchers found that different frequencies affected different muscle groups. The one consistent thing all studies have shown is that vibration does facilitate Ia muscle fibers, which in turn affect muscle contraction of the agonist receiving the vibration. Other sensory systems can assist or override the effect of vibration, but that is because of superspinal influence over motor generators.

Total-body vibration is currently being used to determine if it affects motor performance. Studies have shown that whole-body vibration can enhance motor performance in high-level athletes performing sprints and jumps,\(^{181,182}\) as well as improve trunk stability, muscle tone, and postural control in individuals after stroke while in geriatric rehabilitation.\(^{184}\) Its application for individuals with neurological dysfunction is inconclusive.\(^{194,195}\) Studies specifically directed toward the elderly again show promise, but further research is needed for specificity.\(^{196,197}\) Future research will need to determine the effect of total-body vibration when introduced to all populations of individuals with neurological dysfunction. At that time both amplitude and magnitude will need to be identified in order to replicate studies. Total-body vibration certainly falls under primarily proprioception but also could be classified under combined proprioceptive techniques or multisensory classification techniques because the input affects the muscle spindles, the joints, the vestibular system, and possibly the auditory system with the low frequency noise. And every time vibration is applied, the skin receptors will initially fire although most will adapt quickly to prolonged use of any stimuli.

**The Tendon.** The tendon receptors are specialized receptors located in both the proximal and the distal musculotendinous insertions. In conjunction with the stretch receptors, the tendon plays an important role in the mediation of proprioception.\(^{141,142,108,203}\)

The principal role of the tendon is to monitor muscle tension exerted by the contraction of the muscles or by tension applied to the muscle itself. Research has demonstrated that the tendon is highly sensitive to tension and acts conjointly with the stretch receptors to inform higher centers of continuing environmental demands to modulate or change existing plans; these higher centers in turn regulate tonicity and the state of the motor pool.\(^{43,141}\) The tendon (Ib) signals not only tension but also the rate of change of tension and provides the sensation of force as the muscle is working.\(^{198}\)

A fundamental difference between the tendon organ and the stretch receptors is that the stretch receptors detect length, whereas the tendon monitors tension and force. Sensory input from the stretch receptors and the tendon are mostly opposites.\(^{43,202}\) The stretch receptors regulate reciprocal inhibition, whereas the tendon modulates autogenic inhibition. Table 9-3 lists a variety of known treatment approaches that use the tendon to inform higher centers regarding needed change and regulation over spinal generators.

**Maintained Stretch to the Tendon Organ.** Maintained stretch to a muscle has the potential for triggering the tendon organ if tension is great enough. Once the maintained stretch fires the tendon organ, autogenic inhibition of the same muscle occurs. A therapist will feel a release of the agonist muscle, allowing for elongation of the contractile components. Simultaneously, the tendon organ’s sensory neurons will facilitate motor neurons to the antagonist muscle, thus heightening its sensitivity and potential for activity. This is the technique used when a joint has developed range restriction. The clinician always needs to differentiate whether the tightness found within the joint is caused by compensatory muscles considered *movers* protecting injured postural muscles beneath or by tightness just from positioning, disuse, or fear.

**Inhibitory Pressure.** Pressure has been used therapeutically to alter motor responses. Mechanical pressure (force), such as from cones, pads, or the orthokinetic cuff developed by Blashy and Fuchs,\(^{204}\) provided continuously is inhibitory. That pressure seems most effective on tendinous insertions. It is hypothesized that this deep, maintained pressure activates Pacinian corpuscles, which are rapidly adapting receptors. A variety of researchers have studied these receptors and their relationship to regulating vasomotor reflexes,\(^{205}\) modulating pain,\(^{206-210}\) and dampening other sensory system influence on the CNS.\(^{188,209}\)

This inhibitory pressure technique also works when pressure is applied across the longitudinal axis of a tendon. The pressure is applied across the tendon with increasing pressure until the muscle relaxes. Constant pressure applied over the tendons of the wrist flexors may dampen flexor hypertonicity and elongate the tight fascia over the tendinous insertion (see Chapter 39 for additional information).

Pressure over bony prominences has modulatory effects. A common example is pressure on the medial aspect of the calcaneus, which dampens plantarflexors and allows contraction of the lateral dorsiflexor muscles. Pressure over the lateral aspect of the calcaneus also dampens calf muscles to allow for contraction of the medial dorsiflexor muscles.\(^{25}\) Localized finger pressure applied bilaterally to acupuncture points has been shown to relieve pain and reduce muscle tone.\(^{20,214}\) This technique has also been found to be particularly effective when used in a low-stimulus environment and when combined with deep breathing.

This combination of pressure (manually applied), environmental demands (low), and parasympathetic activity (slow, relaxed breathing) illustrates various systems interacting...
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The real world requires the client to respond to many environmental conditions while relaxed or under stress. Thus, once a client begins to demonstrate normal adaptable motor responses, the therapist needs to change the conditions and the stress level to allow the client to practice variability. That practice should incorporate motor error, especially error or distortions in the plan, yet still achieve the desired goal. As the client self-corrects, greater demand and variability should be introduced.

**Joint Receptor Approximation.** Approximation of the joint mimics weight bearing and facilitates the postural extensor system. Gravity creates approximation and its greatest force is produced down through the body in vertical postures. Approximation should help to stabilize any joint that is in a load-bearing situation by eliciting coactivation of the muscles around the joint in question. In standing, gravity creates approximation down through the entire spine, hips, knees, and ankles. When in a prone position on elbows, the load goes down again through the upper spine while simultaneous going down through the shoulder girdles of both arms. If a therapist increases that load by adding pressure down through the joints in question, then an augmented intervention has been added to the therapeutic environment. Using weight belts around the waist or a weighted vest on the trunk can facilitate the postural coactivation needed during standing or walking. At times, approximation can be used to heighten normal postural tone while simultaneously dampening excessive tone in the other leg. For example, clients who have CNS insult often have an imbalance in function within the two lower extremities. This can be very frustrating for the therapist because bringing the patient to standing to assist in regaining normal postural extension of one leg triggers the other into a strong extensor pattern, causing plantarflexion and inversion of that foot. One way to use approximation in treating both legs simultaneously might be to first bring the patient from sitting onto a high-low mat. Then the therapist can raise the mat high enough that the patient can be lowered into standing on the normal-functioning leg. At the same time the patient’s other leg can be bent at the knee, and that knee placed on a stool or chair. This allows approximation down through the entire leg that is in standing position while approximating the trunk, hip, and knee of the other leg in the kneeling position. The therapist can work on standing and weight shifting in one leg while dampening abnormal tone in the kneeling leg. As the kneeling leg starts to regain postural coactivation in its hip, postural function will often be felt in the knee and ankle.

One very effective way to apply approximation and resistance simultaneously is to use the product similar to a cut

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**TABLE 9-3 ■ PROPRIOCEPTIVE RECEPTORS OF TENDONS AND JOINTS**

<table>
<thead>
<tr>
<th>RECEPTOR</th>
<th>STIMULUS</th>
<th>RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TENDON</td>
<td>Tension on extrafusal muscle</td>
<td>Polysynaptic inhibition of agonist, facilitation of antagonist spinal level circuitry; supraspinal regulation</td>
</tr>
</tbody>
</table>

**Possible Treatment Suggestions**

1. Extreme stretch
2. Deep pressure to tendon
3. Passive positioning in extreme lengthened range
4. Extreme resistance: more effective in lengthened and shortened range
5. Deep pressure to muscle belly to put stretch on tendon
6. Small repeated contractions with gravity eliminated

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**TYPE OF JOINT**

<table>
<thead>
<tr>
<th>TYPE</th>
<th>RECEPTOR</th>
<th>STIMULUS</th>
<th>RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (6-9 μ)</td>
<td>Tendon organ lb</td>
<td>Static and dynamic joint tension: muscle pull</td>
<td>Thought to facilitate postural holding and joint awareness</td>
</tr>
<tr>
<td>II (9-12 μ)</td>
<td></td>
<td>Dynamic: sudden change in joint tension</td>
<td>Thought to facilitate agonist and awareness of joint range of motion</td>
</tr>
<tr>
<td>III (13-17 μ)</td>
<td></td>
<td>Dynamic: linked to Golgi tendon organ traction; activates in extreme range</td>
<td>Thought to inhibit agonist</td>
</tr>
<tr>
<td>IV (5 μ &gt;2 μ)</td>
<td></td>
<td>Pain</td>
<td>Thought to inhibit agonist</td>
</tr>
</tbody>
</table>

**Possible Treatment Suggestions**

1. Manual traction (distraction) to joint surfaces to facilitate joint motion
2. Manual approximation (compression) to joint surfaces to facilitate co-contraction or postural holding
3. Positioning: gravity used to approximate or apply traction
4. Weight belts, shoulder harnesses, and helmets to increase approximation
5. Wrist and ankle cuffs to increase traction
6. Wall pulleys, weights, manual resistance
7. Manual therapy
8. Elastic tubing to provide compression during movement
large elastic rubber band: Thera-Bands. The rubber material is attached under the heel on the right and left side; both ends of the band are brought up across the ankle and then crossed over the lower leg, once more over the back of the thigh, and then anchored onto a belt around the patient’s waist. A similar pattern can be used for the arm; the band is first placed across the palm and then crossed in the forearm and then the arm. Finally one end is brought across the upper chest and the other comes around from the back of the arm. Then the two ends of the band are tied together across the neck. These techniques can be graded by the elasticity of the material.219-221

**Traction and Distraction.** One or more joints are distracted by a force that causes it or them to separate or pull apart, similar to the swing phase of the leg during ambulation or the arms in a reciprocal pattern to each leg. This distraction of the joint receptors also puts stretch on the muscles, which combines to facilitate the pattern into which the limb is moving. Simultaneously, distraction damps the antagonist movement pattern, which allows the agonist movement to continue. A therapist will often use manual traction to get relaxation of hyperactive extensor muscles or for limited mobility.222 Often therapists do not think of the traction when applying resistance to a limb. For example, a mistake made is placing ankle weights to facilitate limbs that are ataxic. Ataxia is an imbalance in coactivation and smooth movement of both agonist and antagonist muscle groups.223 The weight itself slows down the excessive movement by the resistance. However, weight on the ankle creates traction that will facilitate only the flexor group and often creates an additional imbalance in the ataxic leg.224 When the weights are removed, the patient often is more ataxic.

**Combined Proprioceptive Input Techniques.** Many techniques succeed because of the combined effects of multiple inputs. Some of these combined techniques include jamming: ballistic movements; total-body positioning; PNF patterns: postexcitatory inhibition (PEI) with stretch, range, rotation, and shaking; heavy work patterns; Feldenkrais (see Chapter 39)225-227, and manual therapy.20,208,228

**Jamming.** Jamming is usually applied to the ankle and knee with the intent of dampening plantarflexion while facilitating postural co-contraction around the ankle. The client can be placed in a side-lying position, can sit on a chair or mat, or can be positioned over a bolster with the hip and knee in some degree of flexion. This flexion dampens the total extension pattern, including the plantarflexor muscles. With release of plantarflexion these muscles are placed on extreme stretch to maintain the modulation. In this position, intermittent joint approximation and compression of considerable force is applied between the heel and knee. If the client is sitting, this approximation can easily be applied by pounding the heel on the floor and controlling a counterforce at the knee. Once coactivation is minimally palpated, the clinician should initiate a movement pattern such as partial weight bearing to further encourage the CNS to readapt with postural control. This technique can also be used to dampen flexion of the wrist and fingers by applying force to the appropriate upper-extremity patterns, modulating flexor reflex afferent activity, and applying a large amount of joint approximation between the heel of the hand and the elbow. To augment functional outcomes, the technique should be incorporated into functional training to achieve better sensorimotor responses, improved cortical representation of the involved body part, and greater functional carryover.

**Ballistic Movement.** Ballistic movements are effective because of their combined proprioceptive interaction. The client is asked to initiate a movement, such as shoulder flexion while prone over a table with the arm hanging over the side. This component is volitional, but the client then maintains a passive role. As the patient relaxes, the movement patterns become automatic. The physiology behind the automatic movement is easy to understand. As the muscle approaches the shortened range, the amount of ongoing gamma afferent activity decreases. Thus both the agonist alpha motor neuron bias and the inhibition of Ia and II receptors of the antagonistic alpha motor neurons decrease. Simultaneously, the antagonistic muscle is being placed on more and more stretch. This stretch, as well as the lack of inhibition on the antagonistic alpha motor neurons, will encourage the antagonistic muscle to begin contraction and reverse the movement pattern. The tendon organs also play a key role in ongoing inhibition. As the muscle approaches the shortened range and tension on the tendon becomes intense, the tendon organ increases its firing, thus inhibiting the agonistic muscle in the shortened range while facilitating the antagonistic muscle. This technique is highly movement oriented, and the traction applied by gravity to the shoulder joint while swinging the arm further facilitates the movement. These ballistic movements are part of the program generators within the spinal system that facilitate reciprocal movements of the limb. As the client performs the movement, there is little need for conscious attention to drive the movement; it will run automatically. The role of the Ib fibers during this open chain or movement pattern is definitely different from its role in a closed chain or weight-bearing environment.229 Supraspinal influence over programmed activity also plays a role in the effectiveness of this treatment.225 The specific rationale for why ballistic movements have functional carryover may be explained by recent research into cerebellar function and the importance of mechanical afferent input in regulation of movement (see Chapter 21).

The clinician using this technique must exercise caution. ROM can easily be obtained through ballistic movement. Consequently, the clinician must always determine before therapy the reasons for specific clinical signs and whether the total problem will be corrected through an activity such as a ballistic movement. This is the diagnostic responsibility of the professional. If one component of the problem is alleviated, such as limitation of range, while other components are ignored, this can be a dangerous technique. If the lack of range is a result of muscle splinting because there is lack of postural tone or joint stability, then ballistic movement has the possibly increasing the problem. For example, assume that the rotator cuff muscles are slightly torn and the movers of the shoulder are superficially splinting to prevent further tearing. Instructing the client to perform ballistic movement that causes relaxation of more superficial muscles will then place more responsibility for shoulder stabilization on the rotator cuff muscles. If those stabilizers are torn, traction along with relaxation of muscles that are splinting may increase the tear on the rotator cuff muscles and thus increase
the problem. The patient may never return to therapy, but if he does, he will complain of more pain than before.

**Total-Body Positioning.** Total-body positioning implies the use of positioning and gravity to dampen afferent activity on the alpha motor neurons and thus cause a decrease in tone, or relaxation. Today, the rationale for why relaxation of striated muscle occurs after this treatment implies that the effect of the flexor reflex afferents is being dampened by a combination of input and interneuronal activity. These changes in the state of the muscle tone will not be permanent and will revert to the original posturing unless motor learning and adaptation within the central programmer occur simultaneously. Thus for this treatment to effect permanent change, a large number of systems need modification. This modification can be augmented by techniques that facilitate autogenic inhibition, reciprocal innervation, labyrinthine and somatosensory influences, and cerebellar regulation over tone. Changing the degree of flexion of the head also alters vestibular input and the state of the motor pool. But again, the CNS of the client needs to be an active participant and will ultimately determine whether permanent learning and change are programmed.

**Proprioceptive Neuromuscular Facilitation.** To analyze and learn the principles, techniques, and patterns that constitute PNF, a total approach to treatment, refer to the texts by Adler, Voss, and Sullivan and colleagues. This approach is being used extensively for patients with musculoskeletal and neuromuscular problems, with research on this method encompassing more populations with lower motor neuron lesions. When proprioceptive techniques are packaged in specific movement patterns, it may be referred to as PNF. When individual proprioceptive techniques are discussed alone, the specific sensory function is being acknowledged, and these techniques can be integrated into many rehabilitation intervention strategies.

**Postexcitatory Inhibition with Stretch, Range, Rotation, and Shaking.** The concept of PEI is based on the action potential or electrical response pattern of a neuron at the time of stimulation and on the entire phase response until the neuron returns to normal. At the time of stimulation, the action potential will build and go through an excitatory phase. The neuron then enters an inhibitory phase or refractory period during which further stimulation is not possible. This is referred to as the PEI phase or postsynaptic afferent depolarization. These phase changes are extremely short and, in normal muscle, asynchronous with respect to multiple neuronal firing. In a hypertonic muscle more simultaneous firing occurs. When the muscle is lengthened, and thus tension is created, more fibers will be discharged. It is hypothesized that if the hypertonic muscle is placed at the end of its spastic range and a quick stretch is applied and held, then total facilitation followed by total inhibition will occur because of PEI. As the inhibition phase is felt, the therapist can passively lengthen the spastic muscle during the inhibitory phase sets in and the facilitatory phase in repolarization. At that time the clinician holds the lengthened position. Increased tone will ensue, followed by inhibition and continued lengthening. Holding the range (not allowing concentric contraction during the excitatory phase) is critical. If the muscle is held as the tone increases, the resistance and stretch are then maximal and probably further facilitate the inhibitory phase.

At a certain point in the range, if the muscle is not limited by fascial tightness, the hypertonic muscle will become dampened and tone will disappear. It is thought that at this time either the tendon organ activity takes over and maintains inhibition or flexor reflex afferents are modified, thus creating an inhibitory range in which antagonistic muscles can be more easily initiated and controlled by the client. If this technique is performed in a pure plane of motion, the clinician will find it a time-consuming procedure. Range can be achieved quickly by integrating a few additional techniques, that is, incorporating rotational patterns of movement. For example, if the spastic upper extremity is positioned in the pattern of shoulder adduction, internal rotation, elbow flexion, forearm pronation, and wrist and finger flexion, then a pattern in the opposite direction can be incorporated to include external rotation of the shoulder and supination of the forearm. Every time the clinician begins to lengthen the spastic extremity, those rotational patterns should be used. This should be done both on initial stretch and when resisting movement during excitation and then lengthening (allowing movement) during the inhibitory phase. Rotation seems to lengthen the inhibitory phase and allows additional range. If the clinician adds a quick stretch to the antagonistic muscle during the inhibitory phase of the agonistic muscle, then further facilitation of the antagonistic muscle will occur. Because the agonistic muscle is in an inhibitory phase, movement in and out of its spastic range should not affect it. Yet the quick stretch facilitation of the antagonistic muscle inhibits the spastic agonistic muscle and again lengthens the inhibitory phase. This entire procedure occurs very quickly. An observer might say that the clinician “shakes the hypertonicity out of the arm.” The shaking action is thought to be the quick stretch as well as joint oscillations. The degree of success depends on the therapist’s sensitivity to the tonal shifts or phase changes occurring in the client. These tonal shifts are automatic at the hundredth-of-a-millisecond level and not under the client’s conscious control. But the sensitivity of the Meissner corpuscles are at approximately 2 hundredths of a millisecond and provide adequate input to the therapist. If a master clinician responds to each inhibitory phase, it will look like the tone melts away. Most clinicians do not have that keen sensitivity, and the interventions will look more jerky because not every inhibitory phase is sensed and thus there will be a lot of step-and-go movement in very small ranges of movement out of synergy until the hypertonic muscles finally relax.

**Rood’s Heavy Work Patterns.** Rood’s concepts of cocontraction in weight-bearing positions such as on elbows, on extended elbows, kneeling, and standing blend with today’s concepts of motor learning. Concepts explain why postural holding in shortened range for periods of time are valid treatment procedures. Rood stressed the need for patients to work in and out of those shortened ranges in order to gain postural control as well as to practice directing the limbs during both closed and open chain activities.

**Feldenkrais.** The Feldenkrais concepts of sensory awareness through movement place emphasis on relaxation of muscles on stretch, and distracting and compressing joints for sensory awareness. Both techniques reflect combined proprioceptive techniques. Taking muscles off stretch slows general afferent firing and thus overload to the CNS. Compression and distraction of joints enhance specific input
from a body part while simultaneously facilitating input of a lesser intensity from other body segments. This combined proprioceptive approach enhances body schema awareness in a relaxed environment. It also integrates empowerment of the client by use of visualization and asking for volitional control. (See Chapters 27 and 39 for additional information.)

**Manual Therapy, Specifically Maitland’s.** “The peripheral and central nervous systems need to be considered as one because they form a continuous tissue tract.”208,225,243-246 Manual therapy or mobilization of joint or soft tissue structures is not specific to orthopedic conditions, nor are neurological treatment principles ineffective on orthopedic patients. Regardless of the diagnosis or pathological body system leading to joint immobility, the functional consequences can be synonymous. Joint immobility can cause the peripheral nerves to lose their adaptability to change in the length of the nerve bed. This change in neural elasticity then creates additional problems in connective tissue function, which in turn may affect the function of the motor system’s control over the musculoskeletal component.228,247 For this reason alone, discussion of musculoskeletal mobilization needs to be included in this section as a component of classification.

“Pathological processes may interfere with both of these mechanisms: extraneural pathology will affect the nerve/interface relationship and intraneuronal pathology will affect the intrinsic elasticity of the nervous system.”247 Patient complaints of pain that limits functional movements constitute the primary reason clients are referred to a therapist for a musculoskeletal evaluation. During the physical examination, tension tests can be used to determine the degree of pain and joint limitation, to differentiate between somatic and radicular symptoms, and to identify adverse neuro-physiological changes in the PNS.247 “The increased muscle tone (in a peripheral injury) is considered to be a protective mechanism for the inflamed tissue.”248 This increase in tone may be caused by a dampening of presynaptic activity of the flexor reflex afferent by supraspinal mechanisms. This same mechanism may be triggered by a CNS injury. The difference between the orthopedic patient and the neurological patient may be the trigger to the CNS. In a central lesion the motor generators are often not adequately maintained after injury, which results in hypotonia. The hypotonia causes peripheral instability, stretches peripheral tissue, and potentially causes peripheral damage. In both orthopedic and neurological cases, there is peripheral instability, the first the result of peripheral damage and the second the result of hypotonia. The CNS response to the instability may be the same: an increase in muscle tone by dampening of presynaptic inhibition. A decrease in presynaptic inhibition on incoming afferents would cause an increase in spinal generator activity. With an isolated musculoskeletal problem and an intact CNS, the motor system would have the adaptability and control to modulate the spinal generators and isolate only those components in which an increase in tone might directly affect the problems. The client with CNS involvement may lose some of the flexibility of the motor system’s control over the pattern generators, and thus high-tone synergistic patterns may develop.

In either case, the peripheral system needs to be evaluated and intervention provided when necessary. Tension tests look for adverse responses to physical examination of neural tissues. These adverse responses are muscle tone increases as a result of painful provocation of sensitized neural tissue nociceptors attempting to prevent further pain by limiting the movement of the neural tissue.248 Pain increases tone and leads to limited range of passive movement.248,249 Pain-free range suggests CNS sensitivity to the large, highly myelinated alpha fibers and functions in a discriminatory manner. Pain range encompasses the degree of joint motion where neural length, as well as nociceptors in the skin, fascia, muscles, and joints, plays a primary role in CNS attention and protection. Inflammation of neural tissue can also cause the nociceptors to become hypersensitized or more reactive to mechanical or chemical changes. This is particularly true in the joint when the nociceptors react significantly to movement at the end ranges.

Treatment will be based on the degree of immobility, the pain range, the site of the irritability, and the degree of pain. Butler228 not only looks at joint problems but also considers many joint problems as having adverse neural dynamics (tension on the PNS). Treatment still incorporates Maitland’s grades of passive movement, but with consideration across the length of the neural tissue across multiple joints.

Butler247,250 divides treatment of the joint into three categories: limitations, pain, and adverse mechanical tension. When analyzing selective nervous system mobilization as identified by Butler, the therapist needs to mobilize the nervous system and its surrounding fascia rather than stretching it. These techniques may be either gentle (grade I) or strong (grade IV), through the range (grades II and III), or at end range only (grade IV). Different disorders (irritable compared with nonirritable) will require different treatment approaches (Figure 9-3).

Treatment must interface with related tissues. When joint immobility is interfaced with muscle and fascia tightness, all components must be treated simultaneously. If the focus of treatment is the correction of joint and muscle signs, then constant reassessment of the effect on the nervous system is crucial. This aspect would seem even more crucial in clients with CNS and PNS injuries. The treatment may be direct or indirect. Direct intervention involves procedures aimed at rebalancing the neuromusculoskeletal system through strengthening and increasing ROM to improve motor control. Indirect treatment includes the use of movement patterns, especially posture-based patterns. When individuals have nervous system changes, static and dynamic postural patterns often emerge as compensatory reactions to the problem state. Pain posturing, tension, or stiffness from prolonged positioning, and forced postures that are the result of synergy patterns, to name a few, all seem to respond well to indirect treatment with or without passive CNS mobilization. The use of posture-based movement patterns during functional activities also provides for variability and repetition and thus should lead to greater carryover in motor learning.

Many manual therapy approaches affect and use the proprioceptive system as a means to change motor responses. The reader is again reminded that the proprioceptive system affects all systems within the CNS and vice versa. The end effect of all system interactions will be intrinsic reinforcement of existing behavior or changes in and adaptations of behavior to meet intrinsic and extrinsic demands. The
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behavior observed by the therapist as the client initiates motor strategies in response to functional goals will be a consensus of all these interactions.

Exteroceptive or Cutaneous Sensory System

Differentiation of Receptor Site as Augmented Intervention. Humans have many different types of tactile receptors. Some are superficial, and others are deep within the layers of the skin. These receptors have been identified within the chapter on motor learning. Their use as augmented intervention strategies is discussed in the following section.

A list of treatment techniques using the exteroceptive (tactile) input system as their primary mode of entry can be found in Table 9-4.

Grades of Movement

Grade I: A small amplitude movement performed near the beginning of range.

Grade II: A large amplitude movement carried well into range. It's a movement that occupies any part of the range that is free of pain or resistance.

Grade III: A large amplitude movement that moves up to the limit of range or into resistance.

Grade IV: A small amplitude movement performed near the end of range or slightly into resistance.

Maitland has also used the pluses (+) and minuses (−) in his grades of movement for many years now. It enables the therapist to communicate better with other therapists as well as treat the patient with accuracy and skill.

Grade IV−−: just nicking resistance

Grade IV−: touching resistance

Grade IV+: into resistance about 25%

Grade IV++: into resistance about 50%

Grade IV+++: into resistance about 75%

Figure 9-3 ■ Grades of movement. (Modified from Maitland’s theory of joint and tissue mobilization by John Sievert, PT, GDMT. From Course notes, Graduate Diploma in Manipulative Therapy, Curtin University of Technology, Perth, Western Australia, 1990; and from Maitland GD: Peripheral manipulation, ed 3, Boston, 1991, Butterworth Heinemann.)

Treatment Alternatives Using the Exteroceptive System. The function of the exteroceptive system is to inform the nervous system about the surrounding world. The CNS will adapt behavior to coexist and survive within this environment. Although many protective responses are patterned within the motor system, these patterned responses can be changed or modulated according to momentary inherent chemistry, attitude, motivation, alertness, and so on. Different from some of the other treatment approaches, the function of the exteroceptive input system is not reflexive but rather informative and adaptable.

Quick Phasic Withdrawal. The human organism reacts to painful or noxious stimuli at both conscious and unconscious levels. If the stimulus is brief and of noxious quality, it will elicit a protective reaction of short duration with use of the long-chain spinal reflex loops. Simultaneously, afferent impulses ascend to higher centers to evoke prolonged emotional-behavioral responses. Stimuli such as pain, extremes in temperature, rapid movement, light touch, and hair displacement are the most likely to cause this reaction by activating free nerve endings. These stimuli are perceived as potentially dangerous and communicate directly with the reticular-activating system and nonspecific thalamic nuclei. These structures have diffuse interconnections with all regions of the cerebral cortex, ANS, limbic system, cerebellum, and motor centers in the brain stem. Research has shown that children who exhibit hyperactive withdrawal reactions also develop negative emotional reactivity and show significantly more avoidance behavior and in time show right frontal asymmetry. 251 These alerting stimuli have been linked to motor seizures in critically ill patients. 252 As indicated by these research studies, therapists need to be aware of these potential responses, especially in patients with severe neurological insult that has resulted in a lower level of consciousness. These low-functioning clients cannot express their feelings nor how their nervous system is reacting to the input. Thus therapists need to be very aware of any motor response a patient may express and try to avoid using stimuli that might trigger these avoidance behaviors. From observance of the behavior of clients with chronic pain, these responses seem to become habitual and may lead to somatosensory remapping, making it hard to differentiate protective from discriminatory information. Thus, any movement or touch triggers pain. Patients need to be taught to discriminate between tightness and true pain, and therapists need to feel when the muscle response has shifted from muscle gliding to muscle restriction. Therapists need to gain trust, and one way is to not elicit a lot of pain. For example, if a therapist tells a patient to say something when it hurts, and the patient says, “Now,” the therapist should never respond with “Well, just a little more.” In that instant the patient has learned that the therapist lied (because the patient was told to tell the therapist when it hurt, suggesting that the therapist would stop then) or that the therapist is a masochist. If the therapist had stopped when the patient said that it hurt, the patient would then know that he does not need to tell the therapist to stop 10 degrees before it hurts because the therapist is not going to range him that 10 extra degrees. Often the therapist will find that without any effort the patient now has that extra range and has no need to splint the limb because it is not going to hurt to have therapy.
There are some real therapeutic limitations to using stimuli that “load” the spinothalamic system. A painful stimulus will be excitatory to the nervous system and produce a prolonged reaction after discharge. According to Wall’s gate-control theory, all sensory afferent neurons converge and synapse in the dorsal horn in an area called the substantia gelatinosa. Curiously, the large, more discriminatory fibers do outnumber the small fibers. Therefore, physical activity, frequent positioning, deep pressure, and proprioceptive and cutaneous stimulation should cause enough impulses to converge on cells within the substantia gelatinosa to close the gate and thus block transmission of pain messages to the brain. Studies have demonstrated that physical activity (types of physical stress) stimulates the production of endorphins, which in turn release opiate receptors and act as the body’s own morphine for pain control (see Chapters 18 and 32).

Because light touch has both a protective and a discriminatory function, techniques such as brushing or stroking the skin with a soft brush have the potential of informing the CNS about (1) texture, object specificity, and error in fine motor responses or (2) danger (eliciting a protective

<table>
<thead>
<tr>
<th>RECEPTORS</th>
<th>STIMULI</th>
<th>RESPONSE*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free nerve endings: C + A fibers</td>
<td>Pain, temperature, touch</td>
<td>Seem to protect and alert, perception of temperatures, protective withdrawal</td>
</tr>
<tr>
<td>Hair follicles</td>
<td>Mechanical displacement of hair receptors</td>
<td>Increased tone of muscle below stimulus site</td>
</tr>
<tr>
<td>Merkel disk</td>
<td>Touch: pressure receptors</td>
<td>Touch identification</td>
</tr>
<tr>
<td>Meissner corpuscles</td>
<td>Discriminative touch</td>
<td>Postural tone, two-point discrimination</td>
</tr>
<tr>
<td>Pacinian corpuscles</td>
<td>Deep pressure and quick stretch to tissue, vibration</td>
<td>Position sense, postural tone and movement</td>
</tr>
<tr>
<td>Ruffini corpuscles</td>
<td>Touch mechanoreceptor</td>
<td>Touch and spatial discrimination</td>
</tr>
</tbody>
</table>

### TABLE 9-4 ■ EXTEROCEPTIVE INPUT TECHNIQUES

#### SUGGESTED TREATMENT PROCEDURES USING CUTANEOUS STIMULI

**Quick Phasic Withdrawal**
1. Stimulus
   a. Pain
   b. Cold: one-sweep with ice cubes, Rood’s quick ice
   c. Light touch: brush (quick stroking), finger, feather
2. Response
   a. Stimulus applied to an extensor surface: elicits a flexor withdrawal
   b. Stimulus applied to flexor surface: may elicit flexor withdrawal or withdrawal from stimulus into extension

**Prolonged Icing (Repetitive Icing Should Be Used with Caution Because of Rebound Effect)**
1. Stimulus
   a. Ice cube
   b. Ice chips and wet towel
   c. Bucket of ice water
   d. Ice pack
   e. Immersion of body part or total body
2. Response: inhibition of muscles below skin areas iced

**Neutral Warmth**
1. Stimulus
   a. Air bag splints
   b. Wrapping entire body or individual body part with towel
   c. Tight clothing such as tights, fitted turtleneck jerseys, Lycra clothing
   d. Tepid water or shower
2. Response: inhibition of area under which neutral warmth was applied

**Light Touch, Rapid Stroking**
1. Stimulus
   a. Light intermittent tactile stimulus to an identified dermatome-myotome interaction area
2. Response: facilitation of muscle(s) related to the stimulus area

**Maintained Pressure or Slow, Continuous Stroking with Pressure**
1. Stimulus
   a. Slowly rubbing the target area with a towel
   b. Wearing Lycra or spandex clothing
2. Response: sensory receptor adaptation and decrease in afferent firing

*Response: adaptation of many cutaneous receptors to stimulus, thus decreasing exteroceptive input, decreasing reticular activity, and decreasing facilitation of muscles underlying stimulated skin.*
response). If a protective response is triggered, the specific withdrawal pattern will depend on a variety of circumstances. If the stimulus is applied to an extensor surface, then a flexor withdrawal will be facilitated. If the stimulus is placed on a flexor surface, one of two responses occurs. First, the client might withdraw from the stimulus, thus going into an extensor pattern. Second, the stimulus may elicit a flexor withdrawal and cause the client to go into a flexor pattern. Which pattern occurs depends on preexisting motor programming bias as a result of positioning and the predisposition of the client’s CNS. Both responses would be considered normal. The condition or emotional state of the nervous system and whether the stimulus is considered threatening also determine the sensitivity of the response, again reinforcing the systems’ interdependence. These responses are protective and do not lead to repetition of movement or motor learning. For that reason, along with the emotional and autonomic reactions, a phasic withdrawal to facilitate flexion or extension is not recommended as a treatment approach unless other possibilities have been eliminated.

**Short Duration, High-Intensity Icing.** Cold is another stimulus that the nervous system perceives as potentially dangerous. The use of ice as a stimulus to elicit desired motor patterns is an early technique developed by Rood. Her technique was referred to as repetitive icing. An ice cube is rubbed with pressure for 3 to 5 seconds or used in a quick-sweep motion over the muscle bellies to be facilitated. This method activates both exteroceptors and proprioceptors and causes a brief arousal of the cortex. This method can produce unpredictable results. Although initially a phasic withdrawal pattern generator response will be activated immediately after the reflex has taken place, the “rebound” phenomenon deactivates the muscle that has been stimulated and lowers the resting potential of the antagonistic muscle. Therefore a second stimulus to the same dermatome—myotome neural network may not elicit a second response. But, because of reciprocal innervation, the antagonistic muscle may effect a rebound movement in the opposite direction. Icing may also cause prolonged reaction after discharge because of the connections to the reticular system, limbic system, and ANS. Thus the ANS would be shifted toward the sympathetic end. Too much sympathetic tone causes a desynchronization of the cortex. Although the resting state of the spinal generator may be altered briefly, if the heightened state persists the cause is most likely fear or sympathetic overflow (see Chapter 5). This state is destabilizing to the system and most likely will not lead to any motor learning. Because of unpredictable response patterns to Rood’s repetitive icing, this technique is seldom used.

The therapist is cautioned not to use short-duration, high-intensity icing to the facial region above the level of the lips, to the forehead, or to the midline of the trunk. These areas have a high concentration of pain fibers and a strong connection to the reticular system. Ice should not be used behind the ear because it may produce a sudden lowering of blood pressure. The therapist should also avoid using ice in the left shoulder region in patients with a history of heart disease because referred pain from angina pectoris manifests itself in the left shoulder area, indicating that the cold stimulus might cause a reflexive constriction of the coronary arteries. In addition, the primary rami located along the midline of the dorsum of the trunk have sympathetic connections to internal organs. The cold stimulus may alter organ activity and perhaps produce vasoconstriction, causing increased blood pressure and reduced blood supply to the viscera.

Brief administration of ice can have beneficial effects if the nervous system’s inhibitory mechanisms are in place. For instance, in children with learning disabilities or adults with sensorimotor delays, the application of ice to the palmar surface of the hands will cause arousal at the cortical level because of the increased activity of the reticular activating system. This arousal response presumably produces increased adrenal medullary secretions, resulting in various metabolic changes. Therefore icing should be used selectively. If the patient has an unstable ANS, icing should be eliminated as a potential sensory modality.

**Prolonged Use of Ice.** Physicians have used therapeutic cold for the treatment of individuals with high fever and/or intracranial pressure with the intent of reducing the body temperature or brain swelling to prevent brain damage. This procedure is done with cooling pans or blankets. Whole-body cryotherapy has been used to reduce inflammation and pain and overcome symptoms that prevent normal movement. This type of therapy consists of the use of very cold air maintained for 2 minutes in cryochambers. A recent study looked at this type of therapy for injured athletes. It was found that the procedure did not cause harm to the individual. This approach does not seem realistic for use in occupational or physical therapy clinics.

A variety of approaches that incorporate prolonged icing techniques have been used in therapy clinics for decades. The PNF approach may be the most common. Inhibition of hypertonicity or pain is the goal for the use of any of these methods. With prolonged cold the neurotransmission of impulses, both afferent and efferent, is reduced. Simultaneously the metabolic rate within the cooled tissue is reduced (see Chapter 32). Caution must be exercised with regard to the use of this modality. However, for effective treatment results, the client (1) should be receptive to the modality, (2) should be able to monitor the cold stimulus (sensory deficits should not be present), and (3) should have a stable autonomic system to prevent unnecessary adverse effects of hypothermia. Research of the last decade has consistently shown that cryotherapy is an effective tool for reducing pain and has helped individuals regain integration of axial musculature after neurological insults. Individuals of all ages seem to respond similarly, which allows therapists to use this therapeutic tool across generations.

Ice immersion of the contralateral limb was used decades ago in order to get a reflexive decrease in temperature in the affected limb. It was believed that this intralimb reflex was an effective way of treating pain without directly treating the limb. Recent research has validated that belief.

Ice massage is another form of prolonged icing and is often used to treat somatic pain problems. It is also used over high-toned muscles to dampen striated muscle contractions. Caution must be used when eliminating pain without correcting the problem causing pain. For example, if instability causes muscle tone and pain, then icing might decrease pain while causing additional joint instability and potential damage. The end result would be an increase, not a decrease, in pain and motor dysfunction.
Neutral Warmth. Like icing, neutral warmth alters the state of the motor generators, either directly or indirectly through afferent input. According to Farber,\textsuperscript{12} the length of application depends on the client. A 3- to 4-minute tepid bath may create the same results as a 15-minute total-body-wrapping procedure. As with any input procedure, the effects should be incorporated into the therapeutic session to maximize the results and promote client learning. The Johnstone approach uses air splints effectively as a neutral warm treatment intervention while clients work on functional activities.\textsuperscript{37} If neutral warmth is applied as an isolated intervention, the client may feel relaxation or a decrease in discomfort, but neuroplastic CNS changes are unlikely, owing to the lack of repetition, attention, and error correction by the client during activities. A recent study looked at blood pressure, heart rate, and other autonomic mechanisms in subjects using compression hose. The researchers did not look at neutral warmth as a mechanism to maintain a homeostatic state of the nervous system. Yet the use of compression hose does create a state of neutral warmth, and the link to homeostasis can easily be made.\textsuperscript{280}

Maintained Stimulus or Pressure. Because of the rapid adaptation of many cutaneous receptors, a maintained stimulus will effectively cause inhibition by preventing further stimuli from entering the system. This technique is applied to hypersensitive areas to normalize skin responses. Vibration used alternately with maintained pressure can be highly effective. It should be remembered that these combined inputs use different neurophysiological mechanisms. It is often observed that low-frequency maintained vibration is especially effective with learning-disabled children who have hypersensitive tactile systems that prevent them from comfortable exploration of their environment. When children themselves use vibration on the extremities, their hypersensitive systems seem to normalize and they become receptive to exploring objects. If that exploration is accompanied by additional prolonged pressure, such as digging in a sandbox, the technique seems to be more effective because of the adaptive responses of the nervous system.

Maintained pressure approaches using elastic stockings, tight form-fitting clothing (e.g., wet suits, expanded polytetrafluoroethylene [Gore-Tex] biking clothing), air splints, and other techniques can be incorporated into a client’s daily activity without altering lifestyle. The use of TheraTogs in children with various hyperactivity conditions has become an accepted therapeutic tool. They add some resistance, some support, and maintained pressure.\textsuperscript{281} TheraTogs have also been shown to be effective in assisting individuals with hemiplegia to regain abductor control.\textsuperscript{292}

In this way clients can self-regulate their systems, allowing greater variability in adapting to the environment. Owing to the multisensory and multineuronal pathways used when peripheral input is augmented, traditional linear, allopathic research on human subjects is extremely difficult to design or measure with control. But outcome studies demonstrating efficacy are possible. Initially, efficacy confirmed by observation was acceptable. Now it is time to repeat studies and use objective measures to demonstrate the same outcome.

Light Discriminatory Touch. Once an individual can discriminate light touch both for protection and for discriminatory learning, a lot of therapeutic tools become available to the therapist. Using boxes with an opening so the individual can insert a hand and arm but cannot see what is inside, a patient can work on discriminating textures, objects, letter numbers, and so on while working on higher-order processing. Once this touch has been integrated, the patient can also use light touch to determine balance, position in space, and various other types of perceptual tasks.\textsuperscript{283}
the vestibular system differently and may differentially affect the excessive extensor tone observed in the client. The vertical sitting position adds flexion to the system, which has the potential of further dampening extensor tone. This additional inhibition may be necessary to determine whether the slow rocking pattern will be effective with this client. It would seem obvious that if a vestibular procedure was ineffective in modifying the preexisting extensor tone, then use of a powerful procedure, such as spinning, would be inappropriate. Selection of treatment techniques should be determined according to client needs and disability. Clients either with an acoustic tumor that perforates into the brain stem or with generalized inflammatory disorders may be hypersensitive to vestibular stimulation, whereas other clients, such as a child with a learning disability, may be in need of massive input through this system. Heiniger and Randolph\cite{41} and Farber\cite{12,111} present in-depth analyses of various specific vestibular treatment procedures commonly used in the clinic. A general summary of the treatment suggestions is summarized in Table 9-5.

The literature clearly establishes the causation of one vestibular imbalance, dizziness, for all age groups.\cite{288,291} Certainly individuals can have vestibular problems and will present themselves as being dizzy or hyperactive to movement of the head. There is a lot of literature discussing treatment of dizziness, and only a few publications are listed here.\cite{292,294} There is certainly evidence to show how the vestibular system links to the autonomic nervous system and especially the sympathetic pathways.\cite{295} In Chapter 22B the reader will be able to find in-depth discussion of vestibular rehabilitation and the role movement scientists play in that rehabilitation.

**General Body Responses Leading to Relaxation.** Any technique performed in a slow, continuous, even pattern will cause a generalized dampening of the motor output.\cite{296} During handling techniques, these procedures can be performed with the client in bed, on a mat while horizontal, sitting at bedside or in a chair, or standing. The movement can be done passively by the therapist or actively by the client. Carryover into motor learning will best be accomplished when the client performs the movement actively, without therapeutic assistance. In a clinical or school setting, a client who is extremely anxious, hyperactive, and hypertonic may initiate slow rocking to decrease tone or feel less anxious or hyperactive. The reduction of clinical signs allows the client to sit with less effort and to be more attentive to the environment, thus promoting the ability to learn and adapt.

It is the type of movement, not the technique, that is critical. The concept of slow, continuous patterns is used in Brunstrom’s rocking patterns\cite{2} in early sitting, in PNF mat programs, and in therapeutic ball exercise programs; the use of these patterns can be observed in every clinic. Although the therapist may be unaware of why Mr. Smith gets so relaxed when slowly rocked from side to side in sitting, this procedure elicits an appropriate response. The nurse taking Mr. Smith for a slow wheelchair ride around the hospital grounds may do the same thing. Once the relaxation or inhibition has occurred, the groundwork for a therapeutic environment has been created to promote further learning, such as learning of ADL skills. The technique in and of itself will relax the individual but not create change or learning.

Pelvic mobilization techniques in sitting use relaxation from slow rocking to release the fixed pelvis. This release allows for joint mobility and thus creates the potential for pelvic movement performed passively by the therapist, with the assistance of the therapist, or actively by the client. This technique often combines vestibular with proprioceptive techniques, such as rotation and elongation of muscle groups, which physiologically modify existing fixed tonal response through motor mechanisms or systems interactions. Simultaneously, slow, rhythmic rocking, especially on diagonals, is used to incorporate all planes of motion and thus all vestibular receptor sites to get maximal dampening effect, whether directly through the vestibulospinal system or indirectly through the cerebellum and reticular spinal motor system. The same pelvic mobility can be achieved by placing the patient (child or adult) over a large ball. The ball must be large enough for the patient to be semiprone while arms are abducted and externally rotated and legs relaxed (either draped over the ball or in the therapist’s arms). Again, this position allows for maintained or prolonged stretch to tight muscles both in the extremities and in the trunk while doing slow, rhythmical rocking over the ball. The pelvis often releases, and the patient can be rolled off the large ball to stand on a relaxed pelvis preliminary to gait activities. A word of caution must be given regarding use of a large ball for relaxation. It is much easier to control the ball when someone is assisting that control from the opposite direction (in front of the patient). If slow rocking is done and the therapist is keeping his or her voice monotonous for further relaxation, the individual assisting will also relax. One author has had family members fall asleep and slowly or quickly fall to the floor.

**Techniques to Heighten Postural Extensors.** Any technique that uses rapid anteroposterior or angular acceleration of the head and body while the client is prone will facilitate a postural extensor response. Scooter boards down inclines, rapid acceleration forward over a ball or bolster, going down slides prone, and using a platform or mesh net to propel someone will all facilitate a similar vestibular response of righting of the head with postural overflow down into the shoulder girdle, trunk, hips, and lower extremities. Rapid movements while on elbows, on extended elbows, and in a crawling position can also facilitate a similar response. Depending on the intensity of the stimulus, the response will vary. In addition, the client’s emotional level during introduction to various types of stimuli may cause differences in tonal patterns. Clinical experience has shown that facilitatory vestibular stimulation promotes verbal responses and affects oral-motor mechanisms. Children with speech delays will speak out spontaneously and respond verbally.

Because facilitatory vestibular stimulation biases the sympathetic branch of the ANS, drooling diminishes and a generalized arousal response occurs at the cortical level. Therefore the appropriate time to teach adaptive rehabilitative techniques is after vestibular stimulation.\cite{297}

**Facilitatory Techniques Influencing Whole-Body Responses.** Tactile, vestibular, and proprioceptive inputs also assist in the regulation of the body’s responses to movement.\cite{25,111} As stated previously, the vestibular system, when facilitated with fast, irregular, or angular movement, such as spinning, not only induces tonal responses but also causes massive reticular activity and overflow into higher centers.
<table>
<thead>
<tr>
<th>TECHNIQUE</th>
<th>PROPRIOEPTIVE: JOINT, TENDON SPINDLE</th>
<th>EXTEROCEPTIVE</th>
<th>VESTIBULAR</th>
<th>GUSTATORY</th>
<th>OLFATORY</th>
<th>AUDITORY</th>
<th>VISUAL</th>
<th>ANS</th>
<th>LABELED</th>
<th>NOT LABELED</th>
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<td>Sweep tapping</td>
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<td>Brunnstrom rolling (hand)</td>
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<td>Raimiste sign</td>
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<td>Stretch pressure</td>
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<tr>
<td>Digging in sand, and so on</td>
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<td>Gentle shaking</td>
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<td>Prone activities over ball</td>
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<td>Sitting activities on ball</td>
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<td>X</td>
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<td>X</td>
<td>X</td>
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<td>OLR and balance (all systems)</td>
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<tr>
<td>Mat activities</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>Resistive exercises</td>
<td>X</td>
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<td>1. Resistive rolling</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td></td>
<td>If verbal command</td>
<td>If visual leads</td>
<td>Rotatory integration</td>
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<tr>
<td>2. Resistive patterns: PNF</td>
<td>X</td>
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<td></td>
<td>Depends on pattern</td>
<td>X</td>
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<td>3. Resistive gait</td>
<td>X</td>
<td>?</td>
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<td>Depends on pattern</td>
<td>X</td>
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<tr>
<td>4. Isokinetics</td>
<td>X</td>
<td>Some</td>
<td>X</td>
<td>If done in body rotation)</td>
<td>X (if guided toward target)</td>
<td></td>
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<tr>
<td>5. Wall pulleys</td>
<td>X</td>
<td>?</td>
<td>X</td>
<td></td>
<td></td>
<td>If verbal command</td>
<td>X</td>
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<tr>
<td>6. Rowing</td>
<td>X</td>
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<td>X</td>
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<td>If verbal command</td>
<td>X</td>
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<tr>
<td>Feeding</td>
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<tr>
<td>1. Maintained pressure: walking to back of tongue</td>
<td>X</td>
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<td>2. Resistive sucking</td>
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<td>a. Straw</td>
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<td>b. Popsicle</td>
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<td>Interventions for Clients with Movement Limitations</td>
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<td><strong>3. Use of textures</strong></td>
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<td>a. Peanut butter</td>
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<td>b. Applesauce</td>
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<td>Inverted TLR(^{621,624})</td>
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<td>Touch bombardment(^{620})</td>
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<td><strong>1. Tactile discrimination in sand, and so on</strong></td>
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<td>Throwing and catching</td>
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<td><strong>1. Balloon</strong></td>
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<td><strong>Variance in movement</strong></td>
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<td><strong>1. Quick action directed by vision</strong></td>
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<td><strong>2. Postural activities in front of mirror</strong></td>
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<td><strong>3. Therapist using voice command to assist client with movement</strong></td>
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<td><strong>High-level movement</strong></td>
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<td><strong>1. Walking balance beam</strong></td>
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<td><strong>3. Running, jumping, skipping</strong></td>
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\(^{OLR}\), Optic and labyrinthine righting reactions; \(^{PNF}\), Proprioceptive neuromuscular facilitation; \(^{TLR}\), Tonic labyrinthine reflex.
Thus increased attention and alertness are often the outcome. The tracts going from the spinal cord, brain stem, and higher subcortical structures must be sufficiently intact to permit the desired responses from this type of input. If a lesion in the brain stem blocks higher-center communication with the vestibular apparatus, then massive input may cause a large increase in abnormal tone. The therapist needs to closely monitor any distress or ANS anomalies.295

**Total-Body Relaxation Followed by Selective Postural Facilitation.** The use of the inverted position in therapy has become very popular as a way to relax postural muscles and decrease compression between vertebrae.296 Not only does this decrease pain, but it also causes relaxation. Earlier research on the labyrinth’s influence on posture and the influence of the inverted position showed that total inversion (angle of 0 degrees) produced maximal postural extensor tone, and the normal upright position elicited maximal flexor tonicity.297 There seems to be confusion in the literature about the clinical effects of inversion. The initial research was performed on anesthetized animals and cannot be representative of how the human CNS responds to inversion as a system. Kotke298 reports that the static labyrinthine reflex is maximal when the head is tilted back in the semireclining position at an angle of 60 degrees above the horizontal. Conversely, minimal stimulation occurs when the head is prone and down 60 degrees below the horizontal position. Stejskal297 studied the effects of the tonic labyrinthine position in hypertonic patients. This study failed to show labyrinthine reflexes in subjects with hypertonia. The problem with use of the inverted position is its lack of permanency. It is a contrived technique used to relieve pain or to achieve total relaxation. The effectiveness of this approach comes with the next set of therapeutic activities that allow the CNS to maintain that relaxation for a period of time and hopefully indefinitely over a series of multiple treatments.

The explanation for the incongruity in the literature over decades seems to be one of interpretation. Any time a subject is put on a tilt table or even a scooter board, the weight bearing of the body on the surface must cause firing of the underlying exteroceptors while gravity pulls on the proprioceptors. This position also has the potential to create fear.300 As the body shifts and presses onto the underlying surface, stretch reflexes associated with posture and movement must contribute some bias to muscle tone.301 In addition, if the subject is in supine and the neck flexors are activated eccentrically (being lowered to supine) or concentrically (being pulled toward sitting or actively lifting the head), or if the subject is in prone and the neck extensors are activated eccentrically (lowering the head toward the ground) or concentrically (holding the head up in prone), the proprioceptors of the neck could alter the muscle tone of the limbs.302

Another factor that contributes to tonal changes in the extremities is the cervicocular reflex.303,304 Reflex eye movements to center the eyes as the body or neck rotates also exert influences on the muscles of the limbs. Because all the influences brought about by gravity and postural mechanisms in a clinical situation cannot be controlled, the inverted position appears to be an interplay of cutaneous receptors, proprioceptors, and tonal changes in the labyrinthine system.305

Several highly recognized therapists have reported using the inverted position as a therapeutic modality.12,28,41 Generally the inverted position produces three major changes. First, because of the gravitational forces on circulation, the carotid sinus sends messages to the medulla and cardiac centers that ultimately lower heart rate, respiration, and resting blood pressure through peripheral dilation, creating a parasympathetic response pattern. This position may be contraindicated for certain patients with a history of cardiovascular disease, glaucoma, or completed stroke. Clients with unstable intracranial pressure—for example, those with traumatic head injuries, coma, tumor, or postinflammatory disorders—and many children with congenital spinal cord lesions would also be at high risk for further injury if the inverted position were used. However, this position has been used with some success for adult patients with hypertension. In any case, scrupulous recording of blood pressure and other ANS effects should be taken before, during, and after positioning.

Another benefit of the inverted position is generalized relaxation. Farber12 recommends its use as an inhibitory technique. Because the carotid sinus stimulates the parasympathetic system, the trophotropic system is influenced and muscle tonicity is reduced. This has been found to be beneficial to patients with upper motor neuron lesions and also to children who exhibit hyperkinetic behavior. Heiniger and Randolph41 report that severe hypertonicity in the upper extremities is noticeably reduced.

The third benefit of the inverted position is an increased tonicity of certain extensor muscles. This phenomenon is not purely a function of the labyrinth; it is also a result of activation of the exteroceptors being stimulated by the body’s contact with the positioning apparatus.305 Therapists have capitalized on this reaction to activate specific extensor muscles of the neck, trunk, and limb girdles.27,297,299

Because the inverted position decreases hypertonicity and hyperactivity and facilitates normal postural extensor patterns, the responses to the technique should be incorporated into meaningful functional activities. For example, if the position of total inversion over a ball is used, then postural extension of the head, trunk, and shoulder girdles and hips should be facilitated next. Additional facilitation techniques, such as vibration or tapping, could help summate the response. Resistance to the pattern in a functional or play activity would be the ultimate goal. If the inverted position is used in a squat pattern, then squatting to standing against resistance would probably be a primary goal. This can be accomplished by the therapist positioning his or her body behind and over the child, not only to direct the child initially into the inverted position but also to resist the child coming to stand. If the inverted position is used in sitting, activities of the neck, trunk, and upper extremities would be the major focus after the initial responses.

Because the inverted position elicits both labyrinthine and ANS responses, this technique needs to be cross-referenced within the classification schema. Because of its ANS influence, close monitoring is important for all clients placed in an inverted position. As with all labyrinthine treatment techniques, this approach, considered a normal, inherent human response, is used outside the therapeutic setting. For example, standing on one’s head in a yoga exercise causes the same physiological state as that observed in the clinic. In many respects the yoga stance is done for the same reasons: decreasing hypertonicity (generally caused by
tension), achieving relaxation, and increasing postural tone and altered states of consciousness. Clients can certainly be taught to control their own ANS activity and hypertonicity by placing their hands between their legs when they need a generalized dampening effect on motor generators. Thus, when accessing and incorporating other approaches, the therapist analyzes each specific technique with use of a critical neuroscientific frame of reference.

This section has described procedures that use the vestibular system as a primary input modality to alter the client’s CNS. If the client’s vestibular system itself is dysfunctional, this dysfunction has the potential to alter the functional state of the motor system. See Chapter 22A for additional information on balance and Chapter 22B for information on the vestibular system.

The therapist must always remember that in combining vestibular and proprioceptive input or asking the CNS to process this information, a variety of results can develop. When the two input systems are congruent, the response will be summated and the CNS will not need to make a lot of adjustment. However, if the inputs are in conflict, then the CNS needs to update the differences and weigh which stimulus is more relevant. Then the updating and response will be in direct proportion to how both inputs were weighted. 306

**Autonomic Nervous System**

The ability to differentiate tone created by emotional responses versus tone resulting from CNS damage is a critical aspect of the evaluation process. Emotional tone can be reduced when stress, anxiety, and fear of the unknown have been reduced. This is true for all individuals. The client with brain damage is no exception. Six treatment modalities 307 that normally produce a parasympathetic or decreased sympathetic (flight or fight) response are as follows:

1. Slow, continuous stroking for 3 to 5 minutes over the paravertebral area of the spine
2. Inversion, eliciting carotid sinus reflex along with other somatosensory receptors (refer to the discussion of vestibular system earlier in the chapter).
3. Slow, smooth, passive and active assistive movement within a pain-free range (refer to Maitland’s grade II movements (see Figure 9-3)) 20
4. Deep breathing exercises (see Chapter 18)
5. Progressive muscle relaxation
6. Cranial sacral manipulation (see Chapter 39)

When pressure is applied to both the anterior and posterior surfaces of the body, measurable reductions may be recorded in pulse rate, metabolic activity, oxygen consumption, and muscle tone. 266, 308 These pressure techniques are identified as an intricate part of the many intervention approaches such as therapeutic touch, 266, 267 Feldenkrais, 225-227, 309 Maitland, 20 massage, 310, 311 and myofascial release. 5, 212, 312-314 Although not verbally identified, other techniques (e.g., neurodevelopmental treatment (NDT), 31, 32 Rood, 29, 41, 111 Brunstrom, 1 and PNF) 20 also place an important emphasis on the response of the patient to the therapist’s touch.

**Treatment Alternatives Using the Autonomic Nervous System**

**Slow Stroking.** Slow stroking over the paravertebral areas along the spine from the cervical through lumbar components will cause inhibition or a dampening of the sympathetic nervous system. The technique is performed while the client is in the prone position. The therapist begins by stroking the cervical paravertebral region in the direction of the thoracic area, using a slow, continuous motion with one hand. Usually a lubricant is applied to the skin, and the index and middle fingers are used to stroke both sides of the spinal column simultaneously. Once the first hand is approaching the end of the lumbar section, the second hand should begin a downward stroking at the cervical region. This maintains at least one point of contact with the client’s skin at all times during the procedure. The technique is applied for 3 to 5 minutes—and no longer—because of the potential for massive inhibition or rebound of the autonomic responses. 35, 296 It is also recommended that at the end of the range of the last stroking pattern, the therapist maintain pressure for a few seconds to alert both the somatic and visceral systems that the procedure has concluded. Eastern medicine recognizes the importance of the ANS in total-body regulation to a greater extent than Western medicine does. The concepts of meridians and acupuncture points are all intricately intertwined with the ANS (see Chapter 39). For that reason, a technique such as slow stroking would potentially interact with meridians and does extend over the row of acupuncture points referred to as shu points and relates to visceral reflexes connecting smooth muscle and specific organ systems. It is believed that this continuous, slow, downward pressure modulates the sympathetic outflow, causing a shift to a parasympathetic reaction or relaxation. Whether a result of the pressure on the sympathetic chain, some energy pressure over meridian points, a pleasant sensation, or something unknown, slow stroking does elicit relaxation and calming. 30, 31 Clients with large amounts of body hair or hair whorls are poor candidates for this procedure because of the irritating effect of stroking against the growth patterns and the sensitivity of hair follicles.

**Slow, Smooth, Passive Movement within Pain-Free Range.** Increasing ROM in painful joints is a dilemma frequently encountered by therapists caring for clients with neurological damage. Having the client communicate the first perception of pain and then moving the limb in a slow, smooth motion toward the pain range elicits a variety of behaviors. First, the client generally gestures or verbalizes that pain is present 10 to 15 degrees before it may, in reality, exist. This behavior may occur because the patient during previous treatment interventions learned that therapists often responded to the client’s statement of pain by saying, “Let’s just go a little farther.” That additional range is usually 10 to 15 degrees. If the therapist stops at the stated point of pain, retreats back into a pain-free area, and approaches again, possibly with a slight variation in rotation or direction, the client will often relinquish the safety range and a true picture of the pain range will be obtained. The second finding is that if the motion toward the pain range is slow, smooth, and continuous, then frequently much of the range that was initially painful becomes pain free. The hypothesis is that slow, continuous motion is critical feedback for the ANS to handle imminent discomfort. The slow pattern provides the ANS time to release endorphins, thus modifying the perception of pain and allowing for increased motion. If the therapist stabilizes the painful joint and prevents the possibility of that joint going into the pain range, rapid,
oscillating movements can often be obtained within the pain-free range. This maintains joint mobility and often, as an end result, increases the pain-free range. This technique is not unique to the treatment of clients with neurological problems; it is often used as a manual therapy procedure. Furthermore, one can move slowly into a range that actually shortens muscles. If held for 30 seconds, the muscle that is too short can relax, promoting greater motion in the opposite direction. This can be called strain-counterstrain—inhibiting firing by maintaining a position of active insufficiency, making the muscle too short.

Manual therapy can be used to describe the pain and joint changes occurring at the joint level. As the fields of orthopedics and neurology merge into one system, with the brain acting as an organ controlling the entire system and its components, the question of whether the pain reduction is centrally or peripherally triggered may be an important one. The answer is probably both. For example, thumb pain can increase the sensation of the nervous system to the point that even cutaneous and proprioceptive receptors act as nociceptors.

Maintained Pressure. Farber discusses a variety of techniques that facilitate a reduction of tone or hyperactivity. Pressure to the palm of the hand or sole of the foot, to the tip of the upper lip, and to the abdomen all seem to produce this effect. The pressure need not be forceful, but it should be firm and maintained. This same technique is defined as inhibitory casting when applied through the use of an orthosis (see Chapter 34).

Progressive Muscle Relaxation. Progressive muscle relaxation is practiced during both meditation and treatment approaches such as Feldenkrais. These methods of relaxation tend to trigger parasympathetic reactions, which in turn slow down heart rate and blood pressure and trigger slow, deep breathing (see Chapters 18 and 39). The Alexander technique has also been shown to cause relaxation while simultaneously increasing postural tone.

Cranial Sacral Manipulation. Summarizing the complexity of cranial sacral theory is not within the scope of this book. The reader is referred to references to gain a global understanding of the treatment interactions and the ANS response to cranial therapy as well as a brief discussion in Chapter 39. This treatment approach needs to be more intensively researched in terms of physiological effects and clinical effectiveness.

Olfactory System: Smell

The complexity of the olfactory system and how it interacts with nuclei that direct emotion in humans is still not totally understood. Yet quality of life in patients without smell (dysosmic) is often impaired. How the neuroanatomy and neurophysiology of human smell lead to a decreased quality of life is still under investigation.

Smell evokes different responses by means of the limbic system’s control over behavior. Pleasant odors, such as vanilla or perfume, can evoke strong moods. Unpleasant odors can facilitate primitive protective reflexes, such as sneezing and choking. Sharp-smelling substances such as ammonia can elicit a reflex interruption of breathing. As a result of arousal, protective reflexes, and mood changes caused by odors, the use of smell as a treatment modality has been implemented, especially during feeding procedures. Odors such as vanilla and banana have been used to facilitate sucking and licking motions. Ammonia and vinegar have been used clinically to elicit withdrawal patterns and increase arousal in semicomatose patients. When odors are used as a stimulant, the therapist must be aware of all behavior changes occurring within the client. Arousal, level of consciousness, tonal patterns, reflex behavior, and emotional levels all can be affected by odor. Because of limited research in this area, caution must be exercised to avoid indiscriminate use of the olfactory system. Odors such as body odor, perfumes, hairspray, and urine can affect the client’s behavior although the smell was not intended as a therapeutic procedure. Some clients, especially those with head traumas and inflammatory disorders of the CNS, often seem to be hypersensitive to smell. In these cases the therapist needs to be aware of the external olfactory environment surrounding the client and to make sure those odors that are present facilitate or at least do not hinder desired response patterns.

Many clinical questions arise regarding smell as a therapeutic modality. If the choice of odors is between pleasant and noxious, a pleasant odor will theoretically be perceived in a way that should be enjoyable, relaxing, and thus potentially tone reducing. On the other hand, noxious odors should cause a sympathetic reaction and, although producing alertness, may also create a fight-or-flight internal reaction that if repeated frequently could cause an adverse response to the client’s perception of the world. This has the potential for having a profound effect on her or his feelings toward the therapist and the therapeutic environment. The effect may not be observable until the client reaches a level of consciousness or motor skill in which there is some ability to react.

Individuals’ perception of smell is not correlated to their actual olfactory ability. Because of the complex neuronswork of the olfactory system, the specifics between emotional responses and olfactory environment cannot be established, and determining which olfactory input will drive a pleasant, unpleasant, or neutral response is variable. There may be a cultural sensitivity to various smells that would suggest a cultural learning linked with emotional responses to smell. Therefore if a therapist is going to use smell as part of therapy, identification of the individual’s prior likes and dislikes is very important. Family members and close friends will be the best people to consult in order to get this information.

Without a sense of smell an individual may not be able to respond appropriately to various olfactory environments, which may increase a client’s feeling of isolation and lack of social interactive skills. Smell is intricately linked to the sense of taste. Without these sensory systems, individuals tend to stop eating, thus creating an entirely different health care issue.

Gustatory Sense: Taste

Gustatory input is generally used as part of feeding and prefeeding activities. As already mentioned, the oral region is sensitive not only to taste but also to pressure, texture, and temperature. For that reason feeding would be classified as a multisensory technique that uses gustatory input as one of its entry modalities. Specific input modalities are based on the combined taste, texture, temperature, and affective
response pattern—that is, both a banana and an apple may be sweet, yet the textures vary greatly. When mashed, both fruits may have a pudding-like texture, yet the client’s emotional response may differ. Disliking the taste of banana but enjoying apple may cause startling differences in the client’s response during a feeding session. Thus the importance of the clinician’s sensitivity to the client’s response patterns within each sensory modality cannot be overemphasized. Similarly, a therapist needs to take into consideration normal changes with taste and smell that occur as a result of aging and adjust the input threshold appropriately. The inter-relationship of taste and smell leads to the perception of flavor. Current research has shown that the role of taste may be guided more by taste than by smell, but with each a client will not be able to differentiate flavors of food. Understanding this sensory system will lead to a greater understanding of some patient problems that follow CNS damage.

**Auditory System**

**Treatment Alternatives with Use of the Auditory System.** Because of the complexity of the auditory system, a potentially large number of types of input modalities exists. Although some of them might not be considered traditional therapeutic tools, they are nonetheless techniques that affect the CNS. Some treatment alternatives focus on the following:

- Quality of voice (pitch and tone)
- Quantity of voice (level and intensity)
- Affect of voice (emotional overtones)
- Spatial and temporal sound (how fast a stimulus occurs, and how frequently)
- Extraneous noise (sound)
- Auditory biofeedback
- Language
- Volume, level, and affect of voice
- Auditory perception

The therapist’s voice can be considered one of the most powerful therapeutic tools. Even constant sound has the ability to cause adaptation of the auditory system and thus inhibition of auditory sensitivity. Similarly, intermittent, changing, or random auditory input can cause an increase in auditory sensitivity. Because of auditory system connections, an increase or decrease in initial input or auditory sensitivity has the potential for drastically affecting many other areas of the CNS. The connections to the cerebellum could affect the regulation of muscle tone. The collaterals projecting into the reticular formation could affect arousal, alertness, and attention, in addition to muscular tone. The importance of voice level has been acknowledged by colleagues for decades with respect to encouraging clients to achieve optimal output or maximal effort. The use of voice levels is a critical aspect of the entire PNF approach. Yet the volume or intensity of a therapist’s voice is only one aspect of this important clinical tool. Through clinical observation, it has been observed that clients respond differently to various pitches. The response patterns and specific range of comfortable pitch seem to be client dependent. The concept that each individual may have a range within the musical scale or even a specific note that is optimal for biorhythm function has been proposed by one composer-musician. This concept needs research verification but may prove to relate to one of those innate talents some therapists have that distinguish them as gifted therapists.

The emotional inflections used by the clinician certainly have the potential to alter client response. For example, assume the therapist asks Tim, a child with cerebral palsy, to walk. The specific response from the child may vary if the clinician’s voice expresses anger, frustration, encouragement, disgust, understanding, or empathy. Knowing which emotional tone best coincides with a client’s need at a particular moment may come with experience or sensitivity to others’ unique needs.

**Extraneous Noise.** The varying level of sound or extraneous noise in a clinical setting can at times be overwhelming. Dropping of foot pedals, messages over loudspeakers, conversations, computers, printers, telephones, moans, a jackhammer outside the clinic, water filling in a tank, a drip in a faucet, whirlpool agitators, a burn patient screaming, and child crying all are encountered in the clinical environment, and all could be occurring simultaneously. A therapist whose CNS is intact usually can inhibit or screen out most of the irrelevant sound, although his or her voice may rise according to the surrounding noise and the therapist may not even be aware of the vocal change. Clients with CNS damage may not have the ability to filter sensitivity to all these intermittent noise sensations. The protective arousal responses these sounds might produce in a client could certainly elevate tone, block attention to the task, heighten irritability, and generally destroy client progress during a therapy session. Awareness of the noisy environment and the client’s response to it not only is important for treatment modalities but also is critical to the problem-solving process.

Decreasing auditory distracters or sudden noises can drastically improve the client’s ability to attend to a task or to succeed at a desired movement. The therapist is reminded that if the environment has been externally adapted for a client to procedurally and successfully practice the goal, then independence in that functional skill has not been achieved. Reintroduction of the noises of the external world must be incorporated into the client’s repertoire of responses so that the individual can feel competent in dealing with any auditory environment the world might present.

**Music.** Music as an adjunct to therapy has been suggested as a viable way to help clients develop timing and rhythm in a movement sequence (see Chapter 20 for a discussion of basal ganglia disorders and Chapters 5 and 39 for a discussion of music therapy). Consistent sound waves and tempos, such as soft music, allow the patient to develop a neuronal model or an engram for the stimulus. The use of background music during therapy sessions enables the patient to make an association to the sounds, producing an autonomically induced relaxation response to a particular musical composition. Therapists must remember that music has a very strong emotional link to all other areas of the nervous system. For that reason, the use of music needs to be discriminative and not randomly introduced because the therapist likes the sound. Similarly, the music selected should be a piece that assists the patient and does not become a deterrent to succeeding at the current motor task. The clinician will easily tell the difference by the tone the music creates (increase or decrease) and the success made toward achieving the desired task.
Music is used for encouraging not only motor function but also memory and socialization. Rhythmic sound perceived as an enjoyable sensation certainly has the effect of creating motor patterns in response to that rhythm. Individuals, young and old, will tap their fingers or feet to a beat. If the beat has words, people will often sing along, recalling from memory the appropriate words. The movement, memory, and willingness to interact are all critical aspects of the therapeutic environment. Having clients dance with a significant other twice a day to music they have enjoyed in the past encourages both the physical function and the social bonding so important for quality of life. Music affects heart rate, blood pressure, and respiration. It has even been suggested that easy listening music may bolster the immune system.

**Auditory Biofeedback.** Biofeedback as a total therapeutic modality is discussed under the treatment sections in Chapters 33 and 39. Auditory biofeedback is generally thought of as a procedure in which sound is used to inform the client of specific muscle activity. The level or pitch may change in relation to strength of muscle contraction or specific muscle group activity. Yet auditory biofeedback also encompasses feedback as simple as a foot slap that communicates that a client’s foot is on the floor or verbal praise encompassing feedback as simple as a foot slap that communicates that a client’s foot is on the floor or verbal praise after a successful therapeutic session. The importance of the auditory feedback system as a regulatory mechanism between internal and external homeostasis cannot be overlooked. However, the clinician should not assume that this system is intact and can automatically be used as a normal feedback mechanism for clients with CNS damage.

**Language.** Although most therapists thoroughly appreciate the complexity of the language system as a whole, they have little if any in-depth background to help them understand the components or the sequences leading to the development of language. Thus many therapists are extremely frustrated when confronted with clients who show perceptual or cognitive deficits involving the auditory processing system.

Therapists easily identify language comprehension difficulties with adults who have first language differences and with young children because of their age and lack of language experience. Nevertheless, many clients have a language processing dysfunction that leads to communication difficulties, both in reception and appropriate expression. The elderly often can understand a conversation in a quiet room but have difficulty in rooms that are noisy. The environment within which communication occurs can drastically affect both reception and the ability to express to the world inner feelings and thoughts. Creating an environment conducive to that exchange will dramatically affect the motivation and drive of a patient within the therapeutic setting. The complexity of auditory reception, processing, and responses is extremely extensive and could be overwhelming to a PT or OT, but developing an understanding of how auditory information affects motor performance will certainly enhance the therapist’s analysis of movement problems.

**Visual System**

**Treatment Alternatives with Use of the Visual System.** Because light is an adequate stimulus for vision, any light, no matter the degree of complexity, has the potential to affect a client’s CNS. That input not only reaches the optic cortex for sight recognition and processing but also projects to the brain stem and to the cerebellum through the tectocerebellar tract. Simultaneously, these afferents activate the reticular-activating and limbic spinal generators through the tectospinal tract. Thus, as long as light is entering a client’s CNS, it has the potential to alter response patterns either directly—through the tectospinal system or the corticospinal system through occipitofrontal radiations—or indirectly through the influence of the ANS and limbic system on muscle tone resulting from emotional responses to light.

The five categories of visual-system treatment alternatives should not be considered fixed, all-inclusive, or without overlap. The first three categories (color, lighting, and visual complexity) are common everyday visual stimuli. Combined, they make up the visual world.

**Colors.** When colors, hues, tones, the type of lighting, and the degree of complexity of the combined visual stimuli are varied, the treatment modality and the way the CNS processes it change. Because the visual system tends to adapt to sustained, repetitive, even patterns, any input falling under those parameters should elicit visual adaptation. This adaptation response will lead to decreased firing of sensory afferent fibers and have an overall effect of decreasing CNS excitation. A clinician would expect to see or palpate a decrease in muscle tone, a calming of the client’s affective mood, and a generalized inhibitory response. Cool colors, a darkened room, and monotone color schemes all seem to have an inhibitory effect. What a therapist might look for is a change in a patient’s behavior. For example, four days ago Patient A was placed on the green mat for therapy and he seemed interactive, calm, and involved in producing motor function. On the next day, he came to therapy and the red mat was available. When Patient A got on the mat he became agitated and inattentive. The next day again Patient A was placed on the red mat and again was agitated and distracted. On day four, Patient A was placed on the green mat and had a great therapy session. On this fourth day he was calm, interactive, and involved in regaining motor function. It would be easy for a therapist to miss behavioral changes occurring when a patient is placed on a green or a red mat. These problems should be anticipated when treating patients with emotional instability (see Chapters 5, 14, 23, 24, and 26).

In contrast, intermittent visual stimuli, bright colors, bright lights, and a random color scheme seem to alert the CNS and have a generalized facilitatory effect. Research in the 1980s in the area of criminology has produced evidence to suggest that specific shades of colors can produce either a sedating response (such as certain pinks) or general arousal (certain blues). Although a tremendous amount of research is required to substantiate these results if the clinician is to apply them with confidence, research is beginning to show that specific shades of colors and hues may drastically affect a client’s general response to the world and specific response to a therapy session. Within the next few years, many facts regarding the reaction of the CNS to specific visual stimuli may be uncovered, and the clinician will be responsible for integrating this new information into the present categorization scheme. Although a person without body system problems may react
in specific ways to color, intensity, and visual distracters, individuals with CNS may not respond with the same behavior.\textsuperscript{416} In the Netherlands at the Institut de Hartenbuer, playrooms have been designed in different colors.\textsuperscript{14} Except for color, all rooms are exactly the same and originate from a central hub or core.\textsuperscript{14} Children are allowed to select which room they wish to play or be treated in. Children seem to pick the color room that most suits their moods and alertness and creates an environment in which they can learn.\textsuperscript{14}

**Lighting.** Two types of lighting are found in a clinical environment. Fluorescent or luminescent lighting comes by definition from a nonthermal cold source. This type of lighting is generally emitted by a high-frequency pulse. Umphred (clinical observations, 1967 to 2005) has found that many individuals within a normal population complain that this high-frequency flutter is irritating and causes distraction. For this reason, it is recommended that each clinician observe clients’ responses to various types of lighting to determine whether fluorescent visual stimuli cause undesirable output.\textsuperscript{417} This is especially true with clients who already have an irritated CNS, such as those with inflammatory disorders (see Chapter 26), head trauma (see Chapter 24), or seizure disorders.\textsuperscript{418,419} The clinician should also remember that clients frequently lie supine and look directly at overhead lighting, whereas the therapist looking at the client is unaware of that particular visual stimulus. The types of visual stimuli that may cause seizures and are seen by clients within rehabilitation settings include computers, videogames, television, and venetian blinds.\textsuperscript{417} For that reason, any change in lighting should alert the clinicians to watch for changes in their clients’ behavior.

Incandescent lights by definition come from hot sources and emit a constant light without a frequency. The brightness of this type of lighting has the potential to alter CNS response. The visual system quickly responds to bright lights with pupil constriction. After prolonged exposure to a bright environment, the visual system adapts and becomes progressively less sensitive to it.\textsuperscript{141,408} Similarly, when exposed to darkness the retina becomes more sensitive to small amounts of light. Because of the response of the visual system to incandescent lighting, it is recommended that a therapist monitor the brightness of the lighting, especially before any type of visual-perceptual training or visually directed movement.

Although the sun is a natural source of light, it is not generally the primary source in a clinical setting. The sun can effectively be used as indirect lighting, thus eliminating the problems produced by artificial lighting. Sunlight is also more acceptable psychologically. Some clinics have designed the buildings to allow for maximum use of natural light.\textsuperscript{13}

**Visual Complexity.** The visual system is the primary spatial sense for monitoring moving and stationary objects in space.\textsuperscript{420,421} An infant continually refines the ability to discriminate objects in external space until capable of identifying specific objects amid a complex visual array.\textsuperscript{409} When brain damage occurs, the ability to identify objects, localize them in space, pick them out from other things, and adapt to their presence may be drastically diminished.\textsuperscript{208} Because of the distractibility of many clients, reducing the visual stimuli within their external space can help them cope with the stimuli to which they are trying to pay attention.

Using rooms that have been stripped of such stimuli as furniture and pictures can reduce not only distractibility but also hyperactivity and emotional tone. If this method of reduction of stimuli is used, the clinician must remember that this procedure has a sequential component. The client must once again adapt to extraneous visual stimuli. Thus as the client’s coping mechanisms improve, the therapist needs to monitor and change the visual environment. The therapist can monitor the amount of input according to the response patterns of the client but in time needs to have the client function in everyday environments and practice adaptation.

**Cognitive-Perceptual Sequencing with the Visual System.** In sighted individuals the visual system is important for integrating many areas of perceptual development, such as body schemes, body image, position in space, and spatial relationships.\textsuperscript{268,422,423} Vision as a processing system is so highly developed and interrelated with other sensory systems that when intact it can be used to help integrate other systems.\textsuperscript{395,424} Conversely, if the visual system is neurologically damaged, it can cause problems in the processing of other systems.

For example, assume that a child is asked to walk a balance beam while fixating on a target. The child is observed falling off the beam. On initial assessment vestibuloproprioceptive involvement would be primarily suspected. On further testing the therapist might discover that the child, while looking at the target, switches the lead eye in conjunction with the ipsilateral leg. As the child switches from right to left eye, the target will seem to move. Knowing the wall is stationary, the child will assume the movement is caused by body sway, will counter the force, and will fall off the beam. The problem is a lack of bilateral integration of the visual system in contrast to other sensory modalities. The visual system deficit is overriding normal proprioceptive-vestibular input to avoid CNS confusion. Unfortunately, the client is attending to a deficit system and negating intact ones. This visual conflict would be overriding the normal processing of intact systems.\textsuperscript{425}

An intact visual system can be overridden by deficits in other systems. This can be seen in clients who are trying to relearn the concept of verticality. Clients with hemiplegia who demonstrate a “pusher” syndrome illustrate this conflict. This clinical problem originates from a posterior thalamic stroke and less frequently with extrathalamic lesions.\textsuperscript{426,427} An intact visual system can often be used to help reintegrate other sensory systems. First teaching clients to attend to vestibular-propriocceptive cues while vision is occluded or visual stimuli tremendously reduced will help present a kinesthetic conflict. Individuals feel straight at 20 degrees or more to the ipsilesional side yet when not supported they fall. This conflict does not need to be verbally discussed. The patients’ nervous systems will interpret the conflict. The intent of the CNS is not to fall. If the patient does not automatically self-correct, the therapist can add reaching patterns across midline to assist. Then vision can be reintroduced to assist orientation to vertical or upright posture. The pusher syndrome is not just a posterior thalamic problem and can be combined with neglect. When additional perceptual problems are added, the testing results and direction of the backward push can change.\textsuperscript{428} Once the orientation has been reestablished, visual input will often be perceived in a more normal fashion. This syndrome has been
linked to the posterior thalamus as well as other integrative cortical areas within the brain.\textsuperscript{427,429-432} Familiarity with the visual-perceptual system and its interrelationships with all aspects of the therapeutic environment is crucial if the clinician is to have a thorough concept of the client’s problem. (See Chapter 28 for specific information regarding visual deficits and treatment alternatives.)

**Mental Imagery.** As is mentioned in the discussion of neuroplasticity in Chapter 4, and as is discussed further in the section on somatosensory retraining within this chapter, having patients visualize the sensory awareness of input from the environment has a positive effect on treatment outcomes. Similar positive effects have been shown to be effective when having patients practice motor imagery as part of the treatment protocol.\textsuperscript{137,433-436} It is known today that using mental imagery to retrieve past information or experiences does use a variety of pathways within the CNS, depending on the specific task.\textsuperscript{337} Having some cognitive understanding of the correlation between cortical deficits in specific patients and their visual-spatial problems helps the clinician avoid task-specific activities that will lead to failure while introducing task-specific mental imagery that will lead to success.\textsuperscript{338} Having the patient practice mental imagery of the functional activity practiced during a therapeutic session can be an excellent way to empower patients to practice when they cannot perform the activity itself independently, without extreme effort and abnormal movement strategies.\textsuperscript{155,439} A therapist will know whether the patient has mentally practiced the movement strategies by the carryover within the next session. The neurophysiological reason for this perceived contradiction may lie in neuroanatomy, site of the lesion, specificity of the individual client.\textsuperscript{426,439,440} Although imagery usually insinuates visualization, there are also other forms of imagery that can be used as part of intervention.\textsuperscript{155,437,439,441-443} Refer to the music therapy section in Chapter 39 for information on mental imagery.

One extension of mental imagery that came into common usage in the 1990s as a result of videogame popularity was “virtual reality.” Over the last two decades the interface between virtual reality and medical education has included the use of a virtual environment to teach surgeons fine motor skill without having them practice on a live subject.\textsuperscript{444} An inevitable link has currently been identified between virtual reality and motor rehabilitation.\textsuperscript{445-448} Today the literature certainly reflects the potential advantage virtual reality may have with regard to not only motor learning but also the use of these environments as an adjunct to therapy in individuals with CNS damage.\textsuperscript{449-455} The future realization of the potential of this type of augmented intervention will be up to visionary thinkers who “push the envelope” of traditional therapeutic interventions.

**Compensatory Treatment Alternatives with Use of the Visual System.** The visual system can be used effectively as a compensatory input system if the sensory component of the tactile, proprioceptive, or vestibular system has been lost or severely damaged. The procedure for using vision in a compensatory manner should not be attempted until the clinician is convinced the primary systems will not regain needed input for normal processing. Although vision can direct and control many aspects of a movement, it is not extremely efficient and seems to take a tremendous amount of cortical concentration and effort.\textsuperscript{418,456-457} Vision was meant to lead and direct movement sequences.\textsuperscript{297,420,458} If it is used to modify each aspect of a movement, it cannot warn or inform the CNS about what to expect when advancing to the next movement sequence. Thus, using vision to compensate eliminates one problem but also takes the visual system away from its normal function. For example, if a hemiplegic man is taught to use vision to tell him the placement of his cane and feet, his need to attend to proprioceptive cues will decrease. When advancing to ambulatory skills such as crossing the street, the client may be caught in a dilemma. As he is crossing the street, if he attends to the truck coming rapidly down the road, he will not know where his cane or foot is and thus will become anxious and possibly fall. If, on the other hand, he attends to his foot and cane, he will not know if the truck is going to hit him. That may increase emotional tone and make it difficult to move. If normal sensory mechanisms could be re-integrated, this client would have freedom to respond flexibly to the situation. Thus caution should be exercised to avoid automatic use of this high-level system to compensate for what seem to be depressed or deficit systems.\textsuperscript{225,226,309,459,460}

Visual input should be used to check or correct errors if other systems are not available. Movement should be programmed in a feed-forward mode unless change is indicated. Vision often recognizes the need for that change. If a client is taught a motor strategy in which vision is used as feedback to direct each component of the pattern, the pattern itself will generally be inefficient and disorganized and will lack the automatic nature of feed-forward procedural motor plans. If the client is too anxious to practice the procedure physically without overusing vision, then visual mental practice can be introduced.

**Internal Visual Processing: “Visualization Techniques.”** A previous section discussed mental imagery as a substitute in the presence of a sensory deficit or as a practice method for when a patient cannot perform a motor task. The use of visualization of some aspect of bodily function goes far beyond just mental practice. Visualization has been and continues to be used in many forms of therapy.\textsuperscript{359} In a randomized controlled study that looked at normal bone healing versus the use of a specific type of yoga that involves breath control, chanting, and visualization as an adjunct treatment, the individuals who practiced this yoga-based approach had accelerated fracture healing.\textsuperscript{461} It has been shown that individuals can modulate their immune responses and that others can change that response through visualization.\textsuperscript{460,462} Smith and colleagues\textsuperscript{463} showed that individuals could exercise through their thoughts and visualization various degrees of control over what had been thought to be mindless internal processes. These concepts have been used therapeutically but usually when the client is resting or totally relaxed.\textsuperscript{225,226,309}

More recently, technology in neuroscience has allowed for the measure of tissue metabolism (positron emission transaxial tomography [PET])\textsuperscript{463} and changes in blood flow (fMRI) while the brain is engaged in functional mental tasks.\textsuperscript{364,465} All areas of the brain except the cerebellum appear to be activated during intense goal-directed mental imagery. Given that the task is not motorically executed, errors in rhythm and accuracy are not made, and thus the cerebellum is not recruited for correction. This suggests that mental imagery can be used to restore a function that might
have been lost as the result of a stroke or other type of injury because the individual may be able to use kinesthetic memory to facilitate learning even if current kinesthetic recognition is impaired. Visual imagination has the benefit of allowing correct task performance when physical limitations may prevent normal task completion. This could prevent abnormal learning (e.g., like that developing from abnormal posturing in a stroke patient who lacks the voluntary control to ambulate and integrate a primitive synergy). For additional information, see the section on somatosensory discrimination.

Today these concepts can be integrated during active treatment in a variety of ways. Before a client begins to initiate a plan of movement, the therapist could ask the client to close the eyes and imagine the movement and what it felt like in that functional activity before the CNS injury. In this way, the patient is using prior memory and visualization to access the motor systems and hopefully initiate better motor plans. Similarly, if during a movement plan the state of the motor generators builds to such a level that the client is becoming dysfunctional, the therapist can stop the movement; ask the client to visualize a calm, quiet place; and then continue with the movement pattern when the tone is reduced or extraneous patterns cease. The client can be asked to practice mental imagery of the task until she or he can accomplish it normally and then finally carry it over to the real environment. For example, a client may have practiced transferring during an intervention session in which the therapist, using augmented treatment, kept the patient within a biomechanical window or limits of stability. During the interval between sessions, the patient is asked to visualize performing transfers initially from the same surface practiced and later to other surfaces at least a couple of times an hour. At the follow-up session, the therapist will often be able to tell if the patient has done the visualization. If the patient did practice, there is often carryover into the skill performance. If the patient forgot to practice, often the skill has reverted back to the initial level of learning, with little carryover from the last intervention.

Another way to use the visual system to access the processing strategies of the client is to observe eye gaze. Neurolinguistic theory postulates that the eyes gaze in the direction of brain processing. Figure 9-4 illustrates the eye gaze direction along with the suggested processing activity. For example, a client who needs to access and process motor plans through the frontal lobe will look down. A client who needs to visually construct an idea of something new will look up and to the right. Various cortical lobes and hemispheres serve specific global processing functions. There are many ways to apply and interpret this theory. By observing the patient’s eye gaze, the therapist can determine whether processing is conducted in what would be believed to be the appropriate areas. Even more clinically relevant is observing where the eyes are gazing before and during successful functional activities. It may be that the area once used in processing is no longer available to do the function. If gazing to the right and down always leads to motor success, then the therapist can empower the patient to look down and right before dressing or transferring. Similarly, if a patient always looks down at the feet during ambulation, the reason may not be “to look at the feet” but instead may be to access the motor cortex to gain better motor function. If the client is asked to visualize the movement before and during the activity, the head often comes to a posturally correct position as the eyes gaze upward toward the occipital lobe and the body automatically orients to vertical. If the client is asked to walk while visualizing the movement, again the result may be a more upright, posturally efficient pattern. Once the program is set and practice scheduling begun, the patient may no longer need to look down and into the frontal lobe. Thus in this case the client not only learned the procedure but also avoided practicing and learning a posturally incorrect ambulation strategy.

**Combined Multisensory Approaches.** Although all techniques have the potential to be multisensory, the specific mode of entry may focus on one sensory system, as already described, or it may target two or more input modalities along with automatic motor programming. As stated before, Table 9-5 categorizes a variety of treatment techniques that are clearly multisensory. The therapist, analyzing how the summated effect of the combined input and automatic responses influences client performance, gains direction in anticipating treatment outcomes in terms of the problem-solving process. Because the potential combinations of multisensory input classification are enormous, only a few examples of combinations are included in the text to illustrate the process a clinician might use when classifying a new technique or a new approach to intervention. When clinicians select augmented treatment interventions to help a client as part of somatosensory retraining or functional retraining or to establish a procedural program, the basic science understanding behind the clinical decision helps develop questions for future research, determine a prognosis regarding outcomes, and rationally explain why or why not an intervention was effective. Clinical decisions must ultimately be made regarding which techniques or component of an approach should be eliminated first as the patient progresses. These decisions must be based on understanding and integration of neurophysiological mechanisms, learning environments, concepts of motor learning and control, and what motor impairment or body system problems are affecting functional performance and on the client’s and family’s
needs, motivations, and goals. A simple rule a therapist might follow would be to take away the least natural technique first. That technique would be the most artificial or contrived. An example using only one sensory system might help to clarify this point. For example, a therapist might assist a client with elbow flexion during a feeding pattern by (1) vibrating the biceps, (2) quickly tapping the biceps, or (3) quickly stretching the biceps a little beyond midrange by using gravity. The first option would be the least natural and obviously the least socially acceptable at a dinner party. The third option is the most natural and closest to what might exist in the real environment in which the client will need to function. Remember, these contrived techniques are used to assist clients who cannot control or perform the motor programs or functional activities without assistance or who need assistance in learning to modulate motor control for greater functional adaptability. If the therapist added verbal feedback or music as well as asking the patient to visually look at the target, the example would become multisensory.

Within the following section are examples of combined multisensory approaches that might be used to augment sensory feedback to obtain a better environment for regaining functional control.

**Sweep Tapping.** Sweep tapping is usually used to open a hypertonic flexor-biased hand. Many isolated techniques, such as sweep tapping\(^\text{11,12}\) or rolling,\(^\text{8}\) would be considered primarily proprioceptive-tactile in sensory origin. During sweep tapping the clinician first uses a light-touch sweep pattern over the back of the fingers of one of the hands. This stimulus is applied quickly over the dermatome area that relates to muscles the client is being asked to contract. Second, the therapist applies some quick tapping over the muscle belly of the hypotonic muscle. The first technique is tactile and believed to stimulate the reflex mechanism within the cord to heighten motor generators and increase the potential for muscle contraction of the hypotonic muscle or to dampen the hypertonic flexors. The second aspect, tapping, is a proprioceptive stimulus used to facilitate afferent activity within the muscle spindle of the extensors, thus further enhancing the client’s potential for muscle contraction. At the same time the client will be asked to voluntarily activate the extensor motor system, which then automatically augments tactile, proprioceptive, and auditory input with functional control.

**Rolling of the Hand.** Before Brunnstrom’s rolling pattern is implemented, the client’s upper extremity is placed above 90 degrees to elicit a Souque’s sign. This decreases abnormal, excessive tone in the arm, wrist, and hand.\(^\text{8}\) This phenomenon may well be a proprioceptive reaction of joints and muscle. The rolling technique consists of two alternating stimulus patterns. The wrist and fingers are placed on extensor stretch. The ulnar side of the volar component of the hand is the stimulus target. A light-touch sweeping pattern is applied to the hypothenar aspect, which has the potential to elicit an automatic opening of the hand beginning with the fifth digit.\(^\text{5}\) Immediately after the light touch, a quick stretch is applied to the wrist and finger extensors. These two techniques are applied quickly and repeatedly, thus giving the visual impression that the therapist is rolling his or her hand over the ulnar aspect of the dorsum of the client’s hand. In reality, tactile and proprioceptive stimuli are being effectively combined to facilitate the central pattern generators responsible for the extensor motor neurons controlling the wrist and finger musculature. Because the tone is felt in the client’s extensors and thus induces relaxation of the hypertonic flexors, the therapist can more easily open the client’s hand. As the client obtains volitional control, some resistance can be added by the therapist to further facilitate wrist and finger extension. A hemiplegic client can also be taught to use this combined approach to opening the affected hand and give it increased range. This technique is a noninvasive, relaxing approach to opening the hand stuck in wrist and finger flexion hypertonicity. The technique itself also seems to trigger spinal generator patterns that dampen the existing neuron network. It does not teach the patient anything unless that individual begins to assist or take over control of the extensor pattern. This usually occurs first when the therapist feels the flexors relax while the patient is trying to extend the wrist and fingers even if no active extension is palpated. Encouraging the patient at this time, confirming that he or she is thinking correctly, and urging him or her to continue doing it provide important motivation for continued practice.

**Withdrawal with Resistance.** A therapist could combine the technique of eliciting a withdrawal with resistance to the withdrawal pattern. This can be an effective way to release hypertonicity, especially in the lower extremities. The withdrawal can be elicited by a thumbnail, a sharp instrument, a piece of ice, or any adequate light-touch stimulus to the sole of the foot. As soon as the flexor withdrawal is initiated, the therapist must resist the entire pattern. Once the resistance is applied, the input neuron network changes and the flexor pattern is maintained through the proprioceptive input caused by resistance to the movement pattern. The one difficulty with this technique is the application of resistance. The withdrawal pattern directly affects alpha motor neurons innervating those muscles responding in the flexor pattern and simultaneously suppresses alpha motor neurons going to the antagonistic muscles. If the antagonistic muscles are hypertonic, then initially the hypertonicity is dampened within the alpha motor neurons’ neuronal pool. Because of the pattern itself, as soon as the flexor response begins, a high-intensity quick stretch is applied to the extensor muscles. If resistance is not applied to the flexors to maintain inhibition over the antagonistic muscles, the extensors will respond to the stretch. The client will quickly return to the predisposed hypertonic pattern and may even exhibit an increase in abnormal tone. This extensor response is a complex reaction within the spinal generators. The therapist should instruct the patient if appropriate to assist with the flexor pattern to recruit other components of the motor system to enhance the system’s modulation over the spinal generators. This can be a way to generate the early component of rolling when leading from the lower extremity and can get the patient out of an extreme extensor pattern in the supine position.

**Touch Bombardment.** Another example of a proprioceptive-tactile treatment technique is modification of a hypersensitive touch system through a touch-bombardment approach. The goal of this approach is to bombard the tactile system with continuous input to elicit light-touch sensory adaptation or desensitization. Deep pressure is applied simultaneously to facilitate proprioceptive input and conscious awareness. Proprioceptive discrimination and tactile-pressure
sensitivity are thought to be critical for high-level tactile discrimination and stereognosis. A hypersensitive light-touch system elicits a protective, altering, withdrawal pattern that prevents development of this discriminatory system and the integrated use of these systems in higher thought. This method of treatment can be implemented by having an individual dig in sand or rice. The continuous pressure forces adaptation of the touch system, and the resistance and deep pressure enhance the proprioceptive-discriminatory touch system by a complex adaptation process that most likely affects all areas involved in light and discriminatory touch, as well as the complex interaction of all motor system components. Whereas sand is often used in the clinic or outside, rice can be used inside and vacuumed easily whether in the clinic or in a patient’s home.

Pool therapy can be used effectively for the same purpose, with the added advantage of neutral warmth, as long as the temperature is in the neutral warmth parameter. Heat increases the sensitivity of light touch, whereas cold initially heightens the nervous system. In time cold can suppress the state of the motor pool (refer to the section on cold). Any client perceiving touch as noxious, dangerous, and even life-threatening will not greatly benefit from any therapeutic session in which touch is a component. Touch includes contacts such as touching the floor with a foot, reaching out and touching the parallel bar railings, and touching the mat. The client may not respond with verbal clues such as “Don’t touch me” or “When I touch the floor it hurts” but will often respond with increased tone, emotional or attitude changes, and avoidance responses. Nevertheless, this treatment approach has application in many areas of intervention with clients having neurological deficits. As an adjunct to this method, a clinician should cautiously apply light touch when in contact with the client. Deep pressure or a firm hold should elicit a more desirable response for the client even if the light-touch system is functional. The use of Gore-Tex material for clothing can greatly enhance the client’s ability to tolerate the external world, where light-touch encounters cannot be avoided. Similarly, socks can decrease the hyperactive tactile system in the foot and may allow the patient to stand or transfer without the feeling that he is standing on pins or that it is a noxious stimulus.

The therapist may also consider systematic desensitization as a strategy to integrate the touch system. By allowing patients to apply the stimuli to themselves, they can grade the amount that they can tolerate. In this respect they are empowered to control their own environment. They can practice adaptation in many situations. When the environment seems overwhelming, they have learned techniques to dampen the input both from within their own systems and by controlling the external world. For example, the therapist may place a box containing objects of different textures before the patient and encourage exploration and active participation to learn which textures are acceptable or offensive. A gradual exposure to the offensive stimuli will raise the threshold of the mechanoreceptors in the skin. There are also the benefits to the patient of being in control of the stimulus and having awareness of the treatment objectives. In addition, vibratory stimuli through a folded towel provide proprioceptive input to desensitize the touch system. Desensitizing the touch system from a need to protectively withdraw is an important process within the CNS if normal stereognosis is to develop.

**Taping.** Taping procedures normally used in peripheral orthopedic muscle imbalances and pain have the same potential for patients with neurological problems. This adaptation would be a modification of both splinting and slings. Research has been done to demonstrate efficacy of taping to offset peripheral instability in individuals with neurological system impairments. The concepts and ideas remain that taping has implications when treating individuals with neurological problems. Taping hypotonic muscle groups into a shortened range should effectively reduce the mechanical pull of gravity on both the muscle groups and joints and prevent the CNS from developing the need for compensatory stabilization or hypertonicity. If hypertonicity is the result of peripheral instability, then taping a hypotonic muscle into its shortened range should stabilize the peripheral system and eliminate the need for the CNS to create the hypertonic pattern. On the other hand, taping can also be used to heighten information about proprioception and joint position, providing feedback to avoid hyperextension or hypermobility of a joint. This is especially true when there is an imbalance of intrinsics and extrinsics in the hand.

**Oral-Motor Interventions.** There are more research articles available on specific oral-motor dysfunctions in patients with neurological problems than on intervention. These are studies using fMRI of the CNS during oral-motor activity, but the transition to intervention again is limited. Systematic reviews of potential oral-motor interventions are even fewer. When dealing with oral-motor intervention, the complexity of combined proprioceptive-tactile input becomes enhanced by adding another sensory input, such as taste. Implementation of one of a variety of feeding techniques clearly identifies the complexity of the total input system. When taste is used, smell cannot be eliminated as a potential input, nor can vision if the client visually addresses the food. The following explanation of feeding techniques is included to encourage the reader to analyze the sensory input, processing, and motor response patterns necessary to accomplish this ADL task. The complexity of the interaction of all the various systems within the CNS is mind-boggling, but if the motor response is functional, effortless, and acceptable to the client and the environment, then the adaptation should be facilitated after attended repetitive behaviors.

Several feeding techniques have been developed in the past by master clinicians such as Mueller, Farber, and Huss. These techniques were not easily mastered or understood through reading alone. Competence in feeding techniques is best achieved through empirical experience under the guidance of a skilled instructor. Today, some evidence base for implementation of feeding techniques or related motor activities can be found in the literature. The facial and oral region plays an important role in survival. Facial stimulation can elicit the rooting reaction. Oral stimulation facilitates reflexive behaviors, such as sucking and swallowing. Deeper stimulation to the midline of the tongue elicits a gag reflex. These reactions and reflexes are normal patterns for the neonate. When these reactions and reflexes are depressed or hyperactive, therapeutic intervention is a necessity. Oral facilitation is an important treatment.
modality for infants and children with CNS dysfunction. Therapeutic intervention during the early stages of myelination can be crucial to the development of more normalized feeding and speech patterns.

Similarly, adults with neurological impairment often have difficulty with oral-motor integration. Problems with swallowing, tongue control, and hypersensitive and desensitizing areas within the oral cavity and with mouth closure and chewing are frequently observed in adults with CNS damage. 475, 476

Before basic feeding techniques are implemented, clinicians need to understand how the CNS and PNS work collaboratively with the musculoskeletal system to control and perform these complex oral-motor functional movements. 341, 366, 487 Feeding therapy is preceded by observation and examination. With a pediatric client the therapist should observe breathing patterns while the client is feeding to determine whether the child can breathe through the nose while sucking on a nipple. In addition, the child’s lips should form a tight seal around the nipple. Formal assessments should include functional assessments, developmental milestones, and behavioral manifestations. Medical charts and results from neurological examinations should be consulted for baseline data.

Postural mechanisms can influence feeding and speech patterns in clients with neurological dysfunction. 28, 485, 488 A client with a strong extensor pattern may have to be placed in the side-lying, flexed position to inhibit the forces of the extensor pattern. The ideal pattern for feeding is the flexed position, which promotes sucking and oral activity. Basic reflexes such as rooting, sucking, swallowing, and bite and gag reactions should be elicited and graded in children and evaluated in adults. The head needs to be in slight ventralflexion to pull in the postural stabilization of the neck and tongue. This is necessary to effectively facilitate programs that provide functional swallowing and control of foods by the tongue.

The facial region and the mouth have an extraordinary arrangement of sensory innervation. Therefore oral techniques must be used with utmost care. Anyone who has visited the dentist can attest to the feeling of invasiveness when foreign objects are placed in the mouth. With this in mind, the therapist should begin each treatment session by moving the autonomic continuum toward the parasympathetic end. Activation of the parasympathetic system should help to promote parasympathetic “loading.” Another approach that is applicable to feeding techniques is the application of sustained and firm pressure to the upper lip. An effective inhibitory device is a pacifier with a plastic shield that applies firm pressure on the lips. Perhaps this is why a pacifier is a “pacifier.” Adults can acquire resistant sucking patterns with a straw and plastic shield and achieve the same results.

Sometimes children or adults are not cooperative and will not open their mouths. 489, 490 Rather than the mouth being pried open, the jaw is pushed closed and held firmly for a few seconds. On release of the pressure, the jaw reflexively relaxes. The receptors in the temporomandibular joint and tooth sockets may be involved in the production of this response.

A common problem seen in neurologically impaired infants and adults with head trauma is the “hyperactive tongue,” which is often accompanied by a hyperactive gag reflex. To alleviate this problem, the receptors have to be systematically desensitized. The technique called tongue walking has met with clinical success. 12, 41 It entails using an instrument such as a swizzle stick or tongue depressor to apply firm pressure to the midline of the tongue. The pressure is first applied near the tip of the tongue and progressively “walked back” in small steps. As the instrument reaches the back of the tongue, the stimulus sets off an automatic swallow response. The instrument is withdrawn the instant the swallow is triggered. This technique is repeated anywhere from five to 30 times a session, depending on individual responses.

Another technique, which might be called deep stroking, is used to either elicit or desensitize the gag reflex. Again, an instrument such as a swizzle stick is used to apply a light stroking stimulus to the posterior arc of the mouth. The instrument should lightly stretch the lateral walls of the palatoglossal arch of the uvula. Normally, the palatoglossal muscle elevates the tongue and narrows the fauces (the opening between the mouth and the oropharynx). Just behind the palatoglossal arch lies another arch, called the palatopharyngeal arch. Normally, this structure elevates the pharynx, closes off the nasopharynx, and aids in swallowing. Touch pressure to either arch incites the gag reflex. This touch pressure should be carefully calibrated. A hyperactive gag reflex may be best diminished by prolonged pressure to the arcs, whereas light, continuous stroking may be more facilitatory in activating a hypoactive gag reflex.

A child or adult who has been fed by tube for extended periods of time will often have both hypersensitive reactions in various parts of the oral cavity and hyposensitive areas in other locations. This problem needs to be assessed to formulate a complete picture of the client’s difficulties.

The use of vibration over the muscles of mastication appears to be physiologically valid. Muscle spindles have been identified in the temporal and masseter muscles. 19 Selected use of vibration on the muscles of mastication enhances jaw stability and retraction. For protraction to be facilitated, the mandible is manually pushed in. 111

To promote swallowing, some therapists use manual finger oscillations in downward strokes along the laryngopharyngeal muscles and follow up with stretch pressure. Ice is beneficial as a quick stimulus to the ventral portion of the neck or the sternal notch. In addition, chewing ice chips provides a thermal stimulus to the oral cavity and a proprioceptive stimulus to the jaw and teeth; it also increases salivation for swallowing.

It is recommended that a therapist work closely with a colleague who has experience working with functional feeding before independently beginning to work with clients. The possible complications that might develop with individuals aspirating food cannot be overemphasized. 491

The therapist can quickly realize that feeding as a proprioceptive, tactile, and gustatory input modality is extremely complex and often incorporates other sensory systems. Breaking down the specific approaches into finite techniques helps the clinician categorize each component and then reassemble them into a whole. The job of dividing and reassembling the parts becomes more and more difficult as the number of input systems enlarges. 267
Head and Body Movements in Space. Proprioceptive and vestibular input is one of the most frequent combination techniques used by therapists. In fact, client success in almost all therapeutic tasks depends on the coordinated input of these two sensory modalities.

If the head is moving in space and gravity has not been eliminated from the environment, vestibular and proprioceptive receptors will be firing to inform the CNS whether it should continue its feed-forward pattern or adapt the plan because the environment no longer matches the programmed movement. Depending on the direction of the head motion and the way gravity is affecting joints, tendons, and muscles, the specific body response will vary according to the degree of flexibility within the motor system. Bed mobility, transfers, mat activities, and gait all incorporate these two modalities. Although all these functional movements can be performed without these feedback mechanisms, the CNS cannot adapt effectively to changing environments without input from these systems. For that reason alone, a thorough examination of the integrity of both systems and the effect of their combined input seems critical if any ADL is to be used as a treatment goal.

The use of a large ball or a gymnastic exercise ball can be classified under the category of proprioceptive-vestibular input. Many activities can be initiated over a ball. When a child or adult is prone on a ball, righting of the head can often be elicited by quickly projecting the child forward while the therapist exerts control through the feet, knees, or hips. If the weight of the head is greater than the available power, then a more vertical and less gravitationally demanding position can be used. As the head begins to come up, approximation of the neck can be added. Vibration of the paravertebral muscles might also assist. Rocking forward or bouncing the client who is weight bearing on elbows or extended elbows will facilitate postural weight-bearing patterns through the two identified sensory input systems. Having a client sitting on a therapy ball doing almost any exercise will require vestibular and proprioceptive feedback for appropriate adaptive responses to be made. The combination seems to play a delicate role in the maintenance of normal righting and the equilibrium response so important in functional independence.

A trampoline, balance board, or similar apparatus has the potential to channel a large amount of vestibular-proprionceptive input into the client’s CNS. In fact, a trampoline is so powerful it can often overstimulate the client and cause excitation or arousal in the CNS.

The trampoline and balance board are generally used to increase balance reactions, orient the client to position in space and to verticality, and increase postural tone. A client with poor balance, poor postural tone, or inadequate position in space and verticality perception may be justifiably fearful of these two apparatus because of the rate, intensity, and skill necessary to accomplish the task. Because fear creates tone and that tone may be in conflict with the motor response from the client, caution must be exercised with either modality. (See Chapter 22A for further discussion of the interactions of sensory systems and balance.)

Gentle Shaking. A specific technique of gentle shaking can be listed under a combined vestibular, muscle spindle, and tendon category. This technique is performed while the client is in a supine position and the head ventroflexed in midline. The head is flexed 35 to 40 degrees to reduce the influence of the otoliths and unnecessary extensor tone through the lateral vestibulospinal tract. This flexed position should be maintained throughout the procedure. The therapist places one hand under the client’s occiput and the other on the forehead. Light compression is applied to the cervical vertebrae. This technique activates the deep-joint receptors (C1 to C3) and muscle spindles in the neck along with the vestibular mechanism, which in turn connects with the cerebellum and motor nuclei with the brain stem. If the technique is performed slowly and continuously in a rhythmic motion, total-body inhibition will occur. If the pattern is irregular and fast, facilitation of the spinal motor generators will be observed.

Any one of these techniques can be implemented as a viable treatment approach in considering vestibular-proprionceptive stimuli. The selection of an approach or a method will depend on client preference, client response, the clinician’s application skills, and the need for therapeutic assistance.

Summary of Techniques Incorporating Auditory, Visual, Vestibular, Tactile, and Proprioceptive Senses

Most therapeutic activities activate five sensory modalities: auditory, visual, vestibular, tactile, and proprioceptive. Auditory and visual inputs are used as the therapist talks to the client, asks the patient to look, and/or demonstrates the various movement or response patterns to be accomplished during an activity. As the client moves, vestibular, tactile, and proprioceptive receptors are firing as inherent feedback systems. Thus the complexity of any activity with respect to analysis of primary input systems is enormous. Even a sedentary activity such as card playing requires a certain amount of proprioception for postural background adaptations, tactile input from supporting body parts and limbs, and visual input for perception and cognition. When treating an individual with CNS damage, one or a number of sensory systems may not be processing at all or may be processing incorrectly, which confounds the clinical problem even farther.

Thus when the categorization of techniques—such as a PNF slow reversal,19 a Brunnstrom marking time,8 marking time with music,492 Feldenkrais’s sensory awareness through movement,225,226 NDT,31,492 Rood’s mobility on stability,25,28 or any mat or ADL activity—is considered, the therapist must observe the sensory systems being bombarded during the activity. At the same time, if the therapist has determined which sensory systems are intact, which are suppressed or dysfunctional, and which seem to be registering faulty data, then altering duration and intensity of the input environment through any one system and the combined input through multiple systems creates tremendous flexibility in the clinical learning environment. Understanding this diagnostic process leads to more accurate prognosis and selection of appropriate interventions. Highly gifted therapists seem to instinctively go through this diagnostic process. One skill that seems consistent among master clinicians is a highly developed sensitivity to the client’s responses, which represents a summation of expression of all systems within the CNS. Simultaneously, they adjust the quantity and duration of combined input to best meet the needs of the client. These
masters release external control and encourage the client to use normal, inherent monitoring systems to adapt to changing environments as soon as the client is able to function independently, no matter if that is only 5 degrees of motion or an entire functional pattern made up of many motor programs. Control may begin within a part of the range of a functional skill and not necessarily the entire functional activity itself. Therapists must remember that when the control comes from the clinician and not the patient, it is then augmented. The key to carryover will be the client’s empowerment over the motor control system and the degree of practice, self-monitoring, and adaptation available to the client. By analyzing and categorizing input and patient responses, many therapists may develop skills that were initially considered out of reach. Today, clinicians have the examination tools to validate changes in their patients’ motor behavior (refer to Chapter 8).

**Innate Central Nervous System Programming**

The responses of the PNS and CNS to various external stimuli determine the individuality of an organism and its survival potential within the environment. As organisms become more and more complex, the types of external stimuli and the internal mechanisms designed to deal with that input also increase in complexity. As the CNS develops structurally and functionally, inherent control over responses to certain common environmental stimuli seems to be manifested. Different areas of the motor system play different roles in the regulation of motor output. No area is dominant over another. Each area is interdependent on both the input from the environment and the intrinsic mechanisms and function of the nervous system.

As mentioned earlier, the PNS is intricately linked to the CNS and vice versa. Damage to one could potentially alter the neuropathways, their function, and ultimately behavior anywhere along the dynamic loops. Nevertheless, although researchers today emphasize the dynamic interactions of all components, clinicians have observed for decades different motor problems when different areas of the brain are damaged. Thus, when clients with neurological damage are discussed, it seems paramount to identify inherent synergy patterns available to humans, especially if those patterns become stereotypical and limit the client’s ability to adapt to a changing environment.

The authors do not recommend or discredit the use of any stereotypical or patterned response as a treatment procedure. Acknowledging the presence and stressing the importance of knowing how these motor programs affect clients’ functional skills are important. Without this knowledge, therapists working with either children or adults with CNS dysfunction limit their understanding of the normal CNS, the normal motor control mechanism and its components, and the interactive effect of all systems on the end product: a motor response to a behavioral goal.

To conceptualize a systems model, the reader must replace the hypothesis of a stimulus response–based concept of reflexes with a theory of neuronetworks that may be more or less receptive to environmental influences (see Chapter 4). That sensitivity is modulated by a large number of interconnecting systems throughout the CNS and by the internal molecular sensitivity of the neurons themselves. Specific motor patterns seem to be organized or programmed at various levels or areas within the CNS. These synergies or patterned responses are thought to limit the degrees of freedom available to programming centers such as the basal ganglia and cerebellum and to enable more control over the entire body. Having soft-wired, preprogrammed, patterned responses allows organizing systems to activate entire sequences of plans and modify any components within the total plan. Modification and adaptation then become the goal or function of the motor system in response to both internal and external goal-directed activities. The specific location of soft-wired programs is open to controversy, as is the complexity of programming at any level within the CNS. Recognizing that these neuronetworks exist with or without external environmental influences would suggest that patterns can and will present themselves without an identified stimulus. In the past, when an external influence was not correlated with an identifiable stereotypical motor pattern, it was referred to as a "synergy." When a stimulus was identifiable, the entire loop was called a reflex. Reflexes and preprogrammed, soft-wired neuronetworks such as walking are interactive or superimposed on one another to form the background combinations for more complex program interactions. This superimposed network may encompass spinal and supraspinal coactivity, which makes it difficult to specify a level of processing. The exact control mechanisms that regulate the specific pattern may again be a shared responsibility throughout the nervous system, thus providing the plasticity observed when disease, trauma, or environmental circumstances force adaptation of existing plans, as discussed in the neuroplasticity section (see Chapter 4).

One way to conceptualize this complex neuronetwork is to picture a telephone system linking your home to any other home in any city in any country on the planet. If the relay between a friend in New York and you in California develops static, the system may self-correct, relay through another area, or even route through a nonwired mechanism such as a satellite. The options are infinite, but priorities for efficiency and adaptability exist within both the telephone network and the brain. If the wires to your home are cut, the phone will not ring. If your peripheral nerve is cut or the alpha motor neuron damaged, the muscle will not contract. If the relay centers at one end of your block are short-circuited and not working properly, then your phone and those of your neighbors may still function, but not in a fluid or specific manner. That is, someone may be calling your neighbor but both your phone and your neighbor’s phone might ring. Spinal involvement can create a similar problem. The muscles are innervated and the input from the environment is accurate, but the neuronetwork is faulty. Regulation or modulation may be less efficient or controlled, but the system will use all available resources to try to respond to internal and external environmental requirements. This rule seems consistent throughout the nervous system, and the degree of plasticity is tremendous.

When specific patterned responses are observed, the reader must always hold simultaneously the interaction of all other motor programming options. In this way the therapist can easily conceptualize the variations within one response and the reason why, under different environmental and internal constraints, the motor response pattern may show great variations within the same general plan. Similarly, the expected motor response may not be observable,
Although it would seem appropriate and anticipated. The clinician must remember that the more complex the action (e.g., rolling compared with dressing compared with playing hockey), the greater the need for integration and coordination over pattern generators. Similarly, the more complex the desired action (especially in new learning), the greater the potential for needed perceptual-cognitive and affective interactions and the greater the potential for gratification and also for failure.

Certain patterned responses or neuronetworks might be considered more simplistic or protective in function. These patterns were once thought to be hard-wired spinal reflexes. It is now known that these reflexes, as well as complex pattern generators, exist at the spinal level and that their responses affect brain stem, cerebellar, and cortical actions. These centers simultaneously affect the specifics of the spinal neuronetwork responses. With clients who have low functional control over the spinal or brain stem motor networks, identifying existing patterns, optional patterns as a response to environmental demands, and obligatory patterns not within the control of the client’s intentional repertoire of patterns becomes a critical evaluative component before prognosing or identifying the most appropriate interventions.

Recognizing specific patterns and how those patterns and others might affect functional movement or positional patterns has clinical significance. A child with spastic cerebral palsy, for instance, shows extension and “scissoring” when the pads of the feet are stimulated. Sometimes the extension pattern is so strong that the child will arch backward. Sustained positions that oppose pathological patterns are believed to elicit autogenic inhibition. Contraction-relaxation techniques also work on the autogenic inhibition principle.

Just as afferent input can be used to alter tone and elicit movement, it can also become an obstacle when the therapist tries to coordinate complex movement patterns. The human palmar and plantar grasp patterns are often thought of as reflexive patterns, as seen in a newborn. A persistent grasp pattern is a common occurrence in children and adults with a CNS insult. This dominant grasp is often reinforced by the client’s own fingers and frequently prevents functional use of the hand. If a withdrawal pattern is elicited every time a client is touched, the client not only will be unable to explore the environment through the tactile-proprioceptive systems but also will experience arousal by the influence of the cutaneous system over the reticular activating system. Severe agitation could likely be a behavioral outcome from such a persistent reflex.

As with any treatment procedure, a clinician should determine whether the technique will help the client obtain a higher level of function. The clinician must learn to recognize not only specific patterns but also what combinations of responses of pattern generators would look like. If the reader overlaid the map of the pattern generators for any combination of programs, a complex neuronetwork would result. To some it would verify chaos theory, and to others it would verify the end result of multiple systems interacting. The neuronetwork complexity of multiple input can be overwhelming. Thus a therapist must always be observant of the specific behavioral response and the moment-to-moment changes in behavior during a treatment session, even if the specific neuronetwork is not understood.

The clinician needs to observe whether the specific patterned response is (1) triggered by afferent input, (2) triggered by volitional intent, or (3) activated without environmental input including position in space or cortical intent. In the third case, the entire motor system needs to be evaluated to determine which portion might be modulating the observable behavior. Differentiating these motor components will help in selecting appropriate examination tools, making the movement diagnosis, prognosing, and selecting interventions.

**Holistic Treatment Techniques Based on Multisensory Input**

As already mentioned, a variety of accepted treatment methods exist. Each approach focuses on multisensory input introduced to the client in controlled and identified sequences. These sequences are based on the inherent nature of synergistic patterns in humans and lower-order animals, or a combination of the two. Each method focuses on the total client, the specific clinical problems, and alternative treatment approaches within each established framework. Certain methods have traditionally emphasized specific neurological disabilities. Cerebral palsy in children and hemiplegia in adults are the two most frequently identified. In the past two decades, substantial clinical attention has been paid to children with learning difficulties. Yet the concepts and treatment procedures specific to all the techniques have been applied to almost every neurological disability seen in the clinical setting. This expansion of the use of each method seems to be a natural evolution because of the structure and function of the CNS and commonalities in clinical signs manifested by brain insult. Literature in occupational and physical therapy management of individuals with various other neurological problems has also enriched therapists’ identification of efficacious interventions as well as those that should be removed from the toolbox.

**Additional Augmented Interventions: Today’s Focus**

Four augmented therapeutic intervention approaches that have become accepted over the last decade are (1) BWSTT, (2) constraint-induced movement therapy (CIMT), (3) imagery (discussed in the section on the visual system) and virtual reality, and (4) robotic training. Each is discussed as a separate intervention philosophy, but the reader must remember that these are augmented intervention programs. Before an individual would be considered functionally independent, the patient must be able to perform the functional activity in a natural environment, such as ambulation within a home setting or eating using the more involved extremity without having the unaffected extremity restrained. A fourth augmented intervention approach, robotics, will also be presented briefly within this chapter in order to illustrate how therapists and patients have the capabilities to interface with new and sophisticated technology. The reader is also referred to Chapter 38 for more in-depth detail. One additional augmented approach, the Accelerated Skill Acquisition Program (ASAP), has been described here. This approach is currently undergoing, and research is still needed to establish efficacy. This approach is impairment...
Body-Weight–Supported Treadmill Training. Over the last decade BWSTT has been accepted within the therapeutic community as an alternative approach to teaching gait training for individuals with CNS damage and residual motor dysfunction. Students are introduced to the treatment procedures and potential sequences from total dependence to independence of the patient. Colleagues take continuing education courses to learn to position and drive the various motor components of the gait program while using BWSTT. Both a vertical support (harness) or air-distributed positive pressure to unweight the body and a treadmill are combined for BWSTT. The treadmill perturbs the feet backward or shifts the center of gravity forward, and the ground reaction forces are reduced by the support. The clinical environment unloads the CNS’s need to (1) provide protection from falling; (2) trigger and control an effective and efficient postural system reaction; (3) reflexively drive the power stepping reaction necessary to perform upright ambulation; (4) control the balance strategy of stepping to prevent falling; (5) facilitate rhythmic, symmetrical, bilateral stepping; and (6) have a cognitive interface with the various motor programs necessary to run this functional activity. The treadmill perturbation of the lower limb into extension facilitates the transfer of weight to the forefoot. This forward translation forces the feet backward and optimizes the stepping reaction forward. If the moving treadmill is not a sufficient stimulus to trigger a step, this component can be controlled by one or two therapists depending on whether it is a unilateral or bilateral problem. If the patient does not step, has a delayed stepping response, or steps effectively with only one foot, the therapist(s) can help to initiate the desired response at the patient’s feet. The rate of movement or speed of the treadmill can also be controlled, as well as the length of time spent on the affected leg. This treadmill strategy may encourage more symmetrical and faster gait speed in patients after stroke and with Parkinson disease compared with standard physical therapy. This control by the therapist helps to facilitate a patient’s response even if it is slow or inadequate for normal over-ground ambulation. The question remains whether this type of augmented therapeutic intervention does create the best environment to empower the patient to learn or relearn normal locomotion after a neurological insult.

The literature is mixed with regard to this question. The literature supports BWSTT for individuals with incomplete spinal injury, the elderly with Parkinson disease, and some individuals after stroke, but other literature suggests that BWSTT is equivalent to or maybe less effective than over-ground gait training with a PT and still other researchers report that there is no difference among different forms of ambulation training. With the literature so inconsistent, the clinician could be confused as to the effectiveness of BWSTT and whether this type of augmented intervention should even be considered. One primary problem with the research literature is the great variance in training and the identified variables selected by researchers within their respective studies. The following are examples of potential variables:

- Walking speeds
- Frequency of training
- Length of training
- Aerobic levels of training
- Type of unweighting
- Endurance
- Type and severity of the patient’s neurological dysfunction
- Presence of hypertonicity
- Age of patient
- Time since injury
- Level of independence
- Assistance needed during ambulation

There have been some excellent systematic reviews of BWSTT in the literature that help identify many of the reasons the literature seems so inconsistent. The research indicates that the two populations of individuals who most often benefit from use of BWSTT are people with incomplete spinal cord injuries and individuals poststroke. Another problem in BWSTT research is that the harness systems can be uncomfortable at 20% to 30% unweighting. Thus, as stated, the huge number of possible variables and functional ways to measure outcomes using BWSTT or other types of training along with BWSTT has led to confusion in the literature. Even with all the confusion regarding these variables, this form of augmented intervention seems to show promise as a protocol for gait training. Future research studies will still need to determine which patients, their degree of motor involvement, the optimal dosage, the time after insult, the best combination of other interactive interventions (e.g., pharmacological, robotic), the specific type of gait impairments, and where within the gait cycle the clients would most likely benefit from this type of augmented intervention. It is important to continue to obtain evidence to more precisely define the practice guidelines for BWSTT. As has been shown in the past, new treatment ideas gain popularity and become standards of practice without the rigor of establishing an evidence-based practice. Physical therapy and occupational therapy need to establish that evidence as proof of the evolving effectiveness of clinical practice.

Constraint-Induced Movement Therapy. CIMT (or CI therapy) is a type of treatment of clients with motor system limitations that combines constraint or immobilization of the unaffacted arm with forced use of the affected limb. A hand mitt or sling is used to constrain the use of the unaffected arm with forced use of the affected limb.

The treatment focus of CIMT is on shaping behavior to improve functional use of the impaired upper limb. CIMT is based on the theory that impairment in hand and arm function in clients after a stroke is compounded by learned nonuse of that affected upper extremity, which leads to a physical change in the cortical representation of the upper limb in the primary sensory cortex. Learned nonuse develops in the early stages after a stroke in humans as the patient compensates for difficulty using the impaired limb by increasing reliance on the intact limb. This compensation has been shown to hinder recovery of function in the impaired limb.
CIMT and the learned nonuse theory are based on deafferentation experiments in monkeys done by Dr. Edward Taub. Early primate studies demonstrated that if the upper limb was surgically impaired by dorsal rhizotomy to disrupt afferent input to the sensory cortex, the animal stopped using the limb for function. Active mobility was restored by immobilizing the intact upper limb for several days while training the animal to use the affected limb. The first report of CIMT for hemiparesis in humans was by Ostendorf and Wolf in 1981. Since then, investigations have demonstrated the effectiveness of CIMT with individuals who have residual upper-extremity weakness as the result of an upper motor neuron lesion. CIMT has been shown to be an effective therapy in persons with chronic stroke who have sufficient residual motor control to benefit from the exercises, in brain-injured patients, and in patients with Parkinson disease. The CI therapy approach has also been used successfully for the lower-limb rehabilitation of patients with stroke hemiparesis, incomplete spinal cord injury, and fractured hip. Other diverse chronic disabling conditions, including nonmotor disorders such as phantom limb pain and aphasia, may also benefit from CIMT.

The criteria for the inclusion of subjects in most CIMT research studies have focused on voluntary movement ability in the involved upper extremity. These criteria included the ability to start from a resting position of forearm pronation and wrist flexion and actively extend each metacarpal-phalangeal and interphalangeal joint at least 10 degrees and extend the wrist at least 20 degrees through a ROM. It is estimated that approximately 20% to 25% of the population of patients with chronic stroke with residual motor deficit meet this motor criterion. Not all patients with hemiparesis have been found to benefit from CIMT. It has not been shown to be beneficial for clients with severe chronic upper-extremity hemiplegia after a stroke. Attempts to include individuals who did not meet the minimal motor criteria (at least 10 degrees of finger extension and 20 degrees of wrist extension) have failed to demonstrate significant or lasting functional improvements in the involved upper extremity after CIMT.

The criteria associated with successful therapeutic components of CIMT therapy are (1) restraint of the unaffected arm with a mitt, sling, or glove for 90% of waking hours for a 2- to 3-week period; and (2) therapeutic sessions with physical and occupational therapy in which patients concentrate on intense, repetitive task training of the more affected upper extremity for 8 hours a day.

Clients typically participate in 6 to 7 hours of therapy a day; in addition, clients must reinforce this training in home activities and ADLs. The therapist-client ratio is typically 1:1, with the therapist present to give tactile and verbal feedback and instruction, along with assistance for the desired skill training. Clients also typically keep a daily treatment diary to document the amount and intensity of therapeutic intervention and the amount of time spent wearing the mitt or sling each day for the duration of the intervention.

Subjects with chronic stroke hemiparesis who have participated in CIMT rehabilitation programs have demonstrated significant gains in functional use of the stroke-affected upper extremity as measured by the Motor Activity Log. Significant reductions in motor impairment on the upper-extremity motor component of the Fugl-Meyer Test and more efficient task performance as measured by the Wolf Motor Function Test. Fine motor improvements have also been measured with use of the Grooved Pegboard Test and other dexterity tests. These improvements in impairment and function have been shown to persist at follow-up evaluations up to 2 years after training. Individuals participating in CIMT studies have demonstrated improvements in the amount of use and quality of movement in the more involved upper extremity and carryover of skills from the clinic to real-world activities. This functional improvement may be significant even if the patient has previously participated in a conventional rehabilitation program.

The question of when to begin CIMT after a stroke has not yet been definitively answered. CIMT has been applied to clients with subacute strokes. This early use of CIMT is based on the hypothesis that earlier intervention may prevent learned nonuse and may have a greater impact on overall function. Investigators have found no adverse effects of CIMT in the subacute phase and only slightly greater improvement in motor function of the affected upper extremity. There is some evidence from animal studies to suggest that if CIMT is introduced too early (e.g., 24 hours poststroke), it may be detrimental and potentially harmful to humans. It may cause an increase in the size of the cortical lesion. This is based on studies of “forced overuse” in animals. Kozlowski and colleagues also found that early forced overuse of the affected limb within the first 7 days after a sensorimotor cortex lesion impeded motor recovery of the affected limb and enlarged lesion volume. Bland and co-workers also forced overuse of the affected forelimb immediately after a focal cortical middle cerebral artery stroke, which increased the lesion size and impaired motor recovery. The relative risks and benefits of “acute” CIMT, and its optimal timing, remain to be determined.

The neurophysiological mechanisms that are believed to underlie the treatment benefit of CIMT include overcoming learned nonuse and plastic brain reorganization. Studies have confirmed that CIMT produces use-dependent cortical reorganization in humans with stroke-related paresis of an upper limb. Neuroimaging studies such as transcranial magnetic stimulation (TMS), fMRI, and electroencephalography have been used to provide cortical evidence of neuroplasticity and cortical changes after CIMT. These studies have validated that massed practice of CIMT produces a massive use-dependent cortical reorganization. This change increases the area in which the cortex is involved during voluntary movements of an affected limb, even in patients with chronic stroke.
The application of CIMT to real-life clinical environments presents some challenges, including the time and physical demands on therapists, the cost to the patient, and the resources required during rehabilitation. This limits its cost-effectiveness and overall effect.\textsuperscript{546} Many patients in the acute rehabilitation setting do not qualify for CIMT on the basis of limited motor function.\textsuperscript{546} CIMT, by its nature, can prove to be difficult, frustrating, and intense, and progress can be slow. It will create beneficial effects only if all participants put in the time and effort to make it successful.\textsuperscript{572} Many subjects who have been presented with the opportunity to participate in CIMT programs and studies have refused because of the intense practice schedule and the necessity of the restrictive device.\textsuperscript{592} Therapists have also voiced concerns about patient adherence and safety.\textsuperscript{592} Although it has been shown to be effective in laboratory research, CIMT may have limited practicality in some clinical environments.\textsuperscript{592}

The future success of CIMT will depend on its ability to be modified according to disease factors, economic considerations, limitations of the practice setting, and the cognitive and physical status of the patient. Less intense practice schedule models,\textsuperscript{590,593,594} and combining CIMT with pharmacological interventions or robotic assistance may help increase its effectiveness and decrease costs without sacrificing the benefits.\textsuperscript{546,595} Studies are now underway to determine if massed task-specific practice without constraint can be equally beneficial.\textsuperscript{596,597} Patient satisfaction, overall cost, and the impact on quality of life are other areas that require further evaluation.\textsuperscript{598}

**Robotics, Gaming, and Virtual Reality (See Chapter 38).** The most recent augmented intervention procedures involve the use of technology to regain control over functional movement and are the third and fourth approaches mentioned in the first sentence in this section. The use of robotics,\textsuperscript{599,602} virtual reality,\textsuperscript{603,606} and gaming\textsuperscript{607,610} in the clinical environment continues to gain popularity as such technology continues to be more affordable, and their applications are becoming more widespread. A thorough discussion of these technologies can be found in Chapter 38.

**Summary of Augmented Intervention Strategies.** As with many interventions, the therapist may need to start with augmented approaches to reduce impairments and/or gain functional movement in a controlled environment. As the patient demonstrates improvement in this narrow window of movement or function, the clinician could then increase the challenge with the goal of optimizing functional performance and improving quality of life. A summary of the augmented intervention strategies that facilitate neuroplasticity can be found in Box 9-2.

**Case Examples: Using Augmented Intervention Strategies to Optimize Functional Performance**

**Case Study 1: Client with Lack of Head Control.** There is a potential for lack of head control in young, developmentally delayed children or in individuals who have sustained a severe injury to the CNS. For that reason it is a common clinical problem. Furthermore, because of the importance of head and neck control, virtually all functional activities are affected by its absence.

The client is Timothy, a 16-year-old adolescent male with a closed-head injury. He had a lesion in his CNS 3 months ago and currently demonstrates the following attributes regarding head control:

- Mild extensor hypertonicity is present in the supine position, and Timothy is unable to flex and rotate his head off the mat.
- In prone position, extensor hypertonicity is absent and hypotonicity prevails. The client is able to briefly bob his head off the mat in a hyperextension pattern. Mild tonal shifts occur to either side when the head is turned and when it is symmetrically flexed or extended.
- Timothy is unable to roll or perform any functional activity in the horizontal plane.
- When placed in a long sitting position, he is unable to hold the position. General hypotonicity prevails, although slightly more flexion is palpable. His head remains in total flexion with his chin on his chest.
- When placed in a short sitting position on a mat table, he is unable to hold the position. General hypotonicity prevails, although slightly more flexion is palpable. His head remains flexed. When asked to pick up his head, he extends into a hyperextension pattern followed by extensor relaxation into flexion.
- He is unable to hold the head in a neutral postural coactivation pattern in a vertical position.
- Timothy does not mind being touched and responds well to handling techniques.

From the analysis of these clinical signs, the following clinical interpretations are presented:

1. In the horizontal position, Timothy has persistence of a motor program that is enhanced by the spatial position and its influence on the vestibular system. The result might be considered persistence of a tonic labyrinthine reflex (TLR). In this client the dominant synergic pattern is extension. While he is supine, extension prevails. While he is prone, extension is inhibited, although flexion tone is not dominant. Because of the persistence of hyperactivity among the extensor motor generators, the ability to initiate rolling using a neck-righting pattern is prevented. The presence of a mild, asymmetrical tonic neck reflex to both sides and a symmetrical tonic neck reflex has been noted. Because of his instability and low tone, Timothy seems to be using these stereotypical patterns volitionally to assist in gaining some control over his motor patterns. In prone position, Timothy has the ability to move into a neck extension or optic and labyrinthine righting (OLR) pattern but is unable to hold it. Thus movement and range are present but postural holding is missing.

2. As a result of ventroflexion of the head in sitting, the vestibular apparatus is placed in a position similar to that when prone. In a like manner, the total patterns remain fairly consistent. The increase in flexor tone may result from the positioning of hip and knee flexion and kyphosis of the back. The inability to flex the hips with knee extension suggests that total tonal patterns or synergies are dominant. The client is unable to break out of those dominant patterns. Dominant OLR is not present.

3. When asked, Timothy carries out the command to the best of his motor ability. This suggests the presence of
BOX 9-2 SUMMARY OF INTERVENTION STRATEGIES TO FACILITATE NEUROPLASTICITY

There are many different intervention strategies to use when working with patients with neurological problems. These interventions need to be matched to the needs of the individual patient and be consistent with the patient’s goals and objectives. All the intervention strategies should be goal directed and repeated with attention to both the input mechanisms (motivation, sensory) and the output mechanisms (movement). The input and output mechanisms are multifactorial, and they also involve all components of the sensory, emotional, sensorimotor, and motor systems. Although evidence is increasing about the benefit of learning-based activities, research is still needed to help define more precisely when intervention should occur, how intense the intervention should be, how much repetition is needed, how long the learning-based activities need to be continued and spaced, how specific the training needs to be, how quickly behaviors can be progressed and the magnitude of gradation needed, how to keep patients interested, motivated, and compliant in learning, and the magnitude of interference in learning relative to depression, stress, and loss of self-esteem. The intervention strategies can be broadly classified as follows:

1. General body responses leading to quieting of the nervous system
   a. Slow rocking in a rocking chair or hammock.
   b. Slow anterior-posterior, horizontal, or vertical movements (chair, hassock, mesh net, swing, ball bolster, riding in a carriage, glider chair).
   c. Rotating equipment such as a bed, chair, stool, hammock, or therapeutic or gymnastic ball (e.g., rhythmic bouncing).
   d. Slow linear, undulating movements, such as in a carriage, stroller, wheelchair, or wagon.
   e. Wrapping up tightly before rocking (e.g., roll self in sheet; put both arms inside tight tee shirt).
   f. Listening to quiet music or natural environmental sounds (e.g., waves).
   g. Repeating activities listed above first with eyes open and then closed.

2. Techniques to heighten postural righting reactions
   a. Rapid or unexpected anterior-posterior or angular acceleration.
      i. Scooter board: pulled or projected down inclines.
      ii. Prone over ball: rapid acceleration forward.
      iii. Platform or mesh net: prone.
      iv. Slides.
      v. Any proprioceptive input that heightens postural extensors (e.g., quick stretch, tapping, resistance, vibration, joint compression). Remember to use the most natural first, such as quick stretch versus vibration.
   b. Rapid anterior-posterior motion in prone position, weight-bearing patterns such as on elbows or extended elbows while rocking and crawling.
   c. Weight-shifting in kneeling, half-kneel, or standing positions (first in vertical and then off vertical within limits of stability by an activity itself [reaching]).
   d. Do activities with eyes closed.
   e. Create dual-task activities such as walking and talking, stepping over obstacles while on unstable surfaces, reading while maintaining balance in a confusing environment.
   f. Challenge balance in distracting environments (e.g., moving surround, multisensory stimuli in visual surround).

3. Facilitatory techniques to influence whole-body responses
   a. Movement patterns in specific sequences.
      i. Rolling patterns.
      ii. Prop on elbows (prone and side-lying positions) and extend and flex elbows as well as crawling (e.g., side by side, or linear and angular motion).
      iii. Coming to sit (side-lying to sit [using upper trunk and head rotation], prone to four-point position to sit [four-point position to lower trunk rotation to side sit to sit], adult sit [full flexion leading with head]).
      iv. Coming to stand (squat to stand, half-kneel to stand, standing from a chair or stool).
   b. Spinning.
      i. Mesh net.
      ii. Sit and spin toy.
      iii. Office chair on universal joint.
   c. Any activity that uses acceleration and deceleration of head.
      i. Sitting and reaching.
      ii. Walking.
      iii. Running.
      iv. Moving from sit to stand.
      v. Doing activities with eyes closed, head still, and then eyes closed, head turning.
   d. Performing activities that require attention, memory, and cognitive processing at the same time.

4. Combined facilitatory and inhibitory technique: inverted tonic labyrinthine activities
   a. Inverted tonic labyrinthine activities.
      i. Semiinverted in-sitting (head between the legs).
      ii. Squatting to stand (head below heart).
      iii. Thirty degrees to total inverted vertical position beginning in supine.

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some intact verbal processing, which is translated into appropriate motor acts. Similarly, when asked to pick up his head, he does just that, suggesting some perceptual integrity of body image, body schema, and position in space. Knowing where his head is in space and where to reposition it also suggests that some proprioceptive-vestibular input and processing are occurring.

4. Timothy’s enjoyment of being moved in space as related to handling techniques suggests proprioceptive-vestibular integrity. Similarly, his tactile systems seem to be functioning in a discriminatory manner and modifying negative responses of withdrawal and arousal. However, specific tactile perception would need a great deal of further testing. Thus he demonstrates functional strengths in cognition and perception, in limbic motivation, in some areas of sensory integrity, and in control over available but limited motor programming. Yet performance on any functional test would result in identification of an individual whose functional limitations prevent him from independence in any activity. Prognosis must be guarded until the therapist has had an opportunity to augment the environment to determine how quickly he will regain control and retain the learning. The initial plan of care is assumed to focus on development of head control as a preliminary and necessary motor program for all functional daily living activity. The estimated time it will take to regain this function will not be identified until after the first intervention session.

Movement Diagnosis. The client is unable to functionally control his head in any position in space, which limits independence in all functional activities. Lack of postural coactivation and adequate control over the motor generators has led to imbalances in the tonal characteristics of flexor and extensor patterns with the compensatory development of stereotypical patterns of movement.

Goal of Intervention Program. The goal is development of independent head control, initially in a vertical midline posture with the intent of enlarging that biomechanical window to include all positions in space.

Now that the clinical problem has been analyzed and the goal of development of head control set, an intervention

BOX 9-2 SUMMARY OF INTERVENTION STRATEGIES TO FACILITATE NEUROPLASTICITY—cont’d

b. Somatosensory and sensorimotor stimulation (refer to earlier in this chapter).
   i. See detailed progressive learning-based sensorimotor training (Appendices 9-B and 9-C).
   ii. Proprioceptive stimulation.
      (a) Vibration over joints.
      (b) Vibration in opposite direction of movement.
      (c) Wear weights around ankles or on belt.
      (d) Position the limbs and the trunk to match a position visually presented.
      (e) Move slowly to the count of a metronome and then change speeds.
      (f) Look at pictures and position the body to match the pictures.
   c. Auditory discrimination (localization).

5. Techniques to facilitate specific task performance
   a. Forced use.
      i. Create training activities in which patients must use the affected extremity.
      ii. Minimize the need to use the unaffected side.
      iii. Use bilateral activities in which both hands and upper extremities are required.
   b. Constraint-induced movement therapy (CIMT) (forced use) emphasizes the repetitive use of an impaired limb in regular functional activities by restricting the movement of the less affected or unaffected side.
      i. The patient is constrained from using the unimpaired limb on a concentrated task basis.
      ii. The impaired limb is used on a concentrated basis.
      iii. The theory is to reduce motor deficits early in the recovery period (learned disuse).
      iv. The assumption is that the nervous system is adaptable and training for recovery should begin as soon as possible.
      v. If the good arm is constrained, the patient must use the affected limb.
      vi. Set time limits to use the constraint; in one large randomized clinical trial the patients were asked to wear a protective safety mitt on the less affected upper limb for a goal of 90% of the waking hours for 14 consecutive days.
      vii. During constraint, the individual works under supervision on designated functional tasks for 6 hours a day.
      viii. The patient is encouraged to try to use the affected limb during waking hours.
      ix. The constraint is paired with motor or behavioral objectives.
      x. Tasks are practiced and progressed in difficulty or speed.
   c. Mass task practice (see Chapter 4).
   d. Mental imagery.
   e. Mental practice.
   f. Body-weight–supported treadmill training (BWSTT)
   g. Integration of robotics and technology (see Chapter 38)
   h. Use of gaming (Wii Fit, Brain Fit)
sequence or protocol must be established. Timothy lacks head control in all planes and in all patterns of movement. Thus, flexors and extensors must be facilitated to develop a dynamic coactivation or postural holding pattern of the neck. The categorization scheme can now be of some assistance. The therapist can ask, “Are there any inherent mechanisms that enhance flexors or extensors in a holding pattern?” The optic and labyrinthine righting (OLR) reaction should elicit the desired response. Similarly, the clinician can ask, “Are there any inherent motor programs that would prevent righting of the head to face vertical OLR?” The TLR would block or modify the facilitation of OLR. Knowing that the TLR is most dominant in horizontal and least dominant (if at all affected) in vertical is of clinical significance. It is also important to know that the OLR is most frequently tested in a vertical position and seems most active in that position. Awareness that the client is sensitive to total patterns (e.g., flexion facilitates flexion or extension facilitates extension) gives additional treatment clues.

After all this information has been assimilated, the following treatment could be established.

For enhancement of neck flexors, the client will be placed in a totally flexed position in vertical, with the head positioned in neutral. The client will be rocked backward toward supine, allowing gravity to quick stretch the flexors (Figure 9-5, A). As soon as the neck flexors are stretched, the head should be tapped forward and then back to vertical but not beyond. This avoids hyperextension, extreme stretch to the proprioceptors, and the horizontal supine position of the labyrinths, all of which dampen the flexors and facilitate the extensors. The quick stretch and position should optimally facilitate OLR, which should activate the neck flexors. The total flexion of the body similarly facilitates the neck flexors. Once the neck flexors respond, Timothy can be rocked farther and farther backward while maintaining the head in vertical or ventroflexion (Figure 9-5, B). Once Timothy can be rocked from vertical to horizontal and back to vertical while maintaining good flexor neck control, his CNS has demonstrated inherent control and modification over the stereotypical patterns, such as the TLR in supine with respect to its influence over the neck musculature. This rocking maneuver can be done on diagonals to practice flexion and rotation (Figure 9-5, C), the key to eliciting a neck-righting, rolling pattern from supine to prone. The total flexed pattern can also be altered by adding more and more extension of the extremities. This decreases the external facilitation to the flexors and demands that Timothy’s CNS take more and more control (internal regulation). Additional treatment procedures can be extracted from a variety of sensory categories. To add additional proprioceptive input, any one of those listed techniques might be used. The rotation and speed of the rocking pattern affect the vestibular mechanism. Auditory and visual stimuli can be used effectively. If the therapist takes a position slightly below the client’s horizontal eye level, the client (to look at the therapist) will need to look down and flex his head, thus encouraging the desired pattern. Any type of visual or auditory stimulus that directs the client into the desired pattern would be appropriate. The therapist must remember that neck flexion is one of the identified goals. Rotation was added to incorporate and set the stage for inherent programming that will lead to rolling, coming to sit, and reaching while sitting. Because the postural extensor component still needs integration, total head control has not been attained. To facilitate neck extension, a procedure similar to the one for flexion can be established. A vertical position, thus eliminating the influence of the TLR, would again be the starting position of choice. For additional visual feedback on the development of flexor head control, refer to Chapter 3, Figures 3-15 through 3-18.

With extension facilitating extension, the client should be placed in as much extension as possible without eliciting excessive extensor tone. An inverted labyrinthine position, a kneeling position, or a standing position would be viable spatial patterns to facilitate OLR of the head and coactivation of postural extensors. The vestibular system sensory category can be checked to identify the treatment procedure for use with an inverted labyrinthine position. The kneeling or standing position places the client in a vertical position with hip and trunk extension. Kneeling rather than standing is used first because of the influence of the positive supporting reaction in standing and the massive facilitation of total extension. Kneeling avoids total extension while maintaining a predominant extensor pattern. As a result of the gravitational pull of body weight through the joints,

![Figure 9-5](image)

Development of extensor aspect of head control. A, Vertical position: head midline with long extensor in midrange and postural extensors in shortened range; body in postural weight-bearing pattern. B, Facilitating symmetrical extension of head, trunk, and hips while inhibiting abnormal upper-extremity tone. C, Facilitating head and trunk extension and rotation to encourage neck righting pattern; client reaches for an object, which is then placed on the opposite side.
Case Study 2: Initial Augmented Intervention Transitioning to Independence in Bed Mobility. Teaching the client to roll in bed can be approached in a variety of ways to accomplish the goal. The entire rolling pattern may be practiced with enough assistance for the client to be able to accomplish the goal, but also limiting help so that the client must use the maximum amount of power and ROM available within the key movement pattern.

**Rolling.** The patient is a 73-year-old man, status post–ischemic infarct in the frontoparietal cortex with resultant left hemiplegia, hemisensory deficit, and left homonymous hemianopia. The patient demonstrates visual-spatial inattention to the left environment. The client must learn to roll independently in bed for comfort and function. An example of a treatment session aimed at reaching the goal of independent rolling to the right and left may include the following sequence of activities: (1) begin in side-lying on one side; (2) ask patient to tip back a few degrees and then return to the side-lying position (impaired training within limited ROM); and (3) progressively increase the degree the patient must roll backward, assisting (augmenting) him as needed. By the end of several repetitions the patient may be rolling from supine to side lying and the movement is functional because he is performing independently. The client will need to practice many times to relearn the activity before that activity would be considered functional training within the environment practiced. Rolling on a therapeutic mat table is not the same as rolling on a soft mattress at home. There may or may not be carryover. That needs to be identified by the therapist and appropriate steps taken to ensure that independence in all environments is obtained.

Refer to the video for a demonstration of handling while working on rolling for bed mobility.

**Case Study 3: An Individual post Stroke.** A 66-year-old man after a stroke has mild extensor synergic hypertonia within the right lower extremity and hypotonicity within the right upper extremity except within the shoulder girdle, which has weak but functional movement patterns. His stroke was medically considered mild and his prognosis good in relation to the potential of the CNS regarding function. It has been agreed that the therapeutic goals after physical rehabilitation are to ambulate independently and use the right upper extremity to fly-fish, an activity that he loves and has done daily since he retired.

In terms of occupational and physical therapy intervention, the patient would be taught to regain independent functional skills in dressing, feeding, hygiene, transfers, and other ADLs. To facilitate the patient’s goal of fly-fishing, his family is asked to bring in the rod and reel to augment a real situation with the functional skill he possessed within his right shoulder girdle.

**Specific Physical Therapy Task Training: Fly-fishing.** In addition to ADL training, it is decided to use BWSTT as a training tool for his right lower extremity. Manual assistance is used to guide the placement of the right foot into dorsiflexion at heel strike. The training begins with a 30% weight reduction, and the patient is relaxed into the gait pattern. His right arm is suspended with the use of a shoulder harness and a robotic aid that swings through the arm in a reciprocal pattern to the left leg. This intervention is performed twice daily for 3 weeks. During weeks 2 and 3, the patient’s body weight support is reduced to 15%. By the end of the second week the patient is actively assisting the therapist with the entire gait cycle of both legs. By the end of week 3, the patient is able to walk on the treadmill independently. During the second week, over-ground ambulation is begun to transfer the treadmill learning into a functional activity. By the end of the fourth week, the patient is independent on noncompliant surfaces. Over the next month the patient is in an outpatient environment with the primary goal of independent ambulation on compliant surfaces such as sand, dirt hills, and gravel environments.

**Specific Occupational Therapy Intervention with Regard to Fly-Fishing.** It is determined that the OT will work on postural endurance of the trunk and lower extremities while facilitating the right upper extremity to practice fly-fishing. Initially the training is done in sitting to create a stable environment for the right upper extremity. The arm is placed over a ball that the patient can roll back and forth as he visualizes fly-fishing. His right hand is placed in a glove that has a wrist support and is fastened to the rod with Velcro. The rod is placed in a bucket with a hinge joint that allows for anterior and posterior movement of the rod attached to its base of support. Using this adaptation of the ball, rod brace, and wrist support and glove, the patient is able to mimic one half of the range needed to fly-fish. He so enjoys the activity that his family takes it up to the room to allow him to practice between therapy visits. After a week, the patient is brought to stand, and the apparatus is adjusted for height. The ball is still used but placed on an adjustable bedside table. As normal motor programs begin to be generated within the right upper extremity, modifications in size of the ball, angle of the wrist and hand, and range allowed within the hinge joint are made to allow for error and self-correction. Within the 3-week period of inpatient rehabilitation, the patient becomes able to perform the activity normally with only the use of the ball for postural support within the shoulder girdle. The apparatus is taken home and the patient adjusts all components depending on his fatigue level. Within a 2-month period of the patient working at home, he goes from a totally augmented intervention program to functionally being able to stand by a river or lake and fly-fish independently. His endurance for this activity improves as he continues to practice.

**Somatosensory Retraining**

Somatosensory retraining is a multisensory approach to retraining target-specific skills for patients with movement dysfunction that manifests with measurable levels of sensory impairments. This type of therapy is based on the principles of learning and plasticity and progresses from a strong sensory emphasis to sensorimotor practice to motor learning. This approach has been used with patients with various types of hypertonicity resulting from congenital deficits (see Chapter 15) to degeneration (see Chapters 13, 17, 19, and 20) and disease (see Chapters 21, 23, 25, and 26). It has been most commonly used in patients with dystonia and chronic pain. This approach combines a variety of the strategies summarized in the augmented intervention section as well as Box 9-3. The principles for retraining can be found in Appendix 9-A. The progression of specific learning-based sensorimotor training is summarized in Appendix 9-B. Additional ways to enhance sensorimotor training can be found in Appendix 9-C.
After performing examination procedures in which you identify problems with activities and participation, you will then be able to classify these into clusters or syndromes (i.e., the physical therapy diagnosis). You then need to formulate a prognosis and determine the intervention options.

In order to determine the best treatment options for a patient with a neurological condition with movement problems, you must simultaneously consider non–physical therapy–based as well as non–neurological system–based limitations along with the specific neurological impairments. Assume the best case scenario (which never exists) in which there are no limitations in health benefits, from cultural beliefs or family, caused by conflict with other care providers, or in systems other than motor such as cognitive, emotional, vascular, integumentary, pulmonary, cardiac, and so on.

First, what does the patient want to do compared with what his or her motor system can do? Can you work on improvement of impairments and function within activities the patient is motivated to do? If so, do it!

Second, without altering the patient’s normal feedback (intrinsic) mechanisms, can he or she perform the functional activity without causing program adaptations that are so stereotypical that those programs may limit future movement functions and carryover?

For example: can you create an activity that will do the following without contriving the environment and while still running flexible, malleable motor programs?

1. Improve range of motion (ROM) or
2. Improve power or
3. Improve coordination or
4. Improve balance or
5. Improve endurance or
6. Any or all of the above
7. Have any similar effect

If so, do it!

If not, you will need to contrive the environment in order to create functional change through treatment intervention.

**ASK YOURSELF**

1. Where in the activity can you optimize biomechanics, and where are biomechanics deoptimized? If the body was placed at a better biomechanical advantage:
   a. Would the client be able to run and power the program?
   b. Would the motor program run more fluidly and procedurally?
   c. Would there be greater endurance?

   If your answer is yes, then try running the program that way initially and then increase the range and challenge all components of the program.

2. Throughout the activity, where would the least and greatest power be needed? Does the program run differently at different points throughout the activity depending on power production? Optimize what power you have, while maintaining fluid, relaxed program generators. Hypertonicity will often be observed if you ask for more power than the generators can create in a normal fashion.

3. Look at the program itself.
   a. What central nervous system (CNS) components are missing (impairments or functional problems)? These are usually your neurological diagnoses (physical therapy diagnoses).
   b. Can you elicit through treatment intervention corrections of the impairments in any aspect of the program? If so, how?
      - Caused by biomechanical advantage
      - Caused by musculoskeletal advantage
      - Caused by the program advantage itself

   Optimize:
   - Synergistic advantage
   - Balance synergies
   - Sensory processing
   - And so on

   These treatment answers will lay the foundations for your specific intervention strategies.

   c. Can you elicit those components in any other movement programs? If so, these are treatment alternatives, although they will not be task specific and have less immediate carryover.

4. Select movement activities that use existing components procedurally and facilitate or elicit function from impairment component of subsystems.

5. Prioritize functional activities by identifying daily living needs of the patient, goals of the patient, and functional skill of the patient. Determine which impairments affect the greatest number of functional activities. Similarly determine which impairments can be quickly changed in order to gain functional skill. Decide within the limits of the environment which activities to focus on first.
Neural Mobilization

Neural mobilization is often needed as an intervention strategy before somatosensory retraining is begun. Often there is increased sensitivity in a limb from pain, neurovascular restrictions, or soft tissue adhesions limiting the ability of the peripheral nerve to move through the tissue (see Chapter 18). This sensitivity can increase hypertonicity and further interfere with retraining motor control. In order to address this, it is important to quiet the nervous system and then gently mobilize the neural tissue. One way to quiet the nervous system is by “swaddling.” This is often used in newborns to quiet their nervous system. For an older child or an adult, the patient is wrapped similar to the way a baby would be; then gentle rocking in a rocking chair or a swing is added. Patients can do this themselves by putting on a t-shirt with the arms tight to the trunk and then wrapping even further with a blanket. This technique can be used periodically on days that the nervous system appears to be responding primarily to adrenaline rather than purposeful heightened activity. There are a variety of ways to mobilize the PNS. Detailed examples of this can be found in textbooks on the hand.

NATURAL ENVIRONMENTS AND QUALITY OF LIFE

Research has already been identified in the discussions of the various sensory input systems that recognizes that changes in external sensory input such as decreasing sound, light, tactile contact, or color of mats can change the processing of CNS of the clients. The present and future research will recommend that therapists apply changes that affect not only the patient’s inherent sensory systems, but also the environments within which the therapy is done. Therapists are going to have to adapt to change. At this time it is unrealistic to think that acute management of patients after a neurological insult will occur anywhere but in a large medical institution, but treatment needs after that acute stage may better be served in a more natural environment of the individual needing service. Not only has this conclusion been accepted conceptually in postacute pediatric settings, but federal law has ordered that individuals up to 21 years of age must receive educational experiences in the least restrictive environment. This amendment was made to the Individuals with Disabilities Educational Act (IDEA) in 1997. These changes have been mandated within the school systems and have affected therapy environments for clinicians who work in those situations. It is realistic to assume those changes will in time affect all therapy environments.

As the World Health Organization has moved toward an individual-friendly focus and thus a focus on body system strengths as well as impairments, participation in life, and its quality, the term patient may also need to be changed to participant. As can be seen in Chapter 8, examination tools have been included that deal with quality of life and not just functional outcomes from therapy. Therapists, if they have not done so already, are going to have to learn to deal with individuals coming to them for assistance as a partner in the process and not a patient who receives services. Change will come. That is one of the exciting aspects of being an OT or PT in the coming decades.

CONCLUSION

There are treatment techniques that are universally applied to the very young and the very old. As discussed in Chapter 4, the CNS is in a constant state of change throughout life. The brain is unique to each individual. Each brain has idiosyncrasies but also has an enormous number of predictable responses. These factors affect the success or failure of a client-therapist interaction. In Box 9-3 the reader will find guidelines that may assist in determining the type of interventions (functional, impairment, augmented, or somatosensory training) that will best match the patient’s functional movement capability. In answering the questions presented, the therapist will gain a better idea of which examination tools will best help objectively measure the progress of the patient toward that patient’s specific goals. From that thorough evaluation process (see Chapter 8), the therapist must decide which treatment is appropriate and the most efficient course of intervention on the basis of the goals of the patient and family, the movement diagnosis, the prognosis, the resources available, and the skills of the therapist. Once a
decision is made regarding whether the interventions should be based on compensation, substitution, habituation, neural adaptation, or a combination of the four, the team must select the best options available given all the resources. The options include functional retraining, impairment training, augmented and contrived interventions, and somatosensory reintegration. No matter the specifics of the intervention selection, the therapist must cognitively organize intervention options in a sequential process, be willing to change direction or options as the patient changes, and develop a greater clinical repertoire of intervention strategies.

When specific augmented interventions are needed, the therapist must select specific treatments according to the needs of the client, the time available for therapy, the level and extent of the functional involvement, the motivation of the client and family, the creativity of the therapist, and, of course, the existing pathology, whether it be stable or an active disease process. A therapist must choose whether somatosensory retraining, functional training, impairment training, augmented treatment interventions, or any combination of these four will provide the client with the most environmentally effective, cost-efficient, and quickest map to functional independence or maximal quality of life. How each therapist combines the interventions with the client’s specific needs will vary according to education, belief, skill, and openness to learning from the total environment itself. Learning should lead to further learning. Answers to unknowns will be found, with new unknowns coming to consciousness. The brain is still more mystery than not, so for most OTs and PTs beginning or ending their practice, the adventure has just begun. Enjoy the experience.

References

To enhance this text and add value for the reader, all references are included on the companion Evolve site that accompanies this textbook. This online service will, when available, provide a link for the reader to a Medline abstract for the article cited. There are 636 cited references and other general references for this chapter, with the majority of those articles being evidence-based citations.
APPENDIX 9-A  ■ Principles Used by Therapists for Retraining Clients with Pain and Motor Control Problems of the Hand

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A. Positive Foundation for Retraining
1. Carry out a regular exercise program, be well hydrated, eat balanced meals, get adequate sleep, make time to have fun, minimize habitual repetitions, and effectively manage stress.
2. Engage in challenging balance to improve posture and integrating diaphragmatic breathing, neural mobilization, and core trunk strengthening to maintain a healthy posture.
3. Create learning strategies that emphasize sensory input and feedback. You can do this by placing sticky, coarse, or rough surfaces on tools that are used in functional activities (e.g., pen, keyboard, glass, hammer, utensils).
4. Set goals and objectives to guide your training.
5. Think positively about learning to be as good as you can be or to recover after injury; expect to regain function.
6. Analyze and break down the tasks you want to learn or to improve into manageable components.
7. Perform each component of functional tasks without abnormal movements (e.g., pathological synergies, extraneous movements, excessive muscle firing, involuntary movements, strain, pain).
8. Be sure each activity is designed to require attention, repetition, progression of difficulty, feedback regarding accuracy of performance, and positive reinforcement (reward).

B. Stress-Free Hand Use Strategies
1. Strengthen the small muscles inside the hand (intrinsic muscles) to facilitate stability of functional hand use.
   i. Give resistance to spreading fingers apart (try not to use muscles that straighten the fingers).
   ii. Try to hold the fingers together while you use your other hand to try and spread them apart.
   iii. Bend the fingers at the large knuckle (metacarpophalangeal joint) to 90 degrees by placing the back of the hand against the edge of a table. Now, one finger at a time, try to keep the fingers straight as you use the other hand to try and bend the finger, giving resistance at the distal segment of the finger.
2. Concentrate on using the small muscles of the hands in all functional activities.
   i. Initiate bending the fingers from the base joint (the large metacarpophalangeal joint that joins the finger to the palm); try to do this without bending the fingers at the other joints, especially without using the muscles that bend the distal finger joints.
   ii. Avoid heavy gripping; squeeze the fingers in a power grip only when necessary. For example, do not (1) squeeze the steering wheel, (2) exercise while holding on to free weights, or (3) squeeze a ball or strengthen the grip in other ways.
   iii. Practice reaching for common objects with the eyes closed and the hand relaxed. When you contact the object, let the sensation of the surface of the object open the hand. For example, when you reach for your cup, let the cup open the hand (e.g., do not actively spread the fingers first). Do not use the handle of the cup.
3. When practicing tool use, let the sensation of the object teach your hand how hard to squeeze.
   i. Modify the sensation of the object (e.g., very rough, slightly rough, coarse, smooth, silky).
   ii. Take practice lifts of the object to determine how heavy it is.
   iii. Manipulate the object in your hands without visual monitoring before beginning functional use of the tool.
4. Avoid aggressive, precise, rapid, alternating, forceful finger flexion and extension movements of the hand.
   i. Transfer some of the work of the hand from the fingers to the forearm. For example,
      ❏ Lift the fingers by rotating the forearm into supination (e.g., turn palm up). If forearm rotation is limited, let the shoulder externally rotate if necessary.
      ❏ When the hand needs to be palm down (pronated), let the elbow swing away from the trunk if necessary to keep the hand relaxed (e.g., internal rotation of the shoulder can take the stress off the forearm).
   ii. Use the hand in a natural functional position (e.g., rounded palm from the base of the thumb to the base of the fifth finger and rounded from the tips of the fingers to the wrist). Thus all the finger joints are slightly bent, the palm is round, and the wrist is extended about 15 degrees. When your arms are at your side, this will usually be the position of the hand.
   iii. Do not let the joints of the fingers collapse or hyperextend when they are down on a surface. This can be difficult if the joints are hypermobile or the intrinsic muscles (muscles inside the hand) are weak.
      ❏ Practice dropping the hand onto a surface and maintaining the roundness of the hand (a small soft ball under the palm may be used for assistance).
      ❏ Lean lightly onto the hand while it is on a flat surface, pronated and keep the round shape of the hand (e.g., may need to initially keep small round ball under palm).
      ❏ Thread the fingers of one hand through the fingers of the other hand to help stabilize the hand when placing weight onto the hand as noted previously.
      ❏ Put a soft, rubber ball about 2 inches in diameter on the table; roll the palm of the hand over the ball while letting the finger pads (not the tips) drop onto the surface.

C. Using the Computer Keyboard Safely
1. Position yourself comfortably to use the computer.
   i. Sit with feet flat on the floor. Sit tall with hips about 90 degrees (vary this posture throughout the day).
   ii. Place the computer screen at or slightly below eye level.
   iii. Keyboard height should be adjusted to maintain elbow flexion at about 80 degrees (positioned in approximately 100 degrees of extension).
   iv. Forearms should be angled toward the floor and not resting on the table. If it is difficult to let your hands rest lightly on the keyboard with the wrist floating, it may be helpful to have a pillow on your lap (or a lumbar roll around the waist), where the forearms receive positive sensory information to help them relax.

Continued
APPENDIX 9-A □ Principles Used by Therapists for Retraining Clients with Pain and Motor Control Problems of the Hand—cont’d

v. Place the screen about 2 feet away from the eyes for most work; pull the screen closer as necessary for close work.
vi. Consider getting special antiglare glasses for computer terminal display work or use a screen glare protector.

2. Use your hands in a functional (e.g., round, not flat or angular) position on the keyboard.
i. Look at the contour of the hand when it is at your side; maintain that position as the finger pads (not the tips) are dropped on the keyboard.
ii. Place a rough surface on the keys (e.g., Velcro) to make it easier to feel the pads on the keys.
iii. Avoid placing the tips of the fingers on the keys. This creates an obligatory co-activation of the finger flexors and extensors.

3. Keep the wrist in a neutral position (0 to 10 degrees of extension) while working on the keyboard (e.g., a floating wrist).
i. Do not rest the wrist on a “wrist rest.” Resting the wrist and forearm on the work surface will increase the pressure in the carpal tunnel and force all the work to be done with the fingers.
ii. If there is a wrist pad on the computer keyboard tray, think of the pad as a “sensory tickle” to let you know that your wrists should be floating above the rest.

4. Have all the fingers resting on the keyboard.
i. Do not let any of the fingers fly up.
ii. Continue to keep the fingers resting down even when one finger is engaged in depressing a key.
iii. Avoid allowing the adjacent fingers to extend to get them away from the finger actively pressing down.

5. It is not necessary to actively lift the fingers after pressing down. Usually it is sufficient to release the pressure without actively lifting up the digits.

6. Avoid resting the fingers on the keyboard with the finger tips. This leads to a contraction of the fingers and the wrist.
i. Do not keep your fingers excessively curled. In that position it is impossible to keep the fingers on their pads.
ii. Initiate the movement down from the base joint of the fingers.
iii. Imagine that you are using the muscles inside your hand and not the long muscles that bend the fingers.
iv. Avoid reaching one finger out in isolation from the others.

7. In general, change the primary fulcrum of movement from the fingers of the hand to the elbow and shoulder.
i. Allow the elbow to move freely in flexion, extension, and rotation.
ii. Use the trunk with a little shoulder movement when reaching for an object or a paper or to move closer to or away from the computer keyboard or screen.

8. Use the mouse by using forearm rotation rather than individual finger movements.
i. Do not squeeze the mouse; drape your hand on the mouse.
ii. Keep your wrist in neutral position.
iii. Avoid clicking the button by lifting and bending the index finger.
iv. Use rotation of the forearm to activate the button on the mouse.
v. Make sure the mouse is close to you and that the arm is not extended to the side. Place a cover for the mouse over the number keys, if necessary, to keep the arm closer to your trunk.

vi. Consider interfaces other than a mouse (e.g., roller ball, a movement-sensitive pad, pen).

vii. If it is not possible to use the hand in a stress-free way when on the computer, then consider voice-activated software to use your computer.
   □ Use your voice carefully and without excessive force or strain (e.g., loudness).
   □ Be careful to prevent co-contractions and stressful use of the vocal cords.

9. Take regular breaks (e.g., every 15 minutes).
i. Consider obtaining the software that forces a computer breakthrough screen reminder.
ii. Do diaphragmatic breathing continually while working on your computer to minimize tension and facilitate good oxygen exchange.
iii. When taking a break and staying at the desk, get your hands off the computer and change your sitting posture while doing gentle range-of-motion exercises. Occasionally place the arms on the desk and bend the trunk over the arms.

10. At least every 20 minutes, stand up for a few minutes and stretch.

D. Writing

1. The fulcrum for the movement of writing should be the shoulder and elbow, not the fingers.

2. The hand should be round and relaxed.

3. Try putting a sticky or a rough surface on the pen or pencil before you begin to practice.
   a. A sticky surface (e.g., tape with the sticky side facing out) can be strong enough to hold the pen in place without any squeezing.
   b. A fatter pen is not as helpful as a sticky or a rough surface.

4. Practice writing when you are not at work or at a store when you have to write your name.

5. Practice writing non–work-related words and sentences and then progress to meaningful writing.

6. Try holding the pen by different fingers or using different movements.
   i. Try to hold the pen between the second (index) and third (middle) finger rather than the thumb (D1), index finger (D2), and middle finger (D3). The hand should be open, thumb resting down.
   ii. If you must hold the pen in the traditional way, try to hold the pen lightly among D1, D2, and D3, with D1 and D2 moving toward the thumb from the base joint with all joints of the digits extended.
   iii. With a sticky surface on the pen, it is possible to control the pen with minimal squeezing.

7. Practice picking up the pen and putting it down without feeling any tension in your hand.

8. Control the movement of the pen primarily from the elbow and shoulder; keep wrist and fingers quietly positioned on the pen.
   i. Let the arm rest lightly on the table and comfortably on the ulnar (fifth finger) side of your hand. Avoid resting the elbow on the surface. If there is inadequate pronation (e.g., it is uncomfortable to have the hand be palm side down), allow the shoulder to move out away from the trunk (e.g., shoulder abduction or rotation).
Principles Used by Therapists for Retraining Clients with Pain and Motor Control Problems of the Hand—cont’d

ii. Let all fingers rest down on the pen or the support surface. Do not hold any fingers up off the pen or the support surface.

iii. Mentally review relaxed writing before beginning to write with a new technique.

iv. Practice making circles, loops, large numbers, and letters. Consider practicing by writing in shaving cream, finger paints, or water.

v. If you see your fingers moving and your knuckles turning white, you are squeezing too hard and you are using only your fingers.

9. Use a mirror to get some feedback to retrain your style of writing.

i. Place a mirror in front of your affected hand as you write and notice whether it appears relaxed.

ii. Place the unaffected hand in front of the mirror and the affected hand behind the mirror. Look at the image of the unaffected hand (e.g., looks like the affected side), and then have the affected hand behind the mirror copy the mirror image.

10. Put the pen down if any signs of stress develop.

E. Daily Activities in the Kitchen

1. Use two hands to hold a pot or a frying pan.

2. Use an electronic can opener and jar opener.

3. Use an electronic blender rather than hand stirring.

4. Use a chopper to avoid heavy cutting.

5. Stand close to the sink and the work surface so you do not have to have your arms out too far in front of you.

6. Get close to the table for setting the table; avoid having to lean over; bend at the knees.

7. If you are short, stand on a stool to work at the sink.

8. If you are tall, consider raising the refrigerator up higher so you do not have to lean over.

9. Concentrate on eating and using utensils without stress in your hands.

i. Consider putting a sticky or a rough surface on the utensils (e.g., Velcro or flooring with a sticky back).

ii. When eating, hold the utensils lightly, even when trying to cut.

iii. When cutting, move the whole arm from the shoulder; use the weight of the trunk to assist putting force down on the knife.

F. Driving

1. Use a lumbar roll in the back of your seat to support your lower back. Also consider placing a wedge in your seat (varying the placement of the wedge with the high side in front and then toward the back).

2. Pull the seat close to the steering wheel so that you do not have to reach out so far for the gas pedal.

3. Sit tall to ensure good visibility, and try to drive without stress.

4. Consider putting a rough surface on the wheel so you do not tend to squeeze it (you can buy ergonomic steering wheel covers).

5. When you need to look behind you, shift your weight in the opposite direction that you want to look. This will allow you to turn your whole trunk in the desired direction and avoid the isolated neck strain that occurs when you only turn your head.

6. Mentally rehearse and review calm, alert driving.

7. Do not squeeze the wheel in a death grip. Hold the steering wheel by gently pushing your arms together. You only need to hold the wheel with a palmar squeeze when turning.

8. Keep your arms comfortably at your sides.

9. Do not grip the shift knob; press the palm of your hand down on the shift bar to change gears. You may even want to allow your trunk to move with your arm while shifting.

10. If you continue to experience stress with driving, practice braking and turning the wheel in your garage and imagine different scenarios.

11. Also, if you need a diversion to avoid emotional confrontation with rude drivers, bring a plastic bag of buttons that you can manipulate and match to decrease your stress.

G. Other Household Activities

1. As before, do not grip objects too firmly; keep hands open and work with your arms close to the trunk.

2. Always bend your knees to pick up objects from the floor.

3. Be careful to avoid leaning over and straightening the bedding (e.g., when making the bed, ask someone to do it with you; otherwise, make one side of the bed at a time).

4. Put items at eye level; avoid putting things over your head for which you have to reach out and up.

5. Walk close to the vacuum cleaner; try to hold it where you do not have to reach your arms out (e.g., step forward and backward with the movement of the vacuum cleaner).

6. Do not lean over from the waist for dusting; if necessary, dust while kneeling or wipe the floor while you are on your knees; hold the dust cloth lightly.
APPENDIX 9-B  ■  Specific Learning-Based Sensorimotor Training

A. Instructions

Patients
We use our hands for many skilled fine motor and functional tasks. It is important for these movements to be smooth, efficient, and accurate. When there is dysfunction in the central or peripheral nervous system from congenital anomalies, injury, disease, overuse, degeneration, or chronic pain, skilled and functional movements can be impaired. Although it is still important to strengthen the muscles, increase flexibility, and restore normal motor control, it is critical to improve sensory processing. The purpose of learning-based sensorimotor activities is to place demands on the sensory receptors of the skin, the muscle, and the joints to restore normal sensitivity and accuracy of sensory input and feedback. Your brain can change with training. By improving the accuracy of sensory discrimination under conditions of high levels of attention, repetitive activities progressed in difficulty and reinforced with feedback and reward should improve how the hand is mapped on your brain (e.g., primary sensory cortex). When specific tasks involve motor practice, topographical changes will also occur in other parts of the brain (e.g., thalamus, motor cortex, limbic system, basal ganglia, prefrontal cortex, supplementary motor cortex, brain stem). Although most think about the motor requirements for performing a task, it is essential to have accurate sensory information and feedback, which comes from accurate sensory differentiation of the hand. Dynamic sensory topography and function are requisite for the restoration of fine motor control.

Research also suggests that positive expectations can facilitate recovery and maximize performance. Physical impairments can lead to significant handicaps and disability. In these cases it is challenging to maintain a positive attitude and be motivated for recovery and rehabilitation. Depression, anxiety, loss of self-worth, and compromised self-esteem can significantly impair the recovery process, especially when training activities are demanding, intensive, and possibly associated with discomfort or frustration. It is essential to progress activities without causing unnecessary anxiety, apprehension, or pain. With these issues in mind, the initial steps in sensorimotor training may seem unusually simple and involve imagery in lieu of motor practice. Also, although the suggestions here focus on the hand, the principles apply to sensorimotor retraining for other parts of the body as well.

Specific randomized clinical trials have not been carried out on this series of training activities. However, Moseley carried out several studies establishing the procedures to perform recognition training of hand laterality, imagined hand movements, and mirror movements. He also carried out a randomized clinical trial for patients with complex regional pain syndrome using these training techniques. He randomly assigned 20 subjects to one of three different groups: hand laterality recognition, imagined movements, mirror training, or imagined movements; hand laterality recognition, imagined movements, or hand lateral recognition; mirror movements or hand recognition latency. At 6 and 18 weeks after training for 2 weeks on these behaviors, subjects in all groups had a significant reduction in pain and disability (P < .05), with the group doing hand laterality recognition, imagined movements, and mirror training making significantly greater gains than the other two groups. Byl and co-workers also reported significant gains in patients with focal hand dystonia after 6 weeks of learning-based training. Candia and colleagues also reported significant gains in performance for musicians with focal hand dystonia after 1 year of training focusing on task practice while controlling the fingers with a splint to improve isolated control of the dystonic fingers. For patients who are stable after a stroke, Byl and colleagues also reported significant gains in fine motor performance after a sensory retraining program similar to the activities described here.

Therapists and Family Members
When giving these instructions to patients, it is important to supplement the written instructions with pictures or even videos. For patients with significant cognitive impairments, these instructions are almost more important for the family members who are helping reinforce the supervised therapy program.

B. Principles of Learning-Based Sensorimotor Training

1. Learning strategies focus on improving the discrimination of the somatosensory system in a range of tasks that focus primarily on sensory processing during sensory discrimination tasks and fine motor tasks.
2. Successful recovery is contingent on being able to imagine using the hands normally again without abnormal movements, apprehension, or pain.
3. The injured hand (affected limb) needs to recover laterality (right and left).
4. The patient needs to be able to look at a hand and imagine integrating the image of the hand into the movement or positioning of his or her own hand.
5. The hand must be able to interface with the target surface without creating tension, pain, or abnormal movement.
6. It is essential to be able to mentally imagine performing related and target tasks without abnormal movements or pain.
7. Sensory processing must achieve a minimum level of accuracy before functional fine motor movements are integrated.
8. Functional fine motor tasks need to be mentally practiced before they are physically practiced.
9. Tasks must be divided into the smallest components that can be normally executed (e.g., partial task performance), which will serve as the foundation for building skill-based learning on the whole task.
10. Learning requires attention and repetition of behaviors progressed over time.
11. Feedback and reward must be integrated into all learning activities, either by mental imagery, mirror imagery, visual reinforcement, auditory feedback, or objective, accurate task performance.
12. Feedback from error correction may be critical for enhancing learning.
13. Each component of a functional task must be performed as normally as possible before progressing to a more difficult task (e.g., without pathological synergies, extraneous movements, excessive muscle firing, involuntary movements, strain, pain).
14. Repetitive activities must avoid stereotypical movements that occur nearly simultaneously in time.
15. Sensory discriminative retraining should eliminate visual cues to facilitate somatosensory learning (e.g., eyes closed, blindfolded, distorting lenses).
C. Preliminary Activities to Improve
Discrimination Training

16. Begin sensory training on nontarget surfaces or with easy
   tasks that do not trigger abnormal responses (e.g., nontarget
tasks).
   i. Practice on nontarget tasks until sensory processing is
      improved and the task can be performed without any
      abnormal movement.
   ii. Integrate sensory retraining in tasks that historically have
      been associated with abnormal movement (e.g., writer’s
      cramp, keyboarder’s cramp, hand functions associated
      with abnormal synergies related to hypertonicity, tremors,
      dystonia).

APPENDIX 9-B ■ Specific Learning-Based Sensorimotor Training—cont’d

D. Initiate Specific Learning-Based
Sensorimotor Training—cont’d

1. Retrain cutaneous, muscle, and joint receptors at nontarget tasks.
   i. Develop a variety of active sensory discrimination activi-
      ties that you can do by yourself (e.g., actively exploring to
      interpret different object surfaces—stereognosis).
      □ Take the opportunity to feel objects in your environment
      and identify the objects without looking at the object.
      □ Put small objects in bowls of rice or beans and reach in
      and try to find and match the objects.
      □ Hang different objects from a string on a door jamb;
      start the objects swinging and allow them to stimulate
      your hand. See whether you can differentiate the
      different objects as they move across your hand.
   ii. Modify the difficulty of the sensory task.
      □ Change the intensity of the sensory stimuli (e.g., make
      the surfaces less distinct).
      □ Increase the challenge or the complexity of the stimuli
      you are trying to identify.
      □ Change the environment in which you are exploring the
      sensory stimuli (e.g., hand in water, still or agitated; in
      shaving soap; in whipped cream as you discriminate an
      object or manipulate a pen).
      □ Change the position you assume when discriminating the
      stimulus (e.g., lie down on your back or your stomach,
      stand instead of sitting).
   iii. Palpate objects in water or other media for identification;
      have the water be still and then agitate the water.
   iv. Put pairs of coins and objects in your pocket (or a plastic
      bag) and try to match them or discriminate between them.
   v. Purchase clay that can be molded and shaped and then
      heated until firm.
      □ Place or draw different shapes on the clay.
      □ Always include a pair of designs that can be matched.
   vi. Paste matched pairs of items on a card and try to find the
      matched pairs.
      □ Paste stickers with shapes on cards and try to find
      matched pairs.
      □ Paste matched pairs of buttons on a card.
      □ Paste alphabet soup letters on a card and match letters
      or spell words.
      □ Put magnetic letters and other shapes on a card or a
      refrigerator and move them to spell words.
   vii. Take construction paper and create pairs of letters, shapes,
      or other designs by pressing heavily with the pen; this will
      create a raised surface on the other side.
      □ With eyes closed, palpate and try to find matching pairs.
      □ Turn the paper in different directions to make the
      exploration different.
   viii. Make a grab bag of items and reach into the bag and identify
      the objects by gentle touch.
   ix. Obtain Braille workbooks and learn to read Braille.
      □ If you have trouble learning Braille with the affected
      side, try with the unaffected side.
      □ Do not tense your hand as you feel the letters, and do
      not extend the adjacent digits away.

Continued
APENDIX 9-B Specific Learning-Based Sensorimotor Training—cont’d

- Work your hands smoothly over the dots. You can improve your skill, getting other workbooks for the blind and ultimately purchasing books in Braille.
- Obtain “Braille object cards” where the object is described in Braille. Palpate the letters and sentences.
- Place raised numbers and designs on the computer keyboard and try to determine what the number or shape is before striking the key; make some labeled letters match or mismatch the key itself.

2. Practice activities requiring the interpretation of sensory information delivered to the skin (interpretation of sensory inputs without active exploration of the stimulus, graphesthesia).
   - Ask a friend to stimulate your skin with different stimuli (e.g., hot, cold, sharp, dull, rough) and try to identify the stimuli.
   - Have a visual stimulus provided at the same time an object is touched to the skin (on the affected and unaffected side); the goal is for you to accurately describe the cutaneous information delivered to the skin (interpretation of sensory inputs delivered to the skin).
   - Ask this friend to draw numbers, letters, words (upper and lower case or cursive), and designs on your forearm, hands, and fingers when you are not looking.
   - Identify the letters, numbers, words, and shapes verbally (e.g., start with capital letters).
   - When it is easy to be correct on capital letters, have your friend draw lowercase letters, including words.
   - Progress to having designs drawn on your skin; replicate the design by drawing it on a piece of paper or on your own skin.
   - Ask your friend to give you feedback about the drawing to make sure the drawing matches the stimulus.
   - Check the angles where the lines meet.
   - Note accuracy of detection of curves.
   - Note whether all parts of the design are placed in the right relationship and orientation (spatial accuracy).
   - Note whether the design is the correct size.
   - Check whether the drawing has some elaborate components that were not actually drawn on the surface of the skin.
   - Your friend should make the drawings smaller and smaller to increase the challenge of detection (e.g., 2 to 3 mm).

- The drawing or the stimuli should be delivered two or three times. If the design is still missed, look at the design. After viewing the design, repeat the design at the next trial (or the alternate trial), and before progressing determine whether you can recognize the drawing. Use a friend to check on your accuracy.

3. Use other stimuli to reinforce somatosensory learning.
   - Develop tasks to improve sound discrimination (either location or determination of whether you hear one or two sounds delivered).
   - Have a visual stimulus provided at the same time an object is touched to the skin (on the affected and unaffected side); the goal is for you to accurately describe the cutaneous stimulus (e.g., sharp, dull, smooth, rough, silky, hard, soft).

4. Develop activities to emphasize proprioceptive and kinesthetic learning.
   - Where necessary, use tape on the skin, use electrical or auditory biofeedback, or put weights around the wrist and ankle to increase feedback from joint, tendon, and muscle receptors.
   - Create games in which a part of an object has to be accurately placed on a topographical picture.

- Create games in which objects have to be moved accurately across specific distances on a variable surface.
- Create objects of the same weight and place different types of surfaces on the object (e.g., Velcro, sandpaper, flooring). Then practice picking up, moving, and putting down the object with minimal effort.
- Assemble puzzles by feeling the matching pieces rather than looking with the eyes.
- Work with a friend and practice copying movements together (first by looking and then by feeling).
  - Tap one finger while the other fingers are resting down.
  - Bring arms up over head and tap one finger at a time.
  - Bend wrist with one arm and bend elbow with other arm.
  - Circle wrist to the right (right hand) and circle to the left with left hand.
- Have a friend give you some resistance as you move one finger, the wrist, or the forearm up and down.

- On a piece of paper, draw hand diagrams with different angles of each finger and different angles of the wrist. Then put up a vertical screen where you cannot see your hand. Look at each picture and try to copy the pictures with your own hand. Look behind the screen to check to see how accurate you are.
- See if you can rent a continuous passive motion machine.
  - Set the machine at different speeds.
  - Try to follow the movements of the machine.
  - Apply vibration to the skin over the joint in the direction opposite to the movement.
  - Carefully time the movements to enable success.
- Practice grasping objects with a light grip on the object. Use a spherical group (thumb pad to the pads of other fingers). Practice this with objects of different size with minimum graded force.
- Practice bending and straightening the elbow, wrist, or fingers while applying vibration to the appropriate joint.
  - When bending (flexing) the joint, apply vibration on the extensor surface.
  - When straightening the joint, apply vibration on the flexor surface.

E. Sensory and Fine Motor Activities at Nontarget Tasks

1. Move in normal patterns in desired directions without excessive firing of the muscles.
   - Consider a number of strategies to allow you to move the most difficult finger more easily (e.g., stabilize adjacent digits).
   - Use a soft splint to stabilize the fingers adjacent to the finger you want to move.
   - Mold a piece of clay; keep an area clear under the finger you want to move, and place a hole in the clay for the other fingers to rest in.
   - Put a buddy strap on fingers adjacent to most dystonic or painful finger.
   - Put tape on the fingers on the surface that would be most likely to improve movement (e.g., on the flexor surface if the finger extends; on the extensor surface if the finger flexes; on the side of the finger if having difficulty with isolation).
   - Use a finger interphalangeal splint on fingers adjacent to dystonic fingers.
   - Increase sensory feedback on the finger you are trying to move (e.g., use tape on the finger).
APPENDIX 9-B  Specific Learning-Based Sensorimotor Training—cont’d

2. With the eyes closed, play games that require discrimination of sensory information through the skin of the fingers.
   i. Play dominoes.
   ii. Play pick-up sticks.
   iii. Play shape games (e.g., match a shape to an opening, such as in Perfection).
   iv. Play together puzzles that have a raised surface.
   v. Play Scrabble with raised or indented letters.
   vi. Play games that require orientation in place without the benefit of vision.
      ❖ Play pin the tail on the donkey.
      ❖ Walk through the house with your eyes closed and hands out to feel objects in your way and to catch yourself if needed.
   vii. Get a Braille deck of cards and play cards (e.g., Solitaire can be played alone; play hearts, bridge, pinochle, or poker with others).
   viii. Create other sensory games that require planning and control and that can be played without vision.

F. Learning-Based Sensorimotor Retraining (Praxis)
1. Feel objects and then define and demonstrate what to do with the objects.
2. Have a friend provide a sensory stimulus and ask you to do something that indicates you felt the stimulus (e.g., “when I tap with this sharp object, I want you to tap once, but when I touch you with this dull object, I want you to tap twice”).
3. Feel a number of items in a bag that are related to performing a task, and put the items together to do the task.
4. Feel a number of objects put together in a specific design; have someone give you a second set of the objects to replicate or match the design.
5. Practice throwing objects of different size; practice throwing them to a particular spot.
6. Get accustomed to grading movements without uncontrollable contractions.
   i. Place the hand on a moving target and do not stop the movement.
   ii. Manipulate objects without excessive force.
   iii. Put your hand on a record player and do not stop the record movement (e.g., do not change the sound).
   iv. Put your hand on the moving belt of a treadmill and feel the moving belt.
      ❖ Feel the belt moving under the hand.
      ❖ Hold objects under the fingers.
      ❖ Pass objects back and forth between the fingers, and make the objects feel the same.
7. When it is possible to perform the sensory activities in nontarget tasks, begin placing the hand on the target instrument without abnormal movements.
   i. With the hand on the target instrument, mentally rehearse the movements and the tasks you should perform.
   ii. Add rough surfaces to the target instrument if necessary to change the interface with the hand.

G. Sensorimotor and Fine Motor Training at Target Tasks
1. Emphasize the sensory aspects of the task even when beginning to perform the target task.
2. Perform a selected component of the task (e.g., drop one finger down on the keyboard).
3. Progress the ability to complete more and more of a target task, emphasizing sensory exploration as long as the tasks can be done normally.
   i. Increase the speed of the movements on the target task.
   ii. Add multiple digits to the sensorimotor tasks.
4. Be sure to get reinforcement for performing all tasks normally (e.g., use a mirror, use biofeedback, get verbal feedback).
5. Have someone make a video performing the target task with which you are having trouble. Then try to copy the movements. Watch the movements carefully and imagine that the movements are your hands moving.
6. Perform the target task in different, nontraditional positions (e.g., practice in nontraditional positions such as lying on the back, lying on the stomach, reaching hand behind you or over your head).
7. Do the target task in different media (e.g., if having a problem with writing, draw shapes and letters in shaving soap; draw big letters and then small letters and then words).
8. Provide external support of the affected hand to appropriately position the digits (e.g., a splint if necessary to prevent movement of adjacent digits) while doing sensory and sensorimotor tasks on the target instrument.
   i. Begin with a single digit adjacent to the most involved digit, but not the most involved digit.
   ii. When you can do complex sensory exploration with a single finger without abnormal movement, combine sensory exploration with more complete target movements.
   iii. Add multiple digits to the sensorimotor tasks.
9. Without externally supporting the position of the digits (e.g., all digits free) perform one simple movement on the target task.
   i. Integrate sensory exploration with the simple movements and do the movements slowly, in time with a metronome.
   ii. Increase the complexity of the sensory-driven motor tasks (e.g., tapping single note to playing scales and chords to playing new music or performing new keyboard tasks).
   iii. Increase the speed of the movements on the target task, keeping up with the metronome.
   iv. Perform the target task normally for brief periods, and progress the practice time slowly with frequent breaks.

H. Reinforcing Sensorimotor Learning with Feedback
1. Biofeedback can include visual, cutaneous, muscle, vibration, auditory, or stretch stimuli.
2. Biofeedback can be supervised by another person, facilitated with robotic movements, controlled by electronic contraction (activation of muscles), or controlled by a physical constraint of a limb; guided repetitive passive movements can be supplemented with active movements to control motor output.
   i. Put tape on the top of the skin over the extensor surface of the digits to limit motion or emphasize somatosensory input and feedback.
   ii. Use multichannel biofeedback to learn how to avoid abnormal movement strategies.
      ❖ Practice isolated movements and stop practice of unnecessary co-contractions of agonists and antagonists.
      ❖ Use the small muscles inside the hand (intrinsic muscles) to move the digits instead of the extrinsic muscles.
      ❖ Use imagery with mental rehearsal and practice to help restore the image of performing the task normally (see Appendix 9-C).

I. Return to Work
1. Try to return to work part time.
2. Discuss other work options if you cannot resume the original job tasks.
3. Make ergonomic modifications at the workplace.
4. Integrate stress-free techniques.
5. Take frequent brief breaks.
6. Walk or do other exercises at lunch time.
**APPENDIX 9-C  ■  Enhancing Learning-Based Sensorimotor Training: Use of Imagery, Mental Rehearsal, and Mental Practice**

**A. General Comments about Imagery**

It is critical to restore confidence, a sense of wellness, and normal control of the movements of the extremities and trunk. Initially this may be difficult because of pain, lack of accurate sensory information, and difficulty with the control of movement or imagining that the hand or arm could be normal again. One way to begin to restore the accuracy of the information processing system so you can use your hand normally is to begin by changing how the hand and the functional task you are trying to perform are represented on your brain (the internal representation of that injured part).

It is important to be able to restore the normal image of the involved limb, that is, how it used to be and how it will be normal again. In the process of restoring normal control, it is also important to begin to use the hand normally and not increase the pain or repeat the abnormal movements. Thus, visually imagine your hand and how it looks. Making your hand look like the other hand is a good beginning. Then begin to create an image of the hand and the task you want to perform. Imagine using the hand normally to perform all the usual and target tasks. You can start by imaging small parts of a larger task and then finally the whole task and then related skills and activities that would be associated with performing the task.

With advances in magnetic resonance imaging, we can more readily confirm the recruitment of brain processes with imagery. It is possible to activate functional, motor, and sensory representations of the hand with mental imagery. The area of the brain recruited is dependent on the activities imagined by the individual. For example, you have many different maps of your body. Some of the topographical maps may be redundant across different parts of the central nervous system (e.g., motor cortex, sensory cortex, prefrontal cortex, thalamus, basal ganglia). Well-learned functions are also mapped separately from sensory and motor topography. When you visualize a body part, you will activate the somatosensory cortex. When you imagine doing the task (motor imagery), you will also activate the motor cortex. When you can visually and motorically imagine completing the task in your mind, you will activate the cortical areas representing the part of your body that is moving and the part of the brain that is devoted to completing that task (e.g., walking, writing, playing an instrument). The intensity with which the neurons fire when you are imaging is less than the intensity of firing when you are actually performing the task. Try to imagine performing your tasks without mistakes. This will reinforce the positive aspects of the sensorimotor feedback. You must imagine without interruption (e.g., attention), and you must repeat the imaging process with a high level of concentration to help the nervous system learn. If you are imaging and you run into difficulties completing a task normally, try to focus on the source of the difficulty, including asking your inner self what barriers are getting in the way. Once you can get insight into these barriers, you should be able to break them down.

During imaging or mental practice, approximately 30% of the neurons are recruited as would be recruited when the task is physically executed. Furthermore, when learning a new task, more neurons are recruited than when the task is learned. An impairment of structure (e.g., neurological or musculoskeletal) could modify the ability to image performing a task normally. On the other hand, imaging normal function and task performance could be easier than actually executing normal performance. In addition, repetitive imaging could begin to drive neural adaptation and recovery.

When there are conditions of chronic pain, there are changes in the organization and representation of the painful part in the central nervous system (e.g., cortex, thalamus, prefrontal cortex, supplemental motor cortex). Similarly, repetitive, abnormal patterns of movement also can dedifferentiate the representation of the body part. Thus, intervention must focus on restoring the normal representation of the brain. Sometimes it is easier to imagine normal movement or pain reduction than it is to actually change the pattern of movement or turn off the “on cells” for pain.

**B. Suggestions for Goal-Directed Imaging**

1. Set goals for yourself to specifically improve the function of your hand.
   a. Imagine that you are healthy and fit and have full normal control of all of your extremities.
   b. Focus on healing the involved tissues, particularly if you have signs of inflammation and pain.
      i. Focus on diaphragmatic breathing and bringing blood to the tissues.
      ii. Imagine the blood carrying important elements to the area of injury (e.g., the growth factors and oxygen that are requisites for healing tissues).
      iii. Imagine that an injury causes inflammation that triggers the healing response (e.g., laying down collagen [scar]). Also imagine that the body modifies the scar tissue and tries to keep it mobile.
   c. Visualize the anatomy, physiology, and kinesiology of the hand.
      i. Imagine the bones gliding smoothly on one another.
      ii. Imagine the muscles being strong, with a balance between the intrinsic and extrinsic muscles that serve the hand.
      iii. Imagine normal movement patterns.
   d. Imagine normal sensation in the hand.
   e. Imagine pain-free movement.
   f. Imagine the hand being quiet and relaxed.
   g. Imagine smooth control of the hand without involuntary extraneous movements.
   h. Imagine that the affected hand is working just like the unaffected hand.
   i. Imagine using the hand as you used to use it. Go back in time to when your hand felt good and you did not have any problems.
      i. When mentally practicing and imaging, there should be no distractions. Spend at least 30 to 60 minutes a day normalizing the hand and imagining how good it feels.
   j. Mentally practice and perform the target task without any signs of strain or pain.
   k. Concentrate and mentally review each of the components of the hand working normally.
   l. Concentrate on the free flow of rhythmic movements of the hand and arm as you walk.
   m. Recapture the excitement of using your hand while playing your instrument or working at your job without pain or strain.
   n. Reinforce the image of a normal hand by continuing to progress learning, including more complex tasks and public performances.

2. Follow a sequence for learning.
   a. Imagine that you are healthy and fit and have full normal control of all of your extremities.
   b. Focus on healing the involved tissues, particularly if you have signs of inflammation and pain.
   c. Visualize the anatomy, physiology, and kinesiology of the hand.
   d. Imagine normal sensation in the hand.
   e. Imagine pain-free movement.
   f. Imagine the hand being quiet and relaxed.
   g. Imagine smooth control of the hand without involuntary extraneous movements.
   h. Imagine that the affected hand is working just like the unaffected hand.
   i. Imagine using the hand as you used to use it. Go back in time to when your hand felt good and you did not have any problems.
   j. Mentally practice and perform the target task without any signs of strain or pain.
   k. Concentrate and mentally review each of the components of the hand working normally.
   l. Concentrate on the free flow of rhythmic movements of the hand and arm as you walk.
   m. Recapture the excitement of using your hand while playing your instrument or working at your job without pain or strain.
   n. Reinforce the image of a normal hand by continuing to progress learning, including more complex tasks and public performances.