Learning Objectives

control of normal movement, limitations, and clinical applications.

5. Discuss the relationship between theories of motor control and the parallel development of clinical methods related to neurologic rehabilitation.
6. **Compare** and contrast the neurofacilitation approaches to the task-oriented approach with respect to assumptions underlying normal and abnormal movement control, recovery of function, **and** clinical practices related to assessment and **treatment.**

Introduction

What Is Motor Control?

Movement is a critical aspect of life. Movement is essential to our ability to walk, run, and play; to seek out and eat the food that nourishes us; to communicate with friends and family; to earn our living—in essence to survive. The field of motor control is directed at studying the nature of movement, and how movement is controlled. **Motor control** is defined as the ability to regulate or direct the mechanisms essential to movement. It addresses questions such as how does the central nervous system (CNS) organize the many individual muscles and joints into coordinated functional movements? How is sensory information from the environment and the body used to select and control movement? How do our perceptions of ourselves, the tasks we perform, and the environment in which we are moving influence our movement behavior? What is the best way to study movement, and how can movement problems be quantified in patients with motor control problems?

Why Should Therapists Study Motor Control?

Physical and occupational therapists have been referred to as "applied motor control physiologists" (Brooks, 1986). This is because therapists spend a considerable amount of time retraining patients who have motor control problems producing functional movement disorders. Therapeutic intervention is often directed at changing movement or increasing the capacity to move. Therapeutic strategies are designed to improve the quality and quantity of postures and movements essential to function. Thus, understanding motor control and, specifically, the nature and control of movement is critical to clinical practice.

We will begin our study of motor control by discussing important issues related to the nature and control of movement. Next we will explore different theories of motor control, examining their underlying assumptions and clinical implications. Finally we will review how theories of motor control relate **to past** and present clinical practices.

Understanding the Nature of Movement

Movement emerges from the interaction of three factors: the individual, the task, and the environment. Movement is organized around both task and environmental demands. The individual generates movement to meet the demands of the task being performed within a specific environment. In this way, we say that the organization of movement is constrained by factors within the individual, the task, and the environment. The individual's capacity to meet interacting task and environmental demands determines that person's functional capability. Motor control research that focuses only on processes within the individual without taking into account the environment in which that individual moves or the task that he or she is performing will produce an incomplete picture. Thus, in this book our discussion of motor control will focus on the interaction of the individual, the task, and the environment. Figure 1.1 illustrates this concept.

Factors within the Individual that Constrain Movement

Within the individual, movement emerges through the cooperative effort of many brain structures and processes. The term "motor" control in itself is somewhat misleading, since movement arises from the interaction of multiple processes, including those that are related to *perception, cognition*, and *action*.

Movement and Action

Movement is often described within **the context of** accomplishing a particular action. **As a result,** motor

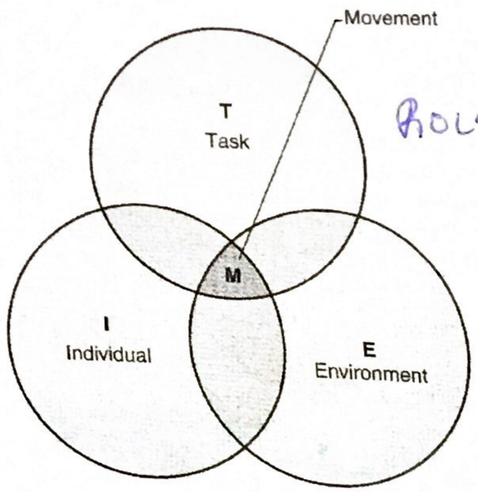

FIGURE 1.1 Movement emerges from interactions between the individual, the task, and the environment.

control is usually studied in relation to specific actions or activities. For example, motor control physiologists might ask: how do people walk, run, talk, smile, reach, or stand still? Researchers typically study movement control within the context of a specific activity, like walking, with the understanding that control processes related to this activity will provide insight into principles for how all of movement is controlled.

Understanding the control of action implies understanding the motor output from the nervous system to the body's effector systems, or muscles. The body is characterized by a high number of muscles and joints, all of which must be controlled during the execution of coordinated, functional movement. This problem of coordinating many muscles and joints has been referred to as the degrees of freedom problem (Bernstein, 1967). It is considered a major issue being studied by motor control researchers and will be discussed in later chapters. So the study of motor control includes the study of the systems that control *action*.

Movement and Perception

Perception is essential to action, just as action is essential to perception. **Perception** is the integration of sensory impressions into psychologically meaningful information. Perception includes both peripheral sensory mechanisms and higher level processing that adds interpretation and meaning to incoming afferent information. Sensory/perceptual systems provide information about the state of the body (for example, the position of the body in space) and features within the environment critical to the regulation of movement. Sensory/perceptual information is clearly integral to the ability to act effectively within an environment (Rosenbaum, 1991). Thus, understanding movement requires the study of systems controlling *perception* and the role of perception in determining our actions.

Movement and Cognition

Since movement is not usually performed in the absence of intent, cognitive processes are essential to motor control. In this book we define cognitive processes broadly to include attention, motivation, and emotional aspects of motor control that underlie the establishment of intent or goals. Motor control includes perception and action systems that are organized to achieve specific goals or intents. Thus, the study of motor control must include the study of *cognitive* processes as they relate to perception and action.

So within the individual, many systems interact in the production of functional movement. While each of these components of motor control—perception, action, and cognition—can be studied in isolation, we believe a true picture of the nature of motor control cannot be achieved without a synthesis of information from all three. This concept is shown in Figure 1.2.

Task Constraints on Movement

In addition to constraints related to the individual, tasks can also impose constraints on the neural organization of movement. In everyday life we perform a tremendous variety of functional tasks requiring movement. The nature of the task being performed in part determines the type of movement needed. Thus, understanding motor control requires an awareness of how tasks regulate neural mechanisms controlling movement.

Recovery of function following CNS damage requires that a patient develop movement patterns that meet the demands of functional tasks in the face of sensory/perceptual, motor, and cognitive impairments. Thus, therapeutic strategies that help the patient (re)learn to perform functional tasks, taking into consideration underlying impairments, are essential to maximizing the recovery of functional independence. But what tasks should be taught, in what order, and at what time? An understanding of task attributes can provide a framework for structuring tasks. Tasks can be sequenced from least to most difficult based on their relationship to a shared attribute.

The concept of grouping tasks is not new to clinicians. Within the clinical environment, tasks are routinely grouped into functional categories. Examples of functional task groupings include bed mobility tasks (e.g., moving from a supine to a sitting position, moving to the edge of the bed and back, as well as

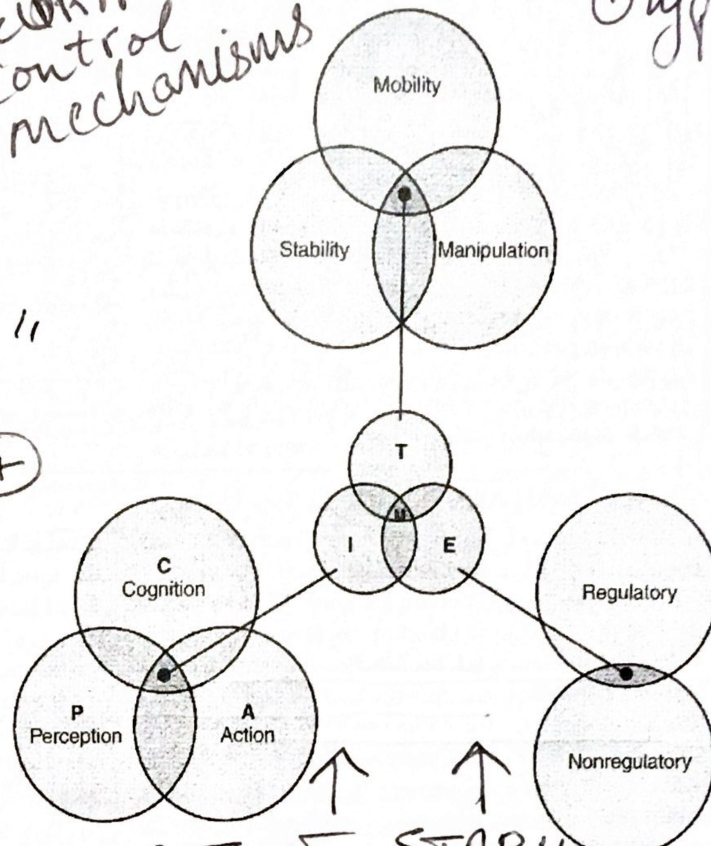

FIGURE 1.2 Factors within the individual, the task, and the environment affect the organization of movement. Factors within the individual include the interaction of *perception, cognition,* and *action (motor) systems.* Environmental constraints on movement are divided into regulatory and nonregulatory factors. Finally, attributes of the task contribute to the organization of functional movement.

changing positions within the bed); transfer tasks (e.g., moving from sitting to standing and back, moving from chair to bed and back, moving onto and off of a toilet), and activities of daily living (ADLs) (e.g., dressing, toileting, grooming, and feeding).

An alternative to classifying tasks functionally is to categorize them according to the critical attributes that regulate neural control mechanisms. For example, movement tasks can be classified as discrete or continuous. Discrete movement tasks, such as kicking a ball or moving from sitting to standing or lying down, have a recognizable beginning and end. In continuous movements such as walking or running, the end point of the task is not an inherent characteristic of the task but is decided arbitrarily by the performer (Schmidt, 1988).

Movement tasks have also been classified according to whether the base of support is still or in motion (Gentile, 1987). So called "stability" tasks such as sitting or standing are performed with a nonmoving base of support, while "mobility" tasks such as walking and running have a moving base of support. In the clinic, tasks involving a nonmoving base of support (e.g., sitting and standing) are often practiced prior to mobility tasks such as walking, on the premise that stability requirements are less demanding in the tasks that have a nonmoving base of support. Support for this type of hierarchical ordering of postural tasks comes from research demonstrating that attentional resources increase as stability demands increase. For example, tasks that have the lowest attentional demand are primarily static postural tasks such as sitting and standing; attentional demands increase in mobility tasks such as walking and obstacle clearance (Chen et al., 1996; LaJoie et al., 1993).

The presence of a manipulation component has also been used to classify tasks (Gentile, 1987). The addition of a manipulation task increases the demand for stability beyond that demanded for the same task lacking the manipulation component. Thus, tasks might be sequenced in accordance with the hierarchy of stability demands (e.g., standing, standing and lifting a light load, standing and lifting a heavy load).

Finally tasks have been classified according to movement variability (Gentile, 1987; Schmidt, 1988). Open movement tasks such as playing soccer or tennis require the performer to adapt their behavior within a constantly changing and often unpredictable environment. In contrast, closed movement tasks are relatively stereotyped, showing little variation, and they are performed in relatively fixed or predictable environments. The training for closed movement tasks is often performed prior to that of open movement tasks, which require adapting movements to changing envi-

LAB *Activity 1–1*

Objective: To develop your own taxonomy of movement tasks.

Procedure: Make a graph like the one illustrated in Table 1.1. Identify two continua you would like to combine. You can begin by using one or more of the continua described above, or alternatively you can create your own continuum based on attributes of movement tasks we have not discussed. In our example we combined the stability–mobility continuum with the open–closed continuum.

Assignment

1. Fill in the boxes with examples of tasks that reflect the demands of each of the continua.
2. Think about ways you could "progress" a patient through your taxonomy. What assumptions do you have about which tasks are easiest and which the hardest? Is there a "right" way to move through your taxonomy? How will you decide what tasks to use and in what order?

ronmental features. Figure 1.2 shows three of the task components we are concerned with in this book.

Understanding important attributes of tasks allows a therapist to develop a taxonomy of tasks that can provide a useful framework for functional examination; it allows a therapist to identify the specific kinds of tasks that are difficult for the patient to accomplish. In addition, the set of tasks can serve as a progression for retraining functional movement in the patient with a neurologic disorder. An example of a taxonomy of tasks using two attributes, stability–mobility and environmental predictability is shown in Table 1.1. However, as discussed above, a taxonomy of tasks can be developed using other attributes as well. Lab Activity 1-1 offers you an opportunity to develop your own Taxonomy of tasks. The answers to this activity may be found at the end of this chapter.

Environmental Constraints on Movement

Tasks are performed in a wide range of environments. Thus, in addition to attributes of the task, movement is also constrained by features within the environment. In order to be functional, the CNS must take into consideration attributes of the environment when planning task-specific movement. As shown in Figure 1.2, attributes of the environment that affect movement have been divided into regulatory and nonregulatory features (Gordon, 1987). Regulatory features specify aspects of the environment that shape the movement itself. Task-specific movements must conform to regulatory features of the environment in order to achieve the goal of the task. Examples of regulatory features of the environment include the size, shape, and weight of a cup to be picked up and the type of surface on which we walk (Gordon, 1997). Nonregulatory features of the environment may affect performance but movement does not have to conform to these features. Examples of nonregulatory features of the environment include background noise and the presence of distractions.

Features of the environment can in some instances enable or support performance, or alternatively, they may disable or hinder performance. For example, walking in a well-lit environment is much easier than walking in low light conditions or in the dark since the ability to detect edges, sizes of small obstacles, and other surface properties is compromised when the light level is low (Patla & Shumway-Cook, 1999).

Thus, understanding features within the environment that both regulate and affect the performance of

TABLE 1.1 A Taxonomy of Tasks Combining the Stability–Mobility and Closed–Open Task Continua

	Stability	Quasimobile	Mobility
Closed predictable environment	Sit/stand/ nonmoving surface	Sit to stand/ Kitchen chair w/arms	Walk/Nonmoving surface
Open unpredictable environment	Stand/rocker board	Sit to stand/ Rocking chair	Walk on uneven or moving surface

movement tasks is essential to planning effective intervention. Preparing patients to perform in a wide variety of environments requires that we understand the features of the environment that will affect movement performance and that we adequately prepare our patients to meet the demands in different types of environments.

We have explored how the nature of movement is determined by the interaction of three factors, the individual, the task, and the environment. Thus, the movement we observe in patients is shaped not just by factors within the individual, such as sensory, motor, and cognitive impairments, but also by attributes of the task being performed and the environment in which the individual is moving. We now turn our attention to examining the control of movement from a number of different theoretical views.

The Control of Movement: Theories of Motor Control

Theories of motor control describe viewpoints regarding how movement is controlled. A **theory of motor control** is a group of abstract ideas about the control of movement. A **theory** is a set of interconnected statements that describe unobservable structures or processes and relate them to each other and to observable events. Jules Henri Poincare (1908) said "Science is built up of facts, as a house is built of stone; but an accumulation of facts is no more a science than a heap of stones is a house." A theory gives meaning to facts, just as a blueprint provides the structure that transforms stones into a house (Miller, 1988).

However, just as the same stones can be used to make different houses, the same facts are given different meaning and interpretation by different theories of motor control. Different theories of motor control reflect philosophically varied views about how the brain controls movement. These theories often reflect differences in opinion about the relative importance of various neural components of movement. For example, some theories stress peripheral influences, others may stress central influences, while still others may stress the role of information from the environment in controlling behavior. Thus, motor control theories are more than just an approach to explaining action. Often they stress different aspects of the organization of the underlying neurophysiology and neuroanatomy of that action. Some theories of motor control look at the brain as a *black box* and simply study the rules by which this black box interacts with changing environments as a variety of tasks are performed. As you will see, there is no one theory of motor control that everyone accepts.

Value of Theory to Practice

Do theories really influence what therapists do with their patients? Yes! Rehabilitation practices reflect the theories, or basic ideas, we have about the cause and nature of function and dysfunction (Shepard, 1991). In general, then, the actions of therapists are based on assumptions that are derived from theories. The specific practices related to examination and intervention used with the patient who has motor dyscontrol are determined by underlying assumptions about the nature and cause of movement. Thus, motor control theory is part of the theoretical basis for clinical practice. This will be discussed in more detail in the last section of this chapter.

What are the advantages and disadvantages of using theories in clinical practice? Theories provide:

- a framework for interpreting behavior;
- a guide for clinical action;
- new ideas;
- working hypotheses for examination and intervention.

Framework for Interpreting Behavior

Theory can help therapists to interpret the behavior or actions of patients with whom they work. Theory allows the therapist to go beyond the behavior of one patient, and broaden the application to a much larger number of cases (Shepard, 1991).

Theories can be more or less helpful depending on their ability to predict or explain the behavior of an individual patient. When a theory and its associated assumptions does not provide an accurate interpretation of a patient's behavior, it loses its usefulness to the therapist. Thus, theories can potentially limit a therapist's ability to observe and interpret movement problems in patients.

Guide for Clinical Action

Theories provide therapists with a possible guide for action (Miller, 1983; Shepard, 1991). Clinical interventions designed to improve motor control in the patient with neurologic dysfunction are based on an understanding of the nature and cause of normal movement, as well as an understanding of the basis for abnormal movement. Therapeutic strategies aimed at retraining motor control reflect this basic understanding.

New Ideas: Dynamic and Evolving

Theories are dynamic, changing to reflect greater knowledge relating to the theory. How does this affect clinical practices related to retraining the patient with motor dyscontrol? Changing and expanding theories of