Following completion of this chapter, the reader will be able to: 1.This problem of choosing among equivalent solutions and then coordinating the many muscles and joints involved in a movement 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 dis- cussed 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 essen- tial to perception. Perception is the integration of sensory impressions into psychologically meaningful information. Perception includes both peripheral sen- sory mechanisms and higher-level processing that adds interpretation and meaning to incoming afferent infor- mation. Sensory/perceptual systems provide informa- tion about the state of the body (e.g., the position of different body parts 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 con- trol. In this book, we define cognitive processes broadly to include attention, planning, problem solving, moti- vation, 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 cogni- tive processes as they relate to perception and action. So within the individual, many systems inter- act 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. Mobility CHAPTER 1 Motor Control: Issues and Theories 5 Task Constraints on Movement In addition to constraints related to the individual, tasks can also impose constraints on the neural orga- nization 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 impair- ments. Thus, therapeutic strategies that help the patient (re)learn to perform functional tasks, taking into consideration underlying impairments, are essen- tial to maximizing the recovery of functional indepen- dence. 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 clini- cians. Within the clinical environment, tasks are rou- tinely grouped into functional categories. Examples of Stability Manipulation T M IE C Cognition PA Regulatory Nonregulatory FIGURE 1.2 Perception Action Factors within the individual, the task, and the environment affect the organiza- tion of movement. Factors within the individual include the interaction of perception, cognition, and action (motor) systems. Environmental con- straints on movement are divided into regulatory and nonregulatory factors. Finally, attributes of the task contribute to the organization of func- tional movement. 6 PART I Theoretical Framework functional task groupings include bed mobility tasks (e.g., moving from a supine to a sitting position, mov- ing to the edge of the bed and back, as well as 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, toilet- ing, 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 continu- ous. 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 move- ments 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, 1988b). Movement tasks have also been classified accord- ing to whether the base of support is still or in motion (Gentile, 1987). 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 those with a nonmoving base of support (often called "static postural control 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).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 3 4 PART I Theoretical Framework 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 con- trol and, specifically, the nature and control of move- ment is critical to clinical practice. We will begin our study of motor control by dis- cussing 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 fac- tors: the individual, the task, and the environment. Movement is organized around both task and envi- ronmental demands. The individual generates move- ment 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 fac- tors within the individual, the task, and the environ- ment. 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 per- forming will produce an incomplete picture. Thus, in this book our discussion of motor control will focus on the interactions 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 some- what misleading, since movement arises from the interaction of multiple processes, including those that are related to perception, cognition, and action.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, 2002). However, just as the same stones can be used to make different houses, the same facts are given differ- ent 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 exam- ple, 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 CHAPTER 1 Motor Control: Issues and Theories 7 LAB ACTIVITY 1-1 Objective: To develop your own taxonomy of move- ment 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. 1. 2. Assignment Fill in the boxes with examples of tasks that reflect the demands of each of the continua. Think about ways you could "progress" a patient through your taxonomy.In order to be functional, the CNS must take into consideration attributes of the environment when TABLE 1.1 A Taxonomy of Tasks Combining the Stability-Mobility and Closed-Open Task Continua Stability Quasimobile Mobility Walk/nonmoving surface Walk on uneven or moving surface Sit/stand/ nonmoving surface Sit to stand/kitchen chair w/arms Stand/rocker board Sit to stand/Rocking chair Closed predictable environment Open unpredictable environment planning task-specific movements.Compare and contrast the following theories of motor control: reflex, hierarchical, motor programming, systems, dynamic systems, and ecological, including the individu- als associated with each theory, critical elements used to explain the control of normal movement, limitations, and clinical applications.Compare and contrast the neurofacilitation approaches to the task-oriented approach with respect to assump- tions underlying normal and abnormal movement con- trol, recovery of function, and clinical practices related to assessment and treatment.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.In contrast, closed movement tasks are rela- tively stereotyped, showing little variation, and they are performed in relatively fixed or predictable envi- ronments.It addresses questions such as how does the central nervous system (CNS) organize the many indi- vidual muscles and joints into coordinated functional movements?The training for closed movement tasks is often performed prior to that for open movement tasks, which require adapting movements to chang- ing environmental features.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 spe- cific kinds of tasks that are difficult for the patient to accomplish.Thus, understanding features within the environ- ment that both regulate and affect the performance of movement tasks is essential to planning effective inter- vention.Thus, tasks might be sequenced in accordance with the hierarchy of stability demands (e.g., standing, standing and lift- ing a light load, standing and lifting a heavy load).Open movement tasks such as playing soccer or ten- nis require performers to adapt their behavior within a constantly changing and often unpredictable envi- ronment.Preparing patients to perform in a wide vari- ety of environments requires that we understand the features of the environment that will affect move- ment performance and that we adequately prepare our patients to meet the demands in different types of environments.A theory is a set of intercon- nected statements that describe unobservable struc- tures or processes and relate them to each other and to observable events.As a result, motor control is usually studied in relation to specific actions Movement T Task M IE Individual Environment FIGURE 1.1 Movement emerges from interactions between the individual, the task, and the environment.Researchers typically study movement control within the context of a specific activity, like walking, with the understanding that control pro- cesses related to this activity will provide insight into principles for how all of movement is controlled.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.Thus, in addition to attributes of the task, movement is also constrained by features within the environ- ment.The addition of a manipulation task increases the demand for stability beyond that demanded for the same task lacking the manipulation component.or activities.2.3.4.5.6.