Introduction to Motor Skills and Abilities

UNIT **ONE**

CHAPTER 1

The Classification of Motor Skills

Concept: Classifying skills into general categories helps us to understand the demands those skills place on the performer/learner.

After completing this chapter, you will be able to

- Define and distinguish the terms *actions, movements, and neuromotor processes,* and give examples of each
- Describe the one common motor skill characteristic for each of three motor skill classification systems, the two categories of skills in each system, and examples of motor skills in each category of each system
- Describe the two dimensions used to classify skills in the Gentile taxonomy of motor skills and the classification characteristic included within each dimension
- Discuss ways to use the Gentile taxonomy of motor skills in physical rehabilitation or physical education and sport contexts

APPLICATION

We are born to move, but *learn* to move skillfully. When people run, walk with an artificial limb, throw a baseball, hit a tennis ball, play the piano, dance, or operate a wood lathe, they are engaged in the performance of *motor skills.* Every motor skill in our repertoire is the product of a long and often arduous process of acquisition. We delight in watching young children acquire the basic skills of sitting, standing, crawling, walking, reaching, and grasping that permit ever-increasing control over the environment. We're enthralled by the elite athlete and the professional musician and dancer who perform feats of movement control that defy the imagination. We're equally impressed by the surgeon and bomb disposal technician who can maintain a steady hand and dexterous coordination under the most intense pressure. Sometimes we even marvel at our own ability to find new and better ways to perform activities of daily living, and when we stop to think, we're often surprised by just how efficiently we're able to perform tasks that once seemed impossible to master. On the other hand, we lament the loss of coordination and control that follow injury, disease, and disability. Such losses help us to realize just how important skill is to our sense of control over the world around us.

These simple observations highlight how dependent we are on our capacity to learn and perform motor skills. Skill, when viewed broadly as a capacity to control our bodies and the world around us, is a biological necessity. The degree of skill we possess is expressed through our use of movements to deal with the myriad problems we encounter on a daily basis. Without some degree of skill to escape from predators, to find food, to find or build shelter, and to procreate, animals would quickly perish. Humans are unrivaled in their capacity for acquiring skill, as witnessed by the incredible feats of the professional athlete, dancer, and musician, but also the young child who can ride a bicycle or the patient relearning to walk after an accident. We are capable of a degree

of resourcefulness and adaptability that far exceeds the capabilities of other animals. These traits have enabled humans to profoundly change the environment in which we live.

This book examines our fascinating capacity to control and acquire motor skills. The book focuses on helping you understand how people perform and learn, and how you can help people perform and learn, motor skills. It highlights a wide range of factors that are known to influence how motor skills are performed, how quickly they are learned, how well they are learned, and how well they are retained over long periods of time. In addition to the traditional factors that have been emphasized in the field, such as the way in which instruction and augmented feedback are provided, and the amount and type of practice given to the learner, the book also covers a range of other variables that have become prominent in the last few years, including the learner's motivation and self-confidence, as well as his or her control over what happens during practice.

As you engage in this study, you will find it useful to draw general conclusions to apply what you learn to a broad range of motor skills, rather than making many specific statements about many skills. The starting point for doing this is the classification of motor skills into broad categories that emphasize the similarities rather than the differences among skills.

For example, the skill of maneuvering a wheelchair through a crowded hallway and that of hitting a pitched baseball seem quite distinct. However, both skills have one characteristic in common that influences how they are learned and performed. People must perform both skills in an "open" environment. This means that to perform the skill successfully, a person must adapt certain aspects of his or her movements to changing characteristics in the performance environment. For the wheelchair skill, this means that the person must be able to maneuver successfully through a crowded hallway in which people are walking in various directions and speeds. For hitting a baseball, the changing environment involves the ball itself as it moves toward the person. For both of these skills, performance success requires the performer to adapt quickly and accurately to changing conditions. When we view them in terms of this common characteristic, we can see that these two seemingly diverse skills are related.

Application Problem to Solve Identify five motor skills that you can perform, either those that you do routinely or those you do for recreation, fitness, or sports, and classify each into one of the categories in each of the motor skill classification systems you will study in this chapter; indicate why each skill would be classified this way.

DISCUSSION

To begin our study of motor learning and motor control, we will describe how researchers and professionals use these two terms to delineate areas of research and professional application. Both areas of study share a focus on the performance of **motor skills**, which we define as *activities or tasks that require voluntary control over movements of the joints and body segments to achieve a goal.* Researchers study motor skills in many ways. Two are especially relevant to discussions in this book: *motor learning* and *motor control;* a third (known as *motor development*) is commonly related to these two areas of study, but it is not a focus of this book.

The study of **motor learning** emphasizes the acquisition of motor skills, the performance enhancement of learned or highly experienced motor skills, or the

motor skills activities or tasks that require voluntary control over movements of the joints and body segments to achieve a goal.

motor learning the acquisition of motor skills, the performance enhancement of learned or highly experienced motor skills, or the reacquisition of skills that are difficult to perform or cannot be performed because of injury, disease, and the like. Of interest are the behavioral and/or neurological changes that occur as a person learns a motor skill and the variables that influence those changes.

reacquisition of skills that are difficult to perform or cannot be performed because of injury, disease, and the like. Of interest are the *behavioral and/or neurological changes* that occur as a person learns a motor skill and the variables that influence those changes. An example of a question that a motor learning researcher would seek to answer is, Does the type of feedback an instructor gives to a person learning (or relearning) a motor skill influence how quickly and how well the skill will be learned?

In the study of **motor control**, the question of interest is how our neuromuscular system functions to activate and coordinate the muscles and limbs involved in the performance of a motor skill. Researchers may investigate this question while a person is learning a new skill or performing a well-learned or highly experienced skill. An example of a question that a motor control researcher would seek to answer is, Are the movements of the arms and legs coordinated in similar or distinct ways when a person walks or runs at various speeds?

A related area is the study of **motor development**, which concerns issues related to either or both motor learning and control, but is primarily interested in the relationship between these issues and human development from infancy through old age. Those who study motor development place much greater emphasis on how processes such as growth and maturation influence changes in motor behavior. An example of a question that a motor development researcher would seek to answer is, How do the elderly compare with young adults in terms of how quickly they can decide what they need to do to avoid a collision with another person while walking in a crowded hallway?

In their investigations researchers in these areas of study assume that motor skill performance is influenced by the (1) motor skill, (2) performance environment, and (3) physical and psychological characteristics of the person performing the skill (see figure 1.1). Researchers use this assumption to investigate questions about learning, control, and development from *behavioral and/or neurophysiological levels of study.*[1] At the *behavioral level*, researchers investigate questions by observing and analyzing human behavior as it is affected by characteristics of any or a combination of these influences. Researchers may observe people performing motor skills in laboratory, clinical, or natural settings. To answer the research questions described in the preceding paragraphs, researchers could engage in either the behavioral or neurophysiological level of study. As you will read in chapter 2, researchers, as well as practitioners, use a variety of performance measures to quantitatively or qualitatively evaluate a person's performance of a skill. Researchers who study motor learning, control, and development will often use their observations of behavior (i.e., motor skill performance) to infer neurophysiological mechanisms that are responsible for the behavior. For investigations at a neurophysiological level of study, researchers directly or indirectly observe central and peripheral nervous system components as they interact with muscles involved in performing a motor skill.

The focus of this textbook is on motor learning and control without reference to developmental concerns, although developmental relevance is considered in several instances. Also, while you will be introduced to some neurophysiological aspects of motor learning and control, a behavioral level of study dominates the textbook's approach. In addition, you will see evidence for and examples of how the three influences on motor skill performance, as described in the previous paragraph, form the basis for our understanding of the learning and control of motor skills.

To establish a foundation on which to build your study of motor learning and control, it is essential to have a good understanding of motor skills, which are the focus of both areas of study and are an important component of the three general influences on motor skill performance depicted in figure 1.1. To help you develop your understanding of motor skills, the remainder of this chapter will address two important points. First, we will consider what distinguishes motor skills from other skills and define some other commonly used terms related to the term *motor skill*. Second, we will discuss four different approaches to classifying motor skills into categories that identify common characteristics of various skills.

[1]You will sometimes see the term *level of analysis* rather than *level of study*. We will consider these phrases to be synonymous and interchangeable.

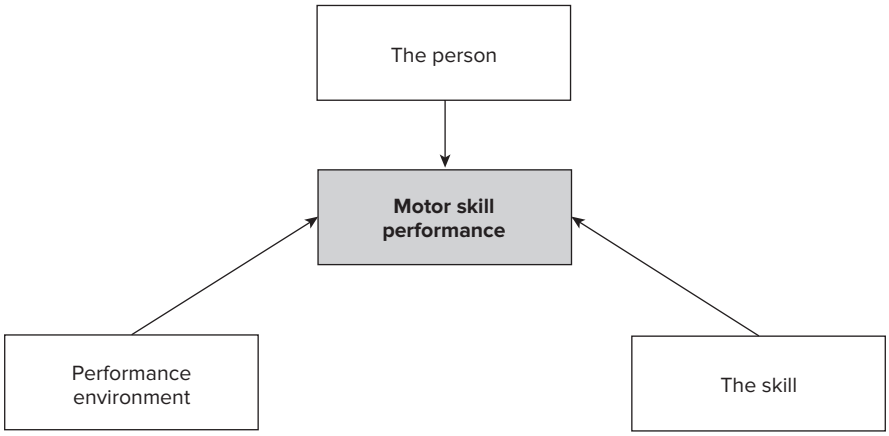


FIGURE 1.1 Three influences on how we perform a motor skill. To understand the learning and control of motor skills, it is important to recognize that the performance of any motor skill is influenced by characteristics of the skill itself, the person performing the skill, and the environment in which the skill is performed.

The benefit of classifying skills is that it can provide you with an appropriate basis for establishing generalizations, or principles, about how we perform and learn motor skills. These generalizations will enable you in turn to understand theories about skill performance and learning. Additionally, they help establish guidelines for instructors, coaches, and therapists who must develop effective strategies that will enhance motor skill learning and rehabilitation.

SKILLS, ACTIONS, MOVEMENTS, AND NEUROMOTOR PROCESSES

Several terms in the motor learning and control literature are related to the term *motor skills.* These are *skills, actions, movements,* and *neuromotor processes.* Each term is used in a specific way you should understand and use correctly.

What Is Skill?

Before differentiating the terms *skills, actions, movements,* and *neuromotor processes* from each other, it is important to differentiate the two ways in which the term **skill** is used. First, *skill* is a commonly used word that in this text denotes an activity or *task that has a specific purpose or goal to achieve.* We will elaborate on this usage of the term in the next section of the chapter. Second, the term *skill* is used to denote some degree of competence or capacity to perform a task. For example, we might refer to someone as a skilled *golfer*, or a *skilled* neurosurgeon, or a *skilled* pianist. When the term is used in this way, we place a value judgment on the quality of someone's performance. We classify their performance somewhere along a continuum that varies from unskilled to highly skilled.

motor control how our neuromuscular system functions to activate and coordinate the muscles and limbs involved in the performance of a motor skill. Researchers may investigate this question while a person is learning a new skill or performing a well-learned or highly experienced skill.

motor development human development from infancy through old age with specific interest in issues related to either motor learning or motor control.

skill (a) an activity or task that has a specific purpose or goal to achieve; (b) an indicator of quality of performance, often referred to as "skill level."

Although the second usage of the term *skill* has been defined in many different ways, three criteria are typically analyzed to determine a person's skill level, which refers to where along the skill continuum a person's performance would be classified. The first criterion is the extent to which the person can consistently achieve the goal of the task, with highly skilled individuals showing a greater capacity to consistently achieve the goal of the task than less-skilled participants. The second criterion is the extent to which the person can achieve the task under a range of different conditions. Highly skilled individuals can achieve success under a much wider range of conditions and circumstances than their less-skilled counterparts. For example, the skilled quarterback in American football can complete passes to many different receivers running many different routes at many different speeds. He can complete the passes on different fields, in different weather conditions, when fatigued or injured, and when faced with many different types of pressure from his opponents or from the consequences associated with not performing up to expectation. The highly skilled individual typically has a much richer repertoire of movements to draw upon when faced with the myriad of situations he or she is likely to encounter.

The final criterion used to assess individuals' level of skill is their *degree of efficiency*. Skilled individuals are much more efficient than less-skilled individuals. Their efficiency can be seen in the strategies they use to solve problems, in the way they pick up and process information and deploy their attention, and in the amount of muscular effort they use to accomplish a task. Skilled individuals often make difficult tasks look effortless and they can appear to have all the time in the world, even in tasks that impose severe time limitations on the performer.

As students of motor learning and control, understanding the characteristics of skill and how we become skillful is a central concern. One might say that it is *the* central concern. Throughout the book you will see many references to the characteristics of skill and we will pay particular attention to the process of becoming skillful in chapter 12 and to the variety of ways in which skill acquisition can be facilitated in chapters 13 to 19.

Skills and Actions

As noted above, the term *skill* is also used to denote an activity or *task that has a specific purpose or goal to achieve.* For example, we commonly say that "multiplication is a fundamental skill of mathematics" or "playing the piano is a skill that takes practice." Of these two examples, the skill of piano playing includes a *motor skill* because it requires voluntary limb movement to achieve its goal, which is to produce music. Looked at this way, the skill of piano playing involves the goal of striking the correct keys in the proper sequence and at the appropriate time, and it requires control over posture and finger and hand movement to achieve that goal. *The purpose of a motor skill is to cause some type of change in the environment or in the person's relation to the environment.* The purpose describes the specific problem for the mover to solve. Sometimes, many different movements are required to solve the problem.

It is important to point out that multiplication, which was used in the previous paragraph as an example of a skill, is commonly referred to as a *cognitive skill.* This means that the skill requires cognitive (i.e., mental) activity, which includes decision making, problem solving, remembering, and the like. It differs from a motor skill in that it does *not* require voluntary limb movement to achieve its goal. Although a person could use a motor skill such as handwriting or pressing the keys on a calculator or computer to carry out the multiplication task, movement activities such as these are not required. In contrast, the skill of piano playing involves cognitive activities, but requires hand and finger movements.

In the motor learning and control research literature, a term that has become increasingly common is **actions**. For our purposes, we will use this term synonymously and interchangeably with the term *motor skills.*

Characteristics of skills and actions. Several characteristics are common to motor skills. First, there is *a goal to achieve.* This means that motor skills have a purpose. Sometimes you will see the term *action goal* used to refer to the goal of a motor skill. Second, the types of motor skills of interest in

this text are *performed voluntarily;* in other words, we are not considering reflexes as skills. Although an eye blink may have a purpose and involve movement, it occurs involuntarily and is therefore not a skill in the sense in which we are using the term. Third, a motor skill *requires movement of joints and body segments* to accomplish the goal of the task. This characteristic is especially important because it is the basis for distinguishing motor skills from other types of human skills.

One additional characteristic identifies the types of motor skills of interest in this text: They *need to be learned, or relearned,* in order for a person to achieve the goal of the skill. In our example, piano playing clearly must be learned. But consider a skill like walking. Although walking may seem to be something that humans do "naturally," it must be learned by the infant who is attempting to move in his or her environment by this new and exciting means of locomotion. And walking is a skill some people may need to relearn. Examples are people who have had strokes, or hip or knee joint replacements, as well as people who must learn to walk with artificial legs.

Movements

In the motor learning and control research literature, the term **movements** indicates *specific patterns of motion among joints and body segments.* This means that movements are the component parts of motor skills. In other words, movements are the means by which action goals are accomplished or problems are solved. For example, locomotion is an action that has the goal of transporting the body from one location to another. The action goal could be accomplished using many different movement patterns, including walking, running, hopping, skipping, galloping, and so on. Each movement pattern is defined by a particular pattern of relative motions among joints and body segments, though each would be an effective way of solving the problem of transporting the body from one location to another. In addition, assuming a person chooses walking as the means to locomote from one place to another, a variety of head, body, and limb motions can occur that enable a person to walk successfully. For example, our arms and legs move in different and distinct ways when we walk on a concrete sidewalk and when we walk on an icy sidewalk—or on a sandy beach. However, although certain motions may differ, the motor skill we perform in each of these different situations is walking.

The important point here is that a variety of movements can accomplish the same action goal. This highlights the *many-to-one* relationship between movements and actions. For example, if a person's goal when walking up a set of stairs is to get to the top of the stairs, he or she can achieve this goal by using a variety of different movements. A person can take one step at a time very slowly, or take each step very quickly, or take two steps at a time, and so on. In each situation, the action goal is the same but the movements the person uses to achieve the goal are different. Similarly, if a person's action goal is to throw a ball so that it hits a target—which might be a person who would catch it—the goal can be achieved with several different movement characteristics. For example, the person could throw the ball overhand, sidearm, or underhand. All would achieve the action goal but would use very different movement characteristics.

The relationship between movements and actions is also *one-to-many,* meaning that one movement pattern could be used to achieve many different action goals. For example, walking or swimming could be used to move the body from one location to another, but they could also be used to maintain the body in one location if walking on a treadmill or swimming against a current. So, when the context changes, the same movement can be used to accomplish completely different purposes. Movie aficionados may remember the classic scene from the movie *The Karate Kid* in which Mr. Miyagi asks Daniel to wash and then polish his car using wax-on-wax-off movements with his hands. This is another example of the one-to-many relationship between movements and actions. In one context,

actions see *motor skills.*

movements specific patterns of motion among joints and body segments used to accomplish action goals.

A CLOSER LOOK

Examples of Skills/Actions, Goals, and Movements

The following examples illustrate how a skill or action can have various goals, which would require movements that differ according to the action goal. For each of the goals within a skill/action, consider different movements that could be used to allow a person to achieve the goal while carrying out the same skill/action.

Skills/Actions	Goal
1. Locomotion	a. To move from the front of an empty room to the back of the room
	b. To move from one store to another store in a crowded mall
	c. To move on a treadmill
2. Throwing	a. To accurately throw a small round ball at a target on the wall
	b. To throw a small round ball as far as possible
	c. To throw a beach ball to a friend to catch
3. Reaching and grasping an object	a. To pick up a full coffee mug from a table and drink from it
	b. To pick up a bowl of soup to move it from one location on a table to another location on the table
	c. To pick up a can of juice and shake it
4. Sit to stand	a. To stand up from sitting in a wheelchair
	b. To stand up from sitting on a seat in a moving bus
	c. To stand up from sitting on the side of a bed

the wax-on-wax-off movements could be used to polish a car, and in another context, they could be used to protect the person against an attacker. The take-home message here is that the purpose any movement fulfills is entirely determined by the context in which the movement occurs.

Neuromotor Processes

Neuromotor processes represent the third level on which motor behavior is often analyzed. In contrast to actions and movements, which can be clearly seen by the naked eye, neuromotor processes are the mechanisms within the central and peripheral nervous system as well as the muscular system that underlie the control of movements and actions. These processes cannot be observed directly with the naked eye, though they can be measured quite precisely using a number of different techniques that are introduced in chapter 2. The relationship between neuromotor processes and movements is also many-to-one and one-to-many. For example, many combinations of muscle fibers could be used to lift the arm above the head. This capacity of the neuromuscular system enables the arm motion to be reproduced consistently even though some muscle fibers might not contribute to the movement because they become fatigued or injured. On the other hand, highlighting the one-to-many relationship between neuromotor processes and movements, a muscle might be activated in an identical way from one moment to the next but lead to a different movement if the context changes. The function of the pectoralis major muscle provides a good example here. When the arm is held out to the side below the horizontal, activation of the pectoralis major muscle brings the arm back to the side (it adducts the arm). However, when the arm is above the horizontal, the same activation of the pectoralis muscle will bring the arm closer to the head (it abducts it). The resulting movement is completely dependent on the initial position of the arm even though the muscle is activated in exactly the same way. Similarly, the same activation of the biceps brachii might flex the elbow in one situation but lead to no movement or elbow extension when a weight is held in the hand. Again, the resulting

movement is dependent on the context in which the neuromotor processes are activated.

Why Distinguish Actions, Movements, and Neuromotor Processes

There are three reasons why it is important and useful to distinguish these three levels of study. First, actions (skills), movements, and neuromotor processes represent the order in which motor control and learning are prioritized, thus highlighting what should be emphasized at different stages of learning. The learner's first priority is to understand the action goal and to explore strategies to achieve it. The second priority is to discover the best movement to accomplish the action goal given the unique characteristics of the learner and environmental context. The third priority is to refine the movement and make it more efficient by modifying neuromotor processes. Too often, practitioners ignore this hierarchy of priorities and introduce skills as movement patterns to be learned rather than as action goals to accomplish. Learners are less actively involved in the learning process when this happens and are less likely to develop the problem-solving skills needed to become independent learners.

The second reason to distinguish the different levels of study is that not all people can accomplish the action goal using the same movement pattern or perform the same movement using the same neuromotor processes. Learners must discover a movement pattern that is effective and efficient given their unique characteristics, including body size, injuries, disabilities, abilities, fitness, prior learning, and psychological attributes among many others. The effective teacher or therapist acknowledges this diversity and helps the learner to discover the most suitable way to perform a skill. Even world-class athletes come up with unique ways to accomplish the skills within their sports. For example, Hall of Fame basketball player, Rick Barry, made 90% of his free throws during his 14-year professional career by tossing the ball "granny style" with two hands. Similarly, Dick Fosbury revolutionized the sport of high jumping when he introduced his "Fosbury Flop" at the 1968 Mexico City Olympics.

The third reason to distinguish the different levels of study is that different measures are used to evaluate what's happening at each level of study. Given the order in which the different levels are prioritized during motor control and learning, this implies that different measures might be taken to assess learning at different stages of practice. In addition, researchers are often interested in asking questions about motor control and learning that require different levels of study. These questions can only be answered by selecting measures that are appropriate for that level of study. In chapter 2 you will see examples of the many different types of measures used to characterize actions, movements, and neuromotor processes.

ONE-DIMENSION CLASSIFICATION SYSTEMS

We can classify motor skills by determining which skill characteristics are similar to those of other skills. The most prevalent approach has been to categorize skills according to one common characteristic. This common characteristic is divided into two categories, which represent extreme ends of a continuum rather than dichotomous categories (as illustrated in figure 1.2). This continuum approach allows a skill to be classified in terms of which category the skill characteristic is more like, rather than requiring that the characteristic fit one category exclusively.

Consider an analogy. The concepts "hot" and "cold" represent two categories of temperatures. Although we typically consider them as distinct categories, we also can view hot and cold as words describing opposite ends of a temperature continuum, because there are degrees of hot or cold that do not fit exclusively into one or the other category. By considering hot and cold as anchor points on a continuum, we can maintain the category distinctions, while at the same time we can more accurately classify various temperature levels that do not fit into only one or the other category.

We will consider three motor skill classification systems that use the one-dimension approach to categorize skills. These classification systems are summarized in figure 1.2.

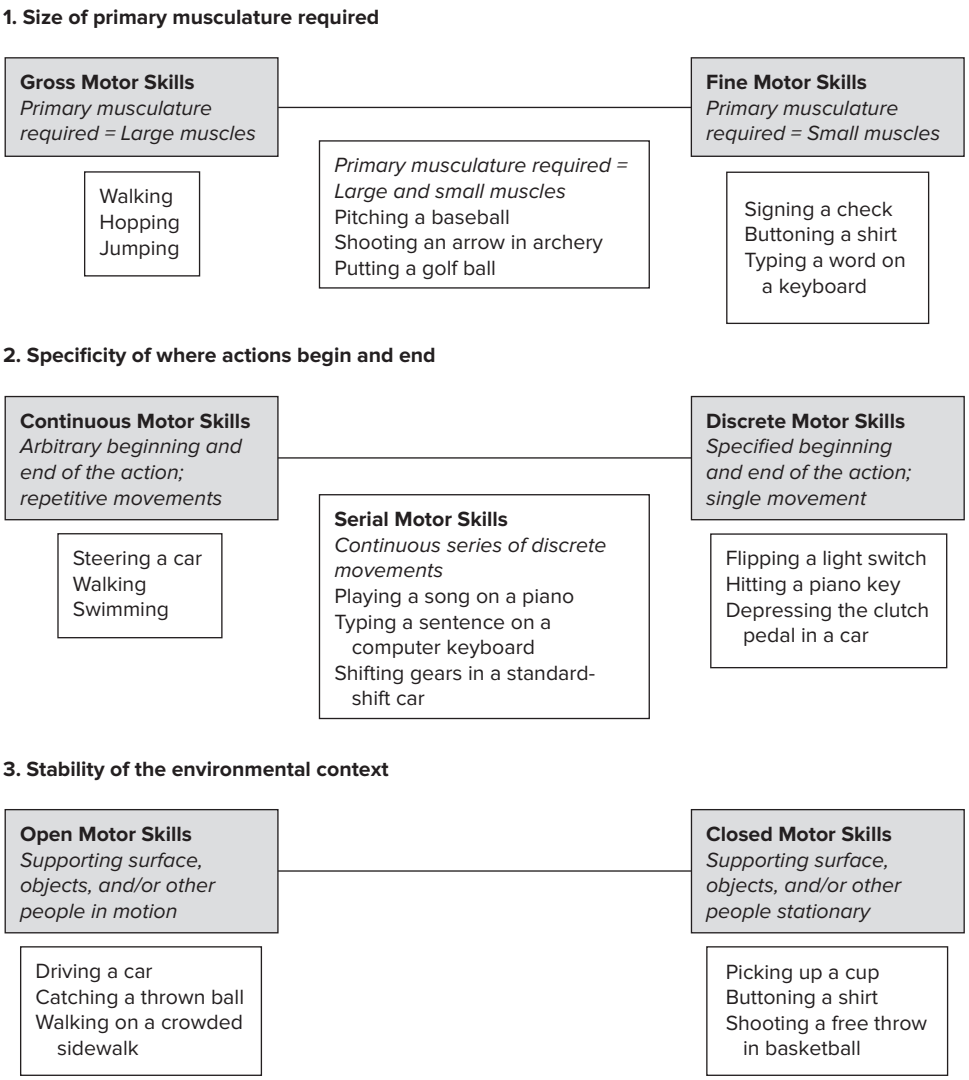


FIGURE 1.2 Three one-dimension motor skill classification systems. Each is illustrated as a continuum of the two skill classification categories for the dimension on which the system is based. Also shown are some examples of motor skills for each of the two categories. For the first two classification systems, skills are also shown that best fit on the continuum between the two categories.

Size of Primary Musculature Required

One characteristic that distinguishes categories of motor skills is the size of the primary muscle groups required to perform the skill. Skills like walking and hopping do not require as prime movers muscle groups of the same size as those used for skills like piano playing and eating with chopsticks. By distinguishing skills based on the size of the muscle groups required to perform the skills, researchers have established a motor skill classification system in which there are two categories, known as gross and fine motor skills.

To achieve the goals of **gross motor skills**, people need to use *large musculature.* These skills

need less movement precision than fine motor skills do. We commonly see skills such as the so-called *fundamental motor skills*—walking, jumping, throwing, leaping, etc.—classified as gross motor skills.

Fine motor skills fall at the other end of this classification continuum. Fine motor skills require greater control of the *small muscles,* especially those involved in hand-eye coordination, and require a high degree of precision in hand and finger movement. Handwriting, typing, drawing, sewing, and fastening a button are examples of motor skills that are on the fine motor skill end of the continuum in the muscle size classification system. Note that although large muscles may be involved in performing a fine motor skill, the small muscles are the primary muscles involved in achieving the goal of the skill.

We can see the benefit of using a continuum for this skill classification system when we consider motor skills that involve both large and small muscles as the primary muscles required to achieve the action goal. We cannot categorize these types of skills as gross or fine, but as shown in figure 1.2, these skills would be located along the continuum between these two categories. For example, to shoot an arrow at a target in archery requires the precision in hand and finger control of fine motor skills and the involvement of the larger arm and shoulder muscles that characterizes gross motor skills. Although many fine motor skills may also involve the arm and shoulder muscles (e.g., the three examples in figure 1.2), these do not constitute the primary musculature required. A person could achieve the action goals of these skills with the arms restricted in such a way that he or she would have to use hand and finger movements only.

The use of the gross/fine distinction for motor skills is popular in a number of settings. In education settings, special education and adapted physical education curricula and tests commonly distinguish skills on this basis. We also find this classification system in rehabilitation environments. Physical therapists typically work with patients who need to rehabilitate gross motor skills such as walking, whereas occupational therapists more commonly deal with patients who need to learn fine motor skills. People who are involved in early childhood development also find the gross/fine categorization useful and have developed tests of motor development along the gross/fine dimension. Also, industrial and military aptitude tests commonly use the gross and fine motor skill distinction.

The Specificity of Where Movements of a Skill Begin and End

Another way to classify motor skills is on the basis of how specific the beginning and end locations are for the movements of a skill. If a skill requires a specified beginning and end location, we categorize the skill as a **discrete motor skill**. Discrete skills include flipping a light switch, depressing the clutch of an automobile, and hitting a piano key. Each of these skills involves a specified place in the environment to begin and end movement. Also, as the examples suggest, discrete skills typically are simple, one-movement skills.

At the opposite end of this classification system continuum fall **continuous motor skills**, which are skills with arbitrary beginning and end locations. In addition, continuous skills usually contain repetitive movements. We can classify skills such as steering an automobile, tracking a moving cursor

gross motor skill a motor skill that requires the use of large musculature to achieve the goal of the skill.

fine motor skill a motor skill that requires control of small muscles to achieve the goal of the skill; typically involves eye-hand coordination and requires a high degree of precision of hand and finger movement.

discrete motor skill a motor skill with clearly defined movement beginning and end points, usually requiring a simple movement.

continuous motor skill a motor skill with arbitrary movement beginning and end points. These skills usually involve repetitive movements.

on a computer monitor with a joystick, swimming, and walking as continuous skills. Although some continuous skills, such as walking and swimming, may have distinct movement beginning locations, the end location is arbitrary, and the movements are repetitive.

Sometimes a skill requires a series or sequence of discrete movements, such as shifting gears in a standard shift car, or playing a piece on a piano. We refer to these types of skills as **serial motor skills**, although sometimes they are called *sequential motor skills.* As figure 1.2 indicates, these skills include the repetitive movements characteristic of continuous skills and the specified beginning and end points of each movement that characterize discrete skills. As a result, it is best to locate serial motor skills on the continuum between the continuous and discrete skills categories. The gear shifting example is a good illustration. To shift gears in a car, the driver must perform a sequence of discrete movements. To shift from second to third gear, the driver performs a sequence of seven discrete movements. First he or she lifts a foot off the accelerator, then depresses the clutch with the other foot, then moves the gear shift forward to neutral, then to the right, then forward again to third gear, then releases the clutch, and finally depresses the accelerator.

This classification system has been especially prevalent in the motor control research literature. Researchers have found, for example, that certain phenomena about how we control movement are applicable to discrete skills but not to continuous skills and vice versa. The distinction between discrete and continuous skills is especially popular in the research literature of those who view motor skill performance from the perspectives of human engineering and human factors.

The Stability of the Environmental Context

One classification system has its roots in industrial as well as educational and rehabilitation settings. Researchers base this system on the stability of the environmental context in which the skill is performed (see Gentile, 2000). For this classification system, the term **environmental context** refers to the specific physical location where a skill is performed. It consists of *three features:* (1) the *supporting surface* on which the person performs the skill, (2) *objects involved* in performing the skill, and (3) *other people or animals* involved in the performance situation. For example, if a person is hitting a ball, the relevant feature of the environmental context is the ball. For the skill of walking, the relevant environmental context features are the surface on which the person must walk, the presence or absence of an object, and/or other people or animals. And if other people are present, what is their activity? For example, walking while carrying luggage on a moving walkway on which some people are standing and others are walking is a much different, and more difficult, environmental context than is walking in a hallway with no other people.

In this classification scheme, the term *stability* refers to whether the relevant environmental context features are *stationary* (i.e., stable) or *in motion* (i.e., not stable). When the supporting surface, object, or other people involved in the performance of a skill are stationary, the skill is a **closed motor skill**. For these skills, *the relevant environmental context features are stationary, which means they do not change locations during the performance of a skill.* For example, picking up a cup from a table while you are sitting on a chair is a closed motor skill; the chair (i.e., supporting surface) and the cup (i.e., object) do not move between the time you decide to pick up the cup and the moment you pick it up. Walking in a room full of furniture is also a closed motor skill, because nothing in the environmental context moves or changes location while you are walking. Other examples of closed motor skills are shooting an arrow at a stationary target, buttoning a shirt, climbing a flight of stairs, and hitting a ball off a tee.

An important feature of closed motor skills is that the performer initiates the movements involved in performing the skill when he or she is ready to do so. Because of this timing of movement initiation characteristic, some motor learning and control researchers refer to these types of skills as *self-paced.*

Conversely, an **open motor skill** is *a skill that a person performs in an environment in which*

supporting surfaces, objects, and/or other people or animals are in motion while the person performs the skill. To perform this type of skill successfully, the performer must act according to the movement of a supporting surface, object, and/or other people or animals. Because performers of open skills must time the initiation of their movements with an external feature in the environment, some motor learning and control researchers refer to these types of skills as *externally paced.*

Some examples of open motor skills that involve the performer's supporting surface in motion include surfing a wave and stepping onto a moving escalator; skills that involve objects in motion include striking a moving ball and catching a thrown ball; and skills that involve other people or animals in motion include walking on a sidewalk crowded with people walking, running a distance race with other runners, coordinating movements with a dance partner, and playing with a puppy.

Notice that we have classified the skill of walking as *both an open and a closed skill.* This example illustrates that to classify a skill as open or closed, it is necessary to determine whether the supporting surface, objects, or other people in the environment are stationary or in motion. This means that when walking occurs in a hallway with no objects or other people, walking is a closed skill. Walking is also a closed skill if objects and/or other people are in the hallway, but stationary. However, if the objects and/or other people are in motion, walking becomes an open skill. Similarly, walking is an open skill when a person walks on a treadmill, which means the supporting surface is in motion. We can make the same distinction for several other motor skills. For example, hitting a ball from a tee is a closed skill, whereas hitting a pitched ball is an open skill. And, throwing a ball is a closed skill when throwing to a stationary person, but an open skill when throwing to a person who is moving.

Consider how closed and open skills differ in terms of the performance demands placed on the person. A person can initiate his or her movements at will when performing a closed skill. In addition, the person does not need to adjust the movements to changing conditions while the performance is in progress. For example, to climb a set of stairs, a person can initiate his or her first step at will. However, quite the opposite is the case when someone performs open skills. To perform an open skill successfully, a person must time the initiation of movement to conform to the movement of the supporting surface, other people or animals, and/or objects involved in the action. If, for example, the person must step onto a moving escalator, the timing of when the first step can be initiated must conform to the speed and position of the escalator. And for many open skills, changes can occur while an action is in progress that will require the person to make movement adjustments to conform to these environmental changes. For example, the spin of a tennis ball will influence the direction and height of its bounce, which may require the tennis player to adjust his or her planned movements to return a serve after the ball hits the ground.

The open/closed classification system has achieved a large degree of popularity in instructional methodology contexts and increasing popularity in rehabilitation contexts. A likely reason for this is that the closed and open skill categories relate so generally and easily to the types of motor skills involved in these settings. Skills in each of these categories follow common principles

serial motor skill a motor skill involving a series of discrete skills.

environmental context the supporting surface, objects, and/or other people or animals involved in the environment in which a skill is performed.

closed motor skill a motor skill performed in a stationary environment where the performer determines when to begin the action.

open motor skill a motor skill performed in a moving environment where the feature of the environmental context in motion determines when to begin the action.

of instruction that instructors and therapists can readily apply to specific situations. The closed and open distinction between motor skills also has become increasingly common in the motor learning research literature, undoubtedly because of its simplicity and its ability to accommodate both complex "real-world" skills and laboratory skills. A final reason for the classification system's popularity is that knowing whether a skill is open or closed provides immediate insights into the demands the skill places on attention, information processing, and movement planning. As discussed earlier, open skills place more demands on the performer because of the need to continuously monitor the environment and make ongoing adjustments to the movement. These insights can be very helpful when designing instruction, organizing practice, and providing feedback.

GENTILE'S TWO-DIMENSIONS TAXONOMY

A problem with the one-dimension basis for the classification of motor skills is that it does not always capture the complexity of many skills that a practitioner must take into account when making decisions about instruction, practice routines, or therapy regimens. To overcome this limitation, Gentile (2000) broadened the one-dimension approach by considering two general characteristics of all skills: (1) the *environmental context* in which the person performs the skill and (2) the *function of the action* characterizing the skill. She then subdivided these two characteristics to create an expansive taxonomy that yields sixteen skill categories, depicted in table 1.1. A **taxonomy** is a classification system that is organized according to relationships

TABLE 1.1 Gentile's Taxonomy of Motor Skills

	Action Function			
	Body Stability		**Body Transport**	
Environmental Context	**No Object Manipulation**	**Object Manipulation**	**No Object Manipulation**	**Object Manipulation**
Stationary Regulatory Conditions and No Intertrial Variability	**1A** Body stability No object Stationary regulatory conditions No intertrial variability • *Standing alone in a room* • *Holding a yoga pose*	**1B** Body stability Object Stationary regulatory conditions No intertrial variability • *Brushing teeth standing alone at a sink each day of the week* • *Shooting basketball free throws*	**1C** Body transport No object Stationary regulatory conditions No intertrial variability • *Climbing stairs* • *Running around an empty track*	**1D** Body transport Object Stationary regulatory conditions No intertrial variability • *Climbing stairs while holding a book* • *Practicing a penalty shot in soccer without a goal keeper*
Stationary Regulatory Conditions and Intertrial Variability	**2A** Body stability No object Stationary regulatory conditions Intertrial variability • *Standing on different surfaces* • *Performing handstands on different gymnastics apparatuses*	**2B** Body stability Object Stationary regulatory conditions Intertrial variability • *Washing dishes while standing at a sink* • *Putting golf balls from various locations on a putting green*	**2C** Body transport No object Stationary regulatory conditions Intertrial variability • *Walking on different surfaces* • *Agility drills through different obstacle courses*	**2D** Body transport Object Stationary regulatory conditions Intertrial variability • *Walking on different surfaces while carrying a bag of groceries* • *Pole vaulting over bars set at different heights*

TABLE 1.1 (*Continued*)

	Action Function			
	Body Stability		**Body Transport**	
Environmental Context	**No Object Manipulation**	**Object Manipulation**	**No Object Manipulation**	**Object Manipulation**
In-Motion Regulatory Conditions and No Intertrial Variability	**3A** Body stability No object Regulatory conditions in motion No intertrial variability • *Walking on a treadmill at a constant speed* • *Riding a mechanical bull with consistent motion*	**3B** Body stability Object Regulatory conditions in motion No intertrial variability • *Walking on a treadmill at a constant speed while using a smartphone* • *Catching a series of softballs thrown at the same speed by a pitching machine*	**3C** Body transport No object Regulatory conditions in motion No intertrial variability • *Standing on a moving escalator at a constant speed* • *Sprinting to the top of an escalator moving in the opposite direction*	**3D** Body transport Object Regulatory conditions in motion No intertrial variability • *Standing on a moving escalator while holding a cup of water* • *Running to hit a tennis ball projected by a ball machine*
In-Motion Regulatory Conditions and Intertrial Variability	**4A** Body stability No object Regulatory conditions in motion Intertrial variability • *Walking on a treadmill at different speeds* • *Cheerleader standing on a swaying teammate's shoulders*	**4B** Body stability Object Regulatory conditions in motion Intertrial variability • *Walking on a treadmill at different speeds while reading a book* • *Catching softballs thrown at various speeds by a teammate*	**4C** Body transport No object Regulatory conditions in motion Intertrial variability • *Walking in a crowded mall* • *Avoiding being caught in a game of tag*	**4D** Body transport Object Regulatory conditions in motion Intertrial variability • *Walking in a crowded mall carrying a baby* • *Practicing several soccer plays with a ball and defenders*

Note: (1) The number/letter labels for each skill category were not included in Gentile's original presentation of the taxonomy, but are included here to provide an easy reference to each skill category. The numbers 1–4 represent the four environmental context subdimensions; the letters A–D represent the four action function subdimensions. (2) The two examples of skills for each of the categories include an example of a daily activity skill and one of a sport/physical education skill.

among the component characteristics of whatever is being classified. For example, taxonomies have been developed in biology to provide systematic classification systems for plants and animals. Gentile's taxonomy presents a similar approach to the classification of motor skills.

In addition to providing a classification system for motor skills, Gentile originally proposed this taxonomy as a functional guide for physical therapists to assist them in assessing patients' movement problems and selecting functionally appropriate activities for these patients. However, *the taxonomy is not limited to the physical therapy context.* It provides an excellent basis for understanding the performer demands for a wide variety of motor skills. Everyone who is involved in teaching or training motor skills can benefit from the use of this taxonomy. It is an excellent means of becoming aware of the characteristics

taxonomy a classification system organized according to relationships among the component characteristics of the group of items or objects being classified.

that make skills distinct from, as well as related to, other skills. It demonstrates that small changes in certain characteristics of a motor skill can result in a considerable increase in the demands placed on a person to perform the skill. And it is an excellent guide for establishing practice or training routines.

Because the taxonomy is complex, the specific parts of it will be described and discussed in the following sections before discussing the taxonomy as a whole. The two dimensions are discussed separately along with the specific characteristics of each dimension. Use table 1.1 as the basis for identifying these dimensions and their subcategories.

Environmental Context

The first dimension of Gentile's taxonomy can be seen in the first column of table 1.1. This dimension is the *environmental context* in which a person performs a skill. Two characteristics are involved in this dimension. We see these in the category labels in the first column in table 1.1.

Regulatory conditions. The first environmental characteristic concerns regulatory conditions. This is the term Gentile used to describe the "relevant environmental context features," which we discussed previously in this chapter in the section concerning the motor skills classification scheme based on the stability of the environmental context. The term **regulatory conditions** refers to *those features of the environmental context to which movements must conform if they are to achieve the action goal.* They regulate spatial and temporal characteristics of the movement as well as the forces that underlie these characteristics. Recall from our earlier discussion about open and closed motor skills that the environmental context features include the supporting surface on which the person performs the skill and any objects or other people that may be involved. It is important to note that regulatory conditions do not refer to characteristics of a person's movements but only to characteristics in the environmental context in which a skill is performed.

Consider, for example, the regulatory conditions involved in walking from one location to another. The surface on which the person walks is a regulatory condition that determines the movement characteristics the person must use to achieve the action goal on that surface. The surface may be soft or hard, rough or smooth, flat or inclined, among other possible characteristics. To walk on a sandy beach, you would very likely move your body, legs, and feet differently from the way you would walk on a concrete sidewalk. Similarly, you would use different movements as you walked on a flat surface compared to a steep incline. In all these cases, you would need to modify how much force you applied to the surface, for how long, and in what direction. Objects and other people may also be regulatory conditions in the walking environmental context. For example, how would your walking movements differ if a child's tricycle were in the pathway from a situation in which no object was there? And how would your walking movements compare when another person walked beside you, behind you, or in front of you?

We can see additional examples of regulatory conditions in the environmental context when a person must manipulate an object. If a person's action goal is to throw a ball to another person, or to catch a ball thrown by another person, important regulatory conditions relate to certain characteristics of the ball, such as size, shape, and weight. The size and shape might regulate where on the object you applied force whereas the weight would regulate how much force you needed to apply. For example, throwing a baseball and throwing a basketball would require distinctly different arm, hand, and finger movements to achieve the throwing action goal and different amounts of force. Similarly, a person could catch a tennis ball with one hand, but may need to use two hands to catch a beach ball.

In Gentile's taxonomy, an important distinction for differentiating motor skills is whether the regulatory conditions are *stationary* or *in motion.* Sometimes the regulatory conditions are stationary; this is the case when you walk

A CLOSER LOOK

Examples of Stationary and In-Motion Regulatory Conditions

Stationary Environmental Context

Spatial features of the environment regulate spatial characteristics of a movement; the *timing* of the initiation of a movement is controlled by the performer.

e.g. picking up a cup from a table top
walking up a flight of stairs
hitting a ball from a tee
throwing a dart at a target

In-Motion Environmental Context

Spatial and timing features of the environment regulate spatial movement characteristics and timing of the initiation of a movement as well as the speed of the movement.

e.g. stepping onto a moving escalator
standing in a moving bus
hitting a pitched ball
running on a treadmill

on a sidewalk or hit a ball off a tee. Sometimes the regulatory conditions are in motion; this occurs when you must step onto an escalator or hit a pitched ball or try to catch a chicken. It is important to note that in this part of Gentile's taxonomy, you can see the application of the closed and open motor skills categories. Skills for which the regulatory conditions are stationary are closed skills, whereas those for which they are in motion are open skills. However, Gentile maintained that this closed/open distinction is too limiting to capture the wide range of skills that people perform every day. Because of this limitation, she added another environmental context characteristic.

Intertrial variability. The second environmental characteristic in the taxonomy is **intertrial variability**, which refers to *whether the regulatory conditions during performance are the same or different from one attempt to perform the skill to another.* We can distinguish motor skills according to whether intertrial variability is *absent* or *present.* For example, when a person walks through an uncluttered room several times, intertrial variability is absent because the regulatory conditions do not change each time the person walks across the room. On the other hand, intertrial variability is present when someone walks through a room several times in which various objects are located in different places each time because each walk through requires the person to walk with different movements to avoid colliding with the objects. It is important to note here that intertrial variability is almost always present when the environment is in motion. The only time motion variability is absent from trial to trial is when the motion is caused by a machine (e.g., a treadmill or a ball machine).

Relating the two environmental context characteristics. One way to illustrate the relationship between the two environmental context characteristics is to use a 2 × 2 diagram, with regulatory conditions either stationary or in motion on one dimension and intertrial variability either present

regulatory conditions features of the environmental context to which movements must conform if they are to achieve the action goal. They regulate spatial and temporal aspects of the movement.

intertrial variability an environmental characteristic in Gentile's taxonomy of motor skills. The term refers to whether the regulatory conditions associated with the performance of a skill change or stay the same from one trial to the next.

TABLE 1.2 Taxonomy of Motor Skills Based on the Environmental Context Dimension of Gentile's Two-Dimensions Taxonomy

	No Intertrial Variability	**Intertrial Variability**
Stationary Regulatory Conditions	Closed skills with no intertrial variability • *Free throws in basketball* • *Walking in an uncluttered hallway*	Closed skills with intertrial variability • *Golf shots during a round of golf* • *Taking several drinks of water from the same glass*
In-Motion Regulatory Conditions	Open skills with no intertrial variability • *Hitting tennis balls projected at the same speed from a ball machine* • *Walking on a treadmill at a constant speed*	Open skills with intertrial variability • *Hitting tennis balls during a rally in a game* • *Walking in a hallway crowded with moving people*

Note: This 2 × 2 taxonomy extends the one-dimension classification of open and closed skills by adding the characteristic of intertrial variability.

or absent on the other. As you can see in table 1.2, this arrangement creates four distinct motor skill categories.

These four categories are the same as those in table 1.1 in the first column under the heading Environmental Context. Gentile (2000) presented the 2 × 2 array as a preliminary way of presenting the complete taxonomy. The addition of the two intertrial variability categories provides a more realistic way of understanding closed and open skills. For example, shooting free throws in basketball and hitting golf balls during a round of golf are both closed skills. But shooting free throws in a game involves no intertrial variability because the regulatory conditions remain the same for each shot, even though the situations in which they are performed may differ. In contrast, hitting golf balls during a round of golf involves regulatory conditions that differ for each shot. Thus, the performance demands of the round of golf require greater amounts of shot-to-shot preparation than shooting a free throw because the golfer cannot plan to repeat the same movements from one shot to the next. Similarly, the regulatory conditions for open skills may remain the same from one performance of the skill to the next. An example is hitting a series of tennis balls projected at the same speed by a ball machine. In contrast, during a tennis match, regulatory conditions change for every shot.

Nonregulatory Conditions

It is important to briefly mention that other features of the environmental context can influence how skills are performed but not as directly as regulatory conditions. Gentile referred to these other features as **nonregulatory conditions**. They include features such as the color of an object, the presence of spectators, the weather conditions, and whether the skill is performed during the day or night. All of these features can influence performance, but they do not determine movement characteristics in the same way as regulatory conditions. For example, the color of a ball (a nonregulatory condition) might influence how well it can be visually tracked and therefore how likely it is to be caught; however, the size and speed of the ball (regulatory conditions) will precisely

A CLOSER LOOK

A Practical Application of the Closed/Open Motor Skills Continuum to Organizing Instruction for Teaching Open Skills

Those who teach motor skills can apply the environmental context dimension of Gentile's taxonomy to the teaching of open skills by changing the 2 × 2 diagram in table 1.2 to the continuum in figure 1.3 to develop a logical progression from completely closed to completely open skills from these components. Consider the following example of a practice sequence when the performance goal of a person is to hit a baseball thrown by a pitcher under game conditions.

1. Practice begins with a closed version of the open skill; the instructor or coach keeps the regulatory conditions "stationary" and has intertrial variability "absent."
   - ➔ the learner bats the ball from a batting tee at the same height on each practice attempt.
2. Next, the instructor or coach keeps the regulatory conditions "stationary" but has intertrial variability "present."
   - ➔ the learner bats the ball from a batting tee, but from different heights on each practice attempt.
3. Next, practice proceeds to an open version of the skill; the instructor or coach has the regulatory conditions "in motion" but intertrial variability "absent."
   - ➔ a pitching machine that can keep the speed and location of each pitch constant puts the ball in motion.
4. Finally, the instructor or coach has the learner practice the completely open skill itself; the regulatory conditions are "in motion" and intertrial variability is "present."
   - ➔ a live pitcher pitches the ball using different speeds and locations on each practice attempt.

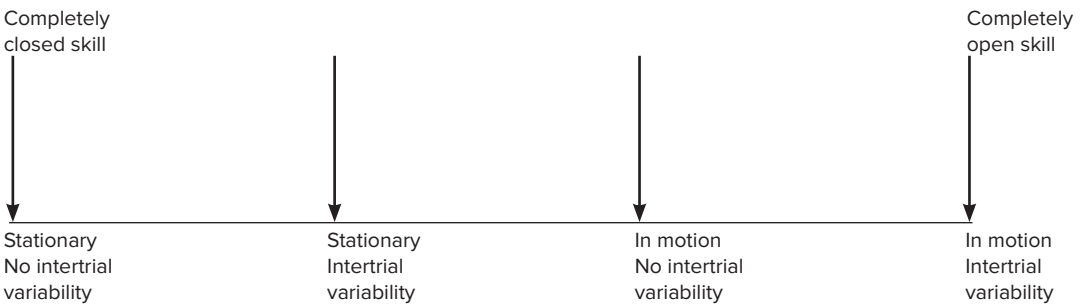


FIGURE 1.3 A skill category continuum for open and closed motor skills. The four subdimensions of the environmental context dimension of Gentile's taxonomy of motor skills on a continuum from the most closed to most open skills. Note that we have taken liberty with the term *continuum* to highlight the progression in task demands. In reality, there is a break in the middle of the continuum because the environment is either stationary or in motion; there is nothing in between.

Note: For research evidence supporting the effectiveness of this progression for helping people learn an open skill, see Hautala and Conn (1993).

regulate the spatial and temporal characteristics of the catching movement. Regardless of what body parts are used to catch the ball, the spatial and temporal characteristics of the catching

nonregulatory conditions features of the environmental context that have no influence or only an indirect influence on movement characteristics.

LAB LINKS

Lab 1 in the Online Learning Center Lab Manual for chapter 1 provides an opportunity for you to become more familiar with Gentile's taxonomy of motor skills by applying it to sports skills or to motor skills we experience in the everyday world.

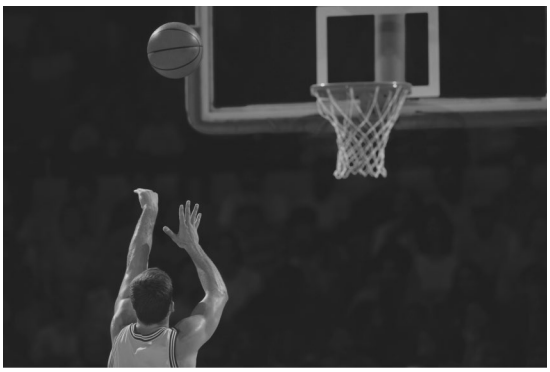
movement must conform to the spatial and temporal characteristics of the ball.

The Function of the Action

The *function of the action* is the second dimension on which the taxonomy is based. It relates to the action goal. This dimension is presented in the top row of table 1.1. We can determine the function of an action by deciding whether or not performing a skill involves moving the body from one location to another, and whether or not the skill involves holding or using an object. Gentile viewed these characteristics as parts of two action functions: body orientation and manipulation.

In the taxonomy *body orientation* refers to the *changing or maintaining of body location.* Two body orientation characteristics are important for classifying motor skills. *Body stability* refers to skills that involve no change in body location during the performance of the skill, such as standing, drinking from a cup, and shooting an arrow in archery. For skills that require the body to move from one place to another, the orientation is *body transport.* Skills such as walking, running, rock climbing, and swimming involve body transport. It is important to note that *body transport includes active and passive changes of body locations.* This means that both walking, which involves the active changing of body location, and standing on a moving escalator, which involves the passive changing of body location, involve body transport.

The second type of action function concerns *object manipulation.* In the taxonomy, the term *manipulation refers to maintaining or changing the position of an object,* such as a ball, a tool,



Shooting a basketball free throw and hitting a golf ball are closed motor skills. But, in a basketball game, the regulatory conditions for free throw shooting do not change from one shot to the next; in a round of golf, they change from one shot to the next.

David Madison/Digital Vision/Getty Images; Halfdark/Getty Images

A CLOSER LOOK

Examples of Using the Gentile Taxonomy to Evaluate Movement Capabilities and Limitations

Physical Therapy

An evaluation of the body stability, body transport, and manipulation capabilities and limitations of a neurologic or orthopedic patient could follow the sequence of taxonomy categories by progressing across the top row of categories. The patient

1. stands without assistance (category 1A)
2. stands without assistance while holding a book (category 1B)
3. walks without assistance a specified distance in an uncluttered walkway (category 1C)
4. walks without assistance a specified distance in an uncluttered walkway while holding a book (category 1D)

Further assessments could then include standing and walking activities that would follow the progression of skill requirements in the three other rows of skill categories in the taxonomy.

Physical Education

An evaluation of a student's ball-catching capabilities and limitations could use the following sequence of taxonomy categories. The student

1. catches a ball thrown from the same distance at the same speed for several trials (category 3B)
2. catches a ball thrown from various distances at various speeds for several trials (category 4B)
3. catches a ball while running along a line parallel to the thrower for several trials. The ball should be thrown the same distance and at the same speed in each trial (category 3D)
4. catches a ball while running along a line parallel to the thrower for several trials. The ball should be thrown from different distances and heights and at various speeds (category 4D)

For both the physical therapy and physical education examples, the performance evaluation steps provide a basis for determining a person's capabilities and limitations by systematically increasing the degree of complexity of the skill. For example, if the physical therapy patient can perform steps one and two but not three, the therapist knows that the patient is capable of static balance without and with holding an object but has limitations when performing body transport skills. Similarly, if the physical education student can perform steps one and two but not three, the teacher knows the student is capable of catching a ball while standing but has limitations when trying to catch a ball while running. Based on these evaluations, the therapist or teacher can then develop a systematic plan of activities to help the patient or student increase his or her capabilities in the performance of these skills. Note that the examples given here involve two motor skills related to two professions. If you are, or will be, involved in a different profession, develop a sequence of steps similar to those described here but that are specific to a skill you currently teach or would teach.

or another person. Another way to think about the meaning of this term would be in reference to *holding or using* an object. Skills that require object manipulation are more difficult to perform than skills that involve no object manipulation because the person must do two things at once. First, the person must manipulate the object correctly, and second, he or she must adjust body posture to accommodate for the imbalance created by the object.

The Sixteen Skill Categories

The interaction of the four environmental context characteristics and the four action function characteristics creates sixteen skill categories. Table 1.1 shows the critical characteristics of these sixteen categories, along with two examples of skills in each category. Gentile specified that each skill category poses different demands on the performer in terms of the characteristics and number of variables the performer needs to physically

control and pay attention to in order to achieve the action goals. Skills that demand the least of the performer are the simplest; those that demand the most are the most complex. Accordingly, the *skill categories in table 1.1 are organized in terms of increasing complexity,* beginning at the top leftmost category with the simplest skills and progressing to the most complex skills in the bottom rightmost category.

The taxonomy specifies that any motor skill must be considered in terms of the environmental context in which it is performed and the functional role it plays when performed. As a result, these two dimensions form the basis for creating sixteen categories of motor skills. The *environmental context dimension* includes the regulatory conditions to which the performer of a skill must conform, and whether these conditions change from one performance attempt to the next. The *action function dimension* establishes that all motor skills are performed to serve a specific purpose, or function. The action function may require the maintaining or changing of the performer's body location and/or the maintaining or changing of the position of objects.

Practical Application of the Taxonomy

Gentile proposed that the taxonomy has practical value for practitioners. First, as noted earlier in the chapter, classifying skills provides insights into the demands that those skills place on the performer. Classification is actually an early step in task analysis—a systematic analysis of the important characteristics of the performance environment and the skill that is used to understand the capabilities a person needs to succeed at the task (Arend & Higgins, 1976; Higgins, 1991). Once the practitioner understands the demands associated with a particular skill, the taxonomy can then be used to *evaluate a learner's movement capabilities and limitations.* The practitioner can determine deficiencies by systematically altering environmental contexts and/or action functions to identify skill performance characteristics that pose difficulty for an individual. The Closer Look box on the previous page provides an example of how a physical therapist could use the taxonomy to evaluate a patient's capabilities and limitations and how a physical education teacher could use it to evaluate a student's catching skills.

Second, after the practitioner assesses performance problems, the taxonomy becomes a valuable tool for systematically *selecting a progression of functionally appropriate activities* to help the person overcome his or her deficits and increase his or her skill performance capabilities. This is an important feature of the taxonomy, because it emphasizes the complementary part of the rehabilitation or skill training process. To assess skill deficits is important, but the effectiveness of any rehabilitation or training protocol depends on the implementation of appropriate activities to achieve functional goals for the patient or student. In the activity selection process, the therapist or teacher begins selecting activities related to the taxonomy category in which the person is not capable at first of handling the demands of the skill. Then, the professional can develop a program of rehabilitation or instruction by systematically increasing the complexity of the skills included in the program.

A third practical use of the taxonomy is as a means of *charting the individual progress* of patients or students as they work to attain their rehabilitation or physical activity performance goals. Gentile emphasized the benefit of using the taxonomy to create a "profile of competencies" that can aid the therapist or teacher in the assessment of the effectiveness of the rehabilitation or instructional program he or she developed for the patient or student. Because the taxonomy follows a simple-to-complex progression of skills, it provides an objective basis for determining progress in overcoming skill performance deficits and increasing skill performance capabilities. When used in this way, the taxonomy provides an effective way for the therapist or teacher to establish a record that can satisfy demands for accountability of his or her time and effectiveness.

SUMMARY

- Researchers and professionals use the terms *motor learning* and *motor control* to describe related areas of research and professional application that emphasize specific interests concerning the performing of motor skills. The study of *motor learning* emphasizes the acquisition of motor skills, the enhancement of performance of learned or highly experienced motor skills, and the reacquisition of skills that are difficult to perform or cannot be performed because of injury, disease, and so on. The study of *motor control* emphasizes how the neuromuscular system functions to activate and coordinate the muscles and limbs involved in the performance of motor skills. A related area of study is known as *motor development,* which emphasizes either or both motor learning and control issues but from the perspective of the relationship to human development from infancy to old age.
- *Motor skills* are activities or tasks that require voluntary control over movements of the joints and body segments to achieve a specific purpose or goal. Motor skills are commonly distinguished from *cognitive skills,* which are activities or tasks that require mental (i.e., cognitive) activity, such as decision making, problem solving, remembering, and the like. People may use a motor skill to perform a cognitive skill (e.g., using a calculator to solve an addition problem), and they may use a cognitive skill while performing a motor skill (e.g., reading music while playing a piano).
- *Motor skills* and *actions* are similar terms that refer to goal-directed activities that involve voluntary control over movements of the joints and body segments. The term *movements* refers to the motions of joints and body segments that serve as components of actions and motor skills. *Neuromotor* processes refer to the mechanisms in the nervous and muscular systems that underlie movement control.
- Motor skills can be classified according to common characteristics. One-dimension classification systems place skills into categories based on one common characteristic; two-dimension classification systems place skills into categories based on two common characteristics.
- Three one-dimension classification systems distinguish skills on the basis of (a) the size of the primary musculature required to perform the skill, classifying skills as gross or fine; (b) the specificity of where movements of the skill begin, classifying skills as continuous or discrete; and (c) the stability of the environmental context in which the skill is performed, classifying skills as open or closed.
- Gentile's taxonomy of motor skills is a two-dimension classification system that describes sixteen categories of skills that are created from characteristics associated with the dimensions: the environmental context in which the skill is performed and the function of the action. The taxonomy provides a means of understanding the factors that influence motor skill complexity and the unique requirements placed on a person when he or she performs skills of different complexity. The taxonomy can serve as (1) a useful guide for the evaluation of movement capabilities and limitations, (2) a valuable tool for selecting a progression of functionally appropriate activities to help a person overcome his or her skill performance deficits and increase performance capabilities, and (3) a means of charting the individual progress of physical rehabilitation patients and students as they work to attain specific physical activity performance goals.

POINTS FOR THE PRACTITIONER

- The distinction between actions and movements indicates that you should evaluate a learner's achievement of the action goal of a skill as well as the associated movements. For many motor skills it is possible for different people to

achieve the action goal of a skill by using different movements.

- Understanding the bases for categorizing motor skills can help you determine how different motor skills place different demands on people to learn and perform them. As a result, you can establish teaching and learning conditions that are appropriate for the person or people with whom you work.
- Evaluation of motor skill capabilities and limitations should follow systematic guidelines. The use of a taxonomy of motor skills, such as the one proposed by Gentile, provides a systematic guide that can be used for this purpose.
- After you determine a person's specific motor skill performance deficits and limitations, you can use the Gentile taxonomy of motor skills to plan a progression of appropriate activities to help the person overcome these deficits and limitations as well as improve his or her performance capabilities.

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STUDY QUESTIONS

1. Discuss how the terms *actions* and *movements* are related to motor skills. Give an example that illustrates this relationship.
2. What are three reasons for distinguishing between actions, movements, and neuromotor processes?
3. Describe the one dimension that distinguishes the two categories in each of the following skill classification schemes, and give three examples of motor skills for each category: (a) gross vs. fine motor skills; (b) discrete vs. continuous motor skills; (c) closed vs. open motor skills.
4. (a) What are the two dimensions used to classify skills in the Gentile taxonomy? (b) Describe the four classification characteristics included under each of these two dimensions.
5. (a) What does the term *regulatory conditions* refer to in Gentile's skill classification system? (b) Why are regulatory conditions important to consider when categorizing skills?
6. What does the term *intertrial variability* mean in Gentile's skill classification system? How does this term provide an additional characteristic for distinguishing open and closed motor skills? Give two examples of motor skills for each of the four categories of skills that are created by this added distinction.
7. Discuss how you would implement the three practical uses Gentile described for her taxonomy of motor skills.

Specific Application Problem:

(a) You are working in your chosen profession. Describe an open skill with intertrial variability that people you work with would perform.

(b) Describe a sequence of three preliminary skills that you would have people practice to provide them with experiences that would increase their chances for performing the open skill you described in part (a).

(c) Provide a rationale for the sequence of three preliminary skills.

(d) Discuss how you would determine which of the three preliminary skills a person should begin practicing.

(e) Discuss how you would determine the amount of practice that a person should devote to each of these preliminary skills.