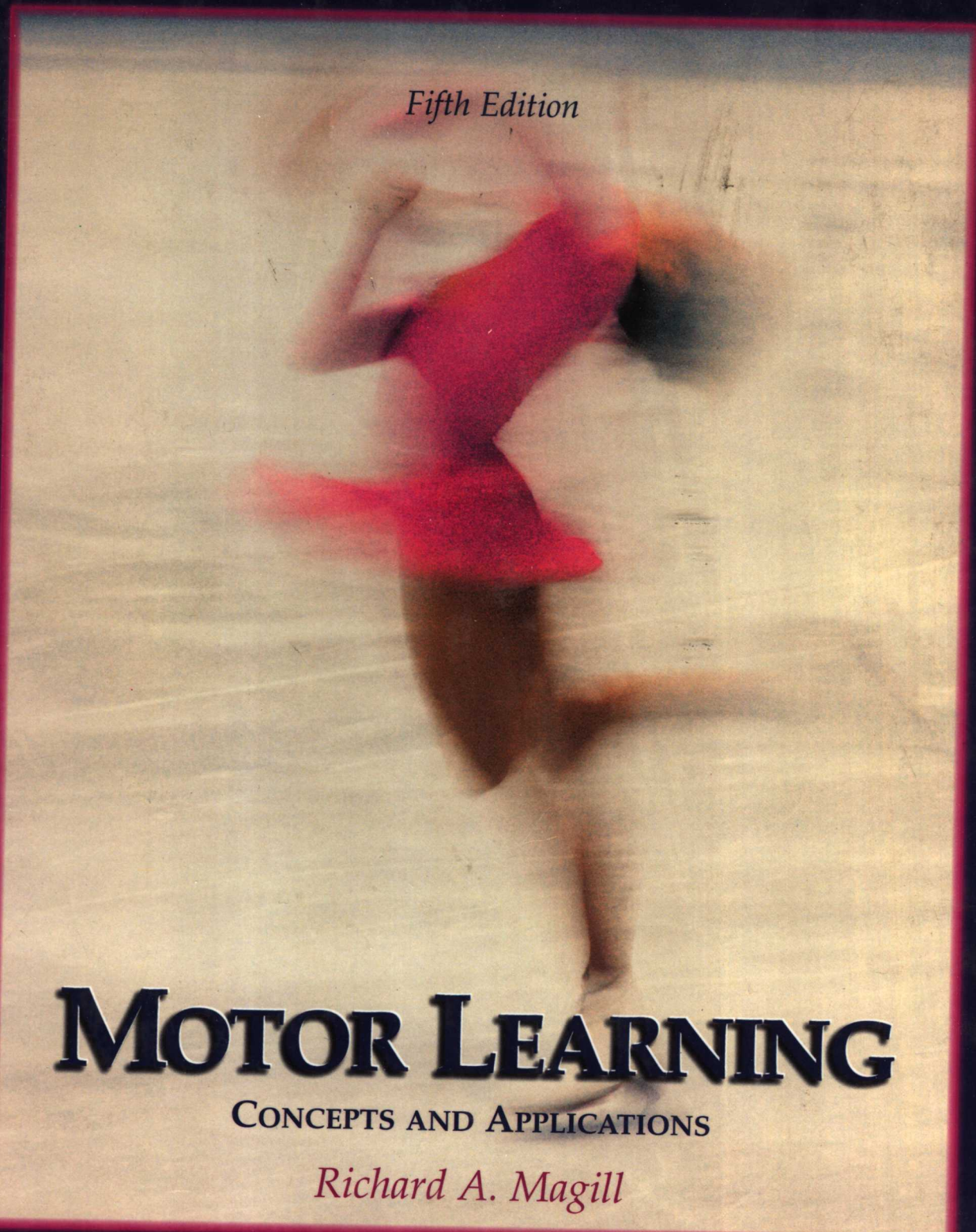

Fifth Edition

MOTOR LEARNING

CONCEPTS AND APPLICATIONS

Richard A. Magill

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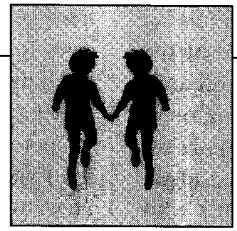
PREFACE



It is both exciting and challenging to prepare the fifth edition of this book. The excitement is due to knowing that there is continued interest in this book and in motor learning as subject matter for the development of students who aspire to professions involving skill acquisition and/or rehabilitation. Preparing this edition is a challenge because the increase in the amount of research done since the fourth edition makes updating the text without expanding it to unrealistic proportions a difficult task. An additional challenge is created by the increased interest by rehabilitation professions to include motor learning as part of the programs of study for students. This means that the text must be amended to establish its relevance for these professions but without diminishing its relevance to teaching and coaching professions, which in the past have been the primary users of motor learning courses.

To achieve the goals established by these challenges, several features of this text have been kept the same as in previous editions while several have been changed and added. Primary among the features that remain unchanged is the "concepts approach" taken to present the content of the text. Again, each chapter presents a different general area of study in motor learning. Each chapter is subdivided into several essential concepts that represent the key points of our present knowledge about the area of study. Then an application section describes motor skill examples of relevance to each concept, adapted to the everyday environment in which we live and work. Finally, a discussion section presents research, theory, and issues that establish how the concept was derived. Within this framework, a special effort has been made to keep the text appropriate for undergraduate students, for whom this book is prepared.

As in every new edition, several changes and additions are included. One important change is that there is a reduction in the number of references cited in text. The purpose of this change is to keep the book focused more on discussing the concept and applying it to the needs of the professional. Reviews of the last edition indicated a drift toward becoming too focused on motor learning research issues and controversies. It is important, however, to keep in mind that the motor learning concepts presented in this text have a research evidence basis

and are not derived from weight of unsubstantiated opinion. Thus, the need is to find the right balance of discussing relevant research while not allowing the research issues to overwhelm the point of the discussion of a concept. Accordingly, research studies included in this edition serve two purposes: to present an example of research done about an issue to substantiate a point and to provide research references for the student and/or instructor who wants more information about a topic.

Another notable change in this edition is the expansion of motor skill learning and performance examples that involve everyday skills and rehabilitative clinical environments. Although the fourth edition began providing these examples, the present edition gives them more prominence and increases the amount of them. Adding these types of skill examples increases awareness of the relevance of motor learning concepts to a broad range of skills and performance situations.

An important change to this edition is the restructuring of some of the content from the previous edition. In some cases, topics have been deleted or integrated with other topics. For example, two chapters from the fourth edition on memory and motivation are deleted. This will help to keep the amount of information appropriate for a one-semester course. Also, some topics included in chapters of past editions are minimally relevant to the undergraduate's needs in acquiring a basic knowledge of motor learning. However, material from those chapters considered essential to that knowledge base has been incorporated into other chapters.

The chapters from the fourth edition on the control of movement and attention have been restructured in this edition to reduce the quantity of information in each. The goal of this restructuring is to maintain a focus on content that is most relevant for understanding of motor skill learning. As undergraduate courses in motor control become more numerous, the need to have an expansive discussion of motor control topics diminishes. However, in keeping with the need to provide a contemporary view of issues, this edition presents a more developed discussion of the dynamical systems theory of the control of coordinated movement.

To provide a better working organization of topics, the three Units in the previous edition have been restructured into four. This new structure allows for a better presentation of the study of motor learning. Now, the book engages the student first in understanding the characteristics and measurement of motor skills, which are essential components of the foundation of knowledge for all professions related to motor skill learning and rehabilitation. In the second unit, the student studies theoretical aspects of how the nervous system controls coordinated movement and limitations built into the system. In Unit Three, the focus shifts to the acquisition of motor skills and the influence on acquisition of a variety of instructional and practice conditions. Finally, the potential caveat in many of the generalizations presented in the preceding chapters is discussed in Unit Four: individual differences. Certainly noteworthy here is that by moving this subject matter to the last chapter, the presentation of topics in Units 2 and 3 now flow with less interruption.

Finally, it is important to point out a prominent new pedagogical feature added to this edition. Several shaded boxes entitled "A Closer Look" are now included in each Concept discussion. The title for each box indicates its content. These boxes typically serve one of two purposes: to provide more detail about a research study to illustrate a point made in text, or to describe situation(s) to apply a discussion point to a context relevant to professional practice. The boxes are included to enhance or enrich the information presented in the discussion of a Concept. Thus, the student can acquire basic knowledge about the Concept without reading the boxed information. But, he or she can enrich that knowledge by reading it.

No edition of a textbook can be developed without sage advice and direction from a number of people. This edition is no exception. I am especially thankful to the many users of the previous editions who have contacted me with feedback on what they like about the book or with suggestions for changes. Howie Zelaznik, Sally White, Tim Lee, and Kellie Hall deserve special recognition and thanks in this regard. Also, the reviewers

selected by my editor to critique the fourth edition provided many useful suggestions for developing this new edition. I also thank my LSU colleagues for their support and patience as I went through this process. Don Franks, as my department chair, has been a constant source of encouragement and bad jokes to keep things from getting bogged down. As I have done in previous editions, I want to emphasize the importance of the contributions to this book from the undergraduate and graduate students I teach at LSU. They continue to remind me why they enroll in and what they need from a motor learning course. Finally, thinks again to the editorial and production staffs at WCB/McGraw-Hill. They and the company have experienced numerous changes during the development of this edition. I appreciate how well they have maintained their focus, encouragement, and sense of humor to enable me to get the job done.

Richard A. Magill
Baton Rouge, Louisiana

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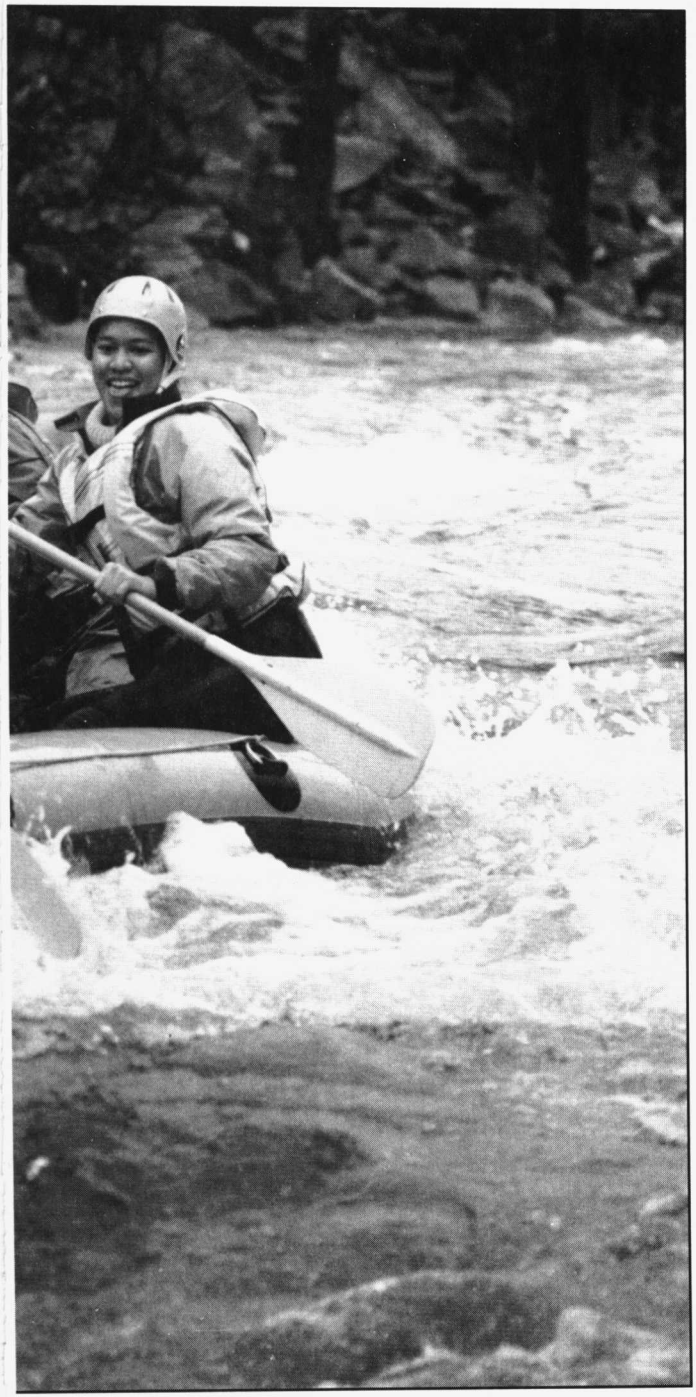
Motor Learning



UNIT

I

INTRODUCTION TO MOTOR LEARNING

CHAPTER

1

INTRODUCTION TO MOTOR SKILLS

CONCEPT 1.1

Motor skills can be classified into general categories

CONCEPT 1.2

The measurement of motor performance is critical to understanding motor learning

CONCEPT 1.1

Motor skills can be classified into general categories

Key Terms

skill
motor skill
movements
actions
gross motor skills
fine motor skills
discrete motor skill
serial motor skill
continuous motor skills
closed motor skill
open motor skill
regulatory conditions
intertrial variability

Application

When a person runs, walks with an artificial limb, throws a baseball, hits a tennis ball, plays the piano, dances, or operates a wood lathe, that person is using one or more of the human skills called *motor skills*. In this book, we focus on helping you understand how people learn, and how you can help people learn, motor skills such as these.

As you engage in this study, you will find it useful to draw general conclusions, applying what you learn to a broad range of motor skills, rather than making many specific statements about many skills. In the Discussion section of this Concept, we provide a starting point for making these kinds of general statements. That starting point 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 these skills have one characteristic in common. People must perform both skills in what we will call 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 standing or walking around. For the baseball-hitting skill, the changing environment includes 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.

Discussion

To begin your study of motor learning, you should understand some things about the skills that are at the heart of this study. To enhance this understanding, we will discuss two important points about motor skills. First, we will define motor skills, considering what distinguishes them from other skills; as we do so, we will 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. The benefit of classifying skills is that it can provide us with an appropriate basis for establishing generalizations, or principles, about how we perform and learn motor skills. These generalizations enable us in turn to develop theories about skill performance and learning. Additionally, they help us to establish guidelines for instructors and therapists who must develop effective strategies that will enhance motor skill learning and rehabilitation.

Skills, Movements, and Actions

Several terms in the motor learning literature are related to the term *motor skills*. These are *skills, movements,* and *actions*. Each term is used in a specific way; we should understand and use each one correctly.

Skills. The term **skill** is a commonly used word that we will use in this text to denote *a task that has a specific goal to achieve*. For example, we 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 is *a skill that requires voluntary body and/or limb movement to achieve the goal*. 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 finger and hand movement to achieve that goal.

Note several characteristics in this definition that are common to motor skills. First, there is *a goal to achieve*. This means that motor skills have a purpose. Some theorists use the term *action goal* in motor learning and control literature to refer to the goal of a motor skill. Second, 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 body and/or limb movement* to accomplish the goal of the task. This characteristic indicates that when we use the term *skill,* we are referring to a specific type of skill. Although calculating math problems is a skill, it does not require body and/or limb movement to achieve its goal. We commonly refer to the type of skill used for math problems as a cognitive skill.

One additional characteristic further identifies the types of motor skills of interest in this text: they *need to be learned* in order for a person to achieve the goal of the skill successfully. The piano-playing example clearly has this characteristic. But consider a skill like walking. While 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 literature, the term **movements** indicates *behavior characteristics of a specific limb or a combination of limbs*. In this sense, movements are component parts of skills. A variety of different limb behavior characteristics can occur that still enable a person to walk successfully. For example, our limbs move differently in distinct ways when we walk on a concrete sidewalk and when we walk on an icy sidewalk—or on a sandy beach. However, while the actual movements may differ, the skill we perform in each of these different situations is walking.

Actions. A term that has become increasingly more common and more important in the motor learning and control literature is the term *actions*. For our purposes, we will use this term as synonymous with *skills* and distinct from *movements*. That is, **actions** are *goal-directed responses that consist of body and/or limb movements*. Another way of defining an action is to say that it is *a family of movements*. Some have referred to an action as *an equivalence class of movements* (see Schmidt and Turvey 1992).

The important point here is that a variety of movements can produce the same action and thereby accomplish the same goal. For example, walking up a set of stairs is an action. The goal is to get to the top of the stairs. However, to achieve this goal a person can use 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 is the same but the movements the person produces to achieve the goal of the action are different.

One-Dimension Classification Systems

Theorists base the process of classifying motor skills on 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. The first three of the four skill classification systems we discuss in this section use this approach.

For each system, the common characteristic is divided into two categories, which represent extreme ends of a continuum rather than dichotomous categories. 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. While 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 more accurately classify various temperature levels that do not fit into only one or the other category.

Size of musculature required. One characteristic describing most motor skills is the type of muscle groups required to perform the skill. Skills like walking and hopping do not require as the prime movers muscle groups of the same size as the muscle groups used for skills like piano playing and sewing. By distinguishing skills based on the size of the muscle groups required to accomplish the actions, 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* to produce the actions. These skills need less movement precision than fine motor skills do. We classify skills such as the so-called *fundamental motor skills*—walking, jumping, throwing, leaping, etc.—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 while large muscles may be involved in the action of a fine motor skill, the small muscles are the primary muscles involved to achieve the goal of the skill.

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 are developed using the gross and fine motor skill distinction.

The distinctiveness of the movements. Researchers also classify motor skills on the basis of how distinct the movements are as a person performs the skill. If a skill requires one distinct movement having an identifiable beginning and end point, 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 requires one distinct movement that begins and ends at clearly defined points.

Sometimes an individual puts several discrete movements together in a series or sequence. When this occurs, we consider the skill a **serial motor skill.** Starting a standard shift automobile is a good example, because the driver must perform a series of distinct movements. First, the driver depresses

the clutch. Next, he or she turns the key to start the engine. Then the person must put the gear shift into first gear, and depress the accelerator properly as he or she lets out the clutch and the car finally begins to move. Each movement in this series is distinct, with a specific beginning and end point. We also can consider playing the piano as a serial motor skill, because the pianist must accomplish discrete movements of striking the piano keys in a definite, serial order.

At the opposite end of this classification system continuum fall **continuous motor skills,** which contain movements that are always repetitive. We can classify skills such as steering an automobile, tracking a moving cursor on a computer monitor with a joystick, swimming, and walking as continuous skills.

This classification system has been especially prevalent in motor skills research literature when authors are focusing on the control of movement. 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 the motor skill performance from the perspectives of human engineering and human factors.

The stability of the environment. One classification system has its roots in industrial as well as educational and rehabilitation settings. Researchers base this system on the stability of the environment in which the skill is performed (Gentile 1972; Poulton 1957). For this classification system, the term *environment* refers specifically to the object the person is acting on or to the characteristics of the context in which the person performs the skill. For example, if a person is hitting a ball, the critical component of the environment is the ball itself. For the skill of walking, however, the critical environment features are the surface on which the person must walk and the characteristics of the environmental context in which the person must walk.

According to this classification scheme, if the environment is stable, that is, if it does not change while the person is performing the skill, then we classify the skill as a **closed motor skill.** For these skills, *the object to be acted on does not change during the performance of a skill.* In effect, the object waits to be acted on by the performer. For example, picking up a cup from a table is a closed motor skill, because the cup does not move between the time you decide to pick it up until you pick it up. Walking in an uncluttered room is also a closed motor skill, because the environmental context does not change while you are walking. Other examples of closed motor skills are shooting an arrow at a stationary target, buttoning a shirt, stair climbing, and hitting a ball off a tee. For each of these skills, the performer can initiate action when he or she is ready to do so and perform the skill according to his or her own wishes.

Conversely, an **open motor skill** is *a skill that a person performs in a non-stable environment, where the object or context changes during the performance of the skill.* To perform such a skill successfully, the performer must act according to the action of the object or the changing characteristics of the environment. For example, skills such as driving a car, stepping onto a moving escalator, walking through the woods, striking a moving tennis ball, and catching a ball are all open motor skills. People perform each of these skills in a temporally and/or spatially changing environment. For example, during a rally a tennis player cannot stand in one spot and decide when and how he or she will respond to the ball. To be successful, the player must move and act in accordance with the ball's spatial location and speed characteristics. Similarly, walking through the woods is an open motor skill, because the person's walking characteristics vary depending on the locations of the trees, stumps, stones, and holes in the ground.

Notice that in the last two paragraphs, we have classified the skill of walking as *both an open and a closed skill.* The distinguishing feature is the situation in which the walker performs the skill. When walking occurs in an uncluttered environment, it is a closed skill. But when a person must walk in a cluttered environment, walking is an open skill. We can make the same distinction for several skills. For example, hitting a ball from a tee is a closed skill, whereas hitting a pitched ball is an open skill.