Fifth Edition

Motor Learning and Control for Practitioners

Cheryl A. Coker

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With an array of critical and engaging pedagogical features, the fifth edition of *Motor Learning and Control for Practitioners* offers the best practical introduction to motor learning available. This reader-friendly text approaches motor learning in accessible and simple terms and lays a theoretical foundation for assessing performance; providing effective instruction; and designing practice, rehabilitation, and training experiences that promote skill acquisition.

Features such as Exploration Activities and Cerebral Challenges involve students at every stage, while a broad range of examples helps readers put theory into practice. The book also provides access to a fully updated companion website, which includes laboratory exercises, an instructors' manual, a test bank, and lecture slides.

As a complete resource for teaching an evidence-based approach to practical motor learning, this is an essential text for undergrad and post-grad students, researchers, and practitioners alike who plan to work in the areas of motor learning, motor control, physical education, kinesiology, exercise science, coaching, physical therapy, or dance.

Cheryl A. Coker is a motor learning specialist who draws from her experiences as a teacher, coach, and athlete to assist practitioners in putting theory into practice. In addition to *Motor Learning and Control for Practitioners*, she has authored numerous journal articles and book chapters, and has given over 100 presentations throughout the United States and internationally. She is a Fellow of the Research Consortium in the Society of Health and Physical Educators and of the North American Society of Health, Physical Education, Recreation, Sport and Dance Professionals. Coker lives in New Hampshire where she teaches in the Physical Therapy program at Plymouth State University, and enjoys outdoor activities and spending time with family, friends, and her Bernese Mountain Dog, Tucker.

"I have found this text to be helpful in engaging my students and creating a learning environment that is interactive. As a result I have had a positive interchange between instructor and students."

Charla Bouranis, *Salem State University, USA*

"Within my 17 years of teaching in higher education, I have never adopted another textbook for teaching motor learning because this text is so complete."

George Walker, *Cumberland University, USA*

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CHERYL A. COKER

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Preface

Human movement is a complex phenomenon. For practitioners concerned with movement enhancement, that complexity presents a constant challenge. The key to meeting this challenge lies in understanding how people learn. *Motor Learning and Control for Practitioners*, Fifth Edition, introduces practitioners to the processes that underlie human movement learning. Bridging the gap between research and practice, this text provides practitioners with the necessary tools to build a solid foundation for assessing performance, providing effective instruction, and designing practice, rehabilitation, and training experiences that will optimize skill acquisition and performance.

APPROACH

The purpose of this textbook extends beyond simply presenting the concepts and principles of motor learning and control. In each edition, one important goal of *Motor Learning and Control for Practitioners* has been to actively engage readers with its content through an applications-based approach. Before readers can be challenged to apply theoretical constructs, however, they must first understand them. To facilitate this understanding, material is presented in an easy-to-read style that incorporates a wide range of examples from everyday life, teaching, coaching, and rehabilitation. Readers have abundant opportunities to interact with the book's key concepts, principles, and basic terminology and then apply that information to real-life situations.

AUDIENCE

This text is designed for future practitioners in physical education, kinesiology, exercise science, physical and occupational therapy, dance, and coaching. Special care has been taken to accommodate the diverse needs of this multifaceted audience, as reflected in the great variety of examples, scenarios, and activities provided throughout the text. Readers in each specific content area will have numerous opportunities to apply principles and concepts to their area of specialization and to develop a working knowledge of motor learning and control as it applies to their chosen profession.

ORGANIZATION

The focus of Chapters 1 through 5 is on the behavioral and neurological processes that influence performance. The text begins by introducing readers to the foundational concept that human movement is a complex phenomenon that is a function of the interaction of the learner, the task, and the environment in which the task is performed (Chapter 1). Readers' working knowledge of this interaction is further developed in Chapter 2, which introduces the underlying processes that govern movement execution and control. Chapter 3 extends this discussion, examining the role of attention in the decision-making process. While Chapters 2 and 3 focus on the factors that influence movement preparation, Chapter 4 explores the theoretical constructs underlying the coordination and control of human movement. Movement is then examined from a neurological perspective in Chapter 5.

Chapters 6 through 12 build on this foundational knowledge of how skilled movements are produced, examining the factors involved in their acquisition and refinement. Chapter 6 begins this discussion, introducing the changing characteristics of learners as they progress from novices to experts, and the role of these characteristics in guiding the practitioner's decision-making throughout the instructional process. Beginning with Chapter 7, the sequence in which concepts are introduced parallels that typically used by practitioners during the instructional process. Chapter 7 discusses pre-instruction considerations to facilitate learning, including communication, awareness, transfer, and motivation to learn and practice. Methods of presenting skills—through both direct instruction and a hands-off approach—are then examined in Chapter 8. Next, to provide learners with ample opportunities to practice presented skills, Chapter 9 examines a number of practice variables, including sequencing and psychological strategies that a practitioner can manipulate to optimize gains in skill proficiency. This focus on practice design continues in Chapter 10, which highlights practice organization and scheduling. Once the learner begins to practice a skill, the role of the practitioner becomes one of error detection and correction. Chapter 11, unique to this text, investigates the role of motor learning and control in diagnosing errors, while Chapter 12 addresses principles and guidelines regarding the provision of feedback as an intervention strategy and the manipulation of practice and task variables for shaping movement patterns. Finally, an epilogue contains two real-life scenarios to test readers' abilities to apply what they have learned.

NEW TO THIS EDITION

This text continues to provide a balance between conceptual and practical material and each chapter has been updated to reflect recent research and best practice. The OPTIMAL theory of motor learning, explicit versus implicit learning, attentional focus, and mixed observational learning are just some of the topics that have been expanded. Additional references have also been made to the constraints-led approach throughout the book, including the concept of representative design. This edition also offers students 18 online lab experiences at www.rouledge.com/cw/coker, representing a significant link between theory and practice. Every chapter includes at least one lab, and many of the labs include videos demonstrating procedural aspects. New Cerebral Challenges, examples, and Research Notes will aid student understanding and inform them about developments in the field. The marginal website feature includes new examples that will appeal to students and instructors alike, directing readers to online resources, including videos, web-based activities, apps, and additional informational sources. Finally, materials for instructors include key talking points, sample responses for selected Cerebral Challenges as well as suggestions about Exploration Activities that can be converted to additional/alternative laboratory experiences.

FEATURES

- **Accessible for all students**: The text's readability and varied applications and examples make it appealing to students pursuing careers as practitioners.
- **Theoretical coverage**: Balanced coverage is provided of movement preparation theories, motor program and dynamic interaction theories, and the constraints-led approach.
- **Broad range of examples**: Examples from sport, physical education, dance, exercise science, athletic training, rehabilitation, and "everyday life" will accommodate the great variety of majors and future professionals in this course.
- **Pretest**: The text opens with a pretest to determine students' current knowledge level with respect to motor learning and control. The test is based on Common Myths that readers will encounter marginally throughout the text, introducing and discussing common misconceptions in the field.
- **Epilogue**: The text concludes with two real-life scenarios, one physical education and one rehabilitation, with associated questions and answers, allowing students to put concepts to work in an applied setting.
- **Error diagnosis and correction**: Chapter 11's unique coverage explores errors based on motor learning and control issues and their diagnosis. The chapter presents critical factors for conducting an observation, offers a categorical model for determining an error and its resolution, and discusses situational factors that should be considered before correcting an error.

PEDAGOGICAL FEATURES

- Online labs use typical classroom and everyday items and enable students to explore key motor learning concepts and translate chapter content into practice.
- Exploration Activities are experiential mini-labs and can serve as an instructor-directed starting point for class discussion, be converted to laboratory experiences, or be completed by students outside the classroom.

- Critical thinking exercises, called Cerebral Challenges, interspersed throughout the text, require readers to engage in higher-order problem-solving activities. This feature can further serve as an instructor-directed starting point for class discussions.
- Putting it into Practice offers the opportunity to apply key chapter concepts to a learning situation in both coaching and rehabilitation. Readers can compare their response to an example response provided online at www.routledge.com/cw/coker.
- Web links (in text margins, in Exploration Activities, and in Cerebral Challenges) direct readers to relevant videos, web-based activities, and additional information sources.
- Boxed Research Notes provide examples of research conducted on the topics discussed in the chapter.
- Key terms are bolded in the text and included in a comprehensive book-end Glossary.

END-OF-CHAPTER FEATURES INCLUDE:

- **A Look Ahead**, previewing the coming chapter.
- **Focus Points**, offering concise bulleted summaries of key concepts.
- **Review Questions**, allowing students to test their comprehension of material.

INSTRUCTOR MATERIALS

- An **Instructor's Manual** available to text adopters that includes key talking points for selected Cerebral Challenges, listings of web links and available labs, as well as suggestions about Exploration Activities that can be converted to additional/alternative laboratory experiences.
- A **test bank** with multiple choice and true/false questions.
- A **PowerPoint presentation** focusing on key content and art is also available.

Acknowledgements

Over 20 years ago I signed the first contract for *Motor Learning and Control for Practitioners*. A lot has changed since then but the one constant is my gratitude to so many people that have helped me along the way. Many thanks to my students, colleagues, and mentors for teaching, shaping, and inspiring me. To all those who have touched this book in some way over the years—reviewers, editors, editorial assistants, proof readers, artists and designers, production teams, marketing teams, and many more—words cannot express my appreciation. I am especially grateful to David Varley and Megan Smith at Routledge for their invaluable assistance with this edition—working with you both has been a pleasure! To my friends and family, thank you for your part in my journey. Finally, I would like to thank Kim for her love and support—you truly are awesome ☺.

Pretest

As a student of human movement, you bring to this course extensive knowledge from your past experiences. To determine your current level of knowledge with respect to motor learning and control, complete the following pretest.

TRUE OR FALSE?

1. Future success in a specific skill can be easily predicted.
2. The higher the level of arousal, the better the performance.
3. All sensory messages must go to the brain for integration.
4. Unless the learner displays some overt changes in performance, he or she is no longer learning.
5. All learners are motivated to learn the skills presented to them.
6. Experts are always the most effective instructors.
7. In order for an observer to learn a movement, the demonstration must be performed correctly.
8. Practice makes perfect.
9. Long-term retention of a motor skill is best achieved by practicing a skill repeatedly before moving to either a different version of the task or a different task altogether.
10. When teaching a youngster how to catch, you should toss the ball with a high arch in order to give them enough time to follow it and get underneath it for a successful catch.
11. The more frequently a practitioner provides feedback to the learner, the greater the gains in learning.
12. A practitioner should give the learner feedback immediately following a movement/performance attempt.

Answers: The answer to all of the above items is *False*. You may have chosen *True* in some cases because these statements represent common myths regarding motor learning and control. Throughout the textbook, each of these statements appears as a "Common Myth" in the margin, indicating where the concept is discussed in detail. Look for them as you begin your journey through the field of motor learning and control.

Introduction to Motor Learning and Control

1

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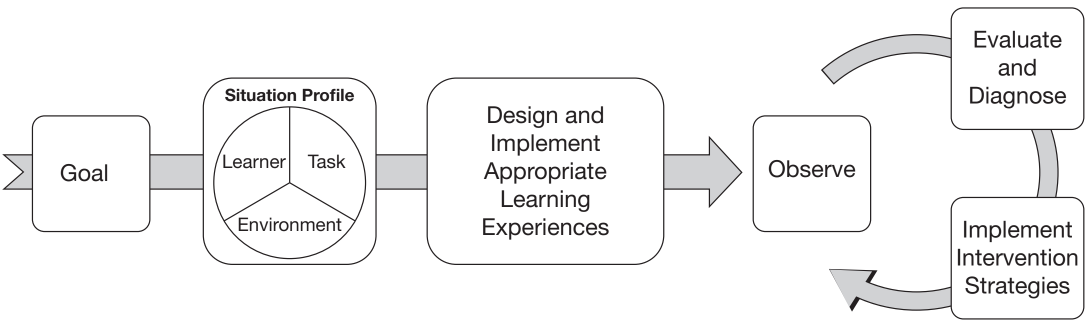
> *I have come to a frightening conclusion. I am the decisive element in the classroom. It is my personal approach that creates the climate. It is my daily mood that makes the weather. As a teacher, I possess the tremendous power to make a child's life miserable or joyous. I can be the tool of torture or an instrument of inspiration. I can humiliate or humor, hurt or heal. In all situations, it is my response that decides if a crisis will be elevated or de-escalated, and a child humanized or dehumanized.*
>
> Haim Ginott, educator

The message of this quotation is clear: the role of instructor—whether in a classroom, playing field, gymnasium, clinic, or other context—is a very powerful one. The climate you create will determine the level of success that your students, patients, clients, or athletes will achieve. Fundamental to creating an effective climate is an understanding of how people learn. *Motor Learning and Control for Practitioners* focuses on the processes that govern movement acquisition and control and provides a foundation for developing effective instructional strategies that facilitate learning and performance.

DESIGNING EFFECTIVE LEARNING EXPERIENCES: AN INTEGRATIVE MODEL

The continuous challenge faced by practitioners is how to best assist learners when introduced to, re-learning, or refining a motor skill; whether to successfully negotiate a sit to stand transfer, intercept a ball at the correct time and location, or improve landing mechanics to reduce the risk of injury and optimize performance. Paramount to the design and implementation of effective learning experiences is the creation of an informed action plan grounded in an understanding of the learning process, the current learning situation, and the potential instructional, practice, and intervention strategies available from which to draw. An integrative model depicting the components of this action plan is illustrated in Figure 1.1.

FIGURE 1.1 Integrative model for facilitating motor skill learning and performance



The first half of the model draws from Schmidt and Wrisberg's (2008) situation-based learning approach and begins with the determination of the intended outcome. Next, a situation profile must be created that considers three elements: the learner, the task, and the environment or context in which the task is performed—critical interacting determinants of movement at any given time (see Figure 1.2). Once the learning situation has been profiled, practitioners can make informed decisions as to how to design and implement the learning experience, the next step in the process. The second half of the model incorporates Knudson's (2013) comprehensive view of qualitative movement diagnosis (QMD). At this point, the practitioner enters a cyclical process that begins with the observation of the learner's performance attempts. Through observations of both specific aspects of the skill's execution (**process assessment**) and the outcome of the performance (**product assessment**), the learner's progress toward goal achievement is evaluated and critical errors identified and prioritized. Intervention strategies for skill refinement are then selected and implemented, which again consider the learner, task, and environment because each element and its reciprocal interaction with the other two are constantly changing. Performance is further observed and the effectiveness of the intervention evaluated. Accordingly, selected intervention strategies are either continued or modified as the learner strives to achieve the intended outcome.

FIGURE 1.2 The interaction of the learner, the task, and the environment in which the task is performed is fundamental to the understanding and facilitation of motor skill acquisition and performance

LEARNER

Does the learner possess the underlying abilities to perform the task?

Is the learner developmentally ready to learn the task?

Has he or she had any past experiences that are relevant to the task?

Is he or she motivated to learn the task?

What individual differences might influence the acquisition of this task?

ENVIRONMENT

In what context will the task be performed?

Is that context predictable or unpredictable?

Is there a time limitation?

TASK

Does the task have a high perceptual component?

Is object manipulation required?

What body movements are required?

Must the task be performed under a variety of conditions, or must the learner be able to replicate the movement pattern consistently and accurately?

As you progress through the upcoming chapters, keep this model in mind. Details and considerations for each step will be revealed. Can you connect them to the Integrative Model?

MOTOR LEARNING, CONTROL, AND PERFORMANCE

As indicated in the previous section, an understanding of the learning process provides the human movement practitioner with foundational knowledge that provides the basis for assessing performance; providing effective instruction; and designing optimal practice, rehabilitation, and training experiences. So how, exactly, do people acquire motor skills? What processes allow the musculoskeletal system to produce intended movements? What variables facilitate or hinder skill acquisition? Questions such as these have led to the evolution of a field of study known as motor learning. **Motor learning** is the study of the processes involved in acquiring and refining motor skills and of variables that promote or inhibit that acquisition. Other questions of interest to motor learning researchers include: How should practice be organized? Where should instruction focus the learner's attention when practicing a new skill? What type and amount of feedback facilitates skill acquisition? A related field of study, **motor control**, focuses on the neural, physical, and behavioral aspects that underlie human movement. Examples of questions that a motor control researcher might ask are: What factors influence postural stability? How does sensory information contribute to movement production and the accuracy of those movements? How are muscular actions coordinated to produce skilled movement? Understanding both motor learning and motor control is necessary for developing a complete understanding of motor skill acquisition.

What Is Learning?

The first question we should ask when we look at how people learn is *What is learning?* Before continuing, complete Exploration Activity 1.1.

When used in reference to motor learning and control, **learning** is defined as a relatively permanent change in a person's capability to execute a motor skill as a result of practice or experience. To know whether you have learned how to juggle as a result of participating in Exploration Activity 1.1, you must determine whether a persistent change in your juggling behavior has occurred.

Part of the problem we face when trying to determine whether a motor skill has been learned is that we can't actually *see* learning, because the underlying or internal processes that result in a relatively permanent change cannot be directly observed. What we can see, however, is performance. **Performance** is the act of executing a skill. Through repeated observations of an individual's performance, we infer whether the individual has learned a skill. These inferences are based on changes that we observe in the individual's performance over time, such as improvements in movement proficiency and consistency. Exercise caution,

explorationACTIVITY 1.1

Learning to Juggle

EQUIPMENT NEEDED

- 2 tennis balls
- Some space to move!

GOAL

The goal of this exercise is to juggle two tennis balls successfully using your non-dominant hand.

PROCEDURE

To start, place both tennis balls in your non-dominant hand. Toss one ball upward. As that ball reaches its peak height, toss the second ball upward, leaving the hand empty to catch the first ball. Continue this pattern, attempting to achieve as many successive catches as possible. Repeat for 10 minutes, recording the number of successful catches you achieve on each trial (from the starting position to the time you drop a ball or miss a catch).

QUESTIONS

1. Assuming that you were eventually able to make two or more catches, could you conclude that you had learned how to juggle two balls with your non-dominant hand? Why or why not?
2. Let's say that in your first 9 minutes of juggling, you spent more time chasing balls than catching them. Up until the 9-minute mark, your record number of catches was two. All of a sudden, in the last minute, you catch six! Does this mean you have learned how to juggle?
3. Based on this juggling experience, can you formulate a definition for learning?
4. What learner, task, and environmental factors affected your performance and learning?

however, to ensure that the inferences are accurate. Numerous learner variables, such as fatigue or anxiety, and task variables, such as problems with equipment, may impair performance but do not necessarily indicate a loss of capability. Alternatively, a learner may perform a given skill at a new level of proficiency during one practice, only to return to the original level at the next practice.

THE NATURE OF MOTOR SKILLS

As we begin our exploration of factors that influence skill acquisition and performance, we must define the term *skill*. That definition depends on the context in which the term is used. The term *skill* may be used to describe the quality of a performance. To identify an individual as *skillful* implies that the person has achieved a high degree of proficiency. LeBron James, for example, is considered a highly skilled basketball player.

The term **motor skill** describes an act or task that satisfies four criteria:

1. It is goal oriented, meaning it is performed in order to achieve some objective.
2. Body and/or limb movements are required to accomplish the goal.
3. Those movements are voluntary. Given this stipulation, reflexive actions, such as the stepping reflex in infants, are not considered skills because they occur involuntarily.
4. Motor skills are developed as a result of practice. In other words, a skill must be learned or relearned.

Crutch walking would be considered a motor skill, as it satisfies these four criteria. It requires voluntary body and/or limb movement to achieve a goal (e.g., move across a room), and it must be learned.

Practitioners should note the distinction between a skill and a sport. Volleyball is a sport. It consists of multiple skills, including the serve, the forearm pass, the overhead pass, and the spike, all of which have different characteristics and impose different demands on the performer.

Skill Classifications

The nature of a skill imposes specific demands on the learner, which practitioners must consider when designing learning experiences. To assist practitioners in understanding the nature of motor skills and the demands they impose, several classification systems or **taxonomies** have been developed that organize motor skills by their common elements. Knowing the relationships among diverse skills can aid the practitioner in planning learning and practice experiences, as well as provide a starting point for performance assessment.

CEREBRALchallenge 1.1

Determine which of the following can be classified as a motor skill. Explain each classification choice.

1. Brushing your teeth
2. Tapping your pencil
3. Solving a word problem
4. Taping a wrist
5. Removing your hand after touching a hot stove
6. Sewing on a button
7. Walking
8. Playing the trumpet
9. Parachute reflex of an infant
10. Performing proprioceptive neuromuscular facilitation (PNF) exercises.

Fine Versus Gross Motor Skills

Frequently used in adapted physical education and motor development is the classification system that distinguishes between fine and gross motor skills. This system is based on the precision of movements and the corresponding size of the musculature required for their successful performance. Skills involving very precise movements, which are accomplished using smaller musculature, are known as **fine motor skills**. These skills tend to be manipulative in nature; examples include sewing on a button, tying a fly (fishing), controlling dental or surgical instruments, entering contact information on a smartphone, or pulling the trigger of a biathlon rifle. Larger muscles are used in the performance of **gross motor skills**, which place less emphasis on precision and are typically the result of multi-limb movements. Examples of these skills, generally known in physical education as fundamental motor skills, include running, hopping, and skipping.

Given that many skills require the combined effort of both large and small muscle groups, a continuum is used for classification. Skills with more large muscle elements are placed closer to the gross end of the continuum, and vice versa. In bowling, for instance, large muscles of the legs propel the body forward in the approach, and the muscles of the shoulder create the arm swing necessary to launch the ball, making these movements predominately gross in nature. At the same time, however, the bowler needs a high degree of fine motor control to manipulate the spin of the ball upon release. In fact, fine motor control has a

FIGURE 1.3

The precise movements required for sewing make it a fine motor skill

FIGURE 1.4

Jumping over a puddle requires larger muscle groups and less precision, making it a gross motor skill

CEREBRALchallenge 1.2

Determine whether each of the following skills would be classified as a fine (F) or a gross (G) motor skill, or has elements of both (B).

1. Signing a check
2. Dribbling a basketball
3. Throwing a discus
4. Walking with crutches
5. Tackling
6. Making a surgical incision
7. Picking up a paper clip
8. Setting a volleyball

significant impact on the extent to which many skills can be performed proficiently (Payne & Isaacs, 2020). Accordingly, the degree of fine motor control displayed during the performance of a skill may be used to assess skill development.

Children tend to achieve gross motor skill proficiency before they develop control over fine motor skills (Eichstaedt & Kalakian, 1993). Developmental readiness must, therefore, be a consideration when designing teaching progressions in which learning tasks become increasingly more difficult. Skills or skill components should be introduced in a sequence moving from gross to fine.

Discrete Versus Serial Versus Continuous Skills

A second taxonomy classifies skills into one of three categories based on the nature of their organization. A **discrete skill** is one whose beginning and end points are clearly defined. Examples are swinging a golf club, moving from sitting to standing, and throwing a horseshoe. When a number of discrete skills are combined into an integrated sequence, such as roping a calf, performing a figure-skating routine, or emptying the flatware bin of a dishwasher, it is classified as a **serial skill**. Finally, **continuous skills** are those whose beginning and end points are either arbitrary or determined by some environmental factor (such as a finish line) rather than by the task itself. Typically, continuous skills are repetitive in nature. They include cycling, working out on an elliptical machine, rowing, propelling a manually powered wheelchair, and tracing a picture.

The nature of a task's organization has implications for practice. Because the movements in continuous skills are highly interdependent, they are typically best practiced as a whole. Serial skills, however, can often be simplified when necessary, by practicing their components separately. The relationship between task organization and whole versus part practice will be discussed in detail in Chapter 9.

CEREBRALchallenge 1.3

Categorize each of the following skills as discrete (D), continuous (C), or serial (S).

1. Triple jump
2. Croquet shot
3. Punting a football
4. Lunges
5. Gymnastics vault
6. Transfer from wheelchair to bed
7. Walking with assistive device
8. Cross-country skiing

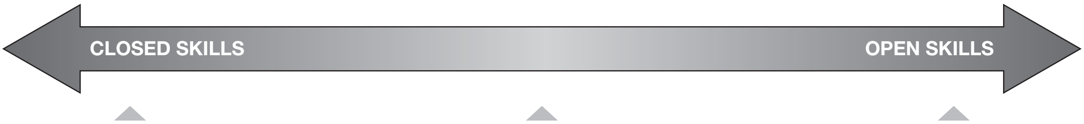
Closed Versus Open Skills

The predictability of the environment in which a skill is performed determines the third classification system. This system is also based on a continuum, as the degree of predictability can vary between low and high. On one end of the continuum are skills performed in stable, predictable environments; these are **closed skills**. With closed skills, the performer controls the performance situation because the object being acted on or the context in which the skill is being performed does not change. For example, in bowling, regardless of how busy the bowling alley is, the pins are stationary and the performer chooses when to initiate the movement. Other examples of closed skills include chopping wood, a free throw, picking up a cup of coffee, zipping up a jacket, and taping an athlete's ankle.

Open skills are at the other end of the continuum, as these are performed in an unpredictable, ever-changing environment. In open skills, the performer will not be aware of what movement type is required until moments before making it (Smith, 2011). Fielding a ground ball is a good example. Once the ball is hit, an infielder receives direction and trajectory information but does not know the exact location where it will bounce. In addition, upon impact or anytime while traveling across the infield, the ball could curve or take a bad hop, forcing players to be ready to make adjustments up to the last moment. Similarly, in mountain biking riders must continually adapt their responses to conform to the trail. Other examples of open skills include pursuing an opponent in field hockey and walking through a crowd after a concert, movie, or sporting event. Figure 1.5 shows the continuum and guiding questions to assist the practitioner in identifying where along that continuum a skill would fall.

The closed/open distinction is an important one for practitioners, as the instructional goals for each differ significantly. For closed skills, consistency is the objective and technique refinement should be emphasized. However, because they are performed in a variety of contexts, some closed skills are known as *closed skills with inter-trial variability*. For these types of skills, while

FIGURE 1.5 Closed–open skill continuum



Reaching for a pen
Bench press

- Type of action needed known ahead of time
- Performer decides when to begin action
- The skill is solely dependent on movement form

Tennis serve
Hitting from a pitching machine

Spotting a gymnast
Blocking a shot in goalball

- Type of action unknown until just before needed
- No control over when to begin the action
- Have to match actions with those of a teammate, an opponent, or other variable(s)

technique development remains important, learners must also be able to adapt that technique according to the situation. For example, bowlers must adjust their performance based on the placement of the pins during any given trial, so they should practice various potential pin combinations. Similarly, putting practice in golf should incorporate a variety of slopes and green conditions, as well as different locations and distances from the hole.

For open skills, where learners must constantly conform their movements to an unstable, unpredictable environment, successful performance depends less on mastering technique and more on the learners' ability to select the appropriate response in a given situation. Consequently, practice should simulate the game or context in which the skill will be performed, with an emphasis on learning to anticipate and adapt to the demands of the ever-changing performance situation.

The closed/open distinction can also assist practitioners in regulating task complexity. For example, throwing a football may be considered either a closed or an open skill, depending on the context. Throwing at a stationary target is considered a closed skill. As other variables are added, such as a moving receiver or a pursuing defense, throwing a football becomes a progressively more open and more complex task. In the early stages of skill acquisition, it is difficult for learners to focus on the execution of the movement while also being aware of aspects of the environment (such as the position of receivers or the movements of defensive players)—traits inherent in open skills. By changing the context of a skill to make it more closed initially, the practitioner can strategically decrease attention demands and simplify the learning process.

Multidimensional Classification System

According to Gentile (2000), one cannot completely understand the demands a task places on a performer by using a single-dimensional system. Instead, Gentile proposed a taxonomy that categorizes skills according to two general characteristics: (1) the context in which they are performed (regulatory conditions) and (2) the action requirements of the skills. Combined, these two dimensions provide insight into the processes involved in skill acquisition.

CEREBRALchallenge 1.4

1. Determine where along the closed–open continuum the following skills fall, by placing the item letters accordingly on the line.

    a. Walking with a cane through a crowded mall
    b. BMX racing
    c. Playing a video game
    d. Guiding a patient through proprioceptive neuromuscular facilitation (PNF) stretching exercises
    e. Hitting a ball from a tee
    f. Hitting a pitched ball
    g. Mowing the lawn
    h. Snowboarding
    i. Balancing on a wobble board
    j. Evasion belt drill shown at www.youtube.com/watch?v=-ohk6XGaQQ&list=TLPQ MTEwNTIwMjCdlZ2wvjP4ag&index=5

2. José has been driving since he was 16. Now, in college, he wants to buy a certain car, but it has a manual transmission. He has never driven a manual stick shift before and has asked if you will teach him. You agree. Rank order the following settings for José's first lesson, with 1 being the best and 3 being the worst. Explain your rankings.

    a. On a rural road
    b. In an empty parking lot
    c. In city traffic

Regulatory Conditions

Skills are not performed in a vacuum. To perform a jump header in soccer, for example, performers must conform their movement to the height, size, speed, and trajectory of the ball, as well as the location of the intended target. For any given skill, therefore, a number of environmental factors exist that specify the movement characteristics necessary for successful performance. These factors are known as **regulatory conditions** (Gentile, 2000) and their determination may be used to differentiate skills. Other factors, like distractions, are considered non-regulatory. While they may be present in the environmental context and may even influence performance, movements do not have to conform to them to achieve the action goal.

CEREBRALchallenge 1.5

1. Determine whether each of the items listed below would be considered as a regulatory (R) or non-regulatory (N) condition for dart throwing:
   a. Height of the dart board
   b. Crowd noise
   c. Distance from the dart board
   d. Sharpness of the dart tip
   e. Score
2. On a separate sheet, identify regulatory conditions for each of the following:
   a. Performing Bosu ball mountain climbers
   b. Hiking along a forest trail
   c. Diving from a springboard
   d. Cross-country skiing
   e. Stepping onto an escalator
   f. Picking up your change from a counter
   g. Dusting the furniture in your house
   h. Retrieving your suitcase from a baggage carousel
3. An occupational therapist instructs a child to string pasta on a cord to improve fine motor control. Determine whether or not this activity has inter-trial variability. Justify your answer.

When examining the environmental context in which a task is performed, one must first determine whether the regulatory conditions are stationary, as in shooting at a stationary target, or in motion, such as in skeet shooting. Notice that this concept parallels that of the open versus closed skill classification, in that the regulatory conditions for closed skills tend to be stationary, whereas those for open skills tend to be in motion. As indicated earlier, when learners must conform to environmentally imposed constraints, they must engage in more complex processes to assess the situation and select appropriate responses.

The next question is whether there is inter-trial response variability—that is, do the regulatory conditions remain fixed or do they change with each performance attempt? A free throw, for example, has low inter-trial variability, because the context in which it is performed does not change from one shot to the next. The basket does not change, the distance from which one shoots remains constant, and defenders do not oppose the shooter. Tail backs, on the other hand, experience a great deal of inter-trial variability; they must change their running pattern each time they receive the ball in order to avoid tackles and gain maximum yardage.

Action Requirements

The other dimension that Gentile (2000) proposed pertains to the action requirements of a skill, specifically with respect to body movement and object manipulation. In this context, body movement refers to whether the performer must change locations (move the body from point A to point B) when performing the skill. Cross-country skiing, performing the high jump, and using an assisted walking device are examples of skills that require the performer to change locations from one place to another (body transport). On the other end of the spectrum are skills that require body stability. Performing push-ups, lifting a coffee mug while seated, executing a golf putt, and playing a drum set all fall into this category. Note that although the body changes locations when, for example, an individual is driving a motorcycle, this action would be categorized as body stability. In this case, the individual is not actually moving the body but the body is instead moving with the motorcycle. Other examples would be getting transported to the top of a ski hill by a rope tow, troll fishing, and doing a city tour on a Segway.

A second determinant of action requirements is object manipulation. Some skills require the performer to manipulate objects or opponents. Knitting, washing dishes, pole vaulting, and wrestling fall into this category. Other skills, such as performing pelvic tilt exercises, the hexagon agility test, and the rhythmic step pattern of the tango, do not require object manipulation.

Application of the Multidimensional Classification System

To use this classification system to understand the demands that a task imposes on a learner, practitioners must ask four questions:

1. Are the regulatory conditions stationary or in motion?
2. Do the regulatory conditions remain fixed (no inter-trial variability), or do they change (inter-trial variability) with each performance attempt?
3. Is the performer required to change locations or maintain body position when performing the task?
4. Does the task require the performer to manipulate an object or opponent?

Once the answer to each question is determined, the skill can be classified into one of 16 resulting categories, as shown in Table 1.1.

For example, in the forearm pass in volleyball, the performer must first track a moving ball, move to a position to intercept it, and then control its deflection to propel it in the desired direction. Consequently, the regulatory conditions

TABLE 1.1 Gentile's multidimensional classification system, with task examples

REGULATORY CONDITIONS	ACTION REQUIREMENTS: Neither body transport nor object manipulation	Object manipulation only	Body transport only	Both body transport and object manipulation
Stationary and fixed	Doing a sit-up 1	Moving a chess piece 2	Climbing a ladder 3	Shot put 4
Stationary and variable	Writing ABCs with foot for ankle rehabilitation 5	"Round the clock" in darts 6	Following a dance pattern that has been placed on the floor 7	With a partner, following a dance pattern that has been placed on the floor 8
In motion and fixed	Floating on a river in an inner tube 9	Quality control inspector retrieving a bottle from a moving conveyor belt in a bottling plant 10	Running down a hill 11	Stepping onto a moving sidewalk when using crutches 12
In motion and variable	Riding in a tube pulled by a speedboat 13	Catching a variety of different sized balls while balancing on one foot 14	Skating on a crowded ice rink 15	A forearm pass in volleyball 16

are moving (open skill) and change from trial to trial, and the performer is required to change locations and manipulate an object. Given this assessment, the forearm pass falls into category 16.

The human movement practitioner may use Gentile's multidimensional classification system in several ways. First, as you move diagonally from the top left cell to the bottom right cell, task complexity increases, with a corresponding increase in the demands placed on the performer. Accordingly, the simplest skill is one where the environment is stationary, involves no inter-trial variability or body transport, and does not require object manipulation. At the other end of the spectrum, the most complex skill is one performed in an environmental context that is in motion, involving high inter-trial variability, and requiring both body transport and object manipulation. To perform such a skill successfully, the performer must be able to scan the environment to identify and process relevant information, decide how to respond, and allocate attentional resources to control body transport and object manipulation concurrently.

Second, by understanding the level of complexity of a skill, the practitioner can better design challenging yet realistic learning experiences. A logical progression that moves from simple to complex ultimately leads to simulation of the actual context in which the skill will be performed. Refer to Figure 1.6 for an example of a simple-to-complex progression for the forearm pass in volleyball.

CEREBRALchallenge 1.6

ASSESSMENT OF REGULATORY CONDITIONS

Using the chart below, assess the regulatory conditions and action requirements of each skill. Based on your assessment, determine into which of the 16 categories in Gentile's multidimensional classification system (Table 1.1) the skill would be classified.

Using the chart below, assess the regulatory conditions and action requirements of each skill. Based on your assessment, determine into which of the 16 categories in Gentile's multidimensional classifi cation system (Table 1.1) the skill would be classifi ed.

SKILL	Regulatory Conditions (environment)		Regulatory Conditions (inter-trial variability)		Body Transport (changing locations)		Object Manipulation		Category Number
	stationary	*in motion*	*fixed*	*change*	*yes*	*no*	*yes*	*no*	
Putting a golf ball	X			X		X	X		6
Propelling a wheelchair through a crowd of people at a concert									
Performing a lunge on a Bosu ball									
Texting on your cell phone									
Short track speed skating									
Wii Fit game shown at www.youtube.com/watch?v=fmHRVjAlt_c									

Designing progressions becomes more challenging, however, when multiple skills or variations of a skill share the same category in the taxonomy. For example, the forearm pass can be used to return the ball over the net, receive a

FIGURE 1.6 Sample simple-to-complex progression for the forearm pass

SKILL: Volleyball Forearm Pass

VARIABLES THAT CAN BE MANIPULATED:

1. Stability of regulatory conditions
2. Inter-trial variability
3. Body transport

Activity	Gentile's Taxonomy
1. Partner tosses the ball at a constant trajectory and location.	1. Regulatory conditions are relatively stable 2. No inter-trial variability 3. No body transport 4. Object manipulation
2. Partner tosses the ball at a constant location but changes the trajectory each time.	1. Regulatory conditions are moving 2. Inter-trial variability 3. No body transport 4. Object manipulation
3. Partner tosses the ball to different locations and with different trajectories but indicates where the ball will go prior to tossing it.	1. Regulatory conditions are relatively stable 2. Inter-trial variability 3. Body transport 4. Object manipulation
4. Partner randomly tosses the ball to different locations and with different trajectories without giving prior notification as to where it is going.	1. Regulatory conditions are moving 2. Inter-trial variability 3. Body transport 4. Object manipulation

serve or opponent's attacking shot, or to place the ball in the air for an offensive attack. While all of these variations would fall into Category 16, ball placement accuracy differs in each, changing the complexity of the task. Similarly, balancing on one leg with your eyes open or closed falls into Category 1, yet the latter is more difficult to perform due to the absence of visual cues. Performing the same task with your hands raised above your head versus out at your side also changes the complexity of the skill due to a shift in the location of the center of gravity, but the skill remains in Category 1. In such cases, practitioners must consider what other task attributes influence the demands the skill places on a performer when sequencing practice activities.

Finally, practitioners may also use Gentile's model to systematically evaluate a learner's movement capabilities and limitations. This evaluation affords a better understanding of the degree of complexity that a learner is able to handle and insight into what performance demands (e.g., scanning the environment, processing information, allocating attention) are problematic. For example, if a learner is no longer able to successfully complete the forearm pass when required to change locations to intercept the ball (Activity #3 in Figure 1.6;

Category 8 classification), the processing demands of body transport and object manipulation combined may be too high. A potential solution might be to have the learner practice changing locations and positioning themselves for a forearm pass without involving the ball. Movement could initially be self-paced and in the same direction each trial (Category 3), progressing to quickly changing locations forward, backward, and side to side where directional information is given in advance (Category 7), and finally to having to move into position without prior notification of direction (Category 15). Once the learner is comfortable with the footwork, Activity #3 in Figure 1.6 would be reintroduced, progressing eventually to Activity #4 where the direction and trajectory of the toss are no longer predictable, simulating game conditions.

CEREBRALchallenge 1.7

Design a simple-to-complex progression that might be used to teach dribbling (basketball) using Gentile's taxonomy.

INDIVIDUAL DIFFERENCES

One challenge facing practitioners is the fact that all learners are unique. Each person's uniqueness is a function of relatively stable and enduring characteristics known as **individual differences**. Factors such as height, body type, sleep deprivation, physiological makeup (e.g., number of fast versus slow twitch fibers), learning styles, type and amount of previous movement experience, motivation, developmental level, cultural background, psychological makeup, attitude, and confidence all affect the rate of and potential for developing skill proficiency. Because of individual differences, teaching strategies will not be equally effective for all learners, and so practitioners must identify the best strategies to employ based on diverse learner needs and qualities.

Motor Abilities

Of interest to human movement practitioners are individual differences in motor abilities. **Abilities** are genetic traits that are prerequisite for skilled performance. Accordingly, the degree to which learners could potentially develop proficiency in a particular motor skill depends on whether they possess the necessary underlying abilities.

Although many different abilities have been identified to date, researchers initially hypothesized that there existed a single general motor ability (Brace, 1927; McCloy, 1934). Behind this notion was the observation that accomplished athletes often picked up new skills quickly and excelled at numerous other skills without much practice. Therefore, it seemed reasonable to surmise that there existed a high correlation between one's level of general ability and one's potential for skill proficiency at a variety of tasks. In other words, if you had inherited a high level of general motor ability, you should be able to achieve a high level of proficiency in all motor skills, from golf to bobsledding to kayaking.

Challenging the existence of a general motor ability, the **specificity hypothesis** proposed that, while individuals may inherit a large number of motor abilities, those abilities are independent of one another (Henry, 1968). In addition, each skill requires a particular set of abilities for successful performance. Consequently, an individual who obtains a high degree of proficiency in archery will not necessarily achieve that same degree of proficiency in wrestling, as these two skills have different underlying ability requirements.

Research examining the strength of interrelationships between motor abilities silenced the debate between proponents of general motor ability and the specificity hypothesis. In general, researchers have found low correlations between an individual's performances of two different tasks (including those that appeared to be closely related), which supported the specificity hypothesis (e.g., Drowatzky & Zucatto, 1967; Henry, 1968; Zelaznik, Spencer, & Doffin, 2000).

RESEARCH NOTES

The importance of eye–hand coordination for a variety of sports and activities cannot be overstated. As a result, a number of companies have created training devices for the enhancement of eye–hand coordination, which they claim can enhance performance across a wide range of tasks. Underlying these claims is the supposition that eye–hand coordination is a general ability. Given the lack of evidence supporting the existence of general abilities, and the current popularity of these devices in the assessment and training of general eye–hand coordination, Ellison and colleagues (2018) investigated the relationships between performances on different tests of eye–hand coordination to evaluate whether it could, in fact, be categorized as a general ability. Eighty-seven volunteers, who were actively involved in sports, completed four eye–hand coordination tests, three involving lab tasks and the wall catch test, a field task. Overall, the correlations between the tasks were weak with the exception of one. In that particular case, the procedures used for the two tests were highly similar. Overall, the generally weak associations found in this study do not support the existence of a general eye–hand coordination ability, but instead are consistent with the specificity hypothesis (Henry, 1968). What does this mean for the practitioner? Because training on general eye–hand coordination training devices is unlikely to transfer to sporting performances, it is not an effective use of practice time. Instead, practitioners should design sport-specific training experiences to enhance competitive/situational performance.

CEREBRALchallenge 1.8

Determine which abilities would be important to become highly proficient in the following:

1. Performing orthopedic surgery
2. Wiring a house (for electricity)
3. Firefighting
4. Decorating a cake

CEREBRALchallenge 1.9

1. Which of the following statements is/are true? Justify your answers.
   a. An individual can have abilities but not be skilled.
   b. An individual can be skilled without ability.
2. Khalilah is strong in control precision, rate control, and finger dexterity but weak in arm–hand steadiness and response orientation. What is her potential for fulfilling her dream of becoming a famous tattoo artist? Fully explain your response.

However, because low correlations were found, rather than no correlation at all, it remained possible that some of the same underlying abilities were required by different tasks. Having recognized this earlier, Fleishman (1962) set out not only to identify underlying motor abilities that were predictive of high skill proficiency levels, but also to create a taxonomy by which skills could be classified.

Categorizing Motor Abilities

Fleishman's taxonomy groups motor abilities in two categories: (1) perceptual motor abilities and (2) physical proficiency abilities, which are identified in Table 1.2, along with an example of a skill for which the ability is elemental. It should be noted that this list is not all-inclusive, nor is it likely that all abilities have yet been identified.

Practical Implications

We all have different abilities that enhance or limit our capacity to become skilled at a particular task. But even if we possess the prerequisite abilities for accomplishing a task, there is no guarantee that we will become skillful. We only have the *potential* to become skillful. Practice and experience play a role in realizing that potential. Consequently, children should be provided with as many varied movement experiences as possible. Those experiences should be

TABLE 1.2 Fleishman's taxonomy of motor abilities

ABILITIES	DEFINITION	ILLUSTRATION
PERCEPTUAL MOTOR ABILITIES		
Control precision	Ability for highly controlled movement adjustments, especially those involving larger muscle groups	Dribbling a soccer ball
Multi-limb coordination	Ability to coordinate numerous limb movements simultaneously	Volleyball spike
Response orientation	Ability to select a response rapidly from a number of alternatives, as in choice reaction time situations	Tail back trying to find an opening
Reaction time	Ability to initiate a rapid response to an unexpected stimulus	Sprint start in swimming
Speed of limb movement	Ability to make gross rapid limb movement without regard for reaction time	Hockey slap shot
Rate control	Ability to make continuous speed and direction adjustments with precision when tracking	Mountain biking
Manual dexterity	Ability to control manipulations of large objects using arms and hands	Water polo
Finger dexterity	Ability to control manipulations of small objects primarily through use of fingers	Texting on a cell phone
Arm–hand steadiness	Ability to make precise arm–hand positioning movements where involvement of strength and speed are minimal	Dentistry
Wrist–finger speed	Ability to move the wrist and fingers rapidly	Blackjack dealing
Aiming	Ability to direct hand movements quickly and accurately at a small object in space	Marksmanship
PHYSICAL PROFICIENCY ABILITIES		
Static strength	Ability to generate maximum force against a weighty external object	Pushing car out of snowbank
Dynamic strength	Muscular endurance or ability to exert force repeatedly	Rock climbing
Explosive strength	Muscular power or ability to create maximum effort by combining force and velocity	Throwing javelin
Trunk strength	Dynamic strength of trunk muscles	Pole vault
Extent flexibility	Ability to move trunk and back muscles through large range of motion	Circus contortionist
Dynamic flexibility	Ability to make repeated, rapid flexing movements	Diving, aerial ski jumping
Gross body coordination	Ability to coordinate numerous movements simultaneously while the body is in motion	Slalom skiing, synchronized swimming
Gross body equilibrium	Ability to maintain balance without visual cues	Tightrope walking while blindfolded
Stamina	Cardiovascular endurance or ability to sustain effort	Climbing Mt. Everest

Fleishman's taxonomy of motor abilities, as summarized in the attached table, from The description and prediction of perceptual motor learning. In R. Glaser (Ed.), *Training research and education* (pp. 137–175), University of Pittsburgh Press. Used with permission.

developmentally appropriate. Learners will modify skills according to their current level of ability.

For example, successful performance of a regulation free throw requires a prerequisite level of strength. A young learner who has not yet developed sufficient strength will modify his or her performance accordingly in an attempt to make a basket. Rather than employing correct technique, the learner may instead execute the free throw using more of a "shot put" type movement in order to generate enough force to project the ball high and far enough. Practitioners should lower the basket to a more suitable height and encourage the learner to employ the correct technique with the nearer target. As learners' physical maturity advances, change the height of the basket accordingly. Note that learners will not progress at the same rate, and that there exists a genetic ceiling for each learner's level of skill regardless of the amount of practice.

FIGURE 1.7

Can future success in a skill be predicted?

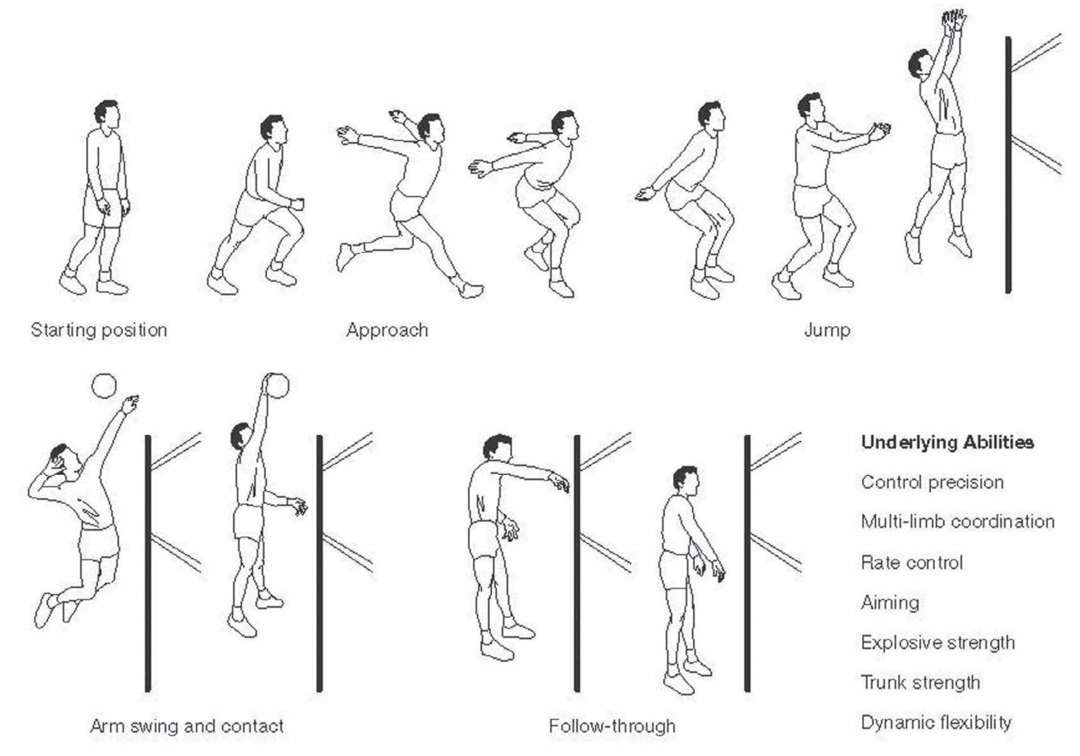
The concept of abilities is also useful for skill classification. Through a method known as **task analysis**, practitioners assess the demands imposed by a skill and the performance context to determine the underlying abilities important for successful performance. Skills can then be grouped accordingly. To perform a task analysis, a skill is first broken down into its key elements or component parts. Once the key components have been identified, the abilities that are necessary to meet their requirements can be more readily determined. By conducting a task analysis, the practitioner can develop a greater understanding of the skill's requirements. Figure 1.8 illustrates a task analysis and subsequent examples of ability prerequisites for a volleyball spike.

If underlying abilities are important to the successful performance of a specific skill, it would stand to reason that an individual who possesses those abilities would be predisposed to achieve a high level of proficiency. Imagine the impact this would have on sports programs, as we could predict future performance simply by screening individuals for certain abilities. In fact, talent identification programs have existed for decades. They screen children and adolescents using a battery of tests constructed to determine the extent to which they possess certain abilities. The test results are then used to select those individuals who appear to have the potential to succeed in a given sport. Other tests screen candidates for

COMMON MYTH

Future success in a specific skill can be easily predicted

FIGURE 1.8 Task analysis of a volleyball spike



WWW

TALENT IDENTIFICATION

Video example of a police physical agility test: www.youtube.com/watch?v=8d5e3Enny98

UK Sport talent identification and development program: https://www.uksport.gov.uk/our-work/talent-id

Canoe slalom talent identification promotion video from Australia: www.youtube.com/watch?v=o6V8fe8R-TE

Listen as Dr. Rob Gray discusses talent identification in his podcast at http://perceptionaction.com/26c/

Read the International Society of Sport Psychology's Position Stand: To Test or Not to Test? The Use of Physical Skill Tests in Talent Detection and in Early Phases of Sport Development at https://www.issponline.org/index.php/publications/position-stands

professions such as firefighting. Visit the websites provided in the margin to view and hear additional examples of agility and talent identification programs.

How successful have these programs been in predicting a person's potential for success in a specific skill? And what can we learn from them to help identify future stars in, for example, T-ball? Results of talent identification programs have been mixed. To understand why, we must consider three limitations of these programs. First, as was indicated earlier, it is likely that not all of the abilities that contribute to skilled performance have been identified. Second, a high level of performance in the early stages of learning does not always correlate to advanced performance later, owing to changes in the requirements of the skill. For example, a child may be an outstanding hitter in T-ball when the ball remains stationary, but the results may be different when he or she moves to the next level, when the ball is pitched. Third, abilities alone cannot predict performance; other individual differences must be considered. Because of differences in reaching physical maturity, for example, players who possess the underlying abilities to excel in a sport but have not yet sufficiently matured may get cut from a team. A great example is Michael Jordan, who did not make the varsity high school basketball team when he was a sophomore, yet went on to become one of the greatest basketball players ever to play the game!

While it is apparent that individual differences must be taken into account for the development of a successful talent identification program, the impact of these

CEREBRALchallenge 1.10

1. For a skill of your choice, perform a task analysis to determine its component parts and the underlying abilities required to achieve a high degree of proficiency.
2. Think about activities that you tend to participate in versus activities you tend to avoid. Speculate as to why you make these choices by comparing the underlying abilities needed to accomplish these activities.

RESEARCH NOTES

The NFL Combine is an annual event where college football players are invited to perform physical and mental tests in front of coaches, general managers, and scouts. How a player performs at the event can influence his future in the league. Kuzmits and Adams (2008) wanted to see whether combine test results actually predicted performance success for players drafted at three different offensive positions (quarterback, running back, and wide receiver). Data from the NFL Combine, specifically the results of all physical exercises and the Wonderlic Cognitive Ability-Personnel Test, were collected for a six-year period. These data were examined to determine their association with performance, which included draft order, three years of both salary received and games played, as well as position-specific data. Results revealed that none of the combine exercises were correlated with success for quarterbacks and wide receivers. For the running backs, only 10-, 20-, and 40-yard sprint times were correlated with NFL performance. In other words, this study calls into question the majority of the combine exercises examined, as they do not appear to predict NFL success. The authors suggest that the league re-evaluate the usefulness of the combine in its current format and consider its restructuring to be more predictive of professional level playing success.

differences on learning should be the practitioner's primary concern. Practitioners must remember that all learners are unique in what they bring to the learning environment. Consequently, a particular teaching strategy will not work for everyone. Practitioners should develop a large repertoire of instructional strategies so they can accommodate the needs of all learners. Furthermore, practitioners should take the time to get to know each learner. What types of past experiences do the learners have? What motivates them? What situations lead to increased anxiety? Because of the influence of individual differences, this will be time well spent.

PUTTING IT INTO PRACTICE

Learning Situation: Rehabilitation of an Ankle Sprain

Darren is a 31-year-old man who works for the forest service as a forestry technician. He spends the majority of his time in the outdoors and his job is physically demanding. On any given day he could be doing trail maintenance, installing drainage systems, cutting trees, stacking wood, preparing an area for revegetation, or a variety of other duties. One of the ways he stays physically active is by playing basketball in the local rec. league. Recently, he went up for a rebound and, upon landing, stepped on an opponent's foot and rolled his right ankle. He was diagnosed with a grade 2 ankle sprain that has sidelined him not only from basketball but also any field work for his job. He hates working at a desk so wants to get back to the field as soon as possible.

Darren has been working on regaining his range of motion and restoring muscle strength, and has progressed from non-weight bearing to partial and now to full-weight bearing. His balance and proprioception have been adversely affected by the sprain and need to be retrained.

Test Your Knowledge

Below are examples of balance tasks from which the therapist can draw. Place them in the appropriate cell of Gentile's taxonomy. Compare your answer with the sample response provided at www.routledge.com/cw/coker.

1. Single leg stance
2. Single leg squat with dumbbell curl
3. Walking a straight line heel to toe
4. Step up to balance position with leg lift and dumbbell press
5. Single leg ball wall toss and catch
6. Squat on Bosu ball
7. Lunge onto Bosu ball with front foot
8. Single leg stance and forward reach to variable illuminated targets (e.g., therapist will turn laser off and on in various locations on the wall)

CEREBRALchallenge 1.11

Refer back to the integrative model for facilitating motor skill learning and performance. List the elements introduced in this chapter that should be taken into consideration as you develop a situation profile.

9. Step up onto Bosu ball with leg lift
10. Walking lunge and weighted ball diagonal chop (alternating sides)
11. Single leg stance reaching forward, to the side, and backwards to targets with non-support leg
12. Sharpened or tandem Romberg stance
13. Single leg stance exchanging a ball from hand to hand above the head
14. Single leg hop and hold

A LOOK AHEAD

Human movement is a complex phenomenon that is a function of the interaction of three elements: the learner, the task, and the environment in which the task is performed. Because this concept is foundational to the development of optimal learning experiences, practitioners must develop a working knowledge of this interaction in order to help learners realize their potential. Further development of this working knowledge requires an understanding of the underlying processes that govern movement execution and control. The following chapter begins this discussion, focusing on the factors that influence movement preparation.

FOCUS POINTS

After reading this chapter, you should know:

- The interaction of the learner, the task, and the environment in which the task is performed is fundamental to understanding and facilitating motor skill acquisition and performance.
- The field of motor learning examines the processes and variables that influence the acquisition and refinement of motor skills, while the field of motor control focuses on the neural, physical, and behavioral aspects that underlie movement.
- Learning and performance are not synonymous. Learning is a relatively permanent change in the capability to execute a motor skill as a result of practice or experience, while performance is simply the act of executing a skill.
- Motor skills are categorized by several classification systems:
  - The gross–fine motor skills classification is based on the precision of the movement.

- Skills may be classified as discrete, serial, or continuous according to the nature of their movement organization.
- The open–closed motor skills continuum is based on the predictability of the environment.
- Gentile's multidimensional classification system categorizes skills according to the context in which they are performed and the action requirements of the skill.

- All teaching strategies will not be equally effective for all learners, owing to individual differences.
- Each of us possesses different levels of abilities, which are genetically determined traits that enhance or limit our potential to become skilled at a particular task.
- By conducting a task analysis, one can identify the underlying abilities important to the successful performance of a specific skill.
- Talent identification programs have shown mixed results when individuals are screened, using a battery of tests, to predict future success based on their possession of a high level of certain abilities.

lab

To complete the lab for this chapter, visit www.routledge.com/cw/coker and select **Lab 1, Abilities**.

REVIEW QUESTIONS

1. Compare and contrast motor learning and motor control.
2. Define learning. What is the relationship between learning and performance?
3. What four criteria must a task meet if it is to be classified as a skill?
4. How are skills and abilities different?
5. Explain why most of the classification systems discussed here involve a continuum.
6. Briefly summarize each classification system.
7. Explain how Gentile's taxonomy differs from the other classification types. Why is this significant?
8. Explain the controversy over general versus specific motor abilities.
9. Explain why predictions of future performance success are not always accurate.
10. What is the relevance of the interaction of the learner, the task, and the environment in human movement?

Understanding Movement Preparation

2

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After 90 grueling minutes of regulation and two sudden-victory overtime periods of 10 minutes, the score remained tied. The conference championship would be decided by penalty kicks. Jennifer was fourth in the order. She watched anxiously as the opposing team's first shooter easily found the back of the net. Fortunately, her teammate promptly tied the score again, answering back by placing the ball in the lower right corner. Both goalkeepers then made successive saves leaving the game still tied after three rounds. When the fourth shooter on the opposing team kicked a straight shot towards the left corner, Jennifer held her breath. No good! The goalie got her hand on it! Now it was up to her. She approached the ball, waited until the last possible moment to reveal her intention, then drilled it off her left foot. The goalie responded, but she was too late!

Penalty kicks present a critical time of decision making for the goalkeeper and penalty kick taker alike. Faced with the task of blocking a penalty kick, for example, the goalkeeper must assess the situation to determine both where the ball will go and what movement will intercept it. The task is further complicated by a time constraint, as she has a fraction of a second to make these decisions and then organize and execute the motor response before the ball reaches the goal line. In fact, a goalkeeper needs to decide which direction she will dive before the kicker's foot even makes contact with the ball, and it could be argued that this decision is merely a guess. So what differentiates a game-winning save from a failed attempt? Simply guessing correctly? Or are there strategies a goalkeeper can use to increase the odds of making the save? Understanding movement preparation will help answer these questions.

THEORETICAL APPROACHES TO MOVEMENT PREPARATION

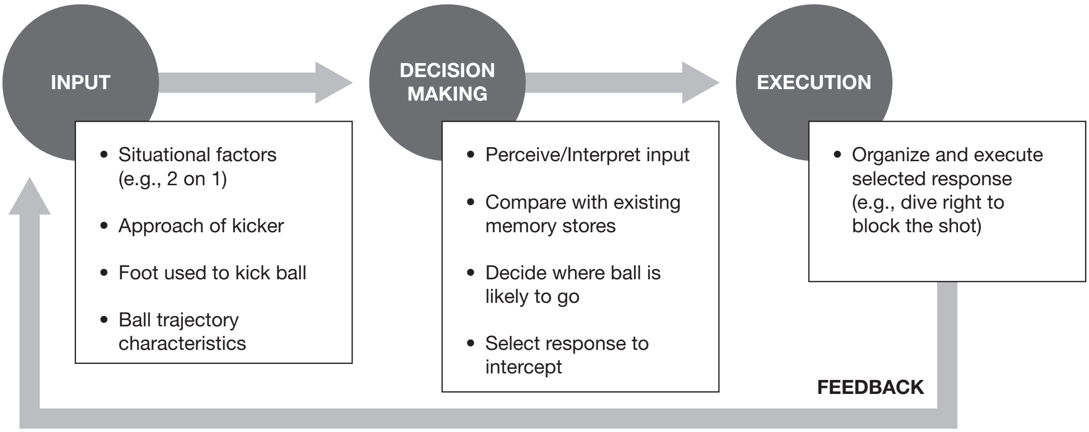
Our senses are constantly bombarded with information from both internal and external sources (sensory information or input). Before any of that information can potentially be used to assist a learner in selecting an appropriate response for a given situation, it must first be actively processed. The recognition and interpretation of sensory stimuli—or, said another way, the process by which meaning is attached to sensory information—is known as **perception**. Two approaches explaining the nature of perception are prevalent today.

Information Processing Model

The first explanation, a product of cognitive psychology, maintains that perceptual processes lead to the creation of some form of symbolic representation of environmental and task information. This information traverses a series of mental processes, including a comparison with existing memory stores, and results in a decision as to which action, if any, is needed in response to the situation. Because there is a "need for sensory input to be processed or elaborated to provide the perceiver a meaningful description of the world," perception in this paradigm is considered to be indirect (Burton, 1987, p. 258).

This view of perception has generally been associated with a model for movement preparation known as **information processing**, shown in Figure 2.1. In this model, a performer, such as a goalkeeper, will receive a wealth of information or input. In the instance of a goalkeeper, this input includes the opponent's foot as she kicks the ball; characteristics of the ball itself, including velocity, trajectory, spin, and direction; the score; the feel of sweat on the goal keeper's skin; the sight and sound of the crowd; the sound of a plane flying overhead; the smell and color of the grass; memories of prior successes or failures in similar situations; and an assessment of the area of the net to be covered. When assessing the demands of the task, the goalkeeper will find some of this information relevant or useful, for example, the velocity, trajectory, and direction of the ball. Other information, such as the plane flying overhead, is not relevant and should be ignored. By focusing on pertinent **stimuli**, the goalkeeper will receive information that is crucial to producing a response that will intercept the shot. Once the information has been gathered, it is transformed into afferent or sensory nerve signals and conducted to the brain; there, during the decision-making process, it is integrated or compared to similar past experiences that are stored in long-term memory. Based on this comparison, a decision is made and a response is selected (dive right, catch, jump), organized, and executed through efferent (motor nerve) commands. This paradigm further suggests that as the movement is initiated, information regarding its progress is fed back to the performer. This information, referred to as **intrinsic feedback**, may be used to make adjustments to the movement if there is a discrepancy in what was intended and what is actually occurring (time permitting). It also enables the performer to evaluate the outcome of the response.

FIGURE 2.1 Information processing model



CEREBRALchallenge 2.1

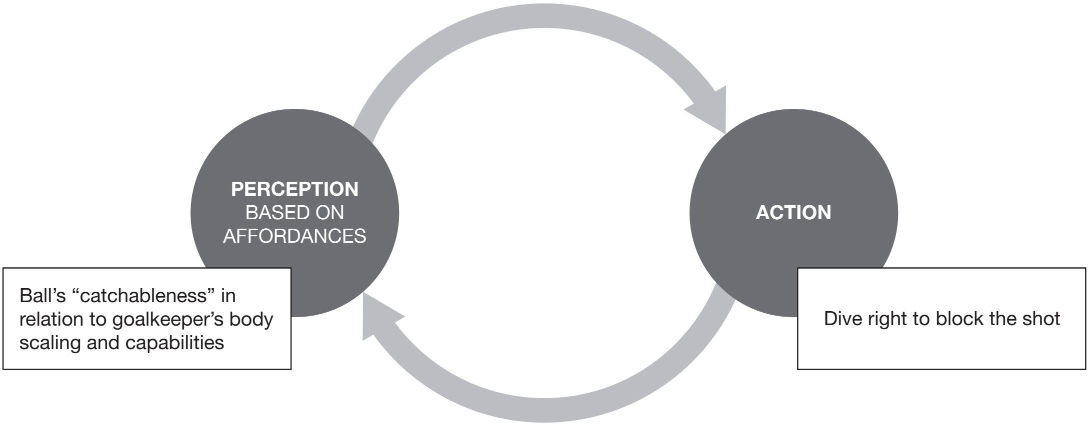
1. Generate a list of stimuli, both relevant and irrelevant, that may be available to a soccer goalkeeper when facing a one-on-one situation with an attacker who has beat all of the defenders (break away).
2. In addition to deciding what response to make, the performer must determine details regarding that response, such as when to initiate it. Generate a list of possible responses and response details for the above situation.
3. For a skill and situation of your choice, repeat items 1 and 2.
4. Speculate as to the differences in processing demands for open versus closed skills. Give examples to support your response.

Ecological Approach

The second prevailing approach regarding perception suggests that the environment and task are perceived or interpreted directly in terms of affordances. **Affordances** are the action possibilities of the environment and task in relation to the perceiver's own capabilities (Gibson, 1979). In other words, the environment or task is perceived in terms of the actions the perceiver can potentially exert on it. Because of individual differences, several learners could be faced with the same situation and perceive entirely different affordances. For example, while walking through a store, the affordances perceived by an adult will be very different from those of a small child because of their differences in height. The actions afforded by a cell phone in the hands of a college student differ from the actions a toddler might perceive. Typically, college students use a cell phone to talk with or text their friends, whereas toddlers might use it for hitting, banging, or chewing. Since affordances are directly perceived, this perspective, known as the **ecological approach** to perception, argues against the need to refer to stored representations; it views the relationship between perception and action as reciprocal, where action is influenced by perception and perception is influenced by action (see Figure 2.2).

Under this paradigm, the goalkeeper searches for opportunities for action or, said another way, attunes to the affordances presented during the penalty kick situation. Rather than making her decision to catch the ball or dive to block the shot based on a consideration of the ball's characteristics and her memory stores of similar experiences, as suggested by the indirect approach to perception, the goalkeeper directly perceives the ball in terms of its "catchableness" in relation to her own body scaling and capabilities (Burton, 1987). If the goalkeeper believes she is quick enough to jump in front of the ball and make the catch, this action will be selected. If she doesn't think she can make it, or she doubts her catching ability, she may choose to block it instead. It should be noted that affordances, or opportunities for action, can fluctuate "as a result of gradual

FIGURE 2.2 The ecological approach to perception suggests a direct relationship between perception and action



changes in the player's action capabilities or changes in playing conditions. A ball that was catchable at the beginning of the game may be uncatchable at some later point due to fatigue" (Fajen, Riley, & Turvey, 2009, p. 80). In addition, opportunities for action can materialize and then vanish in an instant. A gap that affords passing in an 800 m race can open up in one moment and disappear the next, preventing a racer's advances (Fajen et al., 2009).

Designing practice to help learners attune to affordances to facilitate skill acquisition and performance will be discussed later in the book. For now, check out the resources listed in the margin to gain a better understanding of affordances and how they influence movement decisions, and then try Exploration Activity 2.1.

WWW

AFFORDANCES

General explanation:
(a) www.youtube.com/watch?v=81MgPOlq-Uw
(b) www.youtube.com/watch?v=cUH700QUz64

Application to coaching: www.youtube.com/watch?v=qejaHPi9UfE

Affordances for movement: https://www.bettermovement.org/blog/2019/affordances-for-movement

PREPARING A RESPONSE

Scientists continue to debate and explore the merits of these theoretical approaches regarding movement preparation, in addition to the possible integration of the two. But regardless of the paradigm used to explain the internal processes that occur, research has clearly shown that a brief time lag occurs between the moment when a stimulus is presented and the initiation of a response. This time interval, known as **reaction time** (**RT**), is a measure of the time needed to prepare a response. To test your reaction time, try Exploration Activity 2.2.

Reaction time is not constant; it depends on the processing demands imposed by a given situation. As those demands increase, reaction time also increases, indicating the need for more time to prepare a response. The result is a delay that can be detrimental, for example, for avoiding a collision, catching an item that has fallen from the kitchen counter, or defending an opponent from driving or cutting to the hoop in basketball. Understanding the variables that cause such delays is, therefore, paramount for developing strategies to reduce them and, in some cases, eliminate them during the performance of open skills. Of equal interest to coaches and athletes is how to cause delays in an opponent's response time in order to gain an advantage.

explorationACTIVITY 2.1

Affordances

EQUIPMENT NEEDED

- Sliding glass door
- Backpack stuffed with clothes
- 3 friends

PROCEDURE

Task A. Fully open the sliding glass door. Ask each of your friends to walk through it. (Participants may choose the manner in which they go through the door—e.g., they may turn to the side—provided they do not change the width of the opening.) Reduce the opening by 4 inches and repeat the procedure. Continue reducing the opening and repeating the procedure until all three friends have indicated that they cannot go through the door. Record your observations for each friend on each trial.

Task B. Repeat Task A, but have each friend wear the backpack on each trial. Record your observations.

QUESTION

Explain your observations in terms of affordances.

explorationACTIVITY 2.2

Simple Reaction Time

Test your simple reaction time using the following resources:

- https://humanbenchmark.com/tests/reactiontime
- www.exploratorium.edu/baseball/reactiontime.html

Or download a reaction time app to your smartphone or tablet. Examples:

- Android: Reaction Time
- iPhone/iPad: Reaction Test Pro

RESEARCH NOTES

In team sports, like rugby, ball carriers must identify emerging spaces and select an appropriate action to gain a competitive advantage. To see how open spaces influence the perception of action possibilities and ultimately which action a ball carrier chooses, Correia, Araújo, Cummins, et al. (2012) created authentic virtual 3 versus 3 rugby simulations where they manipulated the positions of defenders, creating different defensive gap locations. Four groups defined by level of rugby expertise, ranging from no experience to professional players, were tasked with moving the ball beyond the line of defenders while avoiding contact. To accomplish the task, they could choose to run with the ball, make a short pass, or make a long pass. Four different gap conditions were presented six times for 24 trials. Gap 1 opened in the participant's own running channel. Gap 2 unfolded in their first teammate's running channel. Gap 3 was located in their second teammate's running channel. Finally, the fourth condition presented no gap opening and all defenders ran in a straight line toward the attackers. Gap locations significantly influenced the action carried out, with the run most often performed in Gap 1, the short pass in Gap 2, and the long pass in Gap 3. No particular action occurred significantly more often than any other for the no gap condition. The authors concluded that different emergent gaps in the defensive line afforded different action possibilities. This finding is consistent with the notion that the capacity to perceive affordances improves with expertise.

Factors Influencing Reaction Time

As indicated, a number of variables influences the length of time needed for information processing and the preparation of a corresponding response. The following section introduces those factors and provides practical suggestions for manipulating them.

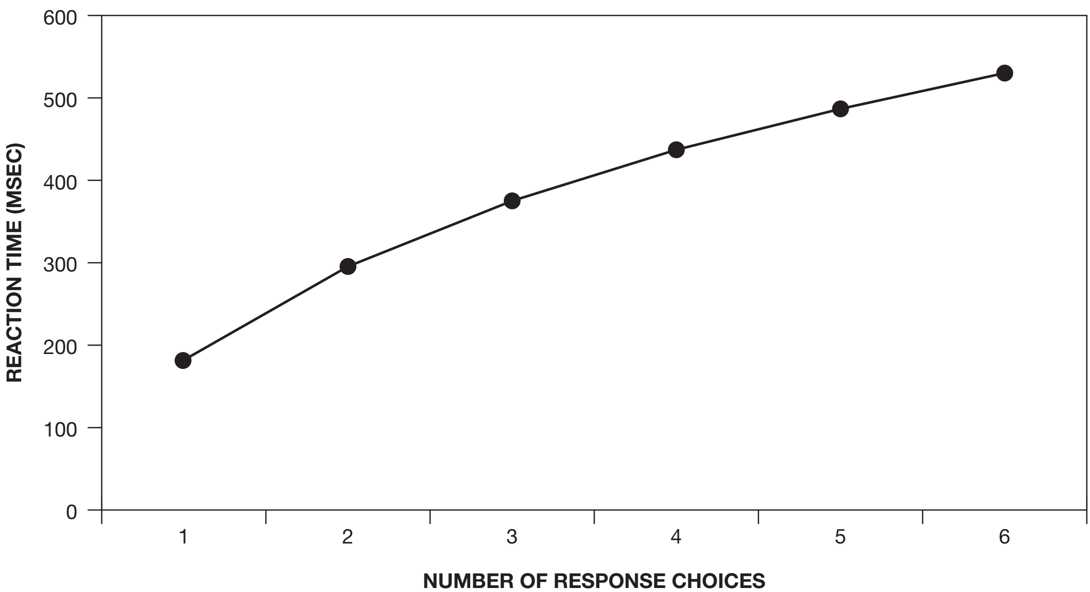
Number of Response Choices

A sprint start has one stimulus—the firing of the gun—and one response choice—exploding out of the blocks. Because a sprinter has only one choice in this situation, uncertainty as to how to respond is essentially eliminated. In contrast, a shortstop faces a number of response choices, as he or she may have to catch a fly ball or a line drive or field a ground ball that's been hit directly at, to the right, or to the left of the fielding position. Similarly, in a penalty kick, a number of possible shots can be taken, leading to a corresponding increase in the number of the response choices available to the goalkeeper. Because of the uncertainty of the impending hit or kick, the shortstop or goalie needs additional processing time to prepare a response. This increase in processing demands is reflected by an increase in RT. Complete Exploration Activity 2.3 to see how the number of response choices influences RT.

The relationship between the number of choices and the time to prepare a response was found to be so stable that it has become known as **Hick's Law** (Hick, 1952), named for its discoverer. Hick's Law states that **choice RT**, the reaction time resulting from a situation that involves a choice as to how to respond, is logarithmically related to the number of response choice alternatives. This relationship is illustrated in Figure 2.3.

Notice that in a situation requiring one definitive response, such as the sprint start discussed earlier, RT is approximately 190 ms; in the situation faced by the shortstop, however, RT may be two to three times that long. This increase in RT has important implications when the movement situation demands a quick and accurate response.

FIGURE 2.3 Predicted relationship between number of stimulus–response choices and reaction time (Hick's Law)

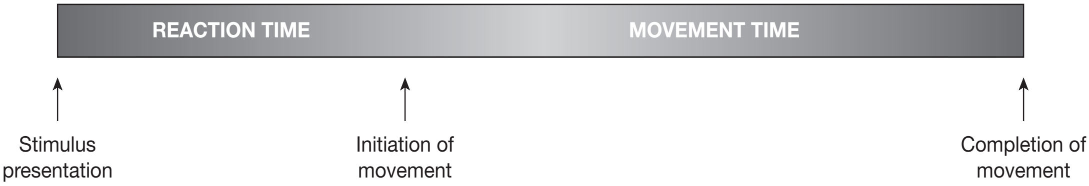


explorationACTIVITY 2.3

Choice Reaction Time

To examine the influence of the number of response choices on reaction time, try the experiment at www.psytoolkit.org/lessons/simple_choice_rts.html/.

FIGURE 2.4 Components of response time



Response time is measured from the moment when a stimulus is presented to when a response is completed, and it includes both reaction and movement time, as shown in Figure 2.4. **Movement time** (**MT**) is the interval between the initiation of the movement and its completion. Both RT and MT must be considered when analyzing a goalkeeper's task of intercepting the ball. For example, suppose that, because of ball placement and speed, a goalkeeper has approximately 360 ms—from the time the ball leaves the kicker's foot until the time the ball crosses the plane of the goal—to decide how to respond and execute that movement (RT + MT). Assuming that she has only two response choices, according to Hick's Law, RT will be approximately 300 ms. This leaves only 60 ms to execute the response. When examined from this perspective, it is not surprising that blocking a shot on goal in soccer is such a difficult task. Watch the ESPN's Sport Science video on penalty kicks at www.dailymotion.com/video/x2obk7b to learn more.

Controlling Levels of Uncertainty

Since, according to Hick's Law, increased uncertainty leads to delayed or even inaccurate responses, practitioners should be aware of strategies that can increase or reduce this uncertainty to facilitate learning and performance. The goal of many competitive situations is to gain an advantage over an opponent. By having a large repertoire of proficient serves, plays, moves, pitches, and the like, the player can increase an opponent's uncertainty of which response will be required and diminish that opponent's ability to respond quickly and accurately. In other competitive tasks, such as those involving open skills, successful performance depends on quick decision making. When a quarterback is executing an option play, trying to read all of the stimuli in order to choose the best option can be overwhelming and, as illustrated by Hick's Law, time consuming. As a result, coaches teach their quarterbacks to look systematically for key defensive characteristics in order to reduce the number of choice alternatives. In play, the quarterback assesses the potential success of the first option. If that option looks good, he takes it; if not, he looks for the second option, and so on. Emergency medical personnel employ this same strategy when they arrive at the scene of an accident. Using the ABC mnemonic (airway, breathing, and circulation), they systematically assess the situation, reducing their decision-making time.

CEREBRALchallenge 2.2

Explain why a racquetball player who can perform five different serves proficiently has an advantage over an opponent who has only two.

The technique of reducing uncertainty by systematically reducing the number of possible response alternatives may be used to facilitate skill learning. When teaching the forearm pass in volleyball, instructors often organize practice so that learners work in pairs. In each pair, one person tosses the ball and the other passes it back. At first, the balls are tossed directly to the learner to eliminate the need to make a choice. Once the learner has developed some proficiency, the tosses may be directed to the right, the left, in front of, or behind the learner, forcing her to move into the correct position and perform the skill. The first step of a normal progression for this drill is for the tosser to tell the passer the direction in which the toss will be made. Because the learner knows in advance where the ball will go, the number of response alternatives is reduced, which reduces the processing demands of the task. The next step is to eliminate the pre-toss information, forcing the passer to be prepared for any of the four possible response alternatives.

CEREBRALchallenge 2.3

1. The goal of some "shooting" video games is to shoot the bad characters but not the good characters. The challenge is that the characters literally jump out of nowhere and the player must quickly decide whether they are "good" or "bad." If you were playing such a video game, what strategies might you use to decrease uncertainty and response time and increase accuracy?
2. What might you suggest to police officers who face this same situation?
3. According to Passos et al. (2008), "Most team-game coaches will agree that a competitive game is a source of unpredictability and uncertainty for all players. A major question faced by all coaches is: How can we reduce the uncertainty inevitably faced by players in all performance contexts" (p. 126). For a skill of your choice, develop strategies that might be used to either increase or decrease uncertainty, depending on your objective.

Anticipation

When the performer is given advance information about what event will occur as well as when it will occur, movement preparation is optimized and response delays are reduced. Although situations exist in which performers are told in