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MOTOR LEARNING AND CONTROL FOR PRACTITIONERS

SIXTH EDITION

Cheryl A. Coker

ROUTLEDGE


Motor Learning and Control for Practitioners

With an array of critical and engaging pedagogical features, the sixth edition of *Motor Learning and Control for Practitioners* continues to offer 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.

This revised edition takes a closer look at the ecological dynamics theory and how it informs practitioners' use of the Constraints-Led Approach as a pedagogical framework for designing practice experiences that facilitate 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, a test bank, lecture slides, and an instructors' manual that includes sample responses to the cerebral challenges.

As a complete resource for teaching an evidence-informed approach to practical motor learning, this is an essential text for undergraduate and post-graduate students, and practitioners 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. She has taught in the fields of physical education, exercise science, and coaching, and most recently in the physical therapy program at Plymouth State University, bringing a broad and interdisciplinary perspective to her work. 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 Research Fellow of the Society of Health and Physical Educators and a Fellow of the North American Society of Health, Physical Education, Recreation, Sport and Dance Professionals. Coker lives in New Hampshire and enjoys outdoor activities, exploring, and travelling.

“Within my 21 years of teaching in higher education and my experience in the area of physical education and athletic coaching pedagogy, I have never found a more in-depth textbook for teaching in the field of motor learning.”

Dr. George Walker, *Cumberland University, USA*

Motor Learning and Control for Practitioners

Sixth Edition

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*, Sixth 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). Chapter 2 develops readers' understanding of movement preparation, emphasizing perception and factors affecting decision-making, which is further explored in Chapter 3 through the role of attention. Chapter 4 then examines the theoretical constructs underlying coordination and control, followed by Chapter 5, which considers movement from a neurological perspective.

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 novice to expert, 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 foundational considerations for effective instruction and practice design including transfer, environmental design principles, Challenge Point Framework, and OPTIMAL theory. Instructional strategies—through both direct instruction and the Constraints-Led Approach—are then examined in Chapter 8. Next, Chapter 9 begins the discussion of practice design by examining approaches for adjusting task demands to manage difficulty, along with psychological strategies to enhance learning and performance. Factors that influence practice design are further explored in Chapter 10 which focuses on practice organization and scheduling. 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, two real-life scenarios are presented in the epilogue to test readers' ability to apply what they have learned.

NEW TO THIS EDITION

This text continues to balance conceptual and practical material, with each chapter updated to reflect recent research and contemporary practice. Substantial revisions have been made throughout to integrate Ecological Dynamics, addressing both its theoretical foundations and practical application. Chapter 4 now provides balanced coverage of traditional and contemporary theories, with particular attention to presenting Ecological Dynamics in clear and accessible terms so its complexity does not overwhelm readers. Chapter 5 includes new material on neuroplasticity from both an Information Processing and Ecological Dynamics perspective. Chapter 6 introduces Newell's framework for skill acquisition,

and Chapter 7 now incorporates environmental design principles. Chapter 8 features an expanded section on non-linear pedagogy and the constraints-led approach, including specific guidelines for implementation. Additional updates related to ecological dynamics include emphasizing simplification rather than decomposition for managing task difficulty, revising applications of variable and interleaved practice, and adding a fourth role of feedback—its use as an instructional constraint. Other updates include revised pretest questions, expanded coverage of proprioception in Chapter 5, and a restructured Chapter 7 emphasizing foundational concepts such as representative design and managing task difficulty. The epilogue also adds new questions and answers reflecting contemporary practice. Throughout, the writing has been refined for clarity and consistency with support from digital editing tools. This edition also offers students 17 lab experiences, which can be accessed at www.routledge.com/cw/coker. Every chapter includes at least one lab, and many of the lab activities can be used for class demonstrations and discussions in addition to data collection. 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 for Exploration Activities that can be converted to additional or 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:** Information Processing and Ecological Dynamics are explored in a balanced and integrated manner throughout the book.
- **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

- Labs use typical classroom and everyday items and enable students to explore key motor learning concepts and translate chapter content into practice either through systematic data collection or exploratory demonstrations.
- 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

Curiosity is key to learning, and it is the curiosity of others that makes this book possible. I have simply gathered and organized the insights, questions, and discoveries of practitioners and researchers whose willingness to ask *why* and explore deeper, continues to drive this field forward. I am grateful to all of you for challenging assumptions, raising new questions, and inspiring the ongoing search for understanding.

I am especially thankful to my students, whose curiosity constantly challenges me to think more critically and teach more clearly, and to my colleagues and mentors, whose ideas, feedback, and conversations have shaped my thinking over the years. I am also indebted to the reviewers whose careful suggestions strengthened this work, and to the editorial, production, and technical teams at Routledge who have contributed to this project, with special thanks to David Varley and Megan Smith for their guidance and support.

Finally, to my partner, family and friends—thank you for keeping me grounded, helping me live a balanced life, and for reminding me that the journey is the reward.

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. The only way to master a skill is to practice the exact same movement repeatedly.
6. All learners are motivated to learn the skills presented to them.
7. Experts are always the most effective instructors.
8. A demonstration must be performed correctly for the observer to learn the movement effectively.
9. Learners cannot succeed unless they are given explicit instructions on how to perform a movement.
10. Practice makes perfect.
11. To simplify learning a complex skill, it should be broken down and practiced in smaller segments.
12. Learning is best achieved when you practice a single skill before moving to another.
13. When teaching a youngster how to catch, you should toss the ball with a high arc in order to give them enough time to follow it and get underneath it for a successful catch.
14. The more frequently a practitioner provides feedback to the learner, the greater the gains in learning.
15. 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, CONTROL, AND PERFORMANCE

How, exactly, do people learn 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**. Specifically, 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? How can different task constraints be used to enhance performance in different contexts? 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 determine whether you have learned how to juggle as a result of participating in Exploration Activity 1.1, you must establish whether a persistent change in your juggling behavior has occurred.

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?

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. Caution must be used 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.

LEARN: INSTRUCTIONAL FRAMEWORK

The continuous challenge faced by practitioners is how to best design practice, rehabilitation, and training experiences that lead to a relatively permanent change in performance; 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. A good starting point to address this challenge is an overview of the instructional process which is illustrated in Figure 1.1. The acronym LEARN has been used to describe this framework in the hopes that it will remind the practitioner that each step is informed by a working knowledge of the motor learning concepts that will be discussed throughout this book.

The instructional process begins with the identification of the learning objective. In other words, what skill or aspect of performance will be introduced and/or practiced and what is the intended learning goal? Next, the characteristics of the task, the individual learner, and the environment or context in which the task is performed must be evaluated as each factor interacts with one another, influencing how a learner approaches and performs a skill (Figure 1.2). This dynamic interplay informs the design and implementation of appropriate learning activities, as the purposeful manipulation of one or more factors can create optimal learning conditions for skill development and adaptation. Consequently, a situational profile involving these elements should be created, and learning activities designed accordingly. The remaining components of the framework incorporate Knudson's (2013) comprehensive view of qualitative movement diagnosis. At this point, the practitioner enters a cyclical process that begins with

FIGURE 1.1 LEARN Instructional Framework

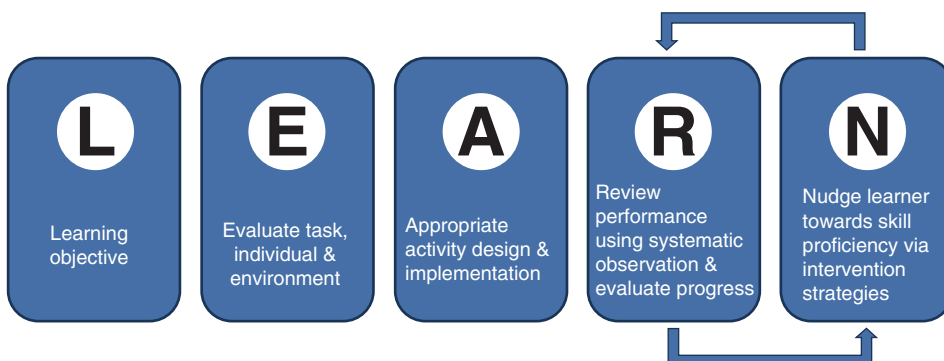
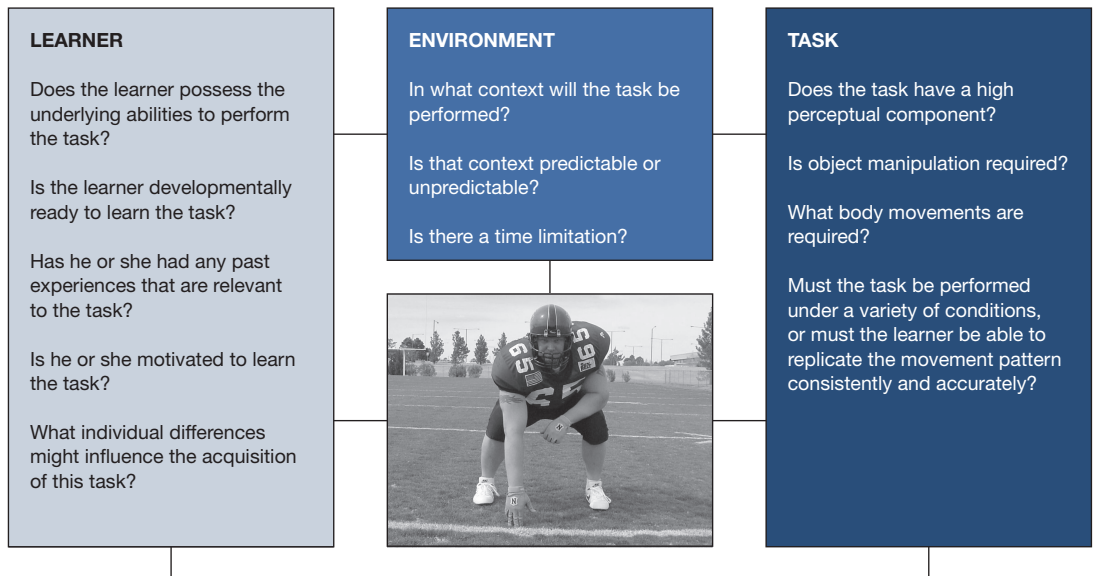


FIGURE 1.2

Evaluate the characteristics of the learner, the environment, and the task to create a situation profile



reviewing the learner's performance attempt(s). Through systematic 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 the target goal is evaluated and critical errors identified and prioritized. Intervention strategies that nudge the learner towards skill proficiency are then selected and implemented, which again consider the individual 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.

As we move through the book, details and considerations for each stage of the framework will be revealed and practical implications discussed. We will begin by examining various properties and classifications of motor skills and how they guide practitioner decision-making.

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 whereby technique can

be adapted according to the performance context presented. Caitlin Clark, for example, is considered a highly skilled basketball player as she is able to quickly analyse game situations, make strategic choices, and adapt her performance to gain a competitive edge.

A **motor skill**, on the other hand, 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.

The distinction between a skill and a sport should also be noted. Volleyball is a sport. It consists of multiple skills, including the serve, the forearm pass, the overhead pass, and the spike. Each skill within a sport must be assessed individually, as each has unique characteristics and places different demands on the performer.

Evaluating Skill Attributes

Several classification systems or **taxonomies** have been developed that categorize skills based on shared characteristics. These classification systems help to systematically evaluate the demands a skill imposes on a performer providing a starting point for performance assessment and informing the design of more tailored approaches to skill development.

CEREBRALchallenge 1.1

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

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

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. Fundamental motor skills including running, hopping, and skipping are examples.

Given that many skills require the combined effort of both large and small muscle groups, a continuum is used for their classification. Skills with more large muscle movements 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 significant impact on the extent to which many skills can

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

be performed proficiently (Payne and 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 and 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 way a task is organized affects how it should be practiced. For instance, because the movements in continuous skills are closely interrelated, practicing the entire movement sequence is typically more effective than isolating individual parts. Serial skills, however, can 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.

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

CEREBRALchallenge 1.3

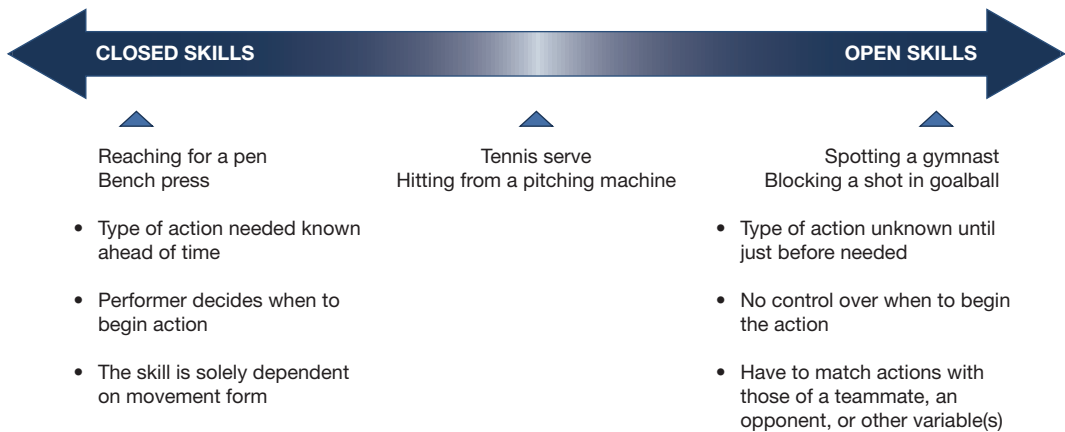
Categorize each of the following skills as discrete (D), continuous (C), or serial (S).

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

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, in some cases, closed skills are performed in a variety of contexts where the conditions or task requirements can change from one attempt to another. For these types of closed skills, known as closed skills with inter-trial variability, while 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.

FIGURE 1.5 Closed–open skill continuum


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. Therefore, practice should replicate the game or context where the skill will be used, focusing on learning to anticipate and adjust to the demands of dynamic performance situations.

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 be more closed initially, limiting (but not necessarily eliminating) environmental factors to which the learner must respond, 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 place 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 <https://www.youtube.com/watch?v=0rgNv4xTT7E&list=TLPQMDQwNjJwMjUNint2E3M7KA&index=2>
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) as they directly influence or regulate how a motor skill is performed. Other factors, like distractions, may also be present in the environmental context and may even influence performance, but because movements do not have to conform to them to achieve the action goal, they are considered non-regulatory. It is important to note that when determining the regulatory and non-regulatory conditions presented by a task,

the determination is task specific and should not consider the characteristics of the performer's movements.

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. 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 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 or in motion. Regulatory conditions are considered stationary when the conditions in the environment remain constant during the task, providing a stable and predictable environment for movement. Performing a yoga pose would be an example. When dribbling a soccer ball downfield, however, players must constantly adjust their foot movements and adapt their speed and direction in response to the ball's movement to keep the ball close, avoid defenders, and make strategic moves. In this case, the regulatory conditions (the ball's position and the actions of opponents) are continuously changing, requiring the player to make real-time decisions and adjustments. Notice that this concept parallels that of the open versus closed skill classification, in that the regulatory conditions for closed skills are stationary, whereas those for open skills are in motion and require performers to engage in more complex processes to interpret situations and respond accordingly.

The next consideration is whether the conditions of the task vary from one trial to the next, that is, does the skill have inter-trial variability? 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. In disc golf, on the other hand, variations in course layout such as hills, trees, and obstacles, can differently influence each throw. When elements change between attempts or trials, the skill is considered more difficult as the ability to adapt becomes critical for successful performance.

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 transporting one's body during skill performance is generally considered more difficult as greater multisystem integration is typically required.

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. The manipulation of objects adds another layer of skill complexity as the performer is required to interact with and adjust for their varying physical properties.

Application of the Multidimensional Classification System

By determining a skill's properties according to both environmental context and action requirements, a deeper understanding of the demands a task imposes on a learner can be realized. This determination can be made by first asking the following four questions:

1. Are the regulatory conditions stationary or in motion? (Remember, regulatory conditions refer to characteristics of the environmental context in which a skill is performed and not to characteristics of the performer's movements).
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?

Next, the skill is classified, according to the responses, into one of 16 resulting categories, as shown in Table 1.1. For example, in the forearm pass in volleyball,

TABLE

1.1

Gentile's multidimensional classification system with task examples

		ACTION REQUIREMENTS			
		Neither body transport nor object manipulation	Object manipulation only	Body transport only	Both body transport and object manipulation
REGULATORY CONDITIONS	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

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 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.

Gentile's multidimensional classification system offers several uses to the practitioner. First, as one moves 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.

SKILL	Regulatory Conditions (environment)		Regulatory Conditions (inter-trial variability)		Body Transport (changing locations)		Object Manipulation		Category Number
	<i>stationary</i>	<i>in motion</i>	<i>fixed</i>	<i>change</i>	<i>yes</i>	<i>no</i>	<i>yes</i>	<i>no</i>	
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 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 can 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 can 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;

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.	<ol style="list-style-type: none"> 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.	<ol style="list-style-type: none"> 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.	<ol style="list-style-type: none"> 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.	<ol style="list-style-type: none"> 1. Regulatory conditions are moving 2. Inter-trial variability 3. Body transport 4. Object manipulation

Category 8 classification), the processing demands of body transport and level of 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 but catching the ball rather than passing it. Movement could initially be in the same direction each trial, progressing to quickly changing locations forward, backward, and side to side where directional information is given in advance, and finally to having to move into position without prior notification of direction. Once the learner is comfortable with the footwork, Activity #3 in Figure 1.6 would be reintroduced, now requiring the learner to pass rather than catch the ball progressing eventually to Activity #4 where the direction and trajectory of the toss are no longer predictable, simulating game conditions.

CEREBRALchallenge 1.7

Select one of the following and design a simple to complex progression using Gentile's taxonomy:

1. A partner play progression for pickleball
2. Helping a patient relearn reaching and grasping following a stroke

INDIVIDUAL DIFFERENCES

One challenge facing practitioners is the fact that all learners are unique. Each person's uniqueness is a function of a wide range of traits known as **individual differences**. Factors such as height, body type, physiological makeup (e.g., number of fast versus slow twitch fibers), type and amount of previous movement experience, motivation, developmental level, cultural background, psychological makeup, attitude, and confidence all affect the potential for and rate of developing skill proficiency. Given that considerable variations exist, teaching strategies will not be equally effective for all learners. By recognizing individual characteristics as specified by step 2 of the LEARN instructional process, practitioners can tailor their approach and create a more effective and personalized learning environment (Anderson and Williams, 2022).

Motor Abilities

One aspect of individual differences that continues to be of interest to human movement practitioners are individual differences in motor abilities (Anderson et al., 2021). 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 assume 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 and Zucatto, 1967; Henry, 1968; Zelaznik et al., 2000). 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.

RESEARCH NOTES

The importance of eye–hand coordination for a variety of sports and activities cannot be overstated. As a result, several 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

continued

RESEARCH NOTES—*continued*

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

1. Determine which abilities would be important to become highly proficient in the following:
 - a. Performing orthopedic surgery
 - b. Wiring a house (for electricity)
 - c. Firefighting
 - d. Decorating a cake
2. 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.
3. 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.

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.

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.

Practical Implications

Identifying the underlying abilities essential for successful skill performance enables practitioners to gain a clearer understanding of the physical and cognitive demands associated with a given task. For example, performing a volleyball spike demands a combination of abilities including control precision, multi-limb coordination, rate control, aiming, explosive strength, trunk strength, and dynamic flexibility (Figure 1.7). By recognizing these specific requirements, practitioners can develop more effective and targeted training approaches to support skill development.

Practitioners should also understand that while individuals may possess the genetic prerequisites identified for a given skill, this alone does not guarantee proficiency. Genetics offer potential—but realizing that potential requires practice and experience. As such, children should be encouraged to participate in a wide range of movement activities to explore and develop their capabilities. At the same time, it would be a mistake to assume that individuals lacking certain prerequisite abilities cannot learn a skill. Although they can improve with practice, their potential to reach high levels of proficiency may be limited by a genetic ceiling, regardless of how much they train.

Talent Identification

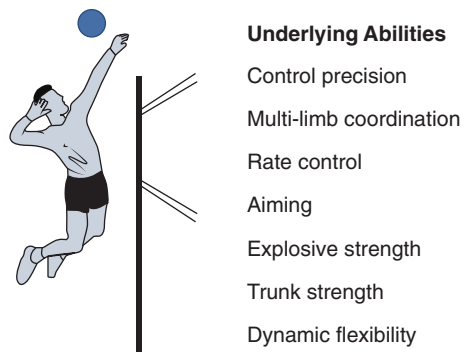
If underlying abilities are important to the successful performance of a specific skill, it would stand to reason that an individual who possesses those abilities would be predisposed to achieve a high level of proficiency. Imagine the impact this would have on sports programs, as we could predict future 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. Visit the websites provided in the margin to learn more about 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 star athletes? Results of talent identification programs have been mixed, and limitations of such programs have been identified (Baker et al., 2017). First, as was indicated earlier, it is likely that not all the abilities that contribute

COMMON MYTH

Future success in a specific skill can be easily predicted

FIGURE 1.7



Underlying abilities of a volleyball spike.

FIGURE 1.8



Can future success in a skill be predicted?

WWW

TALENT IDENTIFICATION

Visit the Australian Sports Commission Olympic Talent Search page at <https://www.ausport.gov.au/talent/olympic>

Learn about England Athletics Youth Talent Programme: <https://www.englandathletics.org/team-england/talent-pathway/youth-talent-programme/>

Listen as Dr. Rob Gray discusses talent identification and selection in his podcast at <https://perceptionaction.com/197/>

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://issponline.org/wp-content/uploads/To_Test_or_Not_To_Test.pdf

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 considered for the development of a successful talent identification program, the impact of these 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.