AN INSTRUCTOR'S MANUAL FOR PRAXIS II EXAM PREPARATION IN THE THREE SUB-AREAS OF MOTOR BEHAVIOR: MOTOR DEVELOPMENT, MOTOR CONTROL, AND MOTOR LEARNING

James Ashburn Reid

A dissertation submitted in

partial fulfillment of the requirements for the

degree of Doctor of Arts in the College of Education and Behavioral Science,

Department of Health, Physical Education, Recreation, and Safety

Middle Tennessee State University

December 2001

UMI Number: 3030578

UMI

UMI Microform 3030578

Bell & Howell Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

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James Ashburn Reid

Graduate Advisory Committee:

Jon L. MacBeth

Major Professor

Martha H. Whaley

Committee Member

Jan Hayes

Committee Member

Martha H. Whaley

Head of the Department of Health, Physical Education, Recreation, and Safety

Donald L. Curry

Dean of the Graduate School

Abstract

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Motor behavior is the area of study in physical education that investigates the principles of human movement behavior. Motor behavior can be subdivided into three related areas: motor development, motor control, and motor learning. The knowledge from the three sub-areas serves as a foundation for college undergraduate and graduate students in physical education, early childhood education, coaching, and sports medicine. Unfortunately, many college motor behavior courses and textbooks are specialized in only one or two of the sub-areas. Thus, many college students graduate with a deficiency of fundamental knowledge from one or two of the sub-areas. In addition, an abundance of content from all three sub-areas of motor behavior is covered on the Praxis II exam, the subject assessment for beginning teachers. Many prospective teachers fail the Praxis II exam because of their motor behavior knowledge deficiency.

The purpose of this manual is to serve as a guide and an outline for college instructors who teach motor behavior courses. This manual is a synthesis of the main motor development, motor control, and motor learning content that is covered on the Praxis II exams in health and physical education, physical education, and early childhood education. This manual will aid college instructors in obtaining an understanding of the relevant motor behavior information covered on the Praxis II, be useful to college or university departments who offer Praxis tutoring or seminars, and assist students in preparation for the Praxis II exam.

ACKNOWLEDGEMENTS

I would like to thank my mother, Judy, for the love, support, and encouragement she has given me. This project would not have been possible without her. I would also like to thank my wife, Sandy, for her patience, understanding, and assistance through the many months of sacrifice. Thanks go to my graduate committee for their guidance through the entire dissertation process. Thanks go to my major professor, Dr. Jon L. MacBeth, for helping to originate the idea for this project and for all of his invaluable ideas with organization. Thanks go to Molly Whaley, Chair of the Department of Health, Physical Education, Recreation, and Safety, for all of her support throughout this process. Thanks go to Dr. Jan Hayes from the Department of Higher Education for her excellent suggestions and insight. Thanks go to my typist, Nan, for her superior help and assistance in completing this project. Thanks also go to Jennifer for meeting my requirements with the drawings.

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CHAPTER 1

Introduction

The study of human movement is an integral part of physical education. Human movement consists of many specialized areas of study that are often required courses for college physical education majors. Kinesiology is the study of human movement from an anatomical perspective of art and science. Biomechanics involves the application of mechanical principles of movement, and exercise physiology is the study of the functioning of the human body during exercise. Sports psychology is the study of psychological, social, and emotional aspects of individual performance in athletics and physical activity. In addition, motor behavior is usually a required course in physical education, and its emphasis is on the investigation of the principles of human movement behavior (Payne and Isaacs, 1999). In recent years, motor behavior has become one of the most important areas of study in physical education.

Motor behavior can be subdivided into three related areas: motor development motor control, and motor learning. Study in any of these three areas is considered motor behavior research. However, because each begins with the term "motor," there can be confusion when trying to distinguish between the three areas. The three motor areas are, in fact, interdisciplinary, and their research often overlaps. Specialists in one area often have a secondary interest in one of the other sub-areas. Each motor area can be defined and characterized to its unique realm of focus.

The motor development area is the study of the biological changes in human movement across the lifespan, the processes that underlie these changes, and the factors that affect them (Payne and Isaacs, 1999). Motor development researchers examine how humans grow, develop, and mature neurologically, physically, physiologically, and perceptually. The "lifespan perspective" is a central theme in the motor development literature, meaning that development is examined from conception to death. Motor development has become a requirement of the college curriculum for a majority of the physical education and early childhood education majors in many states.

The second area, motor control, is defined as the study of the neural, physical, and behavioral aspects of movement (Schmidt, 1999). Of particular concern in the study of motor control is an understanding of the functioning of the nervous system and how it relates to movement. The term "neurophysiology" is often used to describe motor control research. In addition to examining the functional mechanisms of the central and peripheral nervous systems, motor control researchers are interested in topics such as information processing, attention, memory, and reaction time (Gabbard, 2000). Motor control is occasionally integrated into a college motor learning course.

The third area, motor learning, is the study of the processes involved in attaining and perfecting motor skills. According to Schmidt (1991), "motor skills" are movements which depend on experience or practice to be performed. Therefore, motor learning researchers are interested in how types of practice, training, or environments affect the learning of human movement skills. For example, specific research has been performed to examine the effects of various types of mental practice and visualization techniques on performance (Shumway-Cook and Woollacott, 1995). Results from this type of research can be very practical and applied directly by coaches, physical educators, athletes, and others.

Significance of the Study

Motor behavior courses serve as a foundation for college undergraduate and graduate students in many areas of specialization involving human movement. A need exists for professionals in physical education, early childhood education, coaching, and sports medicine to obtain a comprehensive knowledge of how humans develop, control, and learn motor skills. Most of the current textbooks are specialized in only one or two of the sub-areas. Thus, college instructors must often acquire multiple resources and texts for their motor behavior classes. The author has been unable to discover any textbooks that cover the fundamental content of all three sub-areas of motor behavior. This manual should provide the central knowledge and ideas currently presented in the motor development, motor control, and motor learning literature, as they relate to the study of human movement in physical education.

An abundance of motor behavior content from all three sub-areas is covered on the Praxis II exam, the subject assessment for beginning teachers. The emphasis of the information in this manual is on suggested motor behavior content areas covered on the Praxis II exams of health and physical education, physical education, and early childhood education. This information is provided by the Educational Testing Service, the organization responsible for developing the Praxis exams. This manual will aid college instructors in obtaining an understanding of the relevant motor behavior information included on the Praxis II, which covers all three sub-areas. The manual will also be useful to college and university departments who offer Praxis tutoring or seminars. This will assist students in preparation for the Praxis II exam.

Purpose of the Study

The purpose of this manual is to create a guide and an outline for college instructors who teach courses in motor behavior. Course titles differ from school to school, and this has added some confusion. Motor Learning, Lifelong Motor Development, Motor Learning and Development, Motor Behavior and Learning, Motor Control and Learning, and Motor Skills are all course titles that are used in colleges and universities. Many of these courses are specialized in only one or two of the three motor behavior sub-areas and may not include content covered by the Praxis II exam. This manual, a synthesis of the current specialized work of motor development, motor control, and motor learning, may be used as a basic text and study guide. This manual provides future professionals in health and physical education and early childhood education with an overview of the three sub-areas of motor behavior. In addition, the manual will help college instructors to better prepare students for motor behavior content covered on the Praxis II exam.

Limitations

1) Information in this manual is limited to general, undergraduate-level motor behavior content.

2) This manual will in no way attempt to include all theories, ideas, approaches, and terminology central to the study of motor behavior. The information provided in the manual gives a limited overview.

DEFINITIONS OF TERMS

Educational Testing Service: a professional organization that provides tests and other services for states to use as part of their teacher certification process. Educational Testing Service, (2001).

Motor Behavior: the sub-discipline of physical education with an emphasis on the investigation of the principles of human movement. Payne and Isaacs, (1999).

Motor Control: the study of the neural, physical, and behavioral aspects of movement. Schmidt, (1999).

Motor Development: the study of the biological changes in human movement across the lifespan, the processes that underlie these changes, and the factors that affect them. Payne and Isaacs, (1999).

Motor Learning: the study of the processes involved in attaining and perfecting motor skills. Schmidt, (1991).

Motor Skill: a movement which depends on experience or practice to be performed. Schmidt, (1991).

Praxis I: an academic assessment designed to measure general academic skills of college students. Educational Testing Service, (2001).

Praxis II: a subject assessment designed to measure a teaching candidate's knowledge of the subject in which certification is desired. Educational Testing Service, (2001).

Praxis Series: a program developed by the Educational Testing Service to provide tests and other services to states for use as a part of the teacher certification process. Educational Testing Service, (2001).

CHAPTER 2

Review of Related Literature

Introduction

The focus of this review is the historical examination of the motor behavior literature. The origin and evolution of the study of motor behavior is presented, as well as the contributions of the major researchers. This review addresses how these contributions have affected the development of the central concepts, theories, and ideas of the field today. In addition, there is a discussion of the Praxis II subject assessment for beginning teachers and the related motor behavior information that is covered on the health and physical education, physical education, and early childhood education subject tests.

This literature review is divided into five parts. The first part includes a history of motor behavior as a field of study. The second part examines the establishment of the sub-area of motor development, and the third part addresses the historical development of motor control theories and concepts. Part four reviews the history of motor learning research and ideas. The fifth part describes the Praxis II assessments for beginning health and physical education, physical education, and early childhood education teachers. The related motor behavior content that is covered on each of the exams is included.

The History of Motor Behavior as a Field of Study

The study of motor behavior evolved from two major fields of research: a) neurophysiology and b) psychology. For a century, people in these two fields conducted research, but the fields remained separate. Neurophysiologists studied the functioning of the neural mechanisms involved in movement but rarely made reference to motor skills. Psychologists often examined complex, fine motor skills without referring to the neural processes involved. In the 1970s, the fields of neurophysiology and psychology would come together in the study of human movement (Schmidt, 1999).

The earliest studies of motor skills were performed in the early nineteenth century by astronomer Bessel. He became interested in discovering why his colleagues varied in their abilities to record transit times of moving stars, as an image moved across a telescope. Bessel attempted to investigate why some could estimate the movement time of an image, by adjusting a telescope more quickly and accurately than others (Schmidt, 1999). Excluding the early studies by Bessel, the history of motor behavior research is usually categorized into four distinct periods beginning in the late 19th century. These periods are as follows: a) 1890 – 1927, b) 1928 – 1944, c) 1945 – 1966, and d) 1967 – present.

1890 - 1927

The period of 1890 – 1927 was an early period of definition and exploration in motor behavior research. In the late 19th century, researchers began investigating the role of vision in performing manual target tasks. Bryan and Harter (1899) researched the learning of telegraphy and the Morse code, and they proposed some early principles of motor learning. Also in 1899, Woodworth identified some of the fundamental principles of rapid limb movements. This was one of the first systematic approaches leading to the understanding of motor skills. Other notable motor skill researchers at the turn of the century included Book, Leuba, and Hollingsworth. By 1903, numerous studies dealing with motor activity had appeared in various journals sponsored by the American

Psychological Association. One of the earliest motor behavior studies of athletes also occurred during this period. In 1914, Cummins studied the relationship between attention and tapping speed of a small group of basketball players (Sage, 1984). Most of these early studies had roots in experimental psychology, and the data were often unobservable and subjective.

Study of the nervous system paralleled the early motor behavior research, but the two fields of neurophysiology and psychology remained separate. In 1870, Fritsch and Hitzig discovered that the brain is electrically excitable. This led to the invention of electrophysiological recording techniques. In the early 20th century, Sir Charles Sherrington made influential discoveries in the area of motor control. Sherrington was one of the first to classify limb reflexes, and he introduced the idea that voluntary movements resulted from these early involuntary movements. He also introduced the notion of "reciprocal innervation," meaning that as one muscle group contracts, the opposing muscle group relaxes. Sherrington also studied the role of kinesthetic receptors with movement, and he was the first to use the term, "proprioception" (Gallistel, 1980).

<u>1928 – 1944</u>

The second period in the history of motor behavior research was 1928 – 1944. This era was marked by an increase in sophistication of experimentation and the emergence of several new theories. There began to be a shift toward a focus on more systematic and objective motor behavior research. Many studies were geared at industrial settings, with the goal of making movements of workers more efficient. Time and motion studies were performed in the 1930s by researchers who were interested in analyzing assembly line movements. As further interest proliferated in studying movement efficiency in industry, physical educators began to develop early learning theories of athletic movements. Researchers such as Bayley and Espenschade investigated growth and maturation in relation to motor performance. These studies led to the creation of the sub-area of motor development (Payne and Isaacs, 1999).

Neurophysiology remained as a separate research field during this period. The neural studies were done with very simple movements and the neurological processes were usually the main focus of the research. When the movements were examined, very little detail concerning speed, accuracy, or movement patterns was reported. One exception to this trend was the research of Soviet scientist N.A. Bernstein, whose research in the 1930s and 1940s integrated behavioral notions and neurophysiology with the study of locomotion (Bernstein, 1967). However, Bernstein's work was not recognized by United States and English researchers, until his papers were translated in the late 1960s.

1945 – 1966

The third period of motor behavior research was 1945 – 1966, and it was characterized by a proliferation of research and publication. One of the demands of the World War II era was to select the most skilled subjects for pilot training and operators of specialized equipment. Arthur Melton developed the United States Army Air Force's Psycho-Motor Training Program, a series of tests based on perceptual-motor research. The program, however, had little success in selecting proficient pilots. Researchers began to realize that pilot skill training, rather than selection, was the answer. This led to more study on the teaching and learning of motor skills. The United States government began to fund this type of research, and more psychologists moved toward studying motor behavior (Schmidt, 1999).

During the post-war period, motor behavior research was influenced by new learning theories. Hull (1943) developed the general learning theory, which addressed how fatigue and recovery during practice affects the learning of motor skills. Another important concept was developed by Craik (1948). He proposed the idea that information processing of the brain works like a computer, and movements are the human output. Paul Fitts was one of many who studied the concept of behavioral information processing. In 1954, he developed what is known today as Fitts' Law, a human performance law specifying the movement time for an aiming action, when the distance to move and the target size are known (Fitts, 1967). In the 1950s, an abundance of motor behavior research was published in Research Quarterly, and Robert and Carol Ammons created Perceptual and Motor Skills, which published motor research (Schmidt, 1999).

In the 1960s, research in motor behavior by psychologists declined due to decreased federal support and increased interest in other areas of human behavior. In fact, in 1966, motor behavior psychologists gathered at Tulane University for an "academic funeral." Researchers read "last rites" to the study of motor behavior and vowed to move on to new interests in the field of psychology (Schmidt, 1999).

1967 - present

The fourth period of motor behavior research, 1967 – present, has seen a shift from a task-oriented to a process-oriented emphasis in research. Early motor behavior researchers often paid little attention to the underlying processes involved in human movement. However, this era has seen the two areas of behavioral psychology and neurophysiology come together in researching motor behavior. The process-oriented approach concentrates on the underlying neural and cognitive processes that contribute to motor development, control, and learning. In addition, physical educators have taken a leading role in conducting motor behavior research (Sage, 1984).

Motor research survived the 1960s thanks in large part to the study of a physical educator, Franklin M. Henry. Henry worked at the University of California at Berkeley and is considered today as the father of motor behavior research in physical education. He studied gross motor skills representative of those in sport and athletics. Henry had a background in experimental psychology, and he often made his own apparatuses for laboratory tasks. Some of the specific topics of interest to Henry included individual differences, types of practice scheduling, performance curves, and fatigue and rest. Disciples of Henry became leading researchers in the 1970s and succeeding decades (Schmidt, 1991).

The field of motor behavior grew quickly in the late 1960s and 1970s, and physical educators took a leading role in research. New journals such as the Journal of Motor Behavior and the Journal of Human Movement Studies appeared. The first motor behavior textbook was written by Cratty (1964), and formal motor behavior university courses came into existence. Motor learning became a standard subject for teacher preparation in physical education, and by the early 1970s, it was considered one of the primary sub-fields of physical education. Also, a merger of the neural control and behavioral scientists began in the 1970s. This merger has led to the identification of motor development and motor control as specialized areas (Seidentop, 1994).

During the 1970s, more physical education researchers began to show an interest in the underlying processes of motor learning and control. Motor learning research was traditionally oriented around topics such as practice scheduling, feedback, and motivation. However, more researchers began to show an interest in studying the underlying processes involved in the control of movement. Researchers focused more on the interaction of the perceptual modalities and the nervous system, with the muscular system to produce skilled movement. Researchers extended the traditional boundaries of behavioral psychology to neurophysiology. This movement led to the identification of motor control as a motor behavior sub-area. Today, much of the motor control research is interrelated and overlaps with motor learning research (Seidentop, 1994).

The sub-area of motor development also evolved in the last part of the 20th century. Historically, motor development was a descriptive field of study that focused on the growth and developmental changes from birth through adolescence. One of the more recent trends in motor development research has been to study human motor development across the lifespan. Another recent influence has been the dynamic systems perspective. This is the view that many bodily systems, not solely the nervous system, are in constant interaction and adjustment to create movement. Like motor control and learning researchers, motor development researchers are now interested in the processes that underlie movement (Payne and Isaacs, 1999).

In the past two decades, an abundance of brain research with important implications for movement and learning has occurred. In 1997, researchers at the University of California at Irvine discovered that exercise triggers the release of a brain substance that enhances the ability of neurons to communicate with each other. In a 1991 study performed at Scripps College in Claremont, California, researchers demonstrated that exercise improves reaction time, memory, and thought processes. Also, chronic stress has been shown to cause the release of harmful chemicals that kill neurons in the memory areas of the brain. Since exercise has been shown to reduce stress, many researchers now contend that physical activity is one of the best ways to stimulate the brain and learning. In addition, evidence exists that the cerebellum is involved in the learning of almost all physical skills. These and other findings have led to studies which have demonstrated a strong link between physical activity and academic performance (Jensen, 1998).

Today, motor development, motor control, and motor learning are distinct subject areas within the physical education sciences. Many teacher-education programs now require at least one course in either motor development or motor learning, while motor control is occasionally covered in a motor learning course. In addition, early childhood education curricula often include a motor development course. In graduate schools, motor development, motor control, and motor learning have emerged as separate areas of specialization, especially at the doctorate level (Seidentop, 1994).

The History of Motor Development Research

The field of motor development may have evolved from "baby biographers" in the late 19th and early 20th centuries. Included in this group was Charles Darwin. These biographers described physical growth changes at different stages of infant maturation. Clark and Whitall (1989) described the period of 1787–1928 as the "precursor period" in the history of the study of motor development. This period is followed by the "maturational period" (1928 – 1946), the "normative/descriptive period" (1946 – 1970), and the "process-oriented period" (1970-present).

According to Clark and Whitall (1989), the "maturational period" (1928-1946) is characterized as the first time motor development as a primary interest emerged. The maturational philosophy, the idea that genetics and biological processes are the major influence on development, was generally accepted during this period. Gesell and McGraw produced process and product-oriented information concerning human movement in support of the maturational view. In 1936, Bayley developed a scale of motor development which is still used today. The scale is a norm-referenced chart of motor behavior from birth to age three (Payne and Isaacs, 1999).

The "normative/descriptive period" (1946 – 1970) is the third historical period in the history of motor development as proposed by Clark and Whitall. Interest in motor development slowed in the mid 1940s but was revived by physical educators interested in the movement patterns of children. During this time, norm-referenced standardized tests were developed for measuring motor abilities of children. Kephart (1960) published The Slow Learner in the Classroom. His theory maintained that certain movement activities could enhance academic achievement. (Payne and Isaacs, 1999).

The last historical period of the evolution of the field of motor development is the "process-oriented period" (1970-present). This period has been characterized by a shift from describing change to examining the underlying processes involved in motor development. The dynamic systems theory, a recent theory of motor control, is currently being applied by motor development researchers as well. This influential theory brought about the idea that movement patterns may be self-organizing, rather than coded by the brain. This has led researchers in all areas of motor behavior to consider the notion that human movement is a complex process of many biological and chemical systems interacting, rather than a phenomenon that is primarily controlled by the nervous system. In addition, a current theme in motor development textbooks is the lifespan perspective, the concept that development begins with conception and ends with death (Gabbard, 2001).

The History of Motor Control Research

Motor control, the study of the neurological, physical, and behavioral aspects of movement, has its roots from the early neurophysiology research (Schmidt, 1999). Landmark motor control research has included the development of movement control theories, open and closed-loop control systems, Fitts' Law, and Hick's Law. Since the merger of the neural control scientists and behaviorists, the field has become more dynamic.

Theories of motor control have been developed to explain how the nervous system is involved in human movement behavior. One of the most widely accepted theories is the motor program-based theory, and from it comes the concept of a "generalized motor program." Schmidt was the first to propose that a class of actions with common characteristics are stored in memory. Schmidt proposed that a general movement pattern may be retrieved from memory, and then movement-specific parameters can be added to fit a performance situation. The motor program-based theory actually evolved from the ideas of Greek philosophy. Plato wrote about how humans create an image of an act preceding the act itself. In 1890, William James stated that "to perform an action, a person must form a clear image of that action" (Magill, 2001). Karl Lashly (1917) was the first to use the term "motor program" to describe the generalized schemata of a movement. Miller, Galanter, and Pilbram (1960) used the term "motor plan" and compared it to a computer program. This evolved into Schmidt's theory that a motor program is not a specific muscle command, but rather a memory-based representation of a class of actions. For example, a general throwing pattern is considered a class of actions.

A more recent motor control theory is the dynamic systems theory. This approach emphasizes the role of environmental information and the dynamics of the body and limbs. Dynamic systems theorists propose that the body and limbs have the ability to self-organize when presented with environmental conditions. This theory contends that movement is a complex phenomenon that is controlled by multiple bodily systems and chemical changes, rather than simply by the nervous system. An example of the concept of this theory is exemplified when a punter drops a football, and a gust of wind blows the ball from its intended path, the player can adjust the movements of the punting action to achieve a successful kick (Magill 2001).

Motor control theories are based on the concepts of the open and closed-loop motor control models. These models are derived from mechanical engineering models of control, and they help describe how the central and peripheral nervous systems are involved in the control of movement. The open-loop system of control contends that all of the information needed to carry out a planned action is contained in the movement control center, the brain. The open-loop system model does not make reference to any type of feedback that might be sent back to the command center from the environment via the afferent nerves. An example of an open-loop system of control is evident with throwing a dart at a dart board. When an individual initiates a throw, the motion is carried out as specified by movement commands elicited before the initiation of the movement. In the closed-loop control system, the initial commands to the efferent nerves only initiate the movement, but the execution and completion of the movement is dependent upon feedback information. A closed-loop system of control is evident with driving a car. A driver uses visual, auditory, tactile, and proprioceptive feedback to control the steering wheel and make needed adjustments to keep the vehicle in the proper lane (Magill, 2001).

Fitts' Law, another central theme in the motor control literature, is a mathematical law describing the speed-accuracy trade-off in human movement. Fitts' Law, MT = a + b log2 (2D/W), predicts movement time for a task requiring speed and accuracy, where "MT" is movement time, "a" and "b" are constants, "D" is the distance to move, and "W" is the width or size of the target. This law implies that as the speed of a movement increases, the accuracy at a given distance will decrease, and vice versa. Fitts' law has practical applications for specific sport performances. A placekicker can expect improved accuracy of a kick if the speed of the movement is slowed down (Schmidt, 1991).

Another landmark law of motor control is Hick's Law. In 1952 Hick discovered that reaction time increases logarithmically as the number of stimulus-response choices increases. Therefore, as the number of alternatives increases, the amount of time required to prepare the appropriate action increases. This concept has most commonly been applied to sports performance situations. A football quarterback has three basic choices in an option play. He can hand the ball off, run with the ball, or pitch the ball to a trailing player. The option play presents many stimulus choices for the quarterback. The defensive players present sources of information to help the quarterback choose the correct alternative. This is difficult, however, because of the narrow time constraints of the play. The coach may elect to instruct the quarterback to look for a few specific characteristics in the defense to provide a simpler basis to decide on which of three options to select.

The History of Motor Learning Research

The field of motor learning has expanded considerably since the 1970s. Primarily concerned with the processes involved in acquiring and perfecting motor skills, motor learning researchers have presented an abundance of knowledge and concepts relating to models of learning, information feedback, and practice conditions.

One of the most influential models of how humans learn motor skills was presented by Fitts and Posner in 1967. They proposed that learning follows three general stages: a cognitive stage, an associative stage, and an autonomous stage. In the cognitive stage, the focus of a novice is on the cognitive aspects of the movement. Performance is generally characterized as inconsistent. The second stage, the associative stage, is characterized by fewer errors as improvement takes place. This is often referred to as the "refining" phase. The last stage of the Fitts and Posner model is the autonomous stage, and movement during this stage becomes almost automatic to the performer. Since the action can be carried out without conscious thought, other tasks may be able to be carried out simultaneously (Magill, 2001).

Gentile developed a model of learning in 1972. She proposed that the learning of motor skills follows two distinct stages. In the first stage, Gentile described the goal of the learner as "getting the idea of the movement." During this stage, the learner identifies the correct movement coordination pattern. In the second stage of Gentile's model, the learner's focus is on "fixation" or "diversification" depending upon what type of skill is being performed. Fixation refers to the ability to refine movement patterns of closed skills so they can be consistently performed from trial to trial. Diversification refers to the ability to modify movement patterns when performing open skills as the environmental context changes. Both of the learning theories are commonly referred to by motor learning researchers today (Magill, 2001).

Information feedback is another common area of research in the motor learning literature. Newell (1983) suggests that feedback is the single most important variable to the learning and performance of skilled actions. Recently, the terms "knowledge of results" and "knowledge of performance" have been differentiated as separate types of feedback. According to Sage (1984), knowledge of results is a category of augmented feedback that gives information about the outcome of performing a skill or about achieving the goal of its performance. A racquetball instructor telling a student that a serve is long is an example of providing knowledge of results as feedback. Knowledge of performance is defined as a category of augmented feedback that gives information about the movement characteristics that led to a performance outcome. If a racquetball instructor told a student that he or she made contact with the ball above the waist, knowledge of performance is the provided feedback. In the past 20 years, researchers have continued to examine the effects of various types, amounts, and schedules of feedback on performance (Shumway-Cook and Woollacott, 1995).

In addition to feedback research, practice has been a recurring topic in the motor learning literature. Studies of practice variability and distribution have produced very practical knowledge for physical educators. Another area of research pertaining to this domain is the concept of mental practice. In 1972, a landmark study by Rawlings, Rawlings, Chen, and Yilk showed that mental practice alone had a positive effect on the performance of a novel laboratory task. Since then, there has been extensive research performed to examine the effects of different types of mental training on athletic performance (Magill, 2001).

The Praxis Exam

The Praxis Series is a program developed by the Educational Testing Service to provide tests and other services to states for use as a part of the teacher certification process. According to the Educational Testing Service (2001), over 80% of the states that include tests as part of their licensure process rely on the Praxis Series tests. The Praxis assessments contain the most current research and content, and they are continually updated. Praxis I is an academic assessment designed to measure general academic skills of college students. Praxis II is the subject assessment and is designed to measure a teaching candidate's knowledge of the subject in which certification is sought. Many of the tests also measure general and specific pedagogical knowledge. Several different Praxis II tests are offered to enable states to select tests that best meet their requirements. Some of the Praxis II specialty area tests cover motor behavior information. Motor behavior content makes up a large portion of the subject tests in health and physical education, physical education, and early childhood education. These include the following seven tests: a) Health and Physical Education (test code 20850), b) Health and Physical Education: Content Knowledge (test code 20856), c) Physical Education (test code 10090), d) Physical Education: Content Knowledge (test code 10091), e) Physical Education: Movement Forms – Analysis and Design (test code 30092), f) Physical Education: Movement Forms – Video Evaluation (test code 20093), and g) Early Childhood Education (test code 20020).

The Health and Physical Education test (test code 20850) is designed for prospective kindergarten through twelfth grade health and physical education teachers. Approximately half of the test questions deal with health content, and about half focus on physical education content. The content categories include I. Foundations for Health Education, II. Foundations for Physical Education, III. Program Development in Health Education, IV. Program Development in Physical Education, V. Program Content in Health Education, VI. Program Content in Physical Education, and VII. Program Administration in Physical Education and Professional Awareness in Health and Physical Education. Motor behavior content may appear in any one of three of the seven categories, all of which make up 44% of the test. According to the Educational Testing Service, analysis of human movement, growth and development, and developmental stages are all areas that are covered under the content category, Foundations for Physical Education. Instructional strategy is an area covered under the content category, Program Development in Physical Education. Questions related to motor learning, such as types of practice and feedback, could be asked in this area. Finally, human growth and development, biological and environmental influences on development, and changes throughout the lifespan are areas covered under the category, Program Content in Health Education.

The Health and Physical Education: Content Knowledge test (test code 20856) is designed for prospective teachers of health and physical education at any grade level. Approximately 50 of the 120 test items cover health content, and about 70 questions cover physical education content. The three content categories under the physical education portion are I. Fundamental Movements, Motor Development, and Motor Learning, II. Movement Forms, and III. Fitness and Exercise Science. The category of Fundamental Movements, Motor Development, and Motor Learning makes up approximately 18% of the exam. Questions from this area include information related to fundamental movements, movement concepts, growth and motor development, the role of perception in motor development, neurophysiology of motor control, effects of maturation and experience on motor patterns, biological and environmental influences on gender differences in motor performance, motor learning theories, variables that affect learning and performance, and effects of individual differences on learning and performance. The category, Movement Forms, makes up approximately 19% of the exam, and questions from this area include information related to motor skill analysis of dance and rhythmic activities, and individual, dual, and team sports.

The Physical Education test (test code 10090) is designed for potential teachers of physical education at any grade level from kindergarten through grade twelve. The seven content categories are I. The Art of Human Movement, II. The Science of Human Movement, III. The Role of Physical Education as a Profession, IV. The Role of

Physical Education Within the Total School Curriculum, V. Planning the Teaching/ Learning Process, VI. Implementing the Teaching/Learning Process, and VII. Evaluating the Teaching/Learning Process. Motor behavior information is covered on three of the seven content categories. The category, The Art of Human Movement, makes up approximately 25% of the examination. Topics under this category include movement elements of fundamental motor skills and sport skills. The content category entitled, The Science of Human Movement, also makes up approximately 25% of the examination questions. Topics under this category include analysis of basic movement patterns, patterns of neural, physiological, psychological, perceptual, and cognitive development across the lifespan, variables influencing motor development, influence of motor development on performance, application of motor development concepts to teaching and learning, motor learning theories, the effect of variations of feedback and practice on learning and performance, and the application of motor learning concepts to teaching and learning. Motor behavior content is also included on the Implementing the Teaching/Learning Process Category. Topics such as teaching skills and strategies, and teaching models and styles are covered.

The Physical Education: Content Knowledge test (test code 10091) contains six content categories. They are I. Fundamental Movements, Motor Development, and Motor Learning, II. Movement Forms, III. Fitness and Exercise Science, IV. Social Science Foundations, V. Biomechanics, and VI. Health and Safety. The two categories, a) Fundamental Movements, Motor Development, and Motor Learning and b) Movement Forms, make up approximately 48% of the exam questions, and the motor behavior topics in these categories are the same that appear on the Health and Physical Education test (test code 20856). Some motor behavior content is also included in the Biomechanics category of this test. Related information under this category includes application of basic principles of sport skills and analysis of fundamental movement patterns.

A fifth test containing motor behavior information is the Physical Education: Movement Forms – Analysis and Design test (test code 30092). This test is designed to assess the ability of prospective kindergarten through twelfth grade physical education teachers to select appropriate activities, make intelligent decisions about students' needs, and explain the reasons for these decisions. The test consists of two essay questions which deal with health-related fitness, the ability to analyze movement forms in terms of progression from introductory to advanced levels of skill performance, and the selection and description of movement activities that will enable children to reach specified goals in physical education.

A sixth exam, Physical Education: Movement Forms – Video Evaluation (test code 20093), is designed to assess the ability of prospective kindergarten through twelfth grade physical education teachers to identify critical features in the performance of movement forms and exercises, and to describe appropriate ways to communicate with students about changing and/or improving performance. This test consists of two essay questions, each of which covers at least one of the topics related to motor skill performance and fitness, fundamental movements, and movement forms. Each question is based on a videotape of school-age children performing various movements. The video may show a child practicing a skill such as kicking a ball. An examinee might be asked to describe major characteristics of the child's performance and to suggest appropriate remediation to improve that performance.

The Early Childhood Education test (test code 20020) is intended for examinees who are prospective teachers of preschool through the primary grades. The six content categories are I. Growth, Development, and Learning of Young Children, II. Factors Influencing Individual Growth and Development, III. Applications of Developmental and Curriculum Theory, IV. Planning and Implementing Curriculum, V. Evaluating and Reporting Student Progress and the Effectiveness of Instruction, and VI. Understanding Professional and Legal Responsibilities. Approximately 31% of the test questions relate to the Growth, Development, and Learning of Young Children category. This category includes topics of typical and atypical physical growth and development, and patterns of gross and fine motor development. Motor behavior content is also included in the category, Factors Influencing Individual Growth and Development. This category makes up approximately 10% of the examination (Educational Testing Service, 2001).

CHAPTER 3

Manual Organization

Introduction

This manual consists of the following four sections: I. Introduction to Motor Behavior, II. Motor Development, III. Motor Control, and IV. Motor Learning. There are eleven individual chapters within the four main sections. Each section begins with an introduction, and each chapter follows a consistent and specific format (see Appendix A). Each chapter lists objectives, followed by definitions of key terms. This is succeeded by a general outline of the chapter content follows. Each objective is identified in bold heading in the left margin of the text. A brief summary is included, followed by questions for discussion and suggested class activities. Each chapter concludes with a list of references. A complete glossary at the end of the manual includes all of the vocabulary terms presented. Charts and diagrams are included to assist learning (see List of Figures). Included in the appendix is a suggested fifteen-week course outline for instructors (see Appendix B).

Each chapter builds on the next. Thus, instructors should start with the first section, Introduction to Motor Behavior, and progress through the subsequent sections, Motor Development, Motor Control, and Motor Learning. The progression of the manual is designed to introduce the student to the field of motor behavior, characterize human motor development across the lifespan, describe how movements are controlled, and finally, to apply these concepts to learning motor skills.

Section One: Introduction to Motor Behavior

Section one of the manual provides students with an overview of the historical development of motor behavior as a field of study. This section includes one chapter, entitled "What is Motor Behavior?" After covering this chapter, students will gain an understanding of how the main body of knowledge has evolved into the three specialized sub-areas of motor behavior: motor development, motor control, and motor learning. Major contributors to the field are identified, as well as prerequisite terminology. A brief discussion of different specialized professions which require a thorough motor behavior knowledge base is included. The chapter concludes with a discussion of the Praxis II examination and the related motor behavior information that is covered on seven specialized subject assessments. This introductory information will be a foundation for instruction as the manual progresses into subsequent chapters.

Section Two: Motor Development

The second section of this manual, Motor Development, consists of chapters two, three, and four. Chapter Two is entitled "Lifespan Development." This chapter describes the general characteristics of human development across the lifespan. In addition to general terminology, this chapter introduces the nature versus nurture controversy, the continuity versus discontinuity debate, general lifespan stages, general motor development phases, basic assumptions about development, and prenatal factors that affect growth and development.

Chapter Three, "Physical Development," focuses on the normal human growth and change of physique, structure, body mass, and muscle tissue. The two most dramatic periods of physical development, the prenatal period and adolescence, are highlighted. Emphasis is placed on individual and gender differences. The role of the endocrine system is included in the discussion of puberty. Chapter Three also describes physical changes of aging, as well as implications that physical changes have on motor performance.

Chapter Four, "Physiological Changes," begins with an overview of the parts, functions, and development of the cardiorespiratory system. The following general measures of physiological functioning are identified: maximal oxygen uptake, vital capacity, heart rate, blood pressure, cardiac output, blood volume, basal metabolic rate, muscular strength, muscular endurance, and flexibility. Upon completion of this chapter, instructors can expect students to be able to define each measure, explain how each is assessed and expressed, discuss how each measure changes across the lifespan, describe any gender differences for each, and explain how exercise and training can affect each measure.

After acquiring knowledge about how humans develop physically and physiologically across the lifespan, students are prepared for an understanding of the general pattern of motor skill development. Chapter Five, "Phases of Motor Development," analyzes normal patterns of early movement, rudimentary movement, movement in early childhood, movement in late childhood and adolescence, and movement in the adult years. Students are first presented with the purposes of reflexes and spontaneous movements, categories of major infant reflexes, and how involuntary movements evolve into early voluntary behavior. Second, the progression of rudimentary locomotion, postural control, and manual control is examined. Third, the manual covers the three classes of fundamental movement skills: locomotor, nonlocomotor, and manipulative. The manual defines gross skills such as walking, running, jumping, hopping, leaping, galloping, sliding, skipping, throwing, catching, striking, climbing, and ball bouncing. Fine motor skills such as drawing, writing, and tying shoes are also included. The remaining portion of the chapter describes how the proficiency of fundamental skills progresses through late childhood and adulthood.

Upon completion of Section Two: Motor Development, students should have a solid knowledge foundation of how and why human motor development changes over the lifespan. This information provides preparation for Section Three: Motor Control, a more science-based examination of how the nervous system and modes of perception are involved in the control of movement.

Section Three: Motor Control

The third section of the manual, Motor Control, consists of chapters six, seven, and eight. Chapter Six, "The Nervous System," describes the parts and functions of the central and peripheral nervous systems, the parts and functions of a neuron, and the normal development pattern of the brain and nervous system. In addition, this chapter includes information about brain lateralization, motor units, types of nerve fibers, and the effects of aging on neural functioning. Diagrams are included to assist understanding.

Chapter Seven, "Information Processing," begins with an explanation of the general information processing model, a foundation for comprehension of motor control theories presented in Chapter Eight. Also provided in Chapter Seven is an analysis of the importance of vision and kinesthesis with respect to movement. The development of visual abilities such as acuity, depth perception, spatial orientation, and peripheral vision is presented. Students will learn the location of the kinesthetic receptor sites, as well as the importance of kinesthetic abilities, such as kinesthetic memory, kinesthetic acuity, body awareness, spatial awareness, directional awareness, vestibular awareness, and rhythmic awareness. A portion of the chapter is devoted to the role of auditory and tactile perception with respect to movement. An explanation of the role of memory and attention on motor control is also included. The last part of the chapter deals with the effects of aging on information processing.

Once instructors have introduced the fundamentals of the nervous system and information processing, students will be better prepared to understand the theories and laws of human movement control. Chapter Eight, "Motor Control Theories and Laws," presents the most accepted ideas in the current literature. First, the concepts of the open and closed-loop motor control models are covered. This is followed by an explanation of two leading motor control theories: the generalized motor program theory and the dynamic systems theory. A discussion of two historic laws of motor control, Fitts' Law and Hick's Law is included.

Section Three prepares students for Section Four: Motor Learning, a practical and applicable section which addresses how motor skills are classified, how humans learn and retain movement patterns, and how feedback and practice affect learning.

Section Four: Motor Learning

The final section of the manual consists of chapters nine, ten, and eleven. Chapter Nine, "Classifying Motor Skills," includes general motor learning terminology such as "skill," "action," and "movement." Three common one-dimensional classification systems are examined. The following classification terms are introduced: "gross," "fine," "open," "closed," "discrete," "serial," and "continuous." Finally, a two-dimensional model for classifying skills, Gentile's taxonomy, is examined.

Chapter Ten, "Motor Learning Theories," presents Fitts and Posner's Three-Stage Model and Gentile's Two Stage Model of Learning. Students are also introduced to the learning-memory theory. Last, the general versus specific motor ability hypothesis is examined.

The final chapter of the manual is Chapter Eleven, "Feedback and Practice." Topics of discussion include task-intrinsic feedback, augmented feedback, practice variability, practice distribution, whole versus part practice, and mental practice. The emphasis of the chapter is on the practical application of using different types of feedback and practice when teaching or coaching.

CHAPTER 4

Manual Content

PREFACE

This manual is written for college instructors who teach undergraduate courses in human movement and is designed to provide an outline of the three major sub-areas of motor behavior: motor development, motor control, and motor learning. Instructors are encouraged to use the manual's basic outline in preparing for their courses. Instructors should follow the manual's sequence of chapters, beginning with the first section, Introduction to Motor Behavior, and progress through each subsequent section on motor development, motor control, and motor learning. The first chapter of each of the four main sections provides foundational knowledge and concepts necessary to advance to the next chapters. Instructors may opt to use this manual as a basic text, or they may use it as a supplement to any current references. By using the manual as a teaching guide, instructors can be assured that the fundamental knowledge of the three sub-areas of motor behavior is covered. The information in the manual matches the motor behavior-based content items on the Praxis II exams in health and physical education, physical education, and early childhood education.

At the beginning of each chapter, a list of objectives designed to serve as the basis for a lesson or sub-lesson is given. Instructors may choose to cover more than one objective per class period, depending on the content of the objective(s) and the length of the class period. Definitions of key terms of each chapter are provided. The definitions are listed in order of use. The terminology represents the fundamental knowledge of each sub-area of motor behavior. Key terms may be used for the development of vocabulary quizzes at the end of each chapter. In addition, a master glossary is included in the appendices. A summary of chapter content appears at the end of each chapter. The summary is designed to serve as the closure for each chapter and is intended to help students prepare for an exam. Figures and diagrams provide instructors visual material for chalkboards, dry ink boards, computer-generated presentations, handouts, or transparencies.

Questions for discussion are listed after the summary in each chapter and are designed to foster critical thinking over chapter content. The instructor might set aside one day for class discussion over chapter material, using the discussion questions as the lead. Each chapter also includes suggested class activities to provide a variety of lab experiences or active involvement. Instructors are encouraged to incorporate as many of these activities into their course as possible, as they reinforce important concepts.

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SECTION ONE

INTRODUCTION TO MOTOR BEHAVIOR

Introduction

Section I presents an overview of the study of motor behavior. Important prerequisite terms are introduced, followed by an explanation of the three sub-areas of motor behavior. A brief discussion of several related professions which require a comprehensive knowledge of motor behavior is included. In addition, a general historical analysis of the study of motor behavior is covered. Major researchers and contributors to the body of knowledge are mentioned. Last, there is a discussion of the Praxis II exam and the related motor behavior content that is covered on the health and physical education, physical education, and early childhood education specialty area tests. Section I contains Chapter One, "What is Motor Behavior?"

Chapter One

What is Motor Behavior?

Chapter Objectives

1.1 Define the term **motor behavior**, and describe how it fits under the human movement "umbrella."

1.2 Identify the three sub-areas of motor behavior, and define the general terms related to each sub-area.

1.3 Briefly describe several related professions which utilize a foundation of knowledge in motor behavior.

1.4 Name and describe the four historical periods of motor behavior research and the major researchers involved in each.

1.5 Define the **Praxis II** exam, and identify the main motor behavior content areas that are covered on the health and physical education, physical education, and early childhood education tests.

Definitions of Key Terms

motor – the biological and mechanical factors that influence movement

behavior - performance

motor behavior – sub-discipline of the study of human movement, emphasizing the investigation of the principles of human movement behavior

motor development – specialized study of human movement behavior which emphasizes the associated biological changes in human movement across the lifespan, the underlying processes of these changes, and the factors that affect them

development – a change in the level of functioning

lifespan perspective – the examination of development from conception to death

motor control – the study of the neural, physical, and behavioral aspects of movement

neurophysiology – the study of the functioning of the nervous system

motor learning – the study of the processes involved in attaining and perfecting motor skills

learning – a relatively permanent change in performance

motor skill – a movement which depends on experience or practice to be performed

Praxis Series – a program developed by the Educational Testing Service to provide tests and other services to states for use as a part of the teacher certification process

Praxis I – an academic skills assessment designed to measure general academic skills of college students

Praxis II – a subject assessment designed to measure a teaching candidate's knowledge of the subject in which certification is desired

Chapter Content Outline

I. Motor Behavior and the Human Movement "Umbrella"

II. The Three Sub-Areas of Motor Behavior

III. Specialized Professions Which Require a Knowledge of Motor Behavior

IV. History of Motor Behavior as a Field of Study

   A. Introduction

   B. 1890-1927

   C. 1928-1944

   D. 1945-1966

   E. 1967-present

V. The Praxis Series Tests

   A. Introduction

   B. Health and Physical Education (test code 20850)

   C. Health and Physical Education: Contest Knowledge (test code 20856)

   D. Physical Education (test code 10090)

   E. Physical Education: Content Knowledge (test code 10091)

   F. Physical Education: Movement Forms – Analysis and Design (test code 30092)

   G. Physical Education: Movement Forms – Video Evaluation (test code 20093)

   H. Early Childhood Education (test code 20020)

VI. Summary

VII. Questions for Discussion

VIII. Class Activities

IX. References

Motor Behavior and the Human Movement "Umbrella"

Objective 1.1: Define the term motor behavior, and describe how it fits under the human movement "umbrella."

Motor behavior is a sub-discipline of the study of human movement, which emphasizes the investigation of principles of human movement behavior. More specifically, it stresses the principles of human skilled movement. As a phenomenon, motor behavior refers to observable movement performance that is the product of genetic and environmental influence. Broken down into parts, the term **motor** is often used interchangeably with "movement" to mean the biological and mechanical factors that influence movement. The term **behavior** is synonymous with "performance."

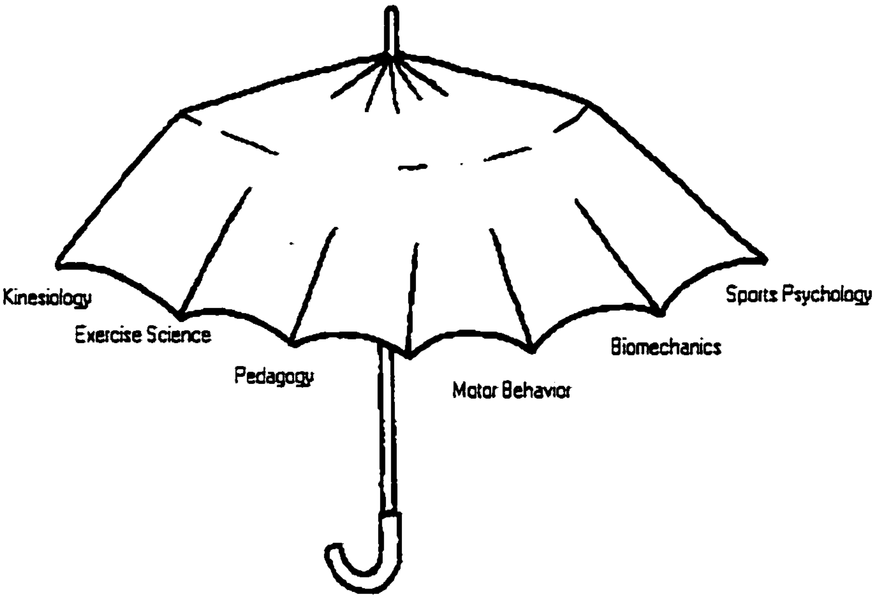

Figure 1.
The Human Movement "Umbrella"

The Three Sub-Areas of Motor Behavior

Objective 1.2: Identify the three sub-areas of motor behavior, and define the general terms related to each sub-area.

The study of motor behavior can be divided into three sub-areas: motor development, motor control, and motor learning. These sub-areas are interdisciplinary, and their research often overlaps. Each motor area, however, can be defined and characterized by its unique area of focus.

Motor development is the specialized study of human movement behavior, which emphasizes the associated biological changes in movement across the lifespan, the underlying processes of these changes, and the factors that affect them. The term **development** means a change in the level of functioning. Thus, motor development can also be described as a process of change in motor behavior resulting from an interaction of heredity and the environment. This process of motor development is typically viewed in phases. To characterize motor skill acquisition, motor development researchers examine how humans develop neurologically, physically, physiologically, and perceptually. The **lifespan perspective** is a central theme in the motor development literature, meaning that development is examined from conception to death (Gabbard, 2000).

The second area, **motor control,** is defined as the study of the neural, physical, and behavioral aspects of movement (Schmidt, 1999). Of particular concern in the study of motor control is an understanding of the functioning of the nervous system and how it relates to movement. The term **neurophysiology** is often used to describe motor control research. In addition to examining the functional mechanisms of the central and peripheral nervous systems, motor control researchers are interested in topics such as information processing, attention, memory, and reaction time (Gabbard, 2000).

The third area, **motor learning,** is the study of the processes involved in attaining and perfecting motor skills. **Learning** is a relatively permanent change in performance, and motor learning researchers are interested in how types of practice, training, or environments affect the learning of human movement skills. By definition, a **motor skill** is a movement which depends on experience or practice to be performed. Results from motor learning research can be very practical and applied directly by coaches, physical educators, and athletes (Schmidt, 1991).

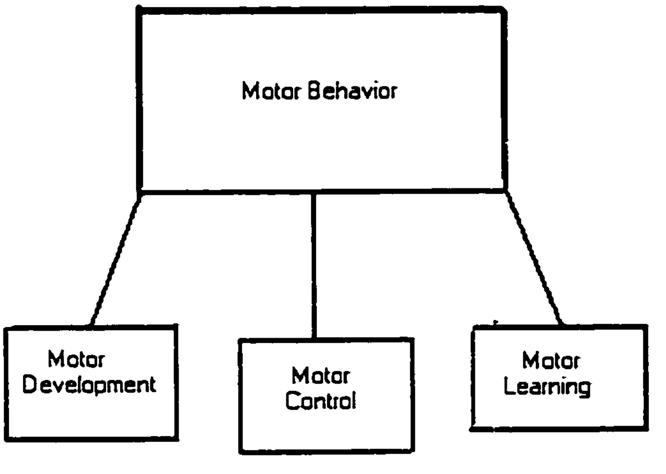

Figure 2.
Motor Behavior and Its Three Sub-Areas

Specialized Professions Which Require a Knowledge of Motor Behavior

Objective 1.3: Briefly describe several related professions which utilize a foundation of knowledge in motor behavior.

Motor behavior's body of knowledge serves as a foundation in many areas of specialization. Physical education and early childhood education teachers need a comprehensive understanding of how humans develop and learn at different stages of the lifespan. This knowledge enables teachers to better select developmentally appropriate activities to facilitate learning. Also, coaches and fitness professionals require a knowledge base in motor behavior, if they are to select appropriate practices or activities to enhance performance. In addition, individuals in the fields of sports medicine, occupational therapy, and physical therapy must know how movements are controlled and how to use progression of gross to fine movements in rehabilitation. Last, infant stimulation specialists and child care specialists need a solid foundation of knowledge in motor behavior. Recent research has revealed that the optimal time for the critical wiring of the brain's neural circuitry is between birth an age five. Hence, individuals who work with infants and small children need knowledge of motor development, motor control, and motor learning to choose the most stimulating and appropriate experiences.

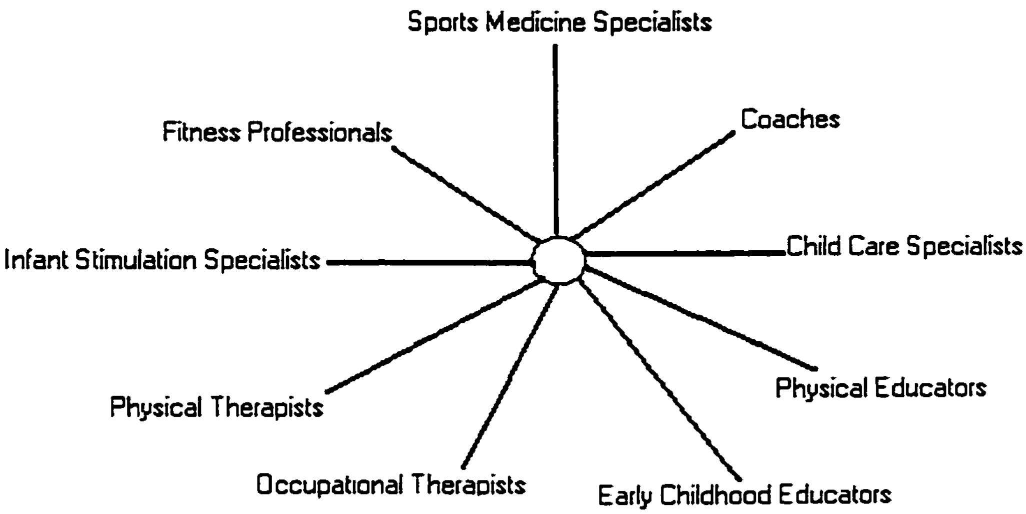

Figure 3.
Related Professions Requiring Knowledge of Motor Behavior

History of Motor Behavior as a Field of Study

Objective 1.4: Name and describe the four historical periods of motor behavior research and the major researchers involved in each.

Introduction

The study of motor behavior evolved from two major fields of research: a) neurophysiology and b) psychology. For a century, people in these two fields conducted research, but the fields remained separate. Neurophysiologists studied the functioning of the neural mechanisms involved in movement, but rarely made reference to motor skills.

Psychologists often examined complex, fine motor skills without referring to the neural processes involved. In the 1970s, the fields of neurophysiology and psychology would come together in study of human movement (Schmidt, 1999).

The earliest studies of motor skills were performed in the early 19th century by astronomer Bessel. He became interested in discovering why his colleagues varied in their abilities to record transit times of moving stars, as an image moved across a telescope. Bessel attempted to investigate why some could estimate the movement time of an image, by adjusting a telescope more quickly and accurately than others (Schmidt, 1999). Excluding the early studies by Bessel, the history of motor behavior research is usually categorized into four distinct periods beginning in the late 19th century. These periods are as follows: a) 1890 – 1927, b) 1928 – 1944, c) 1945 – 1966, and d) 1967 – present.

1890 – 1927

The period of 1890 – 1927 was an early period of definition and exploration in motor behavior research. In the late 19th century, researchers began investigating the role of vision in performing manual target tasks. Bryan and Harter (1899) researched the learning of telegraphy and the Morse code, and they proposed some early principles of motor learning. Also in 1899, Woodworth identified some of the fundamental principles of rapid limb movements. This was one of the first systematic approaches leading to the understanding of motor skills. Other notable motor skill researchers at the turn of the century included Book, Leuba, and Hollingsworth. By 1903, numerous studies dealing with motor activity had appeared in various journals sponsored by the American Psychological Association. One of the earliest motor behavior studies of athletes also occurred during this period. In 1914, Cummins studied the relationship between attention and tapping speed of a small group of basketball players (Sage, 1984). Most of these early studies had roots in experimental psychology, and the data were often unobservable and subjective.

Study of the nervous system paralleled the early motor behavior research, but the two fields of neurophysiology and psychology remained separate. In 1870, Fritsch and Hitzig discovered that the brain is electrically excitable. This led to the invention of electrophysiological recording techniques. In the early 20th century, Sir Charles Sherrington made influential discoveries in the area of motor control. Sherrington was one of the first to classify limb reflexes, and he introduced the idea that voluntary movements resulted from these early involuntary movements. He also introduced the notion of "reciprocal innervation," meaning that as one muscle group contracts, the opposing muscle group relaxes. Sherrington also studied the role of kinesthetic receptors with movement, and he was the first to use the term "proprioception" (Gallistel, 1980).

1928 – 1944

The second period in the history of motor behavior research was 1928 – 1944. This era was marked by an increase in sophistication of experimentation and the emergence of several new theories. There began to be a shift toward a focus on more systematic and objective motor behavior research. Many studies were geared at industrial settings, with the goal of making movements of workers more efficient. Time and motion studies were performed in the 1930s by researchers who were interested in analyzing assembly line movements. As further interest proliferated in studying movement efficiency in industry, physical educators began to develop early learning theories of athletic movements. Researchers such as Bayley and Espenschade investigated growth and maturation in relation to motor performance. These studies led to the creation of the sub-area of motor development (Payne and Isaacs, 1999).

Neurophysiology remained as a separate research field during this period. The neural studies were done with very simple movements, and the neurological processes were usually the main focus of this research. When the movements were examined, very little detail concerning speed, accuracy, or movement patterns was reported. One exception to this trend was the research of Soviet scientist N.A. Bernstein, whose research in the 1930s and 1940s integrated behavioral notions and neurophysiology with the study of locomotion (Bernstein, 1967). However, Bernstein's work was not recognized by United States and English researchers, until his papers were translated in the late 1960s.

1945 – 1966

The third period of motor behavior research was 1945 – 1966, and it was characterized by a proliferation of research and publication. One of the demands of the World War II era was to select the most skilled subjects for pilot training and operators of specialized equipment. Arthur Melton developed the United States Army Air Force's Psycho-Motor Training Program, a series of tests based on perceptual-motor research. The program, however, had little success in selecting proficient pilots. Researchers began to realize that pilot skill training, rather than selection was the answer. This led to more study on the teaching and learning of motor skills. The United States government began to fund this type of research, and more psychologists moved toward studying motor behavior (Schmidt, 1999).

During the post-war period, motor behavior research was influenced by new learning theories. Hull (1943) developed the general learning theory, which addressed how fatigue and recovery during practice affects the learning of motor skills. Another important concept was developed by Craik (1948). He proposed the idea that information processing of the brain works like a computer, and movements are the human output. Paul Fitts was one of many who studied the concept of behavioral information processing. In 1954, he developed what is known today as Fitts' Law, a human performance law specifying the movement time for an aiming action, when the distance to move and the target size are known (Fitts, 1967). In the 1950s, an abundance of motor behavior research was published in Research Quarterly, and Robert and Carol Ammons created Perceptual and Motor Skills, which published motor research (Schmidt, 1999).

In the 1960s, research in motor behavior by psychologists declined due to decreased federal support and increased interest in other areas of human behavior. In fact, in 1966, motor behavior psychologists gathered at Tulane University for an "academic funeral." Researchers read "last rites" to the study of motor behavior and vowed to move on to new interests in the field of psychology (Schmidt, 1999).

1967 – present

The fourth period of motor behavior research, 1967 – present, has seen a shift from a task-oriented to a process-oriented emphasis in research. Early motor behavior researchers often paid little attention to the underlying processes involved in human movement. However, this era has seen the two areas of behavioral psychology and neurophysiology come together in researching motor behavior. The process-oriented approach concentrates on the underlying neural and cognitive processes that contribute to motor development, control, and learning. In addition, physical educators have taken a leading role in conducting motor behavior research (Sage, 1984).

Motor research survived the 1960s thanks in large part to the study of a physical educator, Franklin M. Henry. Henry worked at the University of California at Berkeley and is considered today as the father of motor behavior research in physical education. He studied gross motor skills representative of those in sports and athletics. Henry had a background in experimental psychology, and he often made his own apparatuses for laboratory tasks. Some of the specific topics of interest to Henry included individual differences, types of practice scheduling, performance curves, and fatigue and rest. Disciples of Henry became leading researchers in the 1970s and succeeding decades (Schmidt, 1991).

The field of motor behavior grew quickly in the late 1960s and 1970s, and physical educators took a leading role in research. New journals such as the Journal of Motor Behavior and the Journal of Human Movement Studies appeared. The first motor behavior textbook was written by Cratty (1964), and formal motor behavior university courses came into existence. Motor learning became a standard subject for teacher preparation in physical education, and by the early 1970s, it was considered one of the primary sub-fields of physical education. Also, a merger of the neural control and behavioral scientists began in the 1970s. This merger has led to the identification of motor development and motor control as specialized areas (Seidentop, 1994).

During the 1970s, more physical education researchers began to show an interest in the underlying processes of motor learning and control. Motor learning research was traditionally oriented around topics such as practice scheduling, feedback, and motivation. However, more researchers began to show an interest in studying the underlying processes involved in the control of movement. Researchers focused more on the interaction of the perceptual modalities and the nervous system, with the muscular system to produce skilled movement. Researchers extended the traditional boundaries of behavioral psychology to neurophysiology. This movement led to the identification of motor control as a motor behavior sub-area. Today, much of the motor control research is interrelated and overlaps with motor learning research (Seidentop, 1994).

The sub-area of motor development also evolved in the last part of the 20th century. Historically, motor development was a descriptive field of study that focused on the growth and developmental changes from birth through adolescence. One of the more recent trends in motor development research has been to study human motor development across the lifespan. Another recent influence has been the dynamic systems perspective. This is the view that many bodily systems, not solely the nervous system, are in constant interaction and adjustment to create movement. Like motor control and learning researchers, motor development researchers are now interested in the processes that underlie movement (Payne and Isaacs, 1999).

In the past two decades, an abundance of brain research with important implications for movement and learning has occurred. In 1997, researchers at the University of California at Irvine discovered that exercise triggers the release of a brain substance that enhances the ability of neurons to communicate with each other. In a 1991 study performed at Scripps College in Claremont, California, researchers demonstrated that exercise improves reaction time, memory, and thought processes. Also, chronic stress has been shown to cause the release of harmful chemicals that kill neurons in the memory areas of the brain. Since exercise has been shown to reduce stress, many researchers now contend that physical activity is one of the best ways to stimulate the brain and learning. In addition, evidence exists that the cerebellum is involved in the learning of almost all physical skills. These and other findings have led to studies which have demonstrated a strong link between physical activity and academic performance (Jensen, 1998).

Today, motor development, motor control, and motor learning are distinct subject areas within the physical education sciences. Many teacher education programs now require at least one course in either motor development or motor learning, while motor control is occasionally covered in a motor learning course. In addition, early childhood education curricula often include a motor development course. In graduate schools, motor development, motor control, and motor learning have emerged as separate areas of specialization, especially at the doctorate level (Seidentop, 1994).

The Praxis Series Tests

Objective 1.5: Define the Praxis II exam, and identify the main motor behavior content areas that are covered on the health and physical education, physical education, and early childhood education tests.

Introduction

The **Praxis Series** is a program developed by the Educational Testing Service to provide tests and other services to states for use as a part of the teacher certification process. According to the Educational Testing Service (2001), over 80% of the states that include tests as part of their licensure process, rely on the Praxis Series tests. The Praxis assessments contain the most current research and content, and they are continually updated. **Praxis I** is an academic assessment designed to measure general academic skills of college students. **Praxis II** is the subject assessment and is designed to measure a teaching candidate's knowledge of the subject in which certification is sought. Many of the Praxis II tests also measure general and specific pedagogical knowledge. Several different Praxis II tests are offered to enable states to select tests that best meet their requirements. Some of the Praxis II specialty area tests cover motor behavior information. Motor behavior content makes up a large portion of the subject tests in health and physical education, physical education, and early childhood education. These include the following seven tests: a) Health and Physical Education (test code 20850), b) Health and Physical Education: Content Knowledge (test code 20856), c) Physical Education (test code 10090), d) Physical Education: Content Knowledge (test code 10091), e) Physical Education: Movement Forms – Analysis and Design (test code

30092), f) Physical Education: Movement Forms – Video Evaluation (test code 20093), and g) Early Childhood Education (test code 20020).

Health and Physical Education (test code 20850)

The Health and Physical Education test (test code 20850) is designed for prospective kindergarten through twelfth grade health and physical education teachers. Approximately half of the test questions deal with health content, and about half focus on physical education content. The content categories include I. Foundations for Health Education, II. Foundations for Physical Education, III. Program Development in Health Education, IV. Program Development in Physical Education, V. Program Content in Health Education, VI. Program Content in Physical Education, and VII. Program Administration in Physical Education and Professional Awareness in Health and Physical Education. Motor behavior content may appear in any one of three of the seven categories, all of which make up 44% of the test. According to the Educational Testing Service, analysis of human movement, growth and development, and developmental stages are all areas that are covered under the content category, Foundations for Physical Education. Instructional strategy is an area covered under the content category, Program Development in Physical Education. Questions related to motor learning, such as types of practice and feedback, could be asked in this area. Finally, human growth and development, biological and environmental influences on development, and changes throughout the lifespan are areas covered under the category, Program Content in Health Education.

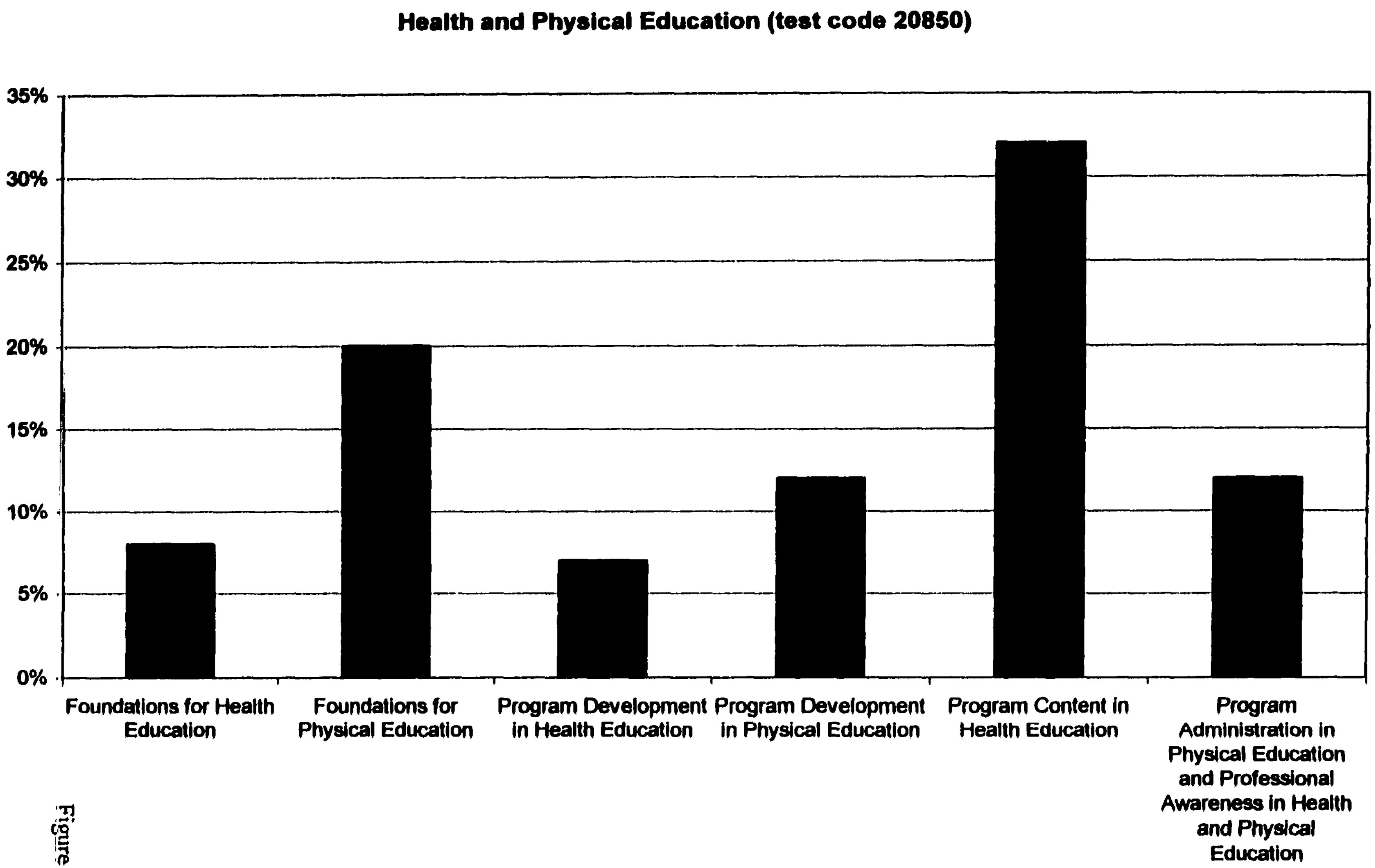
Health and Physical Education (test code 20850)
35%
30%
25%
20%
15%
10%
5%
0%
Foundations for Health Education
Foundations for Physical Education
Program Development in Health Education
Program Development in Physical Education
Program Content in Health Education
Program Administration in Physical Education and Professional Awareness in Health and Physical Education

Figure 4.

Health and Physical Education: Content Knowledge (test code 20856)

The Health and Physical Education: Content Knowledge test (test code 20856) is designed for prospective teachers of health and physical education at any grade level. Approximately 50 of the 120 test items cover health content, and about 70 questions cover physical education content. The three content categories under the physical education portion are I. Fundamental Movements, Motor Development, and Motor Learning, II. Movement Forms, and III. Fitness and Exercise Science. The category of Fundamental Movements, Motor Development, and Motor Learning makes up approximately 18% of the exam. Questions from this area include information related to fundamental movements, movement concepts, growth and motor development, the role of perception in motor development, neurophysiology of motor control, effects of maturation and experience on motor patterns, biological and environmental influences on gender differences in motor performance, motor learning theories, variables that affect learning and performance, and effects of individual differences on learning and performance. The category, Movement Forms, makes up approximately 19% of the exam, and questions from this area include information related to motor skill analysis of dance and rhythmic activities, and individual, dual, and team sports.

Health and Physical Education: Content Knowledge (test code 20856)

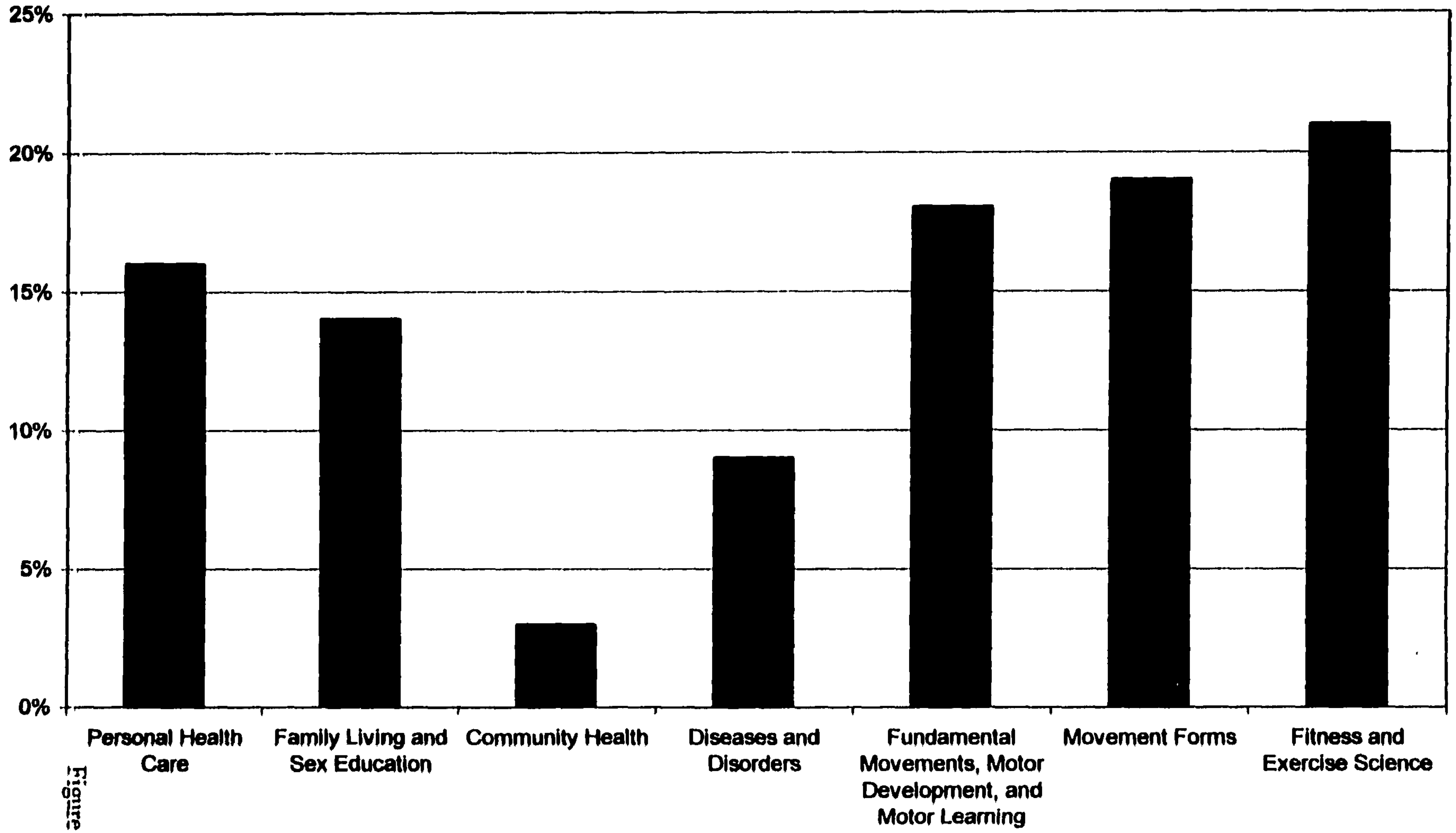

Figure 5.

Physical Education (test code 10090)

The Physical Education test (test code 10090) is designed for potential teachers of physical education at any grade level from kindergarten through grade twelve. The seven content categories are I. The Art of Human Movement, II. The Science of Human Movement, III. The Role of Physical Education as a Profession, IV. The Role of Physical Education Within the Total School Curriculum, V. Planning the Teaching/Learning Process, VI. Implementing the Teaching/Learning Process, and VII. Evaluating the Teaching/Learning Process. Motor behavior information is covered on three of the seven content categories. The category, The Art of Human Movement, makes up approximately 25% of the examination. Topics under this category include movement elements of fundamental motor skills and sport skills. The content category entitled, The Science of Human Movement, also makes up approximately 25% of the examination questions. Topics under this category include analysis of basic movement patterns, patterns of neural, physiological, psychological, perceptual, and cognitive development across the lifespan, variables influencing motor development, influence of motor development on performance, application of motor development concepts to teaching and learning, motor learning theories, the effect of variations of feedback and practice on learning and performance, and the application of motor learning concepts to teaching and learning. Motor behavior content is also included on the Implementing the Teaching/Learning Process category. Topics such as teaching skills and strategies, and teaching models and styles are covered.

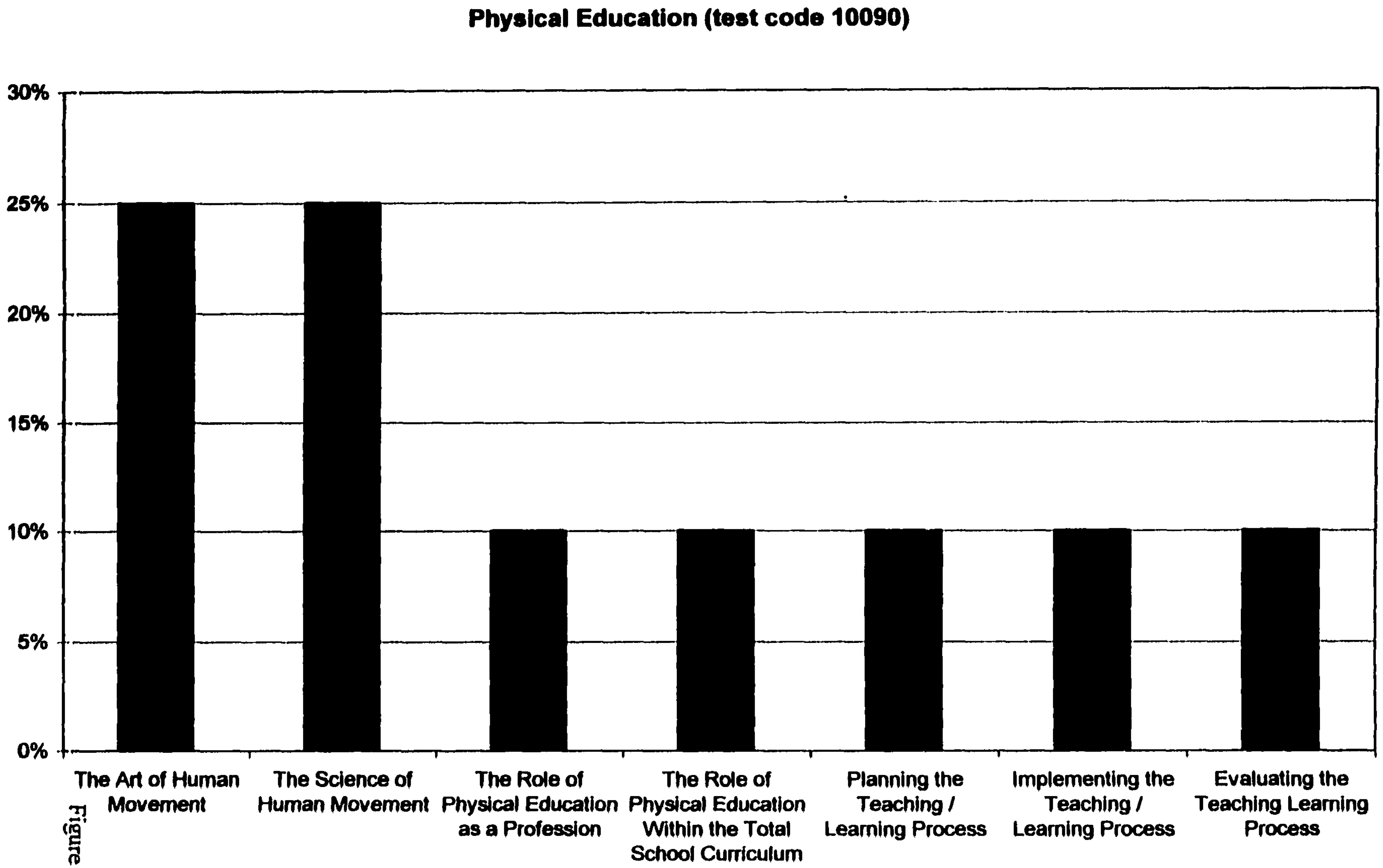
Physical Education (test code 10090)
30%
25%
20%
15%
10%
5%
0%
The Art of Human Movement
The Science of Human Movement
The Role of Physical Education as a Profession
The Role of Physical Education Within the Total School Curriculum
Planning the Teaching / Learning Process
Implementing the Teaching / Learning Process
Evaluating the Teaching Learning Process

Figure 6.

Phvsical Education: Content Knowledge
(test code 10091)

The Physical Education: Content Knowledge test (test code 10091) contains six content categories. They are I. Fundamental Movements, Motor Development, and Motor Learning, II. Movement Forms, III. Fitness and Exercise Science, IV. Social Science Foundations, V. Biomechanics, and VI. Health and Safety. The two categories, a) Fundamental Movements, Motor Development, and Motor Learning and b) Movement Forms ,make up approximately 48% of the exam questions, and the motor behavior topics in these categories are the same that appear on the Health and Physical Education test (test code 20856). Some motor behavior content is also included in the Biomechanics category of this test. Related information under this category includes application of basic principles of sport skills and analysis of fundamental movement patterns.

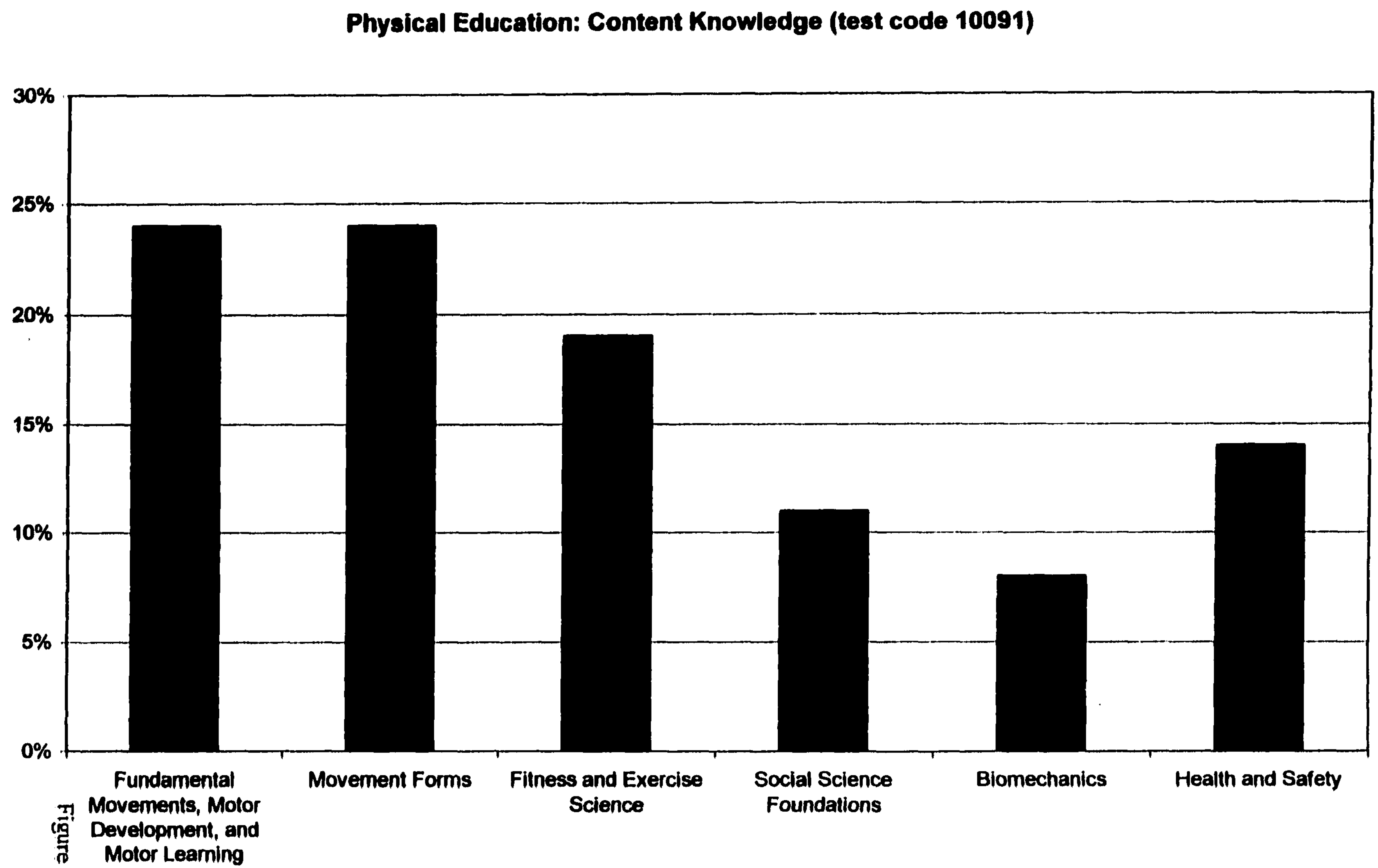
Physical Education: Content Knowledge (test code 10091)
30%
25%
20%
15%
10%
5%
0%
Fundamental Movements, Motor Development, and Motor Learning
Movement Forms
Fitness and Exercise Science
Social Science Foundations
Biomechanics
Health and Safety

Figure 7.

Physical Education: Movement Forms – Analysis and Design (test code 30092)

A fifth test containing motor behavior information is the Physical Education: Movement Forms – Analysis and Design test (test code 30092). This test is designed to assess the ability of prospective kindergarten through twelfth grade physical education teachers to select appropriate activities, make intelligent decisions about students' needs, and explain the reasons for these decisions. The test consists of two essay questions which deal with health-related fitness, the ability to analyze movement forms in terms of progression from introductory to advanced levels of skill performance, and the selection and description of movement activities that will enable children to reach specified goals in physical education.

Physical Education: Movement Forms – Video Evaluation (test code 20093)

A sixth exam, Physical Education: Movement Forms – Video Evaluation (test code 20093), is designed to assess the ability of prospective kindergarten through twelfth grade physical education teachers to identify critical features in the performance of movement forms and exercises, and to describe appropriate ways to communicate with students about changing and/or improving performance. This test consists of two essay questions, each of which covers at least one of the topics related to motor skill performance and fitness, fundamental movements, and movement forms. Each question is based on a videotape of school-age children performing various movements. The video may show a child practicing a skill such as kicking a ball. An examinee might be asked to describe major characteristics of the child's performance and to suggest appropriate remediation to improve that performance.

Early Childhood Education (test code 20020)

The Early Childhood Education test (test code 20020) is intended for examinees whc are prospective teachers of preschool through the primary grades. The six content categories are I. Growth, Development, and Learning of Young Children, II. Factors Influencing Individual Growth and Development, III. Applications of Developmental and Curriculum Theory, IV. Planning and Implementing Curriculum, V. Evaluating and Reporting Student Progress and the Effectiveness of Instruction, and VI. Understanding Professional and Legal Responsibilities. Approximately 31% of the test questions relate to the Growth, Development, and Learning of Young Children category. This category includes topics of typical and atypical physical growth and development, and patterns of gross and fine motor development. Motor behavior content is also included in the category, Factors Influencing Individual Growth and Development. This category makes up approximately 10% of the examination (Educational Testing Service, 2001).

Early Childhood Education (test code 20020)

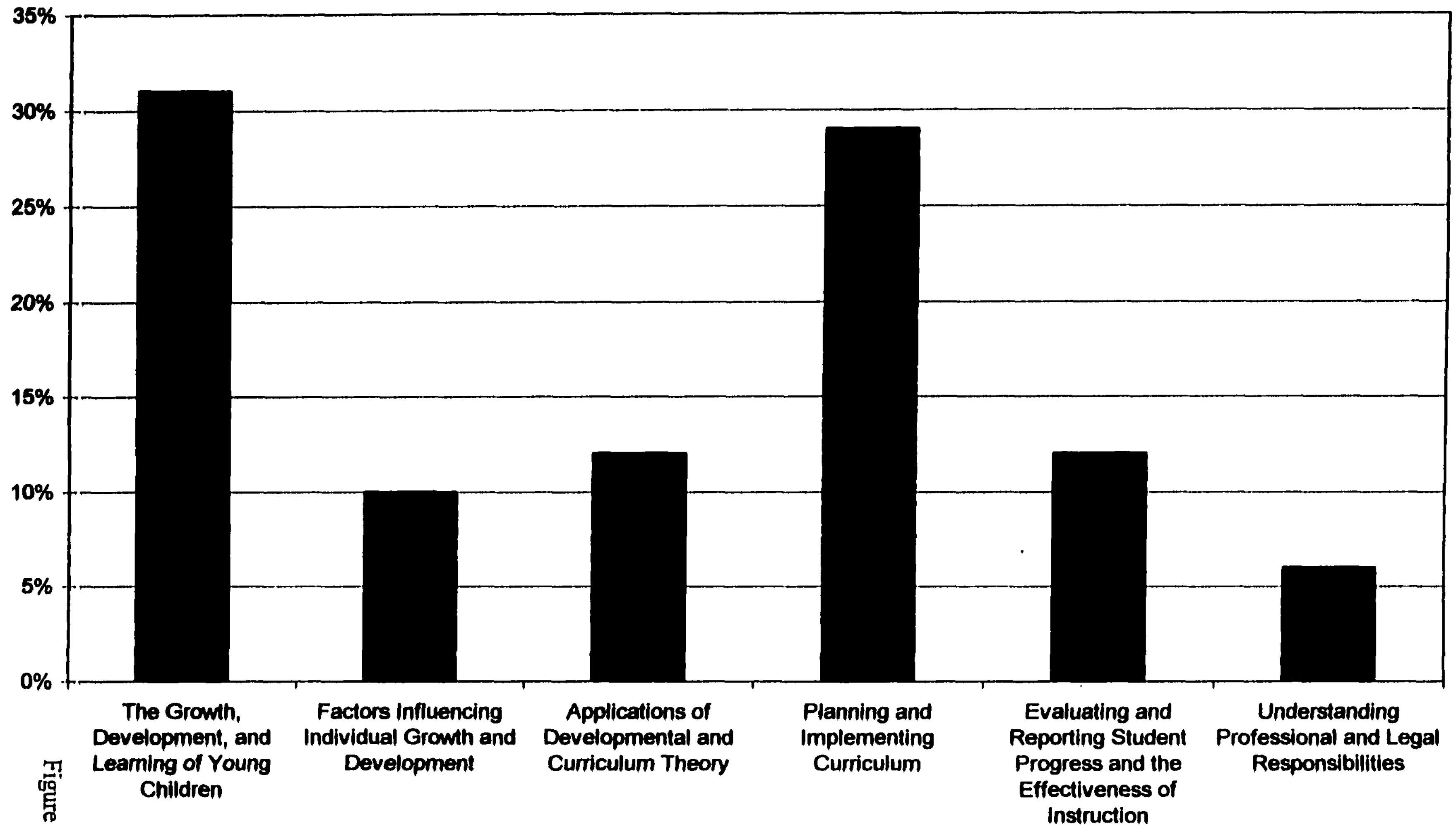

Figure 8.

Summary

Motor behavior is a field of study under the human movement "umbrella" and is concerned with the investigation of the principles of human skilled movements. Three specialized sub-areas fall under the discipline of motor behavior. These are motor development, motor control, and motor learning. Motor development is the study that examines patterns of change in growth, development, and performance across the lifespan. Motor development is also concerned with the underlying processes of these changes and factors that affect them. Motor control is the study of the neurophysiological aspects of movement, and motor learning is the study of the processes involved in acquiring and perfecting motor skills. All three of the sub-areas are interdisciplinary, and their research overlaps.

Motor behavior serves as an important knowledge foundation for many professions. These include, but are not limited to, physical educators, early childhood educators, infant stimulation specialists, childcare specialists, coaches, fitness professionals, sports medicine specialists, occupational therapists, and physical therapists.

The first studies of motor skills were performed by the astronomer, Bessel, in the early 19th century. With the exception of Bessel's work, the history of motor behavior research is typically categorized into four distinct periods: a) 1890 – 1927, b) 1928 – 1944, c) 1945 – 1966, and d) 1967 – present.

Motor behavior content is included on many of the Praxis II subject assessments for beginning teachers. Seven of these tests have been identified. These fall under the specialty areas of health and physical education (2), physical education (4), and early childhood education (1).

Questions for Discussion

1. What do you think the next historical period of motor behavior will bring? Will the three sub-areas become so specialized that each will become isolated from the others? Explain.

2. What curriculum changes may need to be instituted in college teacher education programs to better prepare students for motor behavior content on the Praxis II subject assessments?

Class Activities

1. Take the class to a library with internet access, and have each student look up the physical education course curriculum at *five* major colleges or universities in the United States. If the programs require a motor behavior course(s), have the student report the title and description of the course(s). Expect a variety of course titles and descriptions.

2. Obtain a copy of the Praxis Series Tests at a Glance Booklet, and go over the Praxis II sample questions for each of the tests offered in health and physical education, physical education, and early childhood education. See if the students can identify which questions relate to motor behavior.

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SECTION TWO

MOTOR DEVELOPMENT

Introduction

Section II is an examination of the major ideas and concepts that are central to the sub-area of motor development. Chapter Two, "Lifespan Development," covers general terminology, the nature versus nurture controversy, the continuity versus discontinuity debate, lifespan stages, motor development phases, general assumptions about development, and factors that affect growth and development. Chapter Three, "Physical Development," highlights the major physical changes that take place across the lifespan. Emphasis is placed on individual and gender differences, and special attention is given to the prenatal and pubescent periods. Included is the role of the endocrine system in relation to changes during puberty. Also, there is a short discussion of general implications that physical growth and development have on motor performance. Chapter Four, "Physiological Development," presents general cardiorespiratory terminology and the development of the heart and cardiorespiratory system. In addition, there is discussion of the major measures of physiological functioning. Included in the discussion is information of how each physiological function is assessed, how each physiological function changes across the lifespan, gender differences, and the effects of exercise and training on each measure of physiological functioning. The final chapter of Section Two is Chapter Five, "Phases of Motor Behavior." This chapter presents the general pattern of movement development that is characteristic of infancy to late adulthood. Gross and fine motor skills of infancy through adolescence are emphasized.

Chapter Two

Lifespan Development

Chapter Objectives

2.1 Define general and prerequisite terminology that is central to understanding human motor development.

2.2 Discuss the "nature versus nurture" controversy, and describe how each can affect motor development.

2.3 Describe the "continuity versus discontinuity" debate.

2.4 Name seven stages of lifespan development and the approximate age ranges that correspond with each stage.

2.5 Name seven phases of motor development, and give a general description of the characteristics of each.

2.6 List five general assumptions about development, and define the terms: **critical period, sensitive period**, and **plasticity**.

2.7 Define the term **teratogen**, and discuss prenatal internal and external factors that can affect growth and development.

Definitions of Key Terms

growth – an observable physical change in size

maturation – the qualitative functional changes that occur with age

heredity – the characteristics or qualities passed from parent to offspring

environment – the circumstances, objects, or conditions by which one is surrounded

cephalocaudal – growth and development that begins toward the head of the body and progress downward

proximodistal – growth and development that begins in the center of the body and moves toward the periphery

phylogenetic – behavior that tends to appear automatically and in a predictable sequence

ontogenetic – behavior that is specific to the environment by which one is surrounded

differentiation – process by which behavior becomes more specialized

integration – coordinated interaction of opposing muscle groups or limbs

continuity – the view that development involves gradual and cumulative changes

discontinuity – the view that development is stage-like

stage – age period in which common developmental milestones occur

phase – a part of a sequence of qualitative transitions over time, not affixed to specific age levels

critical period – an optimal time for the emergence of certain developmental processes and behaviors

sensitive period – a time in the lifespan when individuals may be especially sensitive to certain influences

plasticity – the dramatic capacity for change in response to positive or negative life experiences

teratogens – substances from the environment that can cause birth defects or can be fatal to the unborn fetus

Chapter Content Outline

I. Motor Development Terminology

II. Controversial Issues
   A. Nature versus nurture
   B. Continuity versus discontinuity
   C. Stages of the lifespan

III. Phases of Motor Development

IV. General Assumptions About Development

V. Prenatal Factors That Can Affect Growth and Development
   A. Internal factors
   B. External factors

VI. Summary

VII. Questions for Discussion

VIII. Class Activities

IX. References

Motor Development Terminology

Objective 2.1: Define general and prerequisite terminology that is central to understanding human motor development.

There are many general terms which recurrently surface in the study of motor development. Understanding the exact meaning of terms in order to use them appropriately in discussion is important. The terms **development, growth,** and **maturation** are often used interchangeably, but their meanings are different. The term **development**, as defined in Chapter One, means a change in the level of functioning. This change may be quantitative or qualitative in nature and is a product of growth, heredity, maturation, and experience. The sequential process of rolling, crawling, creeping, and walking is an example of human locomotor development. The term **growth** means a physical change in size that is observable. Growth represents quantitative change, such as changes in height and weight. Growth often plays a major role in motor development. **Maturation** is a component of development and refers to the qualitative functional changes that occur with age. These changes are primarily determined by genetics and resistant to environmental influence. Maturation is often used to describe the changes in functional efficiency of body organs and tissues (Payne and Isaacs, 1999).

Heredity and **environment** are two other important terms to consider. The term **heredity** is used to describe the characteristics or qualities passed from parent to offspring by means of genes. These sets of qualities are fixed at birth. Every cell in the human body has 46 chromosomes arranged in 23 pairs. Chromosomes are made up of thousands of genes which determine everything from hair color to muscle fiber type. **Environment** is a term used to describe the circumstances, objects, or conditions by which one is surrounded. It is an individual's experiences in the environment combined with genetic influences that interact to affect and alter development (Gabbard, 2000).

Two other terms that are essential to understanding motor development are **cephalocaudal** and **proximodistal**. These two terms describe the general pattern of growth and development that is characteristic of all humans. The word **cephalocaudal** is made up of two directional terms: "cephalic" (toward the head) and "caudal" (near the tail). Cephalocaudal is used to describe growth or development patterns that begin toward the head of the body and progress downward. An example of cephalocaudal development in humans is evident with infants. After birth, the first muscular control is obtained in the head and neck region, exhibited by an infant's ability to temporarily hold the head erect at about one month of age. Human infants then typically gain control of the trunk area, exhibited by the ability to roll, between two and eight months of age. The legs and feet are the last areas of muscular control to be established, and this becomes evident when infants are able to stand alone, around 11 to 13 months of age. The term **proximodistal** is also made up of directional terms: "proximal" (near the trunk) and "distal" (away from the trunk). Proximodistal growth and development progresses from the center of the body and moves toward the periphery. An example of proximodistal development is evident in the progression of motor control with the skill of writing. Early characteristics of writing include the use of the large muscle groups in or around the trunk and very little control of the small muscles of the forearm, wrist, hand, and fingers. Writing abilities typically progress through childhood until the movements are controlled solely by the smaller muscles of the hand and fingers (Gabbard, 2000).

Other terms to consider include **phylogenetic** behaviors, **ontogenetic** behaviors, **differentiation**, and **integration**. **Phylogenetic** behaviors are those behaviors that tend to appear automatically and in a predictable sequence. Upright locomotion is an example of a phylogenetic behavior in humans. **Ontogenetic** behaviors, on the other hand, are those behaviors that are specific to an individual and influenced mainly by learning and the environment. Surfing, snow skiing, and many sport skills are all examples of ontogenetic behaviors. **Differentiation** is a process by which behavior becomes more specialized. Progression of motor skills from rudimentary movements to more complex movements is an example of differentiation. **Integration** refers to the coordinated interaction of opposing muscle groups or limbs. Typically, as behavior differentiates, it also becomes more integrated. An elementary pattern of throwing is characterized by a throwing arm-dominated movement, with little control or movement from the opposing limbs. Mature throwing is exhibited when the performer is able to take the appropriate steps, make appropriate movements with the legs, trunk, and non-throwing arm, and follow through with the throwing arm. Throwing a curve ball in baseball incorporates a great deal of differentiation and integration.

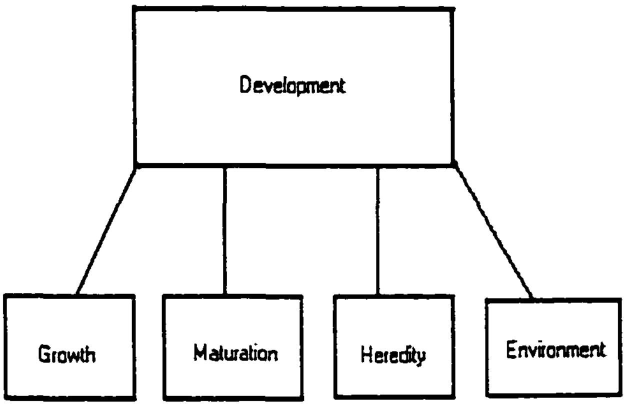

Figure 9.
Components of Development

Controversial Issues

Objective 2.2: Discuss the nature versus nurture controversy, and describe how each can affect motor development.

Nature Versus Nurture

One of the historical debates in developmental literature is the controversy over the question, "Is development the result of an individual's genetics or the kinds of experiences he or she is exposed to?" This debate has come to be known as the "heredity versus environment" or the "nature versus nurture" debate. Early 20th century theorists such, as Gesell (1925), believed that development is mainly the result of inherited factors and requires no stimulation from the environment. Gesell believed that physical growth, intelligence, and motor abilities are all tied closely with the development of the nervous system. Gesell hypothesized that if certain characteristics did not mature, practicing phylogenetic skills is useless. In opposition to this view were researchers such as Watson (1928) and Skinner (1974). They believed that the environment was the most important factor with respect to human development. Skinner's idea of "operant conditioning" implied that human behavior is controlled by environmental reinforcers and can be altered by controlling the reinforcement. Another pro-environment theorists, Bandura (1994), presented the idea of "observational learning," which states that virtually all of what an individual learns comes from modeling and observing others. Most current authors and researchers in motor behavior contend that both nature and nurture play a role in the learning and development of motor skills. Schmidt's (1991) information processing theory emphasizes the importance of the brain and information processing ability such as attention, memory, and perception. Schmidt makes the analogy of the human brain to that of a computer, where the brain is the hardware, and an individual's experiences are the software.

Objective 2.3: Describe the continuity versus discontinuity debate.

Continuity Versus Discontinuity

Another controversial issue in the developmental literature has been the debate over whether development is a continuous and cumulative process or stage-like. This debate has come to be known as the **continuity** versus **discontinuity** controversy. **Continuity** is the view that development involves gradual and cumulative changes without any abrupt starts and stops. **Discontinuity** is the view that development is more stage-like, where common milestones occur with each stage. Piaget (1971) and Erikson (1963) described different aspects of development in stages. Currently, there is little research evidence to support the existence or nonexistence of stages in human motor development. Even though this controversy is unresolved, it is useful to categorize human development into stages for identification purposes (Payne and Isaacs, 1999).

Stages of the Lifespan

Objective 2.4: Name seven stages of lifespan development and the approximate age ranges that correspond with each stage.

A **stage** is an age period in which common developmental milestones occur. The identification of distinct stages throughout the lifespan varies among textbooks. The following seven stages of lifespan development, however, are accepted by many authors: prenatal period, infancy, early childhood, late childhood, adolescence, young adulthood, and older adulthood (Gabbard, 2000).

The first stage of the lifespan is the prenatal period and typically lasts nine months. The prenatal period begins with the uniting of the sperm and egg cells, and the result is a fertilized egg, called a zygote. This process is referred to as conception. This is followed by a 14-day period, called the germinal period, in which two masses form. The inner mass becomes the fetus, and the outer mass becomes the mother-baby barrier. The next portion of the prenatal period lasts from two to eight weeks after conception and is called the embryonic period. During this period, the human form takes shape. The last portion of prenatal development is the fetal period, which lasts from eight weeks to birth.

During this period, the fetus becomes a recognizable human being (Payne and Isaacs, 1999).

The second stage of lifespan development is the infancy period. This period lasts from birth to two years. Infancy includes the neonatal period, which is the first 22 days of infancy. Some authors identify infancy as birth to the onset of independent walking, which is around one year of age (Payne and Isaacs, 1999).

The third lifespan stage is early childhood and lasts approximately from age two to age six. This is a very significant stage in the development of the fundamental movement skills. Some authors use the term "toddlerhood" to describe young children between the ages of one to four (Payne and Isaacs, 1999).

Late childhood is the fourth lifespan stage and lasts from age six to age twelve. During this period, fundamental motor skills are refined. Late childhood is followed by adolescence, the most dramatic period of biological change second to the prenatal period. Adolescence has an approximate age range of 12 to 18 years. During this time, there is accelerated growth, sexual maturation, and a mastery of the fundamental motor skills. The sixth lifespan stage is young adulthood, age 18 to 40, and the seventh stage is older adulthood, age 40 to death (Gabbard, 2000).

Phases of Motor Development

Objective 2.5: Name seven phases of motor development, and give a general description of the characteristics of each.

A **phase** is a part of a sequence of qualitative transitions over time, not affixed to specific age levels. Seven phases of motor development can be identified parallel to the stages of lifespan development. The first two phases overlap, but the last five are distinctly separate from one another. The first phase is the "involuntary movement phase," and it begins about the third fetal month and lasts into the first year of life. Some authors refer to this phase as the reflexive or reflexive/spontaneous phase. Movements during this phase consist of automatic reflexes and stereotypical movements. Between birth and age two, infants exhibit early voluntary movements as well, and this phase is appropriately named the "early voluntary movement phase." Some authors refer to this phase as the rudimentary phase. During this phase, an infant learns to crawl, creep, walk, and grasp objects voluntarily (Gabbard, 2000).

The third motor behavior phase is called the "fundamental skills phase." This phase lasts from age two to age six. Perceptual motor awareness, such as body awareness and balance, begin to develop. The three general categories of fundamental movements also begin to develop. These fundamental movements are the locomotor (i.e. running, jumping), nonlocomotor (i.e. twisting, turning, bending), and manipulative (i.e. throwing and striking) skills (Payne and Isaacs, 1999).

The fourth and fifth phases of motor behavior are mastery phases. Between the ages of six and twelve, children go through the "advanced fundamental phase." Some authors term this the sport skill phase. Between the ages of 12 and 18, individuals go through the "skill refinement phase," sometimes termed the growth and refinement phase. During this phase, motor skill refinement occurs, if there is continued practice (Gabbard, 2000).

The "peak performance phase" occurs between ages 18 and 30, and during this time most neurological and physiological functions climax. The final phase of motor behavior, regression, lasts from age 30 to death. After age 30, most of the neurological and physiological functions begin to decrease by approximately one percent per year (Gabbard, 2000).

General Assumptions About Development

Objective 2.6: List five general assumptions about development, and define the terms: critical period, sensitive period, and plasticity.

There are at least five general assumptions that can be made about human development. These should be taken into consideration when analyzing motor behavior.

1. Development is a continuous process from conception to death. Perhaps the only thing that is constant throughout the lifespan is change. Even though stages are used to identify typical periods of the lifespan, development is an ongoing process that does not stop after childhood or adolescence.
2. There are **critical** and **sensitive periods** in development. A **critical period** is an optimal time for the emergence of certain developmental processes and behaviors. These periods are sometimes referred to as "windows of opportunity." Recent research has supported that the optimal time for brain development is birth to nine years of age. A child who misses an opportunity to develop a portion of the brain's circuitry during this period may never achieve the fullest potential. For basic motor skill development, the optimal time is between birth and five years, and for fine motor skill development, it is between birth and age nine. After this time, the brain becomes a bit more "hard-wired." **Sensitive periods** are times in the lifespan when individuals may be especially sensitive to certain influences.

The embryonic and fetal periods are times in which there is a high sensitivity to outside agents, such as alcohol or drugs.

3. The environment plays a very important role in all aspects of development. Development is aided by positive stimulation. Providing a stimulating environment encourages optimal development. Heredity and environment play interactive roles in development.

4. Humans have a great deal of **plasticity**, the dramatic capacity for change in response to positive or negative life experiences. The human body is very resilient in overcoming many adverse experiences or lack of experiences, as long as the case is not too extreme. **Plasticity** is evidenced by children who are born with no apparent abnormalities given exposure to drugs, smoking, or alcohol by the mother.

5. Regression is unavoidable. Most neurological and physiological functions will regress with aging. Examples include hearing loss, vision loss, decreased muscular strength, and decreased aerobic capacity (Gabbard, 2000).

Prenatal Factors That Can Affect Growth and Development

Objective 2.7: Define the term teratogen, and discuss prenatal internal and external factors that can affect growth and development.

Internal Factors

The unborn child can be affected by prenatal internal or external factors. Internal factors are genetic influences or maternal conditions of the prenatal environment that can affect development. External factors include what the mother brings into her body.

Teratogens are substances from the environment that can cause birth defects or can be fatal to the unborn child. Given mild exposure to these outside agents, human beings are very resilient and often develop normally in spite of them. Approximately 97% of all babies are born without serious birth defects (Gabbard, 2000).

A first internal factor that can affect development is maternal age. A child is at a higher risk of having a birth defect if the mother is younger than age 16 or older than age 35. Women older than 35 years have an increased chance of having a child with Down's syndrome or a child who has trouble developing fine motor skills. The safest ages to have a child are estimated between 22 and 29 (Gabbard, 2000).

A second internal factor is nutrition of the mother before and during pregnancy. Poor nutrition can result in low birth weight, premature birth, and poor motor and neurological development (Gabbard, 2000).

Rh incompatibility is a third internal factor that can affect development. Rh stands for Rhesus and represents the presence or absence of a certain type of blood protein. Eighty-five percent of the population have Rh-positive blood, and 15% have Rh-negative blood. If an Rh-negative mother gives birth to an Rh-positive baby, some of the baby's blood could escape into the mother's bloodstream during labor. Without special medication within 24 hours of labor, the mother could develop antibodies to Rh-positive blood. This could cause problems in a second pregnancy if the antibodies destroy the red blood cells of the second fetus (Gabbard, 2000).

A fourth category of internal factors are genetic-related abnormalities. Down's syndrome is a disorder in which there is the presence of an extra chromosome. Characteristics include retarded mental and motor development. Also, there are usually distinct physical features, such as almond-shaped eyes and short limbs. After age 35, a mother is at a higher risk of having a baby with Down's syndrome. It is estimated that one in 700 births are Down's syndrome babies. Phenylketonuria (PKU) is another genetic-related abnormality. PKU is a hereditary condition in which there is an absence of a liver enzyme which breaks down a protein common in many foods. This rare condition can cause heart and brain damage. Sickle cell anemia is another hereditary condition that can affect development. Sickle cell anemia is rare in Caucasians, but approximately 10% of African Americans are carriers of the harmful gene. Persons with this disorder have abnormal hemoglobin, a blood compound that transports oxygen to the tissues of the body. The hemoglobin becomes deformed or "sickle-shaped," and cells lump together. This thickens blood and prevents blood and oxygen from traveling through the smaller blood vessels. Exercising is very difficult for persons with the disorder (Gabbard, 2000).

A fifth internal factor that can have an affect on development is the emotional state of the mother. Prolonged stress, depression, anxiety, or fear raises the level of adrenaline and restricts blood flow to the fetus (Gabbard, 2000).

External Factors

One external factor that affects development is infection and disease. Diseases such as rubella and the cytomegalovirus can often cause mental retardation and heart defects in the developing fetus. Sexually transmitted diseases such as syphilis can damage the nervous system. The Acquired Immune Deficiency Syndrome (AIDS) virus, if passed to the fetus, can destroy the immune system. There is also an increased risk of fetal death for mothers with diabetes. Surviving children of diabetics may be overweight and experience low blood sugar. Other diseases that can affect development include mumps, hepatitis, and scarlet fever (Gabbard, 2000).

Drugs and chemicals are a second category of external factors that can affect development. When a pregnant woman smokes, the nicotine and carbon monoxide enter the bloodstream of the fetus and cause oxygen deprivation. Oxygen deprivation can stunt physical growth and development, especially in the last three to four months of pregnancy. Babies born to smoking mothers are more likely to weigh less, experience neurological problems, have trouble in reading and math, and show hyperactivity. Mothers who drink alcohol run the risk of having a child born with fetal alcohol syndrome (FAS). FAS causes facial and developmental abnormalities related to the mother's alcohol consumption. Characteristics include low birth weight, abnormally-shaped head and facial features, central nervous system disorders, and abnormal behavior. Even moderate alcohol consumption can result in minor deficiencies in fine motor skill development or balance. Thus, many physicians recommend no alcohol intake during pregnancy. Other drugs can also cross the placental barrier and affect the fetus. Antibiotics, aspirin, marijuana, and cocaine are examples of drugs that pass from mother to fetus. Drugs can be very damaging because a small dose for the mother is often a large dose for the fetus, and the liver of the fetus cannot break down certain drugs; therefore, drugs remain inside the fetal body for long periods of time. Some children are even born addicted to drugs (Gabbard, 2000).

Exposure to other environmental agents can harm the developing fetus. Radiation may cause central nervous system disorders, tumors, or mental retardation.

Other teratogenic agents include chemicals, pesticides, preservatives, and artificial sweeteners (Gabbard, 2000).

Summary

Development, growth, and maturation are all similar terms that have slightly different meanings. Development means a change in the level of functioning, growth refers to a change in size, and maturation means qualitative functional changes of body organs and tissues. Cephalocaudal development is a pattern of growth and development that begins toward the head and moves toward the feet. Proximodistal development is a pattern of growth and development that begins in the center of the body and moves toward the periphery. Humans generally grow and develop in these two specific patterns. Two controversial issues in the developmental literature are nature versus nurture and continuity versus discontinuity.

The lifespan can be divided into the following seven stages: prenatal, infancy, early childhood, late childhood, adolescence, young adulthood, and older adulthood. Seven phases of motor development can also be identified in parallel to the lifespan stages. These phases are the involuntary movement, early voluntary movement, fundamental skills, advanced fundamental skills, refinement, peak performance, and regression phases.

At least five basic assumptions can be made about human development. They are: 1) development is a continuous process from conception to death; 2) there are critical and sensitive periods in development; 3) the environment plays a very important role in all aspects of development; 4) humans have a great deal of plasticity; and 5) regression is inevitable.

Both prenatal internal and external factors can affect development. Internal factors include maternal age, nutrition, Rh incompatibility, genetic abnormalities, and the mother's emotional state. A teratogen is anything from the environment that can harm or kill the fetus. Examples of external factors include infection and disease, drugs and chemicals, and radiation.

Questions For Discussion

1. How are both nature and nurture important factors in the development of the world's greatest athletes? In your own development?

2. Do you think there is a critical period for the development of certain sport skills?

Class Activities

1. Divide the class into groups. Each group writes down as many teratogens as possible. Discuss and compare responses.

2. Divide the class into groups. Each group develops a "new" model of the phases of motor development, including a diagram, such as an hourglass or a beehive. Each group also provides new names and approximate age ranges of the phases. Provide each group a white piece of poster board, a ruler, and colored markers. Have each group present its diagram to the class.

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Chapter Three

Physical Development

Chapter Objectives

3.1 Summarize the major physical growth trends that take place across the lifespan.

3.2 Identify the major growth and development milestones of the prenatal period.

3.3 Discuss the role of the endocrine system in the pubescent growth spurt, and describe the major anatomical differences of males and females following puberty.

3.4 Describe the general body proportion changes from birth to adulthood, and define the three basic somatotypes.

3.5 Discuss the typical changes in stature from birth to adulthood.

3.6 Define **ossification** and **osteoporosis**, and describe the general pattern of skeletal growth across the lifespan.

3.7 Identify general body mass changes across the lifespan.

3.8 Describe muscle tissue growth changes across the lifespan.

3.9 Explain the implications of how changes in physical growth can affect motor performance.

Definitions of Key Terms

prenatal period – the lifespan period from conception to birth

conception – the beginning of the prenatal period; when the sperm unites with the egg

germinal period – the period lasting approximately 14 days after conception

embryonic period – the period lasting approximately two to eight weeks after conception

fetal period – the period lasting approximately eight weeks prenatal to birth

ossification – the process by which cartilage is replaced by bone

age of viability – the age at which the fetus has matured enough that it would have a 50% chance of survival outside of the womb; approximately the 28th prenatal week

puberty – period of accelerated physical growth and maturation occurring in early adolescence

menarche – a female's first menstruation

hormone – a chemical messenger secreted into the bloodstream in response to conditions in the body that require regulation

somatotype – classification of body physique

atrophy – a decrease in size of cells

midgrowth spurt – a brief growth spurt that occurs at about age seven

osteoporosis – loss of bone mass in which the bone becomes porous and fragile

hyperplasia – increase in number of cells

hypertrophy – increase in size of cells

type I muscle fiber – type of skeletal muscle fiber which is resistant to fatigue and associated with endurance activities

type II muscle fiber – type of skeletal muscle fiber which is associated with rapid, forceful, or explosive movements

transitional fiber – type of skeletal muscle fiber that can become type I or type II depending upon training

Chapter Content Outline

I. Overview of Lifespan Physical Growth

II. Prenatal Development
   A. Introduction
   B. Conception
   C. Germinal period
   D. Embryonic period
   E. Fetal period

III. Pubescent Growth Spurt
   A. General characteristics
   B. The role of the endocrine system
   C. Major gender differences

IV. Body Proportion Changes
   A. Head, limb, and trunk proportion changes
   B. The three somatotypes

V. Structural Development
   A. Height changes
   B. Ossification and skeletal development

VI. Body Mass Changes
   A. Body weight
   B. Body composition

VII. Muscle Tissue Changes
   A. Growth of skeletal muscle
   B. Fiber types

VIII. Implications of Physical Growth Changes on Motor Performance

IX. Summary

X. Questions for Discussion

XI. References

Overview of Lifespan Physical Growth

Objective 3.1: Summarize the major physical growth trends that take place across the lifespan.

Physical growth and development is a continuous process that begins with conception and ends with death. Early in life, growth follows a cephalocaudal and proximodistal pattern. Between conception and birth, human beings grow at their fastest rate. Over the first six years of life, growth increases at a steady rate. By middle to late childhood, the growth rate slows considerably. This is followed by puberty, a landmark in physical growth and motor performance. Puberty represents the most dramatic period of biological change second to the prenatal period. After puberty, physical gender differences become very apparent. In early adulthood, physical growth begins to slow. The tendencies during adulthood include an increase in body weight, a decrease in muscle mass, and a decrease in height. The decrease in height and muscle mass continues through old age, but body weight typically lowers.

Prenatal Development

Objective 3.2: Identify the major growth and development milestones of the prenatal period.

Introduction

The term **prenatal** means "before birth," and it represents the time from conception to birth. The prenatal period is very important because it lays the foundation for future development. In addition, the prenatal period represents the time of greatest variation in human development. The prenatal period can be divided into four progressive stages: a) **conception**, b) the **germinal period**, c) the **embryonic period**, and d) **fetal period**.

Conception

Conception represents the beginning of life and is characterized as the point in which a sperm cell unites with an egg cell, or ovum. The size of a sperm cell is approximately 1/150 of one centimeter. Once the tiny sperm cell unites with the egg, the result is a fertilized egg, or zygote (Tortora, 1994).

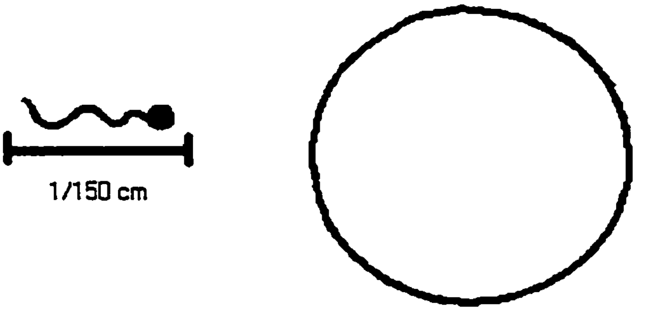

Figure 10.
Diagram of the Sperm and the Egg Cells

Germinal Period

The second stage of prenatal development is the **germinal period**, and this represents approximately 14 days after conception. One of the milestones of this period is that cell differentiation begins. During this time two masses form. The inner mass becomes the fetus, and the outer mass becomes the mother-fetus barrier (Gabbard, 2000).

Embryonic Period

The **embryonic period** is approximately two to eight weeks after conception. By the eighth week, the organism is about one-half inch in length and weighs about one-half ounce. During this period, the human form takes shape with a distinct head, trunk, and ears, eyes, and limbs. The internal organs also begin to develop, and by the eighth week, a basic central nervous system has developed. Development follows a cephalocaudal and proximodistal pattern. An eight-week-old embryo has a very large head and trunk in relation to the rest of body. There is very little detail in the periphery of the body. No fingernails, toenails, fingerprints, or footprints have yet developed (Gabbard, 2000).

Fetal Period

The **fetal period** is the longest period of prenatal development and lasts from eight weeks to birth. The fetus becomes a recognizable human being during this time. At approximately the 12th prenatal week, gender can be distinguished. Around this time, the first skeletal muscle contractions take place. Involuntary contractions of the muscles of the limbs, mouth, and jaw occur. The process of **ossification** also begins early in the fetal period. This is the process by which cartilage is replaced by bone. Significant head growth and development of facial features occur early in the fetal period. By the 16th prenatal week, the fetus grows to approximately six inches and weighs four ounces. At this time, toes and fingers begin to separate, and fingerprints and footprints emerge. This is evidence of proximodistal development. At 20 weeks, the fetus is about 12 inches and weighs about one pound. Further proximodistal development occurs as features on the skin and fingernails and toenails form. At 24 weeks, the eyelids open for the first time, and the fetus is 14 inches and weighs two pounds. The seventh month is a very crucial time for the fetus. Many experts agree that at about the 28th prenatal week, a fetus has matured enough to have a 50% chance of survival outside of the womb. This is known as the **age of viability**, and it represents a time when the internal organs of a fetus are able to function on their own. The brain is able to regulate breathing, heart rate, body temperature, swallowing, and other involuntary functions. At seven months, a fetus is approximately 16 inches and weighs three pounds. Over the next two months, there is rapid weight gain. The fetus gains about a half of a pound per week until birth. This is partially due to the formation of subcutaneous fat that continues through infancy (Gabbard, 2000).

Pubescent Growth Spurt

Objective 3.3: Discuss the role of the endocrine system in the pubescent growth spurt, and describe the major anatomical differences of males and females following puberty.

General Characteristics

The pubescent growth spurt represents the most dramatic period of biological change second to the prenatal period. The term **puberty** is used to describe the time of rapid physical growth and maturation that occurs in early adolescence. Puberty is a period of rapid change in body size and proportions and is controlled mainly by genetics and hormones. Individuals become capable of reproduction during this two to three year period. Females typically will go through puberty between 10 and 13 years of age, and males will go through this period between the ages of 12 and 15. Noticeable changes for males include the appearance of pubic and facial hair, and a deepening of the voice. Changes for females include the appearance of pubic hair, breasts, and the first menstruation, called **menarche** (Payne and Isaacs, 1999).

The Role of the Endocrine System

The **endocrine system**, the hormonal system, is primarily responsible for causing the physical changes of puberty to occur. **Hormones** are chemical messengers secreted into the bloodstream in response to conditions in the body that require regulation. These chemicals act on other organs to regulate conditions. The release of pituitary hormones is regulated by a portion of the brainstem called the hypothalamus. Puberty begins as hormones are secreted, namely by the pituitary gland and the gonads. The pituitary gland, a walnut-sized gland that is located at the base of the brain, is sometimes referred to as the "master gland." The pituitary gland secretes human growth hormone, which interacts with androgens and estrogens to stimulate developmental changes. The gonads are the sex glands. Males' testes and females' ovaries secrete sex hormones, such as androgens and estrogens, but not in equal amounts. The adrenal glands, located on top of each kidney, also secrete androgens. The adrenal glands play a supportive role in puberty. The thyroid gland, located in the neck region, secretes thyroid hormones. These hormones play a role in stimulating the growth spurt and skeletal maturation. In childhood, both genders produce equal amounts of androgens and estrogens. However, during puberty males produce more androgens than estrogens, and females produce more estrogens than androgens. This is significant because androgens promote muscle tissue growth, and estrogens promote the accumulation of body fat. The hormone level difference among genders accounts largely for size, strength, and motor performance differences following puberty (Tortora, 1994).

Major Gender Differences

Following puberty, there are noticeable anatomical gender differences. Males are taller and heavier. Males have wider shoulders and longer forearms. The hip angle of females becomes more oblique, which lowers the center of gravity. Typically, males develop a wider chest and longer legs. Also, males have more muscle mass and greater bone density. Females develop a higher percentage of body fat.

Body Proportion Changes

Objective 3.4: Describe the general body proportion changes from birth to adulthood, and define the three basic somatotypes.

Head, Limb, and Trunk Proportion Changes

Different body parts show varying rates of growth from birth to adulthood. The head will double in size during this time. The trunk will triple in length, and the upper limbs will grow to four times the birth length. In adulthood, the lower limbs reach approximately five times the birth length. This is evidence of cephalocaudal and proximodistal body proportion changes from birth to adulthood. The head of a newborn makes up about one-fourth of the total height, and the legs are less than one-half of the total height. The adult head, however, is approximately one-eighth of the total height, and the legs make up one-half of the total height. The head width of a newborn is almost the same as the width of the hips and shoulders, whereas the adult hips and shoulders are much wider than the head (Payne and Isaacs, 1999).

Head circumference is an example of an anthropometric measure of body proportion. This assessment is taken with a tape measure around the brow ridge to the farthest protrusion in the back of the head. Head circumferences are commonly used to estimate brain growth in infants and young children. These measures are also taken to identify certain abnormalities such as hydrocephalus, a swelling of the brain due to fluid build-up. Head circumference increases steadily in the first three years of life, but after age three very little head growth occurs. An adult brain weighs approximately three and one-half pounds. The brain of a three year old is approximately 90% of its adult size (Gabbard, 2000).

Another body proportion measure is sitting height. This is a measurement from the seat of a chair to the vertex, or top of the head. Sitting height subtracted from total height equals leg length. During early childhood, sitting height is 60 to 70% of the total height. By early adulthood, sitting height is approximately 50% of the total height. The rapid growth of the legs through late childhood and adolescence is evidence of cephalocaudal development. After puberty, gender differences in total height are mainly due to the growth of the legs (Payne and Isaacs, 1999).

Shoulder and hip widtha are also used to measure proportional growth. Newborns typically have wider shoulders than hips. From birth to puberty, males and females experience a steady rate of growth in shoulder and hip width, and shoulder width is almost always greater. During puberty, males' shoulders grow wider, while the shoulder width of females levels off. The hip width of males typically levels off during this time, and females' hips grow slightly wider. Individual differences are due to underlying body type (Gabbard, 2000).

The Three Somatotypes

The term "physique" is often used synonymously with body type. Physique is a subjective measure that takes into consideration a person's body composition and proportions. Since body composition and proportions do change over time, accurately identifying what physique someone has is sometimes difficult. There are three basic body builds, or **somatotypes.** A **mesomorph** is a physique that is muscular and balanced in proportion. A mesomorph has a high percent of muscle mass as compared to fat mass. An **endomorph** is a soft and round body type, with a tendency to be obese. Endomorphs typically have a high percent of body fat. An **ectomorph** is a lean body type and is associated with very thin individuals. Somatotypes are inherited, and rarely does a person fall solely into one of these types. Most individuals have characteristics of at least two body types. Subjective scales are used to identify which somatotype an individual most resembles. Exercise and training can have an effect on a person's physique. Weight training increases a person's mesomorphic characteristics. Aerobic exercise and training helps to reduce endomorphic characteristics by reducing stored body fat. Physique will also change with age. Mesomorphic characteristics tend to diminish with age in the adult years. This change is due to disuse of skeletal muscle, causing the tissue to shrink in size, or **atrophy**.

Structural Development

Objective 3.5: Discuss the typical changes in stature from birth to adulthood.

Height Changes

Height measurement is the distance from the vertex to the heel, and it can be determined lying or standing. The greatest increases in height occur in the first three years of life. A two year old is typically about 50% of his or her adult height. At age seven, some children experience a short growth spurt, called the **midgrowth spurt**. This is much less dramatic than the growth spurt of puberty. Males, on average, are only slightly taller than females until adolescence. Since females tend to reach puberty two to three years earlier than males, there is a short period when girls grow taller than boys. Upon reaching puberty, males experience a more dramatic growth spurt and grow considerably taller than females. Females generally reach their peak growth spurt at 16 ½ years, and males generally peak at 18 years. Growth in height may continue to age 30 (Gabbard, 2000).

Objective 3.6: Define ossification and osteoporosis, and describe the general pattern of skeletal growth across the lifespan.

<u>**Ossification and Skeletal Development**</u>

Skeletal growth and development begins in the embryonic phase. **Ossification** first begins in the jaw and collarbones. By the second prenatal month, the long bones of the arms and legs take a cartilage form. **Ossification** is the process by which cartilage is replaced by bone. The process begins in the center of a bone and moves outward in both directions. Most bones reach full maturity in early adulthood. Complete ossification of long bones occurs at approximately age 18 for females and age 21 for males. Thus, the skeletal maturity of females is typically two to three years ahead of males (Tortora, 1994).

Females begin to lose bone density before males as well. Many women will begin to lose bone at age 30, while men will not begin to lose bone until age 50. The gradual loss of bone causes a decrease in height and rounding of the back, or kyphosis. Bone loss is specific to individuals, but a typical female may lose up to two inches in height from age 35 to 75. Males will typically only lose one inch in height during this period. Bone loss accelerates for females during menopause, and by age 70, there can be a bone loss of 25 to 30%. This is compared to an approximate bone loss in men of 15%. Some men and women will experience **osteoporosis**, an accelerated loss of bone mass due to bone becoming porous and fragile. Osteoporosis is a complex condition, which is caused by nutritional, hormonal, and genetic factors. Approximately two-thirds of all women over the age of 60 have osteoporosis (Gabbard, 2000).

Body Mass Changes

Objective 3.7: Identify general body mass changes across the lifespan.

Body Weight

A common measure of body mass is body weight. Body weight increases steadily from birth to adolescence. By age one, body weight is three times the birth weight. At age seven, body weight is seven times the birth weight. Body weight increases continue until puberty, then there is an acceleration of growth. Males on average are heavier than females across all ages after puberty. Body weight tends to increase during adulthood but starts to decrease in old age.

Body Composition

Body composition is an assessment of lean body mass and body fat. All measurements of body fat are estimates. Historically, the gold standard for measuring body composition has been hydrostatic weighing. Other methods for measuring body composition include skin fold caliper measurements, bioelectrical impedance, x-ray technology, anthropometric measurements, and body mass index. Males typically have a lower percent body fat than females at all ages. Values are closer until puberty, then gender differences become more pronounced. The body fat composition of a newborn is about 16%. This increases to 24 to 30% by age one. By age six, body fat is about 14%. Females experience a considerable increase in body fat during puberty, while males often experience a decreased body fat percentage. Body fat composition typically increases through adulthood in both males and females. This trend reverses in old age (Gabbard, 2000).

Fat cells grow by **hyperplasia**, an increase in number, and by **hypertrophy**, an increase in size. An average adult has approximately 25 to 50 billion fat cells. An obese adult may have as many as 75 billion fat cells. Fat cells quadruple in size from age one to adulthood. The number of fat cells increases dramatically during the third trimester of the prenatal period. By age one, the number of fat cells is approximately three times what it was at birth. After age one, fat cell hyperplasia continues steadily until puberty. Fat cell hyperplasia increases significantly during puberty, especially in females. After adulthood, the number of fat cells becomes fixed, and any increases in body fat are due only to hypertrophy of the cells (Gabbard, 2000).

Muscle Tissue Changes

Objective 3.8: Describe muscle tissue growth changes across the lifespan.

Growth of Skeletal Muscle

The first muscle fibers are developed around the 16th prenatal week. Growth of skeletal muscle tissue in the prenatal period is due both to hyperplasia and hypertrophy of the cells. Hyperplasia of muscle cells continues until shortly after birth. Increases in the size of skeletal muscle after this time are due solely to hypertrophy. The thickness of skeletal muscle at birth is approximately one-fifth of that of an adult. About 24% of the body weight of a newborn is muscle tissue. Increases in muscle fiber size continue steadily throughout childhood. During puberty, males experience a dramatic increase in lean mass, whereas females typically do not. The gender difference is due to the hormonal influence in puberty. Approximately 40 to 50% of the body mass of an adult male is muscle tissue. A fully mature female has about 60% of the muscle mass of a male (Gabbard, 2000).

Fiber Types

There are two general types of skeletal muscle fibers in humans. The first are called **type I fibers**, or slow twitch fibers. These muscle fibers are resistant to fatigue and associated with endurance activities. Type I fibers are sometimes referred to as aerobic fibers because of the association with aerobic activities. Type I fibers are utilized in activities such as walking, jogging, distance cycling, and cross-country skiing. The second muscle fiber type is **type II fibers**, or fast twitch fibers. These fibers are associated with rapid, forceful, and explosive movements. Type II fibers are sometimes referred to as anaerobic fibers because they are recruited and utilized with activities that are anaerobic in nature. Examples of anaerobic activities include sprinting, jumping, and weight training. The percentage of type I or type II fibers an individual has is largely due to genetics. However, humans are born with some muscle fibers that can become type I or type II. These are known as **transitional fibers**. The type of training and physical activity an individual engages in will primarily determine if transitional fibers become aerobic or anaerobic (Tortora, 1994).

Implications of Physical Growth Changes on Motor Performance

Objective 3.9: Explain the implications of how changes in physical growth can affect motor performance.

There are some general implications that can be made of how physical growth and development can affect motor performance. Infants who are longer for their weight tend to walk at an earlier age. Shorter and fatter babies catch up quickly, however, and there is little difference in proficiency. Also, research has demonstrated that children who are heavier and have a higher percent body fat perform more poorly with tasks requiring the body to be propelled (i.e. running and jumping). Heavier and fatter children tend to outperform other children with tasks that require an object to be propelled for distance (i.e. striking and throwing). Individuals with mesomorphic and endomorphic traits typically have greater muscular strength, and ectomorphic individuals tend to have better aerobic capacity. Specific gender differences can also be noted. Females have a wider pelvis and a more oblique femur angle than males. This gives females a lower center of gravity, which translates into better balance and stability. Thus, females tend to outperform males with tasks that require balance and stability (i.e. gymnastics). Males typically outperform females with tasks such as sprinting and jumping. The longer legs and more narrow hips give males an advantage with these skills. Also, males' longer arms and wider shoulders present an advantage when performing skills such as throwing and striking (Gabbard, 2000).

Summary

Physical growth and development is a continuous process that begins with conception and ends with death. The two most dramatic periods of biological change are the prenatal period and the pubescent growth spurt. The prenatal period can be divided into four stages: conception, the germinal period, the embryonic period, and the fetal period. Puberty is the term used to describe the time of rapid physical growth and maturation in early adolescence. This two to three year process is controlled by genetics and hormones.

Body proportion changes are cephalocaudal and proximodistal in nature from birth to adulthood. Increases in height and weight are steady until puberty, and then an acceleration of growth occurs. Height gains may continue until age 30, and body weight continues to increase through adulthood. Skeletal growth and development begins in the embryonic phase, and ossification is not completed in some bones until early adulthood. Males typically have a lower percent body fat than females at all ages. Values are closer before puberty, but gender differences become more pronounced in adolescence. Skeletal muscle composition is similar in males and females until adolescence. After puberty, females gain very little muscle tissue compared to males. Two general types of muscle fibers are type I and type II fibers. Transitional fibers can become type I or type II depending upon training.

Several implications can be made about the effects of physical growth and development on motor performance. One of the most apparent implications is the relationship between physique and selected motor tasks. In addition, the physical changes of puberty offer some important implications of gender differences on a variety of performances.

Questions for Discussion

1. List some of the reasons why males and females can compete in sports together prior to adolescence. Why is it more difficult for girls to compete with boys in sports after adolescence? List some of the sports or games that males and females can compete in together regardless of age.

2. What are some of the ways the environment can change a person's underlying body type?

3. How can muscle fiber type affect an individual's motor performance?

Class Activities

1. Obtain permission to visit a coeducational elementary and high school physical education class. Have college students measure and record standing height, sitting height, head circumference, shoulder width, and hip width of the students. Notice the differences in age and gender.

2. Obtain permission to observe a middle school physical education class. Have college students identify mesomorphic, endomorphic, and ectomorphic body types. Have college students document the strengths and weaknesses of children with different physiques. Also, observe and list physical and motor performance differences between males and females.

3. Measure your students' static balance by having them stand on one foot for as long as possible. Have students record their times for two trials. Next, measure your students' dynamic balance by having each student walk across a balance beam as quickly as possible. Have them record their times, and note who falls off earlier and more frequently. See if your data reinforce the concept of females having a lower center of gravity and better balance and stability.

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Chapter Four

Physiological Development

Chapter Objectives

4.1 Define the term **cardiorespiratory system**, and trace the flow of blood through the heart, lungs, and peripheral blood vessels.

4.2 Briefly describe the normal pattern of heart development up to adulthood.

4.3 Define **maximal oxygen uptake** and **vital capacity**, and describe how each changes across the lifespan.

4.4 Explain the difference between **heart rate** and **cardiac output**, and describe how each changes across the lifespan and among gender.

4.5 Differentiate between **blood pressure** and **blood volume**, and discuss the changes that occur over time.

4.6 Explain how **basal metabolic rate** changes across the lifespan.

4.7 Define **muscular strength, muscular endurance**, and **flexibility**, and describe how each varies through lifelong development.

Definitions of Key Terms

cardiorespiratory system – the cardiovascular (heart and blood vessels) and the respiratory (lungs) systems collectively

arteries – blood vessels that carry oxygen-rich blood from the heart

veins – blood vessels that carry oxygen-poor blood toward the heart

capillaries – small interconnecting blood vessels

pericardium – outer layer of the heart

myocardium – middle, muscular layer of the heart

endocardium – inner layer of the heart

maximal oxygen uptake – the maximum amount of oxygen that can be taken in, transported, and utilized by the body

hemoglobin – compound of blood that helps carry oxygen to the tissues of the body

vital capacity – total amount of air that can be voluntarily expired after a maximal inspiration

heart rate – number of heart beats per minute

cardiac output – quantity of blood ejected by the heart per minute

stroke volume – the quantity of blood ejected per heartbeat

peripheral vascular resistance – the resistance to blood flow offered by the blood vessels

systolic blood pressure – the highest pressure on the blood vessel walls during contraction of the heart

diastolic blood pressure – the lowest pressure on the blood vessel walls during filling and relaxation of the heart

blood volume – amount of blood in the body

basal metabolic rate – the measure of the amount of heat produced by the body at rest

muscular strength – the maximal amount of force that a muscle or muscle group can generate

isometric – refers to a muscle action in which there is no change in the length of the muscle

isotonic – refers to a muscle action in which there is change in the length of the muscle

muscular endurance – the ability of a muscle or muscle group to perform repeated contractions against a light load

flexibility – the range of motion possible at a joint

Chapter Content Outline

I. The Cardiorespiratory System
   A. The flow of blood through the heart, lungs, and blood vessels
   B. Heart development

II. Maximal Oxygen Uptake and Vital Capacity

III. Heart Rate and Cardiac Output

IV. Blood Pressure and Blood Volume

V. Basal Metabolic Rate

VI. Muscular Strength, Muscular Endurance, and Flexibility

VII. Summary

VIII. Questions for Discussion

IX. Class Activities

X. References

The Cardiorespiratory System

Objective 4.1: Define the term cardiorespiratory system, and trace the flow of blood through the heart, lungs, and peripheral blood vessels.

The Flow of Blood Through the Heart, Lungs, and Blood Vessels

The term **cardiorespiratory system** refers to the system of the body that includes the cardiovascular system (heart and blood vessels) and the respiratory system (lungs). The three major types of blood vessels of the cardiorespiratory system are **arteries, veins**, and **capillaries. Arteries** carry oxygen-rich blood to the tissues of the body, and **veins** carry oxygen-poor blood back to the heart from the body's periphery. **Capillaries** are the small interconnecting vessels through which materials are exchanged between blood and body cells. The heart is a muscular organ with four chambers. The top two chambers are known as the atria, and the bottom two chambers are known as the ventricles. The heart has three layers. The **pericardium** is the outer layer of fatty and fibrous tissue. The **myocardium** is the middle layer of cardiac muscle tissue, and the **endocardium** is the layer that lines the inside of the heart. The right atrium of the heart receives deoxygenated blood via two large veins called the inferior and superior venae cavae. This blood passes through the tricuspid valve into the right ventricle, where it is sent out to the lungs via the pulmonary arteries. The pulmonary arteries are the only arteries in the body that ever carry oxygen-poor blood. Once the blood becomes saturated with oxygen in the lungs, the blood is sent back to the heart by way of the pulmonary veins. The pulmonary veins are the only veins in the body that ever carry oxygen-rich blood. The blood enters the left atrium of the heart and passes through the mitral valve into the left ventricle. The left ventricle is the largest and most muscular chamber of the heart, and it ejects blood out through the aorta to the tissues of the body (Gabbard, 2000).

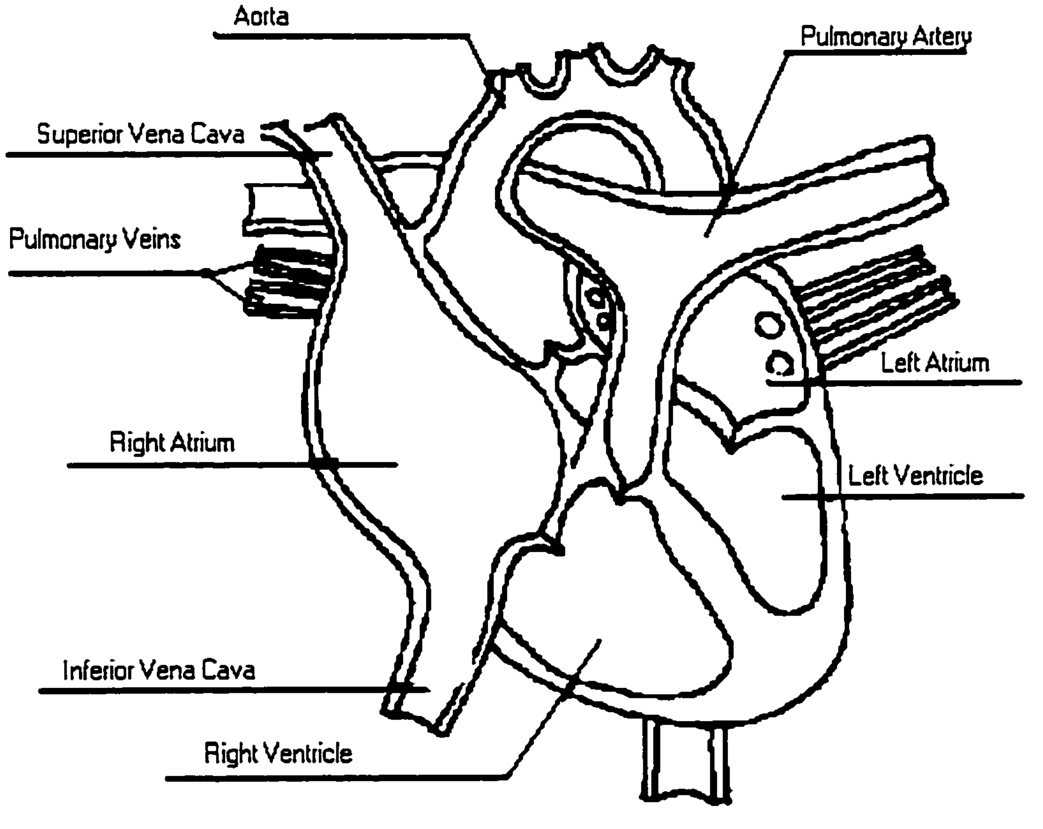

Figure 11.
Diagram of the Heart

Objective 4.2: Briefly describe the normal pattern of heart development up to adulthood.

Heart Development

The heart begins as a single tube in the early prenatal period. The circulatory system becomes functional around the 12th prenatal week, and by the fourth or fifth fetal month, the heartbeat is regular and strong. The weight of the heart doubles after the first year of life. By age five, the heart grows to four times its birth weight. The heart of a nine year old is approximately six times as heavy as a newborn's heart. There is rapid growth of the heart up until age 16. There is very little difference in the heart size of males and females up to puberty. After puberty, males' hearts grow 15% larger than the hearts of females (Gabbard, 2000).

Maximal Oxygen Uptake and Vital Capacity

Objective 4.3: Define maximal oxygen uptake and vital capacity, and describe how each changes across the lifespan.

Maximal oxygen uptake is the maximum amount of oxygen that can be taken in, transported, and utilized by the body per unit of time (Bowers and Fox, 1992). Maximal oxygen uptake is usually expressed as milliliters or liters of oxygen per minute. Maximal oxygen uptake is used as a measure of cardiorespiratory fitness and can be assessed by using a treadmill or cycle ergometer test. Factors that may affect a person's maximal oxygen uptake include body weight, body composition, the size of the heart and lungs, and blood volume. Maximal oxygen uptake values increase steadily over the first 10 to

12 years of life, and there is little difference among gender during this time. Typically, maximal oxygen uptake peaks at age 14 for females and age 18 for males. Increased values for males during and after adolescence are due to the larger heart and lungs, more lean body mass, and higher amounts of the oxygen-transporting compound of blood called "hemoglobin." Maximal oxygen uptake values decline steadily after age 25 for sedentary individuals. Most physiological functions begin to decrease by about .75 to 1% per year. Improvements in maximal oxygen uptake can occur with exercise, however, at almost any age (Payne and Isaacs, 1999).

The total amount of air that can be voluntarily expired following maximal inspiration is called **vital capacity** (Bowers and Fox, 1992). This physiological parameter can be measured by a respirometer and is usually expressed as liters of oxygen. The amount of air that the lungs can hold increases in parallel to physical growth and increases in the size of the lungs. Vital capacity increases are similar in males and females up to puberty. After puberty, males have approximately a 20% greater vital capacity than females. This is due to the larger body size and lungs of males. Vital capacity declines by about one percent per year after age 25, and elderly individuals may lose up to 40% of their lung capacity (Gabbard, 2000).

Heart Rate and Cardiac Output

Objective 4.4: Explain the difference between heart rate and cardiac output, and describe how each changes across the lifespan and among gender.

Heart rate, the number of times the heart beats in one minute, is a physiological measure that changes considerably over the lifespan. Heart rate can be measured by using a heart rate monitor or by feeling the pulse and counting the number of heart beats in one minute (American College of Sports Medicine, 1993). The first fetal heart beats occur in the fourth prenatal week. Fetal heart rates are very rapid and irregular, and values may reach as high as 160 beats per minute. A newborn will average about 100 to 130 beats per minute. The resting heart rate of children is much higher than that of an adult. As the cardiorespiratory system develops and matures, the efficiency of the heart and lungs improve. This is evidenced by a continuously decreasing resting heart rate from infancy to adulthood. On average, females have a resting heart rate of about five beats per minute higher than males, even before puberty. Research has been inconclusive in explaining this phenomenon. Resting heart rate normally declines into middle adulthood, but sedentary individuals may experience an increase in resting heart rate into late adulthood and old age (Payne and Isaacs, 1999).

Exercise and training have a profound effect on an individual's heart rate. One of the conditioning effects of physical activity is a lowered resting heart rate. This adaptation occurs because the trained heart becomes able to eject the same amount of blood per minute with less beats. Thus, individual's who are in good cardiorespiratory condition often have very low resting heart rates. It is not uncommon for a trained adult athlete to have a resting heart rate value of 40 to 55 beats per minute.

Maximal heart rate (Max HR), the maximum number of times the heart can beat in one minute, decreases by about one beat per year from birth to death. This value can be estimated by using the following formula: Max HR = 220 – age. No researchers have been able to explain why maximal heart rate decreases at this rate.

Cardiac output is the quantity of blood pumped by the heart per minute. Cardiac output is a product of **stroke volume**, the quantity of blood ejected per heartbeat, and heart rate (Bowers and Fox, 1992). Cardiac output is a major variable of maximal oxygen uptake because the amount of oxygen that can be utilized by the body is related to the amount of blood in circulation per unit of time. Cardiac output increases with age, mainly due to an increase in the size of the heart. Children have a lower cardiac output because of a lower stroke volume. Males and females have similar cardiac output values before puberty, but afterwards males exhibit higher values. This is due mainly to an increased heart size. Cardiac output begins to decrease after age 25 due to a decline in stroke volume and heart rate. The amount of blood the heart can pump per unit of time may decrease by almost 60% between the ages of 25 and 85 (Gabbard, 2000). Like other physiological measures, however, this decline can be slowed through regular exercise.

Blood Pressure and Blood Volume

Objective 4.5: Differentiate between blood pressure and blood volume, and discuss the changes that occur over time.

Blood pressure is the product of cardiac output and **peripheral vascular resistance**, the resistance to blood flow offered by the blood vessels (blood pressure = flow x resistance). An increase in either variable will raise blood pressure. Blood pressure is measured by using a sphygmomanometer and a stethoscope. **Systolic blood pressure** is the highest pressure exerted on the vessel walls during the contraction of the heart. Systolic blood pressure is the top number when blood pressure is expressed as millimeters of mercury (mm Hg). Normal systolic blood pressure for an adult is 120 mm

Hg. **Diastolic blood pressure** is the lowest pressure exerted against the vessel walls during the filling and relaxation of the heart. Diastolic blood pressure is the bottom number in the expression of blood pressure. Normal adult diastolic blood pressure is 80 mm Hg. Systolic blood pressure increases steadily from infancy to adolescence, mainly due an increased cardiac output. Diastolic pressure may change very little during this time. After puberty, systolic blood pressure increases more in males because of an increase in heart size and cardiac output. Changes in blood pressure through adulthood and old age vary considerably among individuals. Some people experience lowered values into old age. Other individuals may experience dangerously elevated blood pressure due to heart and blood vessel disease (Gabbard, 2000).

Blood volume refers to the amount of blood in the body per kilogram of body weight. Red blood cells contain a compound called **hemoglobin**, which assists in delivering oxygen to the tissues of the body. Red blood cells begin to be produced in the second prenatal week, and at birth there is approximately 4.7 million red blood cells in the body. The amount of blood in circulation and the production of red blood cells increase gradually from infancy to adolescence. Males typically have more hemoglobin in the blood than females, and this is one of the reasons why males have a greater exercise capacity (American College of Sports Medicine, 1993).

Basal Metabolic Rate

Objective 4.6: Explain how basal metabolic rate changes across the lifespan.

Basal metabolic rate is measured by the amount of heat produced by the body during rest. Basal metabolic rate represents the amount of energy expended to sustain the body's vital functions, and it is usually expressed as calories expended at rest per kilogram of body weight. Individuals with a high percentage of muscle mass typically have a higher basal metabolic rate because muscle tissue is more metabolically active than fat tissue. Thus, males usually have a higher basal metabolic rate than females, especially after puberty. Basal metabolic rate, relative to body weight, decreases continuously from birth to old age.

Muscular Strength, Muscular Endurance, and Flexibility

Objective 4.7: Define muscular strength, muscular endurance, and flexibility, and describe how each varies through lifelong development.

Muscular strength is the maximum amount of force or tension that can be generated by a muscle or muscle group. Strength can be measured "isometrically" or "isotonically." **Isometric** refers to muscle actions in which tension develops in the muscle but with no change in the length. Attempting to lift an immovable object is an example of an isometric action. Hand dynamometers and cable tensiometers are common instruments used to assess isometric strength. **Isotonic** refers to actions in which the muscle changes its length to produce the force. The gold standard test for measuring isotonic muscular strength is a one-repetition maximum lift. Common exercises used include bench press, squat, and leg press (Bowers and Fox, 1992).

Muscular strength generally increases with age and peaks between 25 and 29 years of age. Both sexes demonstrate steady increases in muscular strength through childhood, with males having a slightly higher value as early as age three. Significant improvements in muscular strength occur during puberty, with males exhibiting substantially more muscle mass. Regardless of gender, human skeletal muscle generates about three to four kilograms of force per square centimeter. When strength is compared on an absolute basis, adult males are typically 30 to 50% stronger in most muscle groups. When strength is compared relative to body weight, males are generally still stronger because lean body mass is a greater component of body weight in males than females. Muscular strength decreases by about .75 to 1% per year after age 30. Active individuals, however, can maintain and even improve muscular strength into late adulthood (Gabbard, 2000).

Muscular endurance is the ability of a muscle to perform repeated contractions against a light load. Activities that incorporate muscular endurance include running, swimming, and cycling. Common tests of muscular endurance include push-ups, curl-ups, and pull-ups. The primary component of muscular endurance is muscular strength. Thus, changes across the lifespan and gender differences for muscular endurance are very similar to those of muscular strength (Gabbard, 2000).

The range of motion possible at a joint is called **flexibility** (Bowers and Fox, 1992). Flexibility is specific to a joint or area of the body. For example, some individuals may have good flexibility in the shoulders but have poor hamstring flexibility. Common tests used to measure flexibility include the v-sit test, the sit and reach test, and the shoulder raise test. Flexibility continuously increases from birth to adulthood, and females tend to be more flexible than males across all ages. After age 25, flexibility declines steadily through the remainder of life (Payne and Isaacs, 1999). However, individuals who stretch as little as five minutes per day, can maintain and even improve flexibility into old age.

Summary

The cardiorespiratory system is made up of the cardiovascular system and the respiratory system. The heart begins as a single tube in the early prenatal period, and by the fourth prenatal month, there is a strong heartbeat. There is rapid growth and development of the heart up to age 16. After puberty, males' hearts become 15% larger than females' hearts.

Maximal oxygen uptake is one of the best measures of cardiorespiratory fitness. This measure increases steadily over the first 10 to 12 years of life. Females will experience peak values at age 14, and males will peak at age 18. Increased values for males are due to the development of a larger heart and lungs, higher lean body mass, and greater amounts of hemoglobin in the blood. Vital capacity is also similar among males and females up to puberty. Males' larger body size and lungs account for a 20% greater vital capacity after puberty.

Resting heart rate generally decreases from infancy into adulthood. Females' average resting heart rate is five beats per minute higher than males at all ages. One of the training effects of exercise is a lowered resting heart rate. Maximal heart rate decreases by about one beat per minute per year from birth to death. Heart rate and stroke volume are the two components of cardiac output. Cardiac output increases with age as the heart volume increases. Males exhibit higher values after puberty because of the larger heart.

Systolic blood pressure increases with age from childhood to adolescence. Changes with aging vary among individuals. The production of red blood cells begins as early as the second prenatal week, and blood volume increases from infancy to adolescence. Because of greater body mass, adult males have more blood in circulation than adult females. Males also have more hemoglobin than females per unit of blood at all ages.

Basal metabolic rate is highest in individuals who have more muscle mass. This is because muscle tissue is metabolically more active than fat tissue. Relative to body weight, basal metabolic rate declines sharply from birth to old age.

Muscular strength, muscular endurance, and flexibility are all physiological measures that are specific to an area of the body. Each of these parameters increases steadily from birth to adulthood. Dramatic improvements are exhibited after puberty. Males have greater muscular strength and endurance values at all ages, especially after puberty. Females have greater flexibility than males at all ages.

Most physiological functions will decline by .75 to 1% per year after age 25. However, most functions can be maintained or improved with exercise and training.

Questions for Discussion

1. Do you think a one-mile run/walk test is appropriate to administer to a kindergarten or first grade physical education class? Why or why not?

2. Why do you think females are more flexible than males?

Class Activities

1. Divide your class into groups of three or four. Instruct each group to devise a "new" test to measure cardiorespiratory fitness, muscular strength, muscular endurance, and flexibility. Allow access to any appropriate facilities and equipment.

2. In a gymnasium, make an outline of the heart, its chambers, major blood vessels, and the lungs with jump ropes, mats, or any other equipment. Make signs to indicate each area. Starting in the right atrium, have the students run in a single file line through the path that the blood takes to get to the body tissues, or use chalk to draw the heart on the asphalt or concrete and have students perform the same activity.

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Chapter Five

Phases of Motor Development

Chapter Objectives

5.1 Define and list three purposes of reflexes.

5.2 Identify three categories of reflexes, and give examples of each.

5.3 Differentiate between **reflexes** and **spontaneous movements.**

5.4 Describe the general characteristics of voluntary postural control, locomotion, and manual skills during infancy.

5.5 Name the three fundamental skill groups, and give examples of each.

5.6 Identify developmental characteristics of various locomotor and manipulative skills.

5.7 Describe the general characteristics of motor development in late childhood and adolescence.

5.8 Discuss motor development characteristics of adulthood.

Definitions of Key Terms

reflex – involuntary movement initiated by a stimulus

primitive reflex – reflex associated with an infant's instinct for protection and survival

postural reflex – reflex which helps an infant to maintain posture when presented with a change in the environment

locomotor reflex – reflex that is a precursor to voluntary locomotion

spontaneous movement – involuntary movement that appears in the absence of a stimulus

crawling – locomotion in a prone position with the abdomen dragging the ground

creeping – locomotion on the hands and knees with the abdomen clear of the ground

walking – locomotion by means of alternating weight from one foot to the other with at least one foot in contact with the ground at all times

prehension – ability to grasp

manipulation – ability to skillfully use the hands

thumb opposition – ability to use the thumb in opposition to the fingers while manipulating an object

pincer grasp – a true thumb opposition grasp involving the thumb and index finger

locomotor skill – a basic motor skill involving a change of the position of the feet or the body's direction

running – an extension of walking where the body is propelled into "flight," with no base of support by either leg

jumping – a transfer of weight from one or both feet to one or both feet

leaping – type of jump in which there is a transfer of weight from one foot to the opposite foot

vertical jumping – a type of jump with the desired goal being height

standing long jumping – a type of jump with the desired goal being distance

hopping – a repeated jump in which there is a transfer of weight from one foot to the same foot or both feet to both feet

galloping – step and leap combination locomotor skill

skipping – step and hop combination locomotor skill

nonlocomotor skill – movements of the body performed with a relatively stable base of support

manipulative skill – a movement which involves the control of objects

throwing – a manipulative skill in which one or two arms are used to propel an object away from the body

catching – a manipulative skill in which an object is tracked and gained control of with the hands

striking – a manipulative skill in which an object is contacted by a part of the body or an implement

dribbling – a manipulative skill in which a ball is bounced with the hand

climbing – ascending or descending the body using the hands and feet

power grip – writing grip in which all four fingers and the thumb are wrapped around the implement

dynamic tripod – writing grip in which the thumb, index finger, and middle finger are used to hold a writing utensil

bimanual control – the ability to coordinate both hands together

ambidexterity – the ability to use either limb in equal proficiency

Chapter Content Outline

I. Early Movement
   A. Reflexes
   B. Categories of reflexes
   C. Spontaneous movements

II. Rudimentary Movement
   A. Postural control
   B. Early locomotion
   C. Early manual control

III. Movement in Early Childhood
   A. Locomotor skills
   B. Nonlocomotor skills
   C. Manipulative skills
   D. Developmental patterns of selected skills

IV. Movement in Late Childhood and Adolescence

V. Movement in Adulthood

VI. Summary

VII. Questions for Discussion

VIII Class Activities

IX. References

Early Movement

Objective 5.1: Define and list three purposes of reflexes.

Reflexes

A **reflex** is an involuntary movement initiated by a stimulus. Many reflexive movements begin as early as the third prenatal month and continue into the first year of life. There are approximately 27 major infant reflexes, and most disappear by six months of age. There are three main purposes of reflexes. One purpose is to stimulate the nervous system and muscular system until voluntary movements are possible. A second purpose of reflexes is a survival advantage. Reflexes such as rooting and sucking allow an infant to seek and obtain nourishment. A third purpose of reflexes is protection. When an infant is startled or falls, the limbs flex and are drawn in to protect the body (Gabbard, 2000).

Objective 5.2: Identify three categories of reflexes, and give examples of each.

Categories of Reflexes

The three categories of reflexes are **primitive, postural,** and **locomotor. Primitive reflexes** are associated with an infant's instinct for protection and survival. One of the earliest primitive reflexes to appear is the sucking reflex. Touch of the lips will stimulate sucking, and this reflex is evident by the fourth prenatal month. Sucking becomes voluntary by nine months. A second primitive reflex is the rooting or "search" reflex. With this reflex, a touch of the cheek will cause the head to turn toward the stimulus for nourishment. Rooting usually appears at birth, but becomes voluntary by three months. A third primitive reflex, the Moro reflex, is elicited when an infant is startled or falls. The limbs extend, the arms are drawn in, and the baby wails. The Moro reflex can be observed from the seventh fetal month to the third postnatal month. A fourth primitive reflex, the startle reflex, is similar to and is initiated by the same stimuli as the Moro reflex. The startle reflex, however, causes the infant to flex rather than extend the limbs upon being startled. The startle reflex is usually evident between nine and twelve months of age. A fifth primitive reflex is the palmer grasp reflex. The touch of the palm of an infant's hand will initiate grasping. This reflex is evident between the seventh prenatal month and the fourth postnatal month. A stroke or pressure beneath the toes of an infant will causes the toes to grasp. This reflex, the plantar grasp, is apparent between three and twelve months. The asymmetric tonic neck reflex occurs when the neck of an infant is turned, while in a prone or supine position. If the neck is turned to either side, the limbs extend on the side of the body in which the head is facing, and flex on the opposite side. The symmetric tonic neck reflex is initiated by placing an infant in a supported, semi-standing position and tilting the head backward or forward. If the infant is tipped backward, the neck extends, the arms extend, and the legs flex. If the infant is tipped forward, the neck flexes, the arms flex, and the legs extend. Tonic neck reflexes appear in the seventh prenatal month and last until the fifth postnatal month. One of the most unusual primitive reflexes is the Babkin reflex. This reflex is initiated by applying pressure to both palms. The infant opens the mouth, closes the eyes, flexes the neck, and tilts the head forward. The Babkin reflex is evident at birth and usually lasts until three months of age. A final type of primitive reflex is the Babinski reflex.

This reflex is stimulated by stroking or applying pressure to the sole of the foot. This will cause the toes to extend (Payne and Isaacs, 1999).

Postural reflexes are those which help an infant to maintain posture when presented with a change in the environment. Head and body righting is a postural reflex that is evident between two and four months of age. This reflex is a precursor to voluntary rolling movements. Head and body righting is initiated by rolling an infant to one side, which causes the head and body to turn with the direction of the roll. The labyrinthine righting reflex occurs as an attempt to maintain upright posture of the head. This reflex appears first at approximately two months and is observed by placing an infant in a prone position, causing the head to raise. Labyrinthine righting is also evident when an infant's body is tilted sideways, forward, or backward. The head will extend in an attempt to maintain its original upright position. This reflex is crucial for the development of upright posture and forward locomotion. The pull-up reflex is an attempt to maintain upright posture when the body is tilted in any direction, while seated or standing. This reflex is initiated by holding the infant's hands and carefully tipping the infant. This causes the infant's supporting arms to flex or extend in an attempt to maintain an upright position. The pull-up reflex lasts from three months to one year of age. The parachute reflex, another postural reflex, is evident between four months and one year of age. This reflex can be observed by holding an infant in an upright position and tilting the body toward the ground. The infant extends the arms and legs in an attempt to prop or brace the body in the event of a fall. The parachute reflex is related to the attainment of upright posture; however, it is also considered a protective reflex (Payne and Isaacs, 1999).

Locomotor reflexes are involuntary responses that are precursors to voluntary locomotor skills. The crawling reflex is evident at birth and is stimulated by placing an infant in a prone position and applying pressure to the sole of the foot. The infant exhibits arm and leg movements similar to voluntary crawling and creeping. The crawling reflex usually disappears by four months of age. The stepping reflex can be observed by holding an infant upright and applying slight pressure to the sole of the foot. This will cause the knee to lift, with little arm or hip movement involved. This crude stepping movement is a precursor to walking. The stepping reflex lasts from one to four months of age. Another locomotor reflex that lasts from one to four months of age is the swimming reflex. The swimming reflex is initiated by holding an infant horizontally in water with the head in an upright position. This causes rhythmical swimming-type movements of the limbs (Gabbard, 2000).

Objective 5.3: Differentiate between reflexes and spontaneous movements.

Spontaneous Movements

Spontaneous movements, also called stereotypies, are involuntary rhythmic patterns of movement that appear in the absence of stimuli. Examples of spontaneous movements include arm waving, leg kicking, and finger flexing. Spontaneous movements first appear as early as the 10^{th} prenatal week, and last until around 10 months of age. The only known purpose of these movements is to stimulate the central nervous system and the musculature (Gabbard, 2000).

Rudimentary Movement

Objective 5.4: Describe the general characteristics of voluntary postural control, locomotion, and manual skills during infancy.

Initial rudimentary voluntary movements occur during the first two years of life. Movement patterns develop in a cephalocaudal and proximodistal pattern. The three basic abilities that are established during this time are the control of posture, locomotion, and manual control.

Postural Control

The ability to maintain posture provides the foundation for all motor behaviors. The development of postural control in human infants follows the following sequence of events: the ability to control the muscles of the neck and upper trunk, roll, sit, and stand. At one month of age, an infant can temporarily hold the head erect. At two months of age, an infant can temporarily hold the head and chin upright, and by three months of age, an infant can hold the head and chest up with arm support. At four months of age, most infants can elevate the head in a supine position. Infants are able to roll from one side to the back at two months of age. At eight months, an infant can roll from the stomach to the back. Four month old infants are usually able to sit with support, and by nine months are able to sit down alone. Between six and eight months, infants are able to stand holding on to something. By 11 to 13 months, infants are able to stand alone (Gabbard, 2000).

Early Locomotion

Rudimentary locomotion follows the sequence of **crawling, creeping,** and **walking. Crawling** is locomotion in a prone position with the abdomen dragging the ground. Infants establish the ability to crawl between six and eight months of age. **Creeping** is locomotion on the hands and knees with the abdomen clear of the ground. Infants typically develop the ability to creep between eight and ten months of age. **Walking** is locomotion by means of alternating weight from one foot to the other with at least one foot in contact with the ground at all times. Between nine and ten months, infants can walk with support. Twelve to fourteen-month old infants are usually able to walk alone, and between 14 and 18 months, infants can walk backward. Rudimentary walking is marked by inefficient movement in which balance is easily lost, and falls are common. An infant usually takes very short steps with little leg and hip extension, makes flat-footed contact with the ground, keeps one leg bent and one leg locked at all times, and keeps a wide base of support (Payne and Isaacs, 1999).

Early Manual Control

The development of voluntary manual control involves **prehension** and **manipulation. Prehension** is the ability to grasp, and **manipulation** is the ability to skillfully use the hands. The first manual movements are exhibited as reflexes and spontaneous movements. Four-month-old infants begin to voluntarily reach and grasp objects using a "corralling" action with the arms and hands. Between nine and ten months, a major milestone occurs with respect to manual control. The infant begins to use true **thumb opposition**, the ability to use the thumb in opposition to the fingers while manipulating an object. At this time, infants are able to grasp objects with the thumb and index finger. This grip is referred to as the **pincer grasp**. By eight months of age, an infant displays the crude ability to release objects, but there is little accuracy until approximately 18 months. A two-year-old generally has the ability to reach, grasp, and release objects in a fairly coordinated fashion (Gabbard, 2000).

Movement in Early Childhood

Objective 5.5: Name the three fundamental skill groups, and give examples of each.

Motor development between the ages of two and six provides the foundation for more complex motor skills. Three general skill groups are established during early childhood. These are **locomotor, nonlocomotor**, and **manipulative skills.**

Locomotor Skills

Locomotor skills are basic motor skills involving a change of the position of the feet or the body's direction. **Running** is an extension of walking in which the body is propelled into "flight," with no base of support on either leg. A two to three year old child is able to run in a crude fashion. By age six, a child is reasonably skilled at running, as speed and stride increase. **Jumping** involves a transfer of weight from one or both feet to one or both feet. **Leaping** is a type of jump in which a child propels forward with one foot, landing on the opposite foot. Two-year-old children are able to leap, and the distance and height increases up to age six. **Vertical jumping** is a type of jump with the desired goal being height. Mastery of the fundamentals of vertical jumping occurs at approximately age five. **Standing long jumping** is a type of jump with the desired outcome being distance. Mastery of standing long jumping occurs by age six. **Hopping**

is repeated jumping in which there is a transfer of weight from one foot to the same foot, or both feet to both feet. Hopping is the most difficult type of jump because of the increased requirements for balance, agility, and leg power, strength, and endurance. Because of the difficult nature of hopping, advanced levels may not be reached until after age six (Payne and Isaacs, 1999).

Other locomotor skills, such as **galloping, sliding**, and **skipping**, are combination skills. **Galloping** is a step and leap combination locomotor skill, and it is usually the first combination skill to emerge. **Sliding** is galloping in a sideways motion. **Skipping** is a step and hop combination locomotor skill, and it may not be mastered until age six or seven. Females tend to be better skippers because they show more interest in the movements and practice them more. Also, girls have a slightly higher biological maturity level at this age (Gabbard, 2000).

Nonlocomotor Skills

Nonlocomotor skills are movements of the body performed with a relatively stable base of support. Examples of nonlocomotor skills include bending, twisting, and swaying. There has been little research performed to document the ages at which major nonlocomotor skills are developed (Kirchner and Fishburne, 1995).

Manipulative Skills

Manipulative skills are movements which involve the control of objects. **Throwing** is a manipulative skill in which one or two arms are used to propel an object away from the body. Between two and three years of age, throwing is an arm-dominated movement. By age six, a child uses the body more, takes steps, and follows through with the throwing arm. **Catching** is a manipulative skill in which an object is tracked and gained control of with the hands. A two to three-year-old child often will turn the head, react after a ball hits the hands, and use the chest to trap the ball. A six-year-old child is able to watch the object into the hands, properly get into position, and the arms become less stiff. **Striking** is a manipulative skill in which an object is contacted by a body part or an implement. Various striking skills are related to specific sports, and development of these skills depends on practice and experience. For example, a child who plays soccer is provided with greater opportunity to develop kicking skills than a child who does not play soccer. **Dribbling** is a manipulative skill in which a ball is bounced with the hand. Progression of dribbling follows a pattern of using the palm of the hand to using fingertip control. **Climbing**, which can also be considered a locomotor skill, involves ascending or descending the body using the hands and feet. Children as young as two years of age have been observed to exhibit rudimentary climbing patterns. Most children are reasonably skilled climbers by age six (Kirchner and Fishburne, 1995).

Fine motor manipulative skills begin to emerge in early childhood as well. Drawing and writing skills begin to develop very early. At one and a half years of age, a child can hold a writing implement with a **power grip**, a writing grip in which all fingers and the thumb are wrapped around the implement. Usually an advanced grip is developed between four to six years. The **dynamic tripod** is an advanced writing grip in which the thumb, index finger, and middle finger are used to hold the utensil. Drawing and writing skills develop in a proximodistal pattern, and refinement continues into adolescence. Refinement is evident as the fingers move toward the point of the implement, and the muscles of the hand and fingers are primarily used (Gabbard, 2000).

Young children develop **bimanual control**, the ability to coordinate both hands together. This ability is evident by age six with the development of skills such as cutting paper with scissors, tying shoes, and stacking with blocks (Gabbard, 2000).

The development of right or left-side preference is also noticeable during early childhood. Handedness is usually evident in skills such as writing, striking, throwing, cutting, and stacking. Approximately 80 to 90% of the population will establish right-handed preference. By age five, handedness is well established. Footedness is usually evident in skills such as kicking, stamping, and jumping. Eighty percent of the population displays right footedness (Gabbard, 2000).

Objective 5.6: Identify developmental characteristics of various locomotor and manipulative skills.

<u>**Developmental Patterns of Selected Skills**</u>

Running: stride length increases, base of support narrows, amount of vertical movements decreases, duration of the "flight" phase increases, support knee on contact increases, flexion of the recovery leg increases, height of the forward knee increases, horizontal movements are decreased, arm action evolves to the elbows being flexed at approximate right angles that move in opposition to the legs.

Vertical Jumping: preparatory crouch increases, efficient arm movements increase, body extension during take-off and flight improve, height of the jump increases.

Standing Long Jumping: preparatory crouch increases, arm efficiency increases, take-off angle decreases, body extension during take-off increases, hip flexion during flight increases, coordination of a two-foot landing improves, distance of the jump increases.

Hopping: forward body lean decreases, arm action efficiency increases, leg clearance becomes the result of leg thrust rather than leg flexion, improved use of the swing leg.

Galloping: increased forward thrusting with the lead leg, improved rhythm.

Skipping: improved rhythm and coordination, increased use of the arms to provide momentum.

Throwing: backswing increases, evolvement of the movement to the horizontal plane, improved ability to step forward with the foot opposite the throwing arm during the backswing, follow through becomes complete, hips and shoulders rotate through, fingertip control of the ball.

Catching: improved ability to use the fingertips to the catch the ball, improved ability to track the ball and move the body into the correct position, arms become less stiff and become able to absorb the impact of the ball, eyes stay on the ball until it hits the hands.

Striking With an Implement: increased use of a forward step to initiate the strike, increased range of motion of the swing, rotation of the hips and trunk increases, ability to cock and uncock the wrists during the swing improves.

Kicking: number of steps increases, range of motion of the backswing and follow through increases, accuracy of the plant leg increases, increased ability to keep the body's momentum going forward after the kick, increased ability to use the arm opposite the kicking leg for balance and control, improved ability to keep the eyes on the ball until contact (Payne and Isaacs, 1999).

Movement in Late Childhood and Adolescence

Objective 5.7: Describe the general characteristics of motor development in late childhood and adolescence.

Motor development in late childhood and adolescence is marked by significant improvements in motor skill performance. Sport skills become advanced versions of the fundamental skills. A child may begin to learn how to specialize the basic kicking pattern to kicking a football. This period is marked by gender differences in motor performance. Until puberty, gender differences are minimal and are due to sociocultural factors. Females typically become more proficient hoppers and skippers because of the practice time they give to these skills. After puberty, males have greater muscular strength and aerobic capacity. Given the physiological advantages, males outperform females with skills such as striking, throwing, kicking, and running. Both male and female motor performance improves through adolescence because of increased practice and experience, increased physical growth, improved physiological development, and improved neurological functioning (Gabbard, 2000).

Movement in Adulthood

Objective 5.8: Discuss motor development characteristics of adulthood.

During adulthood, motor performance and gender differences are maximized. Some physical growth will continue. Some bones, such as the vertebrae and long bones, can continue growing up to age 30. Peak physiological functioning occurs between ages 22 and 25 for females and between ages 28 and 30 for males. After age 30, most physiological and neurological functions decline by approximately .75 to 1% per year, although much of the decline can be attributed to inactivity. Physical activity can have a positive effect on an adult's longevity. Some of these effects include: increased cardiorespiratory functioning, increased lung capacity, improved body composition, lower body weight, decreased psychological problems, decreased resting heart rate, decreased blood pressure, delayed progression of certain diseases, lower cholesterol and blood fats, increased muscular strength and endurance, increased bone density, and increased flexibility (Gabbard, 2000).

Summary

Reflexes are involuntary movements that appear in the presence of a stimulus. Reflexes provide protection and survival advantages, and stimulate the nervous system and musculature. Three categories of reflexes are primitive, postural, and locomotor. Spontaneous movements are involuntary movements that appear in the absence of stimuli. Examples include arm waving, leg kicking, and finger flexing.

Between birth and age two, infants begin to develop rudimentary voluntary skills. The three basic abilities that are established are the control of posture, locomotion, and manual control. Milestones of this period include the ability to stand upright, walk, and use the opposable thumb.

Three general skill groups are established between the ages of two and six. These skill groups are locomotor, nonlocomotor, and manipulative skills. By age six, children are reasonably proficient in performing most fundamental movements, able to write and draw using an advanced grip, and have established a right or left-side preference.

During late childhood and adolescence, improvement of motor skills occurs because of increased practice and experience, increased physical growth, improved physiological functioning, and improved neurological functioning. Before puberty, gender differences in motor performance are mainly due to cultural factors. Gender differences in performance following puberty are primarily due to the physical and physiological differences of males and females.

Motor performance and gender differences are maximized during adulthood. When individuals reach 22 to 30 years of age, most physiological and neurological functions begin to decline by approximately .75 to 1% per year. Physical activity that is continued throughout adulthood, however, can have a positive effect on a person's longevity.

Questions for Discussion

1. What are some reflexes that remain after infancy?

2. What locomotor, nonlocomotor, and manipulative skills have already been established by age two?

3. What can elementary physical education teachers do to stimulate the progression of throwing and catching skills of young children? What type of equipment would be appropriate?

Class Activities

1. Observe at a day care, an elementary physical education class, and a junior or senior high school physical education class. Each college student must create a table that documents developmental characteristics of fundamental movement patterns displayed by students in each setting.

2. Assign groups of three or four students one locomotor or manipulative skill. Each group practices and then demonstrates elementary, intermediate, and mature patterns of the skill.

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Section Three

Motor Control

Introduction

Section III is an examination of the central theories, ideas, and concepts of the sub-area of motor control. Section III consists of three chapters. Chapter Six, entitled "The Nervous System," presents the parts and functions of the central and peripheral nervous systems, the parts and functions of a neuron, brain and nervous system development, brain lateralization, the effects of aging on neural functioning, and other neural terminology. Chapter Seven, "Information Processing," covers the general information processing model, the role of vision and kinesthesis with respect to movement, the role of auditory and tactile perception with respect to movement, the role of attention and memory on motor control, and the effects of aging on information processing. Chapter Eight, "Motor Control Theories and Laws," presents the concepts of the open and closed-loop motor control models, the generalized motor program theory, the dynamic systems theory, Fitts' Law, and Hick's Law.

Chapter Six

The Nervous System

Chapter Objectives

6.1 Differentiate between the central and peripheral nervous systems, and name three functions of the nervous system as a whole.

6.2 Identify the three major parts of the brain and functions of each.

6.3 Identify the two systems that make up the peripheral nervous system, and name two types of peripheral nerve fibers.

6.4 Discuss the parts of a neuron and functions of each.

6.5 Describe the general developmental pattern of the brain and nervous system.

6.6 Discuss the functions of the left and right hemispheres of the brain.

6.7 Describe the general effects of aging on neurological functioning.

Definitions of Key Terms

central nervous system – the brain and spinal cord

peripheral nervous system – the network of nerves covering the entire body

brain – the command center of the nervous system

spinal cord – the pathway for nerve impulse transmission

brainstem – the part of the brain responsible for controlling involuntary functions

cerebrum – the part of the brain responsible for controlling voluntary motor function

cerebral cortex – the outermost layer of the cerebrum composed of 75% of the total neurons in the central nervous system

motor area – a small strip of the cerebral cortex responsible for the control of all voluntary movements

cerebellum – the part of the brain responsible for determining coordinated sequences of muscle contractions during complex movements

somatic nervous system – part of the peripheral nervous system that controls skeletal muscles during voluntary contraction

autonomic nervous system – part of the peripheral nervous system that controls the regulation of smooth muscles of the internal organs

afferent fibers – type of peripheral nerve fibers that send information into the spinal cord and brain from the periphery of the body

efferent fibers – type of peripheral nerve fibers that channel information from the central nervous system to the periphery

neuron – a nerve cell

synapse – the space between neurons

soma – the cell body of a neuron

dendrites – finger-like nerve fiber projections which receive information from other neurons

axon – the part of a neuron that carries information away from the cell body

myelin – a fatty, insulating material located around axons

nerve conduction velocity – the speed of a nerve impulse

motoneurons – neurons that innervate a muscle fiber

motor unit – a neuron and the muscle fiber it innervates

corpus callosum – myelinated tissue connecting the two hemispheres of the brain

psychomotor slowing – decrease in neuron activity and excitability with aging due to deterioration of neural structures

Chapter Content Outline

I. The Nervous System

II. The Brain

III. The Peripheral Nervous System

IV. The Neuron

V. Nervous System and Brain Development

VI. Brain Lateralization

VII. The Effects of Aging on Neurological Functioning

VIII. Summary

IX. Questions for Discussion

X. Class Activities

XI. References

The Nervous System

Objective 6.1: Differentiate between the central and peripheral nervous systems, and name three functions of the nervous system as a whole.

The nervous system is made up of the **central** and **peripheral nervous systems.** The **central nervous system** includes the brain and spinal cord, and the **peripheral nervous system** is the network of nerves that cover the entire body. Not a single cubic millimeter of tissue in the body is without nerves. The three main functions of the nervous system are the control of perception, movement, and memory and thought processes (Tortora, 1994).

The Brain

Objective 6.2: Identify the three major parts of the brain and functions of each.

The **brain** is the command center of the nervous system. Nerve impulses and motor commands originate in the brain and are sent out to the peripheral nerves through the **spinal cord,** the pathway for nerve impulse transmission. The three major parts of the brain are the **brainstem, cerebrum,** and **cerebellum.** The **brainstem** is responsible for controlling involuntary actions such as reflexes, spontaneous movements, metabolic functions, breathing rate, and heart rate. The **cerebrum** is the largest portion of the brain and is responsible for critical thinking, information processing, and voluntary motor functions. The outermost layer of the cerebrum, the **cerebral cortex,** is composed of 75% of the total number of neurons in the central nervous system. A small strip of the cerebral cortex, the **motor area,** is responsible for the control of all voluntary movements. The **cerebellum** is the part of the brain responsible for determining the coordinated sequences of muscle contractions during complex movements. The cerebellum is also involved in the control of balance and posture. In addition, recent research has revealed that the cerebellum may be involved, to some degree, in all movement (Tortora, 1994).

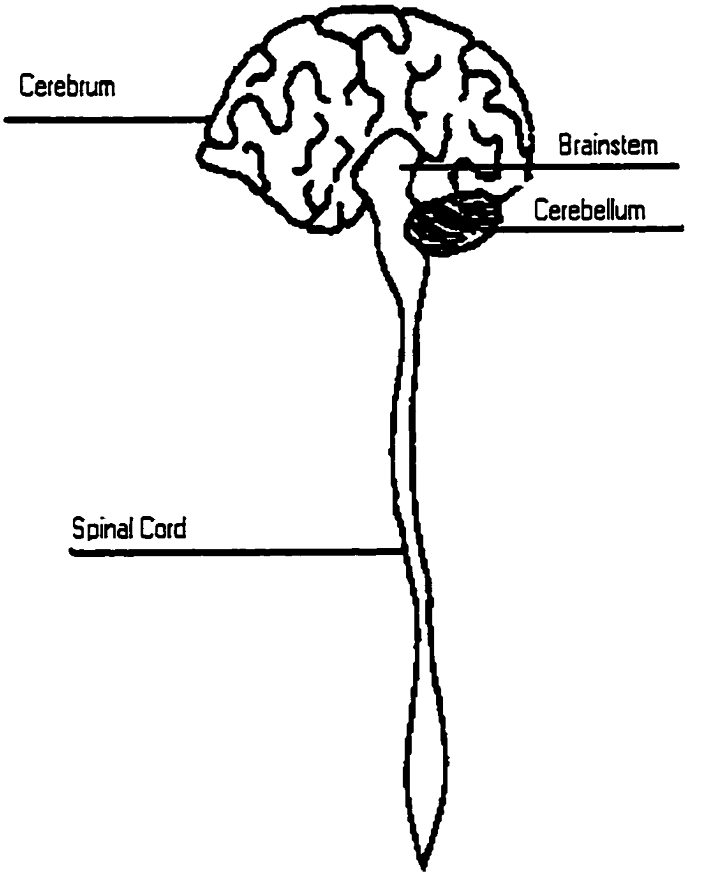

Figure 12.
Diagram of the Brain

The Peripheral Nervous System

Objective 6.3: Identify the two systems that make up the peripheral nervous system, and name two types of peripheral nerve fibers.

The peripheral nervous system is made up of two systems, the **somatic nervous system** and the **autonomic nervous system**. The somatic system controls skeletal muscles during voluntary contractions. The autonomic system controls the regulation of smooth muscles of the internal organs. There are two types of peripheral nerve fibers (Tortora, 1994). **Afferent fibers** send information into the spinal cord and brain from the periphery. When an individual touches something hot, the information is sent via the afferent nerve fibers to the brain. **Efferent fibers** channel information from the central nervous system to the periphery of the body. The instructions from the brain to the muscles of the hand to lift off of the hot surface, are sent through efferent nerve fibers (Shumway-Cook and Woollacott, 1995).

The Neuron

Objective 6.4: Discuss the parts of a neuron and functions of each.

A **neuron** is a nerve cell. Information in the form of electrical and chemical impulses travels along neurons. One neuron can share information with as many as 50,000 other neurons. Neurons do not actually touch each other. Impulses are transmitted across the **synapse**, the open space between neurons. A neuron's cell body is called the **soma**. The soma is the metabolic center which contains the nucleus.

Dendrites are finger-like projections that extend outside of the cell body of a neuron. Neurons can have thousands of dendrites. Dendrites receive information from other neurons and pass the information into the soma. Neurons have only one **axon**. The **axon** is the part of a neuron that carries impulses away from the cell body. Axons are surrounded with **myelin**, a fatty, insulating material (Tortora, 1994). The greater the amount of myelin around an axon, the quicker nerve impulses will travel. The speed of a nerve impulse is known as **nerve conduction velocity** (Gabbard, 2000).

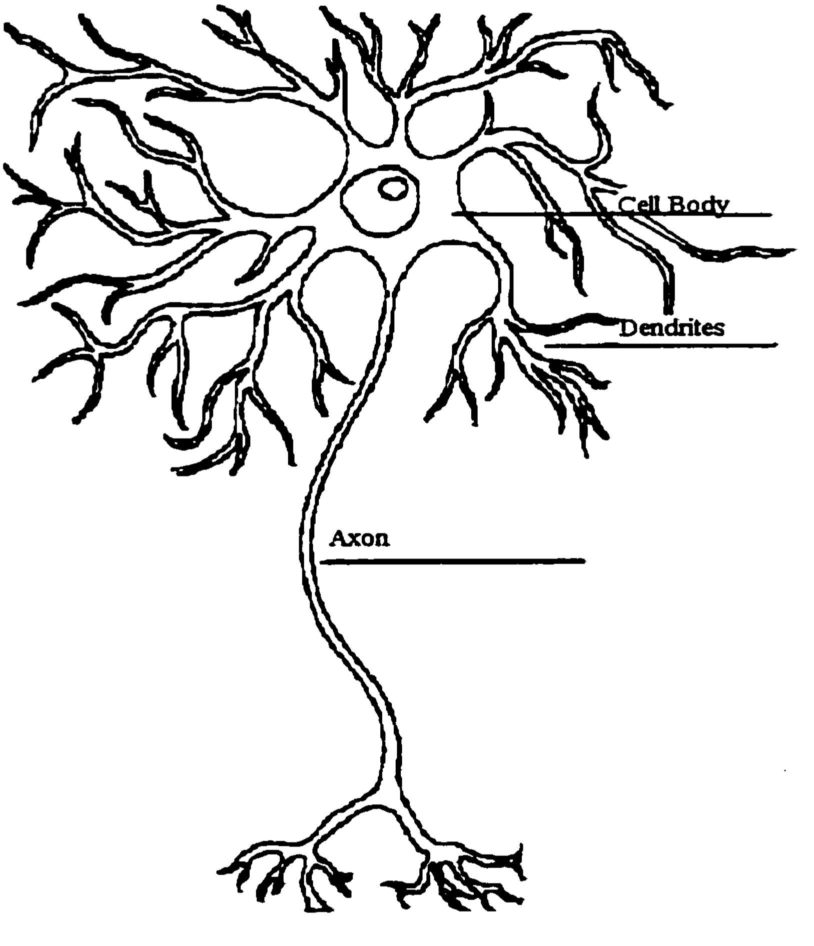

Figure 13.
Diagram of a Neuron

Nervous System and Brain Development

Objective 6.5: Describe the general developmental pattern of the brain and nervous system.

The nervous system begins to develop early in the prenatal period. At the end of the embryonic period, a basic central nervous system has developed. Neurons first appear in the second prenatal month, and proliferation is complete by birth. At birth, there are approximately one hundred billion neurons. Neurons grow dramatically in size in the first year of life. Between the third trimester to age four, humans experience a brain growth spurt. Some authors term this period as a "once only opportunity" for optimal brain development. This is a period of vulnerability in which stimulation is important, and the effects of harmful substances, malnutrition, or lack of experiences can have a damaging impact on the development of the nervous system. Dendridic development continues through childhood and is crucial in allowing the brain to do multiple things at once, such as with critical thinking. Myelination of axons continues into adolescence, increasing nerve conduction velocity, which results in improved quickness and reaction time (Gabbard, 2000).

At birth, the most fully developed portion of the brain is the brainstem. The cerebrum is the next part of the brain to be fully developed, followed by the cerebellum. By age three, the brain develops to approximately 90% of its adult size. At age six, the brain achieves its adult size (Gabbard, 2000).

Brain Lateralization

Objective 6.6: Discuss the functions of the left and right hemispheres of the brain.

The brain is made up of two hemispheres. In most humans the left hemisphere controls language, logic, information processing, and voluntary movements of the right side of the body. The right hemisphere controls non-verbal functions, music awareness, artistic ability, and voluntary movements of the left side of the body. The **corpus callosum** is the myelinated tissue that connects the two hemispheres. This provides a link for each hemisphere to share information (Tortora, 1994). The ability of the right and left hemispheres of the brain to communicate is crucial in all skills that involve both sides of the body. For example, a juggler needs to be able to know simultaneously what either hand is doing.

The Effects of Aging on Neurological Functioning

Objective 6.7: Describe the general effects of aging on neurological functioning.

The brain's plasticity declines with age. A child who misses an opportunity to develop a portion of the brain may never achieve the fullest potential. For basic motor skill development, the optimal time is between birth and age five. For fine motor skill development, the optimal time is between birth and nine years. With old age, there is a five to ten percent loss of neurons if an individual lives to be 75 years of age. Most humans will experience the phenomenon of **psychomotor slowing** if they live long enough. **Psychomotor slowing** is the decrease in neuron activity and excitability with aging due to deterioration of neural structures, such as myelin, axons, and dendrites.

Characteristics of psychomotor slowing include decreased balance, slower reaction time, slower movement patterns, decreased fine motor control, memory loss, and decreased coordination (Gabbard, 2000).

Summary

The three main functions of the nervous system include the control of perception, motor behavior, and memory and thought processes. The central nervous system is made up of the brain and spinal cord, and the peripheral nervous system includes the network of nerves that cover the entire body. The three main parts of the brain are the brainstem, cerebrum, and cerebellum. The brainstem controls involuntary movements, the cerebrum controls voluntary movements, and the cerebellum is responsible for determining the coordinated sequences of complex movements. The peripheral nervous system consists of two types of nerve fibers. Afferent nerve fibers send information into the spinal cord and brain from the periphery. Efferent nerve fibers channel information from the central nervous system to the body's periphery. Neurons, or nerve cells, are composed of three basic structures. The soma is the cell body, which contains the nucleus. Dendrites are finger-like projections that receive information from other neurons. The axon of a neuron sends information out of the soma to other neurons.

The development of the nervous system begins early in the prenatal period. By the end of the embryonic period, a basic central nervous system has been established. A brain growth spurt occurs between the third trimester to age four. Complete development of neural structures does not take place until adolescence.

The left hemisphere of the brain controls language, logic, information processing, and voluntary movements on the right side of the body. The right hemisphere of the brain controls non-verbal functions, music awareness, artistic ability, and voluntary movements on the left side of the body. The corpus callosum provides a link for each hemisphere to share information.

Psychomotor slowing is a decrease in neuron activity and excitability with aging due to the deterioration of neural structures. Characteristics of this phenomenon include decreased balance, slower movements, and decreased coordination.

Questions for Discussion

1. Name some practical ways to stimulate the brain development of an infant or young child.

2. Why do you think there are great variations in the neural functioning of the elderly?

Class Activities

1. Instruct small groups to construct a neuron using various materials, such as Styrofoam, toothpicks, Play-Doh, wire, and felt.

2. Visit a senior center and observe an activity class. Have students document any characteristics of psychomotor slowing that individuals may display.

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Chapter Seven

Information Processing

Chapter Objectives

7.1 Briefly describe each part of the general information processing model.

7.2 Describe the importance of vision with respect to human movement.

7.3 List and define several visual abilities.

7.4 Define **kinesthesis,** and name the kinesthetic receptor sites.

7.5 Name and define various kinesthetic abilities.

7.6 Discuss how auditory and tactile perception are involved in motor behavior.

7.7 Discuss the role of attention and memory with respect to motor performance.

7.8 Describe the effects of aging on information processing abilities.

Definitions of Key Terms

kinesthesis – sense of movement awareness

motor program – a memory representation of a coordinated movement sequence

visual acuity – the clearness of vision

depth perception – the ability to judge the distance of an object from oneself

binocular vision – vision with both eyes

peripheral vision – an individual's entire field of vision when the eyes are fixated

size constancy – the ability to perceive constant size

spatial orientation – the ability to perceive an object in three dimensional space

object permanence – the awareness that objects exist even when they are no longer in view

figure-ground perception – the ability to recognize an object as separate from the background

perception of movement – the ability to detect and track moving objects

visual-motor coordination – the ability to coordinate visual functions with movement

vestibular apparatus – kinesthetic receptor site located inside of the inner ear

muscle spindle receptors – kinesthetic receptor site located between skeletal muscle fibers

joint receptors – kinesthetic receptor site located in the capsules and ligaments of many joints

Golgi tendon organs – kinesthetic receptor site located at the muscle-tendon junction

kinesthetic acuity – the ability to detect differences or likenesses with respect to location, distance, weight, velocity, and acceleration

kinesthetic memory – the ability to remember and reproduce movements

body awareness – the awareness of the name and location of body parts, their relationship to one another, and their abilities and limitations

spatial awareness – the ability to recognize objects in three-dimensional space, in relation to the body's space and position

directional awareness – the awareness of the two sides of the body, and the ability to recognize movements through various planes.

vestibular awareness – the ability to establish and maintain balance

postural balance – the ability to maintain upright posture, hold the head erect, sit, and stand

static balance – the ability to maintain posture when the body is stationary

dynamic balance – the ability to maintain posture while in motion

rhythmic awareness – the ability to create and maintain a pattern or rhythm during movement

tactile perception – the ability to detect and interpret information through the skin

attention – the conscious or unconscious ability to engage in mental concentration or readiness

automaticity – the ability to execute a movement with little or no demand on attention capacity

attentional focus – the ability to direct attention to specific characteristics of a performance or environment

memory – the capacity to store and process past experiences

short-term memory – the component of memory that temporarily stores and uses recently processed information

long-term memory – the component of memory that stores information in a relatively permanent area

forgetting – the loss of the ability to retrieve specific information from memory

Chapter Content Outline

I. The General Information Processing Model

II. Vision
   A. Functions of vision
   B. Visual abilities

III. Kinesthesis
   A. Kinesthetic receptor sites
   B. Kinesthetic abilities

IV. Auditory and Tactile Perception

V. Attention and Memory

VI. The Effects of Aging on Information Processing

VII. Summary

VIII. Questions for Discussion

IX. Class Activities

X. References

The General Information Processing Model

Objective 7.1: Briefly describe each part of the general information processing model.

Human motor behavior is dependent on how sensory information from the internal and external environments is processed. A wide receiver must rely on visual, kinesthetic, auditory, and tactile stimuli to catch a football. Vision and **kinesthesis**, the sense of movement awareness, are the two most crucial perceptual modalities with respect to human movement (Gabbard, 2000). A general model of information processing has three basic parts: input, processing, and output. The input is the stimuli that come from the internal and external environments. Light, kinesthetic information, sound, tactile information, smell, and taste are all types of input that are received by the body's receptor locations. Processing of information begins at the receptor sites of the perceptual modalities. The six modes of perception in humans are visual, kinesthetic, auditory, tactile, olfactory, and gustatory. Receptor sites of each perceptual mode receive sensory information and send it to the brain via afferent nerve fibers. The information is processed by the central nervous system and compared with memory. For example, by watching the trajectory of a shot, a basketball rebounder can anticipate where on the court to move to be in good position to play the ball. The output is the movement, or motor response (Schmidt, 1999).

Vision

Objective 7.2: Describe the importance of vision with respect to human movement.

Functions of Vision

Vision is the dominant perceptual modality in humans. Approximately 80% of all sensory information from the external environment is derived from vision. Vision helps an individual formulate a **motor program**, a memory representation of a coordinated movement sequence (Schmidt, 1991). Examples of generalized motor programs include walking, skipping, throwing, kicking, and catching. A skill such as catching a ball would be difficult to develop without some visual information. Visual stimuli allow a movement pattern to be reinforced and remembered. Vision also helps an individual monitor a movement and detect errors. A placekicker can visually monitor different body parts throughout the kicking motion. If the plant foot points in an unintended direction, the error can be detected by vision. Vision is also a good source of feedback. A golfer will be aware of a slice by observing the resulting flight of the ball. The information can be used to make an appropriate adjustment in the golfer's set-up or swing.

Objective 7.3: List and define several visual abilities.

Visual Abilities

Vision is a complex and multi-faceted mode of perception. Visual function can be broken down into several separate abilities, such as **visual acuity**, **depth perception**, **peripheral vision**, **size constancy**, **spatial orientation**, **object permanence**, **figure-**

ground perception, perception of movement, and **visual-motor coordination** (Gabbard, 2000).

Visual acuity is the clearness of vision. "Static" acuity is the ability to detect the detail of a stationary object, and "dynamic" acuity is the ability to detect the detail of a moving object. The estimated static visual acuity of a newborn is between 20/200 and 20/600. This means that a newborn is able to see an object 20 feet away as it would appear normally 200 to 600 feet away. Usually by age five, 20/20 vision is developed (Gabbard, 2000).

Depth perception is the ability to judge the distance of an object from oneself. True depth perception cannot be developed without **binocular vision**, vision with both eyes. Most infants six months and younger have little or no depth perception. By six or seven months, depth perception becomes fairly accurate. Kinesthetic perception is a component of judging distances. For example, when a person reaches for an object, the kinesthetic receptors provide the individual with more cues about the absolute distance of the object from the limb (Payne and Isaacs, 1999).

Peripheral vision is an individual's entire field of vision, when the eyes are fixated. By age five, a complete visual field is developed. Normal lateral peripheral vision is approximately 180 degrees (Gabbard, 2000).

Size constancy is the ability to perceive constant size. This visual ability begins almost immediately outside of the womb. An example of size constancy is the ability to recognize an airplane on the ground as the same-sized object when it is thousands of feet in the sky. Size constancy becomes mature at or around 10 or 11 years of age (Gabbard, 2000).

Spatial orientation is the ability to perceive an object's position in three-dimensional space. Infants and young children have difficulty recognizing differences in the spatial orientation of objects. By the age of eight, the ability becomes more refined (Gabbard, 2000).

Object permanence is the awareness that objects exist, even when they are no longer in view. This is one of the early visual abilities to develop. Object permanence is established between 18 months and two years (Gabbard, 2000).

Figure-ground perception is the ability to recognize an object as separate from the background. This ability requires selective attention. A baseball outfielder must be able to focus solely on the baseball in the visual field in order to make a successful catch. Children four to eight years of age develop this ability but are still mildly distracted by background objects. Figure-ground perception is usually refined between the ages of 13 and 18 (Gabbard, 2000).

One of the most important visual abilities with respect to movement is the ability to detect and track moving objects. This is called **perception of movement**. Most infants are able to track slow moving objects, but the ability to accurately perceive and track objects that move quickly is not refined until around age 12. The development of skills such as catching and striking is very dependant on the improvement of this visual ability (Gabbard, 2000).

Visual-motor coordination is the ability to coordinate visual functions with movement. Kinesthesis and vision both contribute to this ability to produce coordinated movements involving hand-eye or hand-foot integration. Visual-motor coordination typically follows cephalocaudal, proximodistal, and gross to fine motor patterns. Fine motor skills such as shoe tying and writing are evidenced by young children. These skills develop from gross, rudimentary movements of infancy (Gabbard, 2000).

Kinesthesis

Objective 7.4: Define kinesthesis, and name the kinesthetic receptor sites.

Kinesthetic Receptor Sites

Kinesthesis, or proprioception, is the perception of movement and body awareness. Internal information is provided to the brain, such as movement direction, speed, and location. Signals are received by various receptor sites and sent to the brain via afferent nerve fibers. There are four general kinesthetic receptor locations. One of the receptor locations is the **vestibular apparatus**. This receptor site is located inside of the inner ear, and its function is to provide information about movement or position of the head. Vestibular information is crucial to the ability to establish and maintain balance and equilibrium. A second kinesthetic receptor site is the **muscle spindle receptors**. These are cigar-shaped structures located between all skeletal muscle fibers. Muscle spindles gauge the degree of tension on a muscle and detect changes in muscle fiber length, acceleration and velocity, and spatial position of a limb. A third proprioceptor area is the **joint receptors**. **Joint receptors** are located in the capsules and ligaments of many joints. These receptors provide information such as range of motion, tension, acceleration, velocity, and location of a joint. A fourth kinesthetic receptor location is the **Golgi tendon organs**. **Golgi tendon organs** are located at the muscle-tendon junction. Functions of Golgi tendon organs are to detect the force applied to a tendon and spatial position of a limb.

Objective 7.5: Name and define various kinesthetic abilities.

<u>Kinesthetic Abilities</u>

Various kinesthetic abilities have been identified in the motor behavior literature. **Kinesthetic acuity** refers to the ability to detect differences or likenesses with respect to location, distance, weight, velocity, and acceleration. An example of kinesthetic acuity is the ability to differentiate between two objects of slightly different weights, while blindfolded. Kinesthetic acuity reaches adult levels at around age eight. **Kinesthetic memory** is the ability to remember and reproduce movements. Elite athletes have the ability to effortlessly reproduce proficient patterns of movement. This ability is evident in professional golfers, who must be able to accurately repeat the golf swing 60 to 90 times per round. Normal adult levels of kinesthetic memory are usually attained by age 12 (Gabbard, 2000).

Body awareness is the awareness of the name and location of body parts, their relationship to one another, and their abilities and limitations. Body awareness is usually fully developed by age seven. **Spatial awareness** is closely related to the visual ability, spatial orientation. The difference is that **spatial awareness** involves the ability to recognize objects in three-dimensional space in relation to the body's space and position. Spatial awareness is usually well established by age eight. Any manipulative skill involving a moving object requires some degree of spatial awareness. **Directional awareness** is the awareness of the two sides of the body, and the ability to recognize movements through various planes. Typically, children between the ages of 10 and 12 develop the ability to respond to verbal cues about spatial movements in the frontal, transverse, sagittal, and oblique planes. A ten-year-old boy should understand various movement requirements of pitching a baseball, such as stepping with the non-dominant foot, rotating the shoulders and hips, and following-through squared to the target (Payne and Isaacs, 1999).

Vestibular awareness is the ability to establish and maintain balance. **Postural balance** is the ability to maintain upright posture, hold the head erect, sit, and stand. **Static balance** is the ability to maintain posture when the body is stationary. A task that tests static balance is standing on one foot. **Dynamic balance** is the ability to maintain posture while in motion. Walking across a balance beam tests a person's dynamic balance. Major milestones with respect to vestibular awareness occur during early childhood. At three years of age, children are usually able to balance on one foot for three to four seconds and walk along a one-inch straight line. By age six, children are able to balance on one foot while in an inverted position and are able to hop on one foot proficiently (Gabbard, 2000).

Rhythmic awareness is the ability to create and maintain a pattern or rhythm during movement. Young children develop the ability to keep time with music by stamping or clapping. Also, many sports skills require the ability to keep a proper tempo or rhythm. By age ten, children generally understand this concept and develop basic rhythmic awareness (Gabbard, 2000).

Auditory and Tactile Perception

Objective 7.6: Discuss how auditory and tactile perception are involved in motor behavior.

Auditory perception provides information such as feedback and auditory cues. A baseball batter is provided information about the performance of hitting by hearing the sound of the ball strike the bat. A high-pitched sound indicates that the ball was not struck in the sweet spot. This feedback might lead the player to make a slight adjustment in the swing, in order to make a more solid contact. Also, verbal cues from a coach or teacher are crucial to learning a motor skill. A child who is learning how to perform the forward crawl in swimming does not have the advantage of visually observing all body parts throughout the movement. A coach or teacher is able to provide the swimmer with this information via verbal feedback before, during, and following the performance. Hearing is functional prior to birth, and mastery of basic auditory skills occurs by age three. Refinement of auditory perception will continue until approximately age 13 (Magill, 2001).

Tactile perception is the ability to detect and interpret information on the skin. Sensory information provided through tactile receptors include heat, cold, pain, vibration, pressure, and texture. Tactile information is a useful form of feedback in the performance of many skills. For example, a softball batter is provided tactile information about the location of the contact point of the ball on the bat. A strong vibration would indicate that the ball was struck close to the handle of the bat. An adjustment in the stance could be made based on this information, to allow more solid contact with the bat.

Also, a punter in football is aware of the performance immediately when the foot makes contact with the ball. Receptors on the skin of the kicking foot supply the brain with the information about where the ball contacted the foot. If the ball is struck high on the ankle, an adjustment can be made on the next punt. The punter can extend the drop out, in order to make solid contact with the foot. Tactile perception is usually the first sensory modality to completely develop, and it is fully functional at birth. Young infants will rely heavily on the sense of touch to learn about the environment, until the other senses are refined (Magill, 2001).

Attention and Memory

Objective 7.7: Discuss the role of attention and memory with respect to motor performance.

Attention refers to the conscious or unconscious ability to engage in mental concentration or readiness. Much of the knowledge about attention is unknown or highly theoretical. Humans have a limited capacity to engage in perceptual and cognitive activities while performing motor skills. As a result, it is difficult to perform more than one task at a time. Patting the head and rubbing the abdomen simultaneously is difficult for many individuals. However, if one of the movements becomes "automatic," full attention can be devoted to the other movement. **Automaticity** refers to the ability to execute a movement with little or no demand on attention capacity. Automaticity usually occurs in the final stage of learning a motor skill. A skilled basketball player can dribble a ball down court almost "automatically," with little attention given to the various movements that need to be made to execute the skill. This frees the player to be able to attend to other aspects of the game, such as the position of defensive players on the court. Another important aspect of attention with respect to the performance of motor skills is **attentional focus**. **Attentional focus** is the ability to direct attention to specific characteristics of a performance or environment. Vision plays a major role in this function, and humans have the capacity to focus broadly or narrowly, and internally or externally. For example, race car drivers may need to visually focus attention on only a small detail of a car that is a short distance ahead. At other times in a race, however, a driver may need to widen the attention focus to larger areas of view (Schmidt, 1991).

Memory is another aspect of information processing that is abstract and hypothetical. **Memory**, the capacity to store and process past experiences, consists of two major components, **short-term** and **long-term memory**. **Short-term memory**, or working memory, is the component of memory that temporarily stores up to 10 bits of information and uses recently processed information. Information can remain in short-term memory for a brief amount of time, generally 20 to 30 seconds. Short-term memory provides an area to integrate new information with information in long-term memory. An individual who glances at a phone number in a telephone book may be able store the number in memory just long enough to pick up the phone and dial the number. **Long-term memory** stores information in a relatively permanent area. There appears to be no limit for how much information is stored there or how long information will remain there. The characteristics of movement patterns that are repeated and practiced over a period of time are stored in long-term memory (Schmidt, 1999). Once an individual learns how to ride a bicycle, the movement will remain in the long-term memory for years or decades. **Forgetting** refers to the loss of the ability to retrieve specific information from memory.

Both time and activity are influences on forgetting in the short and long-term memories. Memory information will deteriorate over time due to lack of retrieval or various types of interference. Certain continuous motor skills, such as walking, running, and swimming are very resistant to forgetting over long periods of time (Magill, 2001).

The Effects of Aging on Information Processing

Objective 7.8: Describe the effects of aging on information processing abilities.

Regression of perceptual functioning generally begins in middle adulthood. Many of the changes, however, often do not affect everyday life until old age. Typically, decrements in visual functioning begin between the ages of 40 and 50. Visual acuity, sensitivity to light, perception of movement, and visual processing speed all begin to regress during this time. A decline in auditory function begins at approximately age 35. Diminished sensitivity to high and low frequencies is a characteristic of this decline. Little information is available as to the ages at which tactile and kinesthetic functioning begins to regress. However, touch sensitivity, weight discrimination, and balance all regress with age. Other changes in information processing ability with aging include decreased attention, decreased short and long term memories, slowed processing speed, and slowed movement and response times (Gabbard, 2000).

Summary

Information processing models have three basic parts: input, processing, and output. Sensory information is received by various receptors, and the signals are sent to the brain via the afferent nerves. The information is processed in the brain and compared with memory. A motor command is delivered by the brain via efferent nerves to the skeletal muscles. The resulting movement is the output.

The two most important perceptual modalities with respect to human movement are vision and kinesthesis. Approximately 80% of all sensory information from the external environment is derived from vision. Vision helps to formulate a motor program, monitor movement and detect error, and provide feedback. Various visual abilities include visual acuity, depth perception, and spatial orientation. Kinesthesis is the perception of movement awareness. Internal information is provided to the brain, such as movement direction, speed, and location. Kinesthetic receptor sites include the vestibular apparatus, muscle spindle receptors, joint receptors, and Golgi tendon organs. Kinesthetic abilities include body awareness, directional awareness, and vestibular awareness.

Auditory and tactile perceptions also provide useful information for the performance of motor skills. Examples of auditory information include feedback and verbal cues. Sensory information provided through tactile receptors includes heat, cold, pain, vibration, pressure, and texture.

Two aspects of information processing that are fairly abstract and hypothetical are attention and memory. Attention refers to the conscious or unconscious ability to engage in mental concentration or readiness. Memory is the capacity to store and process past experiences.

Regression of perceptual functioning begins in middle adulthood but often does not affect everyday life until old age. Various changes in information processing with aging include decreased visual acuity, decreased sensitivity to high and low auditory frequencies, decreased touch sensitivity, decreased balance, and slowed response time.

Questions for Discussion

1. What perceptual modalities and abilities are utilized in archery?

2. How can auditory and tactile information be useful to a golfer?

Class Activities

1. Demonstrate the importance of vision with motor performance by having students perform the following skills blindfolded: throwing a ball to a partner from short, medium, and long distances, catching a ball from a very short distance, serving a tennis ball, and shooting a basketball.

2. Demonstrate the importance of auditory perception on learning a motor skill. Divide the class into partners. Have each student attempt to teach his/her partner a selected motor skill without providing *any* verbal cues or instructions.

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Chapter Eight

Motor Control Theories and Laws

Chapter Objectives

8.1 Explain the difference between the **open** and **closed-loop systems** of motor control.

8.2 Explain the **motor program-based theory** of motor control.

8.3 Define the **dynamic systems theory** of motor control.

8.4 Describe **Fitts' Law** and **Hick's Law**, and explain how each can be applied to motor performance.

Definitions of Key Terms

open-loop control system – motor control model that contends that all of the information needed to carry out a planned action is contained in the brain

closed-loop control system – motor control model that proposes that the initial commands to the efferent nerves only initiate a movement, but the execution and completion of a movement is dependent on feedback information

motor program-based theory – motor control theory that proposes that movement patterns are stored in memory as an abstract representation of the information needed to carry out the action

generalized motor program – a class of actions with common characteristics stored in memory

dynamic systems theory – motor control theory that emphasizes the role of environmental information and the dynamics of the body and limbs

Fitts' Law – a mathematical law describing the "speed-accuracy trade-off" in human movement

Hick's Law – law of motor control that states that reaction time increases logarithmically as the number of stimulus-response choices increases

Chapter Content Outline

I. Motor Control Systems
  A. Open-loop control model
  B. Closed-loop control model

II. The Generalized Motor Program Theory

III. The Dynamic Systems Theory

IV. Motor Control Laws
  A. Fitts' Law
  B. Hick's Law

V. Summary

VI. Questions for Discussion

VII. Class Activities

VIII. References

Motor Control Systems

Objective 8.1: Explain the difference between the open and closed-loop systems of motor control.

Motor control theories are based on the concepts of the **open** and **closed-loop systems** of control. These models are derived from mechanical engineering models of control, and they help describe how the central and peripheral nervous systems control movement.

Open-Loop Control Model

The **open-loop control system** contends that all of the information needed to carry out a planned action is contained in the movement control center, the brain. The open-loop model does not make reference to any type of feedback that might be sent to the command center from the environment via the afferent nerves. Even though feedback is available, it is not used in executing the movement. An example of an open-loop system of control is evident with throwing a dart at a dartboard. When an individual initiates a throw, the movement is carried out as specified by movement commands elicited before the initiation of the movement. Feedback is not utilized, because it is not needed or because the speed of the movement does not allow enough time to use feedback efficiently (Schmidt, 1999).

Closed-Loop Control Model

The **closed-loop control system** is a motor control model that proposes that the initial commands to the efferent nerves only initiate a movement, but the execution and completion of a movement is dependent on feedback information. An example of a closed-loop system of control is evident with driving a car. A driver uses visual, kinesthetic, auditory, and tactile feedback to control the steering wheel and make needed adjustments to keep the vehicle in the proper lane (Magill, 2001).

The Generalized Motor Program Theory

Objective 8.2: Explain the motor program-based theory of motor control.

Motor control theories have been developed to help explain how the nervous system is involved in human movement behavior. One of the most widely accepted theories is the **motor program-based theory**, which proposes that movement patterns are stored in memory as an abstract representation of the information needed to carry out an action. The motor program-based theory actually evolved from the ideas of Greek philosophy. Plato wrote about how humans create an image of an act preceding the act itself. In 1890, William James stated that "to perform an action, a person must first form a clear image of that action" (Schmidt, 1991). Karl Lashly (1917) became the first to use the term "motor program" to describe generalized schemata of a movement. Miller, Galanter, and Pilbram (1960) used the term "motor plan" and compared it to a computer program. Recently, Schmidt originated the concept of the **generalized motor program**, a class of actions with common characteristics stored in memory. Schmidt hypothesized that the generalized motor program provides the basis for explaining how a specific action can be controlled within a class of actions. A throwing movement pattern is an example of a generalized motor program. Any number of specific throwing movements may be executed from the basic motor program.

The Dynamic Systems Theory

Objective 8.3: Define the dynamic systems theory of motor control.

A more recent motor control theory is the **dynamic systems theory**, an approach that emphasizes the role of environmental information and the dynamics of the limbs and bodily systems. Dynamic systems theorists propose that the body and limbs have the ability to self-organize when presented with environmental conditions. The theory contends that movement is a complex phenomenon that is controlled by multiple systems of the body and chemical changes, rather than solely by the nervous system (Schmidt, 1999). For example, when a punter drops a football, and during the drop a gust of wind blows the ball slightly off path, the player can adjust the movements of the punting action to achieve a successful kick. The kicking limb has the ability to reorganize the initial movement command, without obtaining "permission" from the brain.

Motor Control Laws

Objective 8.4: Describe Fitts' Law and Hick's Law, and explain how each can be applied to motor performance.

Fitts' Law

Fitts' Law is a mathematical law describing the "speed-accuracy trade-off" in human movement (Fitts, 1954). Fitts' Law, $MT = a + b \log2 (2D/W)$, predicts movement time for a task requiring speed and accuracy, where "MT" is movement time, "a" and "b" are constants, "D" is the distance to move, and "W" is the width or size of the target. This law implies that as the speed of a movement increases, the accuracy at a given distance will decrease, and vice versa (Magill, 2001). Fitts' Law has practical applications for specific sport performances. A placekicker can expect improved accuracy of a kick from a given distance, if the speed of the movement is slowed. Furthermore, if the goal posts were narrowed, the speed of the movement would have to be slowed down to achieve the same degree of accuracy on a normal goal post.

Hick's Law

Another landmark law of motor control is **Hick's Law** (Hick, 1952). Hick discovered that reaction time increases logarithmically as the number of stimulus-response choices increases. Therefore, as the number of alternatives increases, the amount of time required to prepare the appropriate action increases. This concept has most commonly been applied to sports performance situations. A football quarterback has three basic choices in an option play. He can hand the ball off, run with the ball, or pitch the ball to a trailing player. The defensive players present sources of information to help the quarterback choose the correct alternative. This is difficult, however, because of the narrow time constraints of the play. The coach may elect to instruct the quarterback to look for a few specific characteristics in the defense to provide a simpler basis to decide on which of the three options to select (Magill, 2001).

Summary

Motor control theories are based on the open and closed-loop models of control. The open-loop control system contends that movements are carried out by motor commands from the brain, and feedback is not used in determining the action. The closed-loop control system proposes that movements are initiated by the brain, but the execution and completion of a movement is dependent on feedback. The motor program-based theory of control supports that movement patterns are stored in memory. Recent motor program theorists argue that specific movements are stored in a generalized motor program, a class of actions with common characteristics stored in memory. The dynamic systems theory contends that body limbs have the ability to self-organize when presented with feedback from the environment. The basis of this theory is that movement is a complex phenomenon that is controlled by multiple body systems and chemical reactions, rather than solely by the nervous system. Fitts' Law is a mathematical law describing the "speed-accuracy trade-off" in human movement. The law implies that as the speed of a movement increases, the accuracy at a given distance will decrease, and vice versa. Hick's Law is a motor control law that states that reaction time increases logarithmically as the number of stimulus-response choices increases. Thus, as the number of alternatives increases, the amount of time to prepare the appropriate action increases.

Questions for Discussion

1. What evidence could support that motor programs exist?

2. Explain whether shooting a basketball is controlled by an open or closed-loop system?

Class Activities

1. Demonstrate the concept of the "speed-accuracy trade-off" by instructing students to serve a racquetball or a tennis ball at various speeds, distances, and to different target sizes.

2. Assign each student a sport, and instruct them to think of at least *three* skills related to that sport that would show evidence of the dynamic systems theory of motor control. Have each student report and demonstrate to the class.

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Section Four

Motor Learning

Introduction

Section IV is an investigation of motor learning content. There are three chapters in Section IV. Chapter Nine, "Classifying Motor Skills," presents prerequisite motor learning terminology and three one-dimensional motor skill classification systems. Gentile's Taxonomy, a two-dimensional motor skill classification system, is also examined. Chapter Ten, "Motor Skill Learning," compares Fitts and Posner's Three-Stage Model of learning and Gentile's Two-Stage Model of learning. This chapter also includes an explanation of the learning-memory theory and the general versus specific motor ability hypothesis. Chapter Eleven, "Feedback and Practice," explains the concepts of task-intrinsic feedback, augmented feedback, practice variability, practice distribution, whole versus part practice, and mental practice. The emphasis of Chapter Eleven is on the practical applications of using different types of feedback and practice when teaching or coaching.

Chapter Nine

Classifying Motor Skills

Chapter Objectives

9.1 Define and differentiate between the following terms: **skill**, **motor skill**, **action**, and **movement**.

9.2 Explain the difference between **gross** and **fine motor skills**, and provide examples of each.

9.3 Identify three skill classifications based on where an action begins or ends, and give examples of each.

9.4 Define **open** and **closed motor skills**, and provide examples of each.

9.5 Describe **Gentile's Two-Dimensional Taxonomy** of motor skills.

Definitions of Key Terms

skill – an action or task with a specific goal

motor skill – a skill requiring voluntary movement to achieve a goal

action – a class of movements that is goal-directed

movement – a characteristic or component of an action or skill

gross motor skill – a skill in which the large musculature is primarily involved to produce the movement

fine motor skill – a skill which requires the control of small musculature

discrete motor skill – a skill which has a clearly defined beginning and end point

serial motor skill – a skill which involves a series of discrete skills

continuous motor skill – a skill which has arbitrary beginning and end points

open motor skill – a skill that is performed in an unstable environment

closed motor skill – a skill that is executed in a predictable environment

Gentile's Two-Dimensional Taxonomy – a two-dimensional motor skill classification system that takes into consideration the environmental context in which a skill is performed and the function of the action

Chapter Content Outline

I. Motor Learning Terminology

II. Skill Classification Based on the Size of the Primary Musculature Involved

III. Skill Classification Based on Where an Action Begins or Ends

IV. Skill Classification Based on the Stability of the Environment

V. Gentile's Taxonomy

VI. Summary

VII. Questions for Discussion

VIII. Class Activities

IX. References

Motor Learning Terminology

Objective 9.1: Define and differentiate between the following terms: skill, motor skill, action, and movement.

There are several terms in the motor learning literature that are closely related but have separate meanings. Professionals should understand the difference in the meanings between **skill, motor skill, action**, and **movement**. The term **skill** means an action or task with a specific goal. Skills are generally acquired through practice and experience. Reading is a fundamental skill of academia that requires years of practice to be perfected. Skills that require voluntary movement to achieve a goal are termed **motor skills**. Playing the drums, typing, and skipping are all examples of motor skills. An **action** refers to a class of movements that is goal-directed. Actions may incorporate two or more motor skills to achieve the goal. The action of a tennis serve incorporates tossing and striking skills. A **movement** is a behavioral characteristic or component of an action or skill. The goal of the action of walking down a flight of stairs is to get to the bottom. An individual could incorporate a variety of movements to achieve the goal. A person might slowly take one step at a time or walk briskly, taking every other step. In either scenario the action is the same, but the movements are different (Magill, 2001).

Skill Classification Based on the Size of the Primary Musculature Involved

Objective 9.2: Explain the difference between gross and fine motor skills, and provide examples of each.

One method of classifying motor skills is based on the size of the primary musculature involved in the execution of the skill. **Gross motor skills** are skills in which the large musculature is primarily involved to produce the movement. Examples of gross motor skills include walking, running, and jumping. Gross motor skills may incorporate limited use of small musculature, but the movements typically require less precision as fine motor skills. **Fine motor skills** require the control of the smaller musculature to achieve the goal. These movements call for greater precision than gross motor skills. Fine motor skills include writing, drawing, and threading a needle. Large muscles are sometimes involved in a fine motor skill but only to a limited capacity (Magill, 2001).

Many motor skills do not fit into gross or fine categories exclusively. Throwing a baseball involves the use of the small muscles of the hands and fingers. Throwing also involves movements of large musculature of the arms, torso, and lower body. This example illustrates how there is often overlapping in one-dimensional classification systems.

The gross/fine motor classification is used in various settings including adapted physical education, special education, physical therapy, occupational therapy, and early childhood education. Physical therapists are often concerned with the rehabilitation of gross skills, such as walking. Occupational therapists more often work with patients who need rehabilitation of fine motor skills, such as writing.

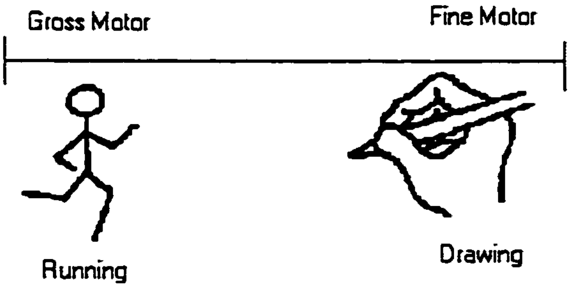

Figure 14.
The Gross/Fine Motor Skill Continuum

Skill Classification Based on Where an Action Begins or Ends

Objective 9.3: Identify three skill classifications based on where an action begins or ends, and give examples of each.

A second motor skill classification system is based on where an action begins or ends. Skills in this classification system are termed **discrete, serial,** or **continuous motor skills. Discrete motor skills** have clearly defined beginning and end points, and usually involve simple movements. Examples of discrete motor skills include pressing a piano key and flipping a light switch. **Serial motor skills** involve a series of discrete skills. Examples of serial motor skills are playing a piano piece or performing a triple jump. **Continuous motor skills** are skills which have arbitrary beginning and end points and are usually repetitive in nature. Running and swimming are examples of continuous motor skills (Schmidt, 1999).

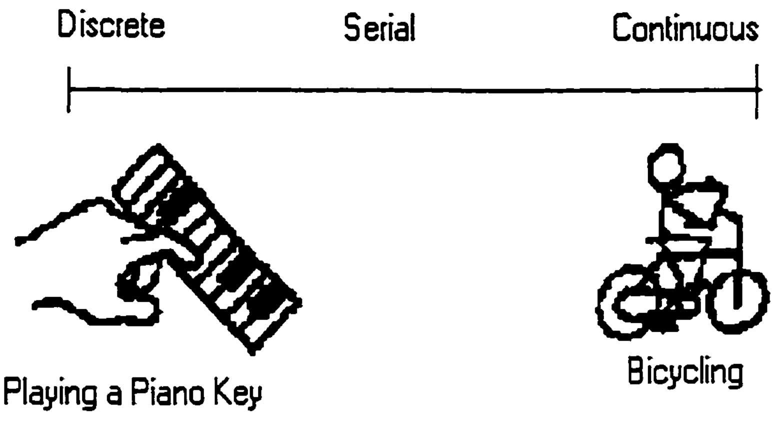

Figure 15.
The Discrete/Serial/Continuous Motor Skill Continuum

Skill Classification Based on the Stability of the Environment

Objective 9.4: Define open and closed motor skills, and provide examples of each.

A third one-dimensional motor skill classification system is based on the stability of the environment in which a skill is performed. Skills in this classification system are identified as either **open** or **closed motor skills. Open motor skills** are skills that are performed in an unstable environment. A moving object or the environmental context determines when the action will begin. Hitting a return shot in tennis, hitting a pitched baseball, or walking through a crowded mall are all examples of open motor skills. A motor skill that is executed in a predictable environment is called a **closed motor skill** (Schmidt, 1999). With a closed motor skill, the performer determines when to initiate the movement, and the environment remains stable. Closed motor skills include bowling, shooting a bow and arrow at a stationary target, dart throwing, and striking in tee ball. Overlapping occurs with the open/closed classification system as well. Many skills involve elements that are open and closed in nature. Placekicking a football involves striking a stationary object. This is a closed aspect of the skill. The environment of a football game, however, can be unpredictable. Eleven defensive players attempt to block the kick, and the kicker is dependent upon a good snap and hold. These aspects of placekicking are open in nature.

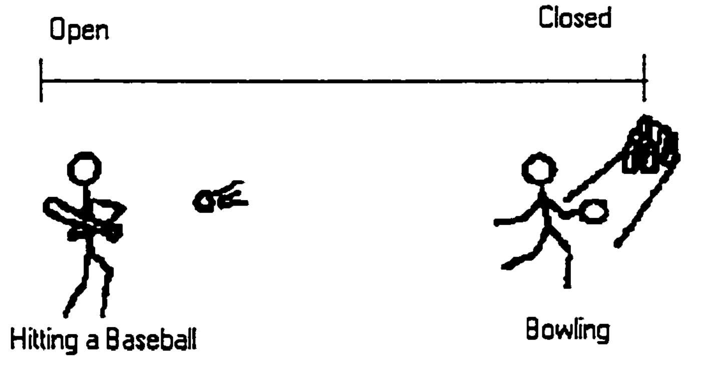

Figure 16.
The Open/Closed Motor Skill Continuum

Gentile's Taxonomy

Objective 9.5: Describe Gentile's Two-Dimensional Taxonomy of motor skills.

An alternative to the one-dimensional classification systems of motor skills is **Gentile's Two-Dimensional Taxonomy**. Gentile's classification system takes into consideration two variables of a skill: a) the environmental context, and b) the function of the action (Gentile, 2000).

The environmental context is divided into two areas: "regulatory conditions" and "intertrial variability." Regulatory conditions refer to characteristics of the environment that determine the movement. An individual's movement must conform to specific environmental features to be successful. Walking surface or the size, shape, or speed of a ball are examples of regulatory conditions. According to Gentile (2000), regulatory conditions are either stationary or in motion. Stationary regulatory conditions are common with closed skills such as hitting a ball off of a tee. Regulatory conditions that are in motion are characteristic of open skills, such as hitting a pitched ball. Intertrial variability refers to whether the regulatory conditions during performance are the same or different from one attempt to perform a skill to the next. According to Gentile, intertrial variability is either absent or present. Absent intertrial variability is evident in a skill such as walking across an uncluttered room. An example of the presence of intertrial variability is a baseball batter facing a pitcher who uses several different speeds of pitches.

The second variable of Gentile's Taxonomy is the function of the action, which is made up of two parts: "body orientation" and "manipulation." Body orientation is subdivided into either body stability or body transport. A skill that involves body stability is performed with the body still. Archery is an activity that involves body orientation that is stable. Skills that incorporate body transport involve the body moving from one place to another to perform the skill. Swimming is a skill that is performed with body transport. Manipulation is the second portion of the function of the action. Skills are classified within Gentile's Taxonomy as having an object manipulated during the skill or no object manipulation. Manipulating an object automatically increases the complexity of a skill. Serving a shuttlecock in badminton is an example of a skill that involves object manipulation. Running is a skill in which no object manipulation is involved (Magill, 2001).

According to Gentile's 16 skill categories, the simplest skills to perform are those which have stationary regulatory conditions, an absence of intertrial variability, stable body orientation, and no manipulation (Gentile, 2000). The most difficult skills to perform are those which have regulatory conditions in motion, the presence of intertrial variability, body transport, and object manipulation. Punting a football is an example of the most difficult skill category of Gentile's Taxonomy.

Gentile's classification system is used by rehabilitation specialists in the evaluation of movement capabilities and limitations. Teachers and coaches may also apply Gentile's Taxonomy to the selecting of progression of functionally appropriate activities.

Summary

The terms skill, motor skill, action, and movement all have slightly different meanings. Skill refers to an action or task with a specific goal, and a motor skill is a skill that requires voluntary movement to achieve the goal. An action is a class of movements that is goal-directed. Many actions, such as a tennis serve, incorporate two or more skills. A movement is a behavioral characteristic or component of an action or skill.

There are three one-dimensional classification systems of motor skills. These classifications are used for identification purposes, but there is often overlapping among skills. Gross/fine motor classification is based on the size of the primary musculature involved in the execution of the movement. Discrete/serial/continuous classification is based on where an action begins or ends. Finally, the open/closed classification is based on the stability of the environment in which the skill is performed.

A two-dimensional classification system of motor skills was developed by Gentile. Gentile's Taxonomy is divided into 16 skill categories which vary in terms of the complexity of the skill. This classification system considers the environmental context of the skill and the function of the action.

Questions for Discussion

1. Classify the various motor skills in the game of soccer?

2. Why are open skills generally considered more difficult to perform than closed skills? What are some of the most difficult closed motor skills to perform?

3. What are some of the purposes for classifying motor skills?

Class Activities

1. Instruct each student to choose and perform an action. Ask students to identify the specific skills and movements that make up the action.

2. Instruct the class to develop a progressive series of drills for various motor skills, based on Gentile's Taxonomy.

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Chapter Ten

Motor Learning Theories

Chapter Objectives

10.1 Explain **Fitts and Posner's Three-Stage Model** of learning.

10.2 Describe the elements of **Gentile's Two-Stage Model** of learning.

10.3 Explain the **learning-memory theory**.

10.4 Define **ability**, and differentiate between the **general motor ability hypothesis** and the **specificity of motor abilities hypothesis.**

Definitions of Key Terms

Fitts and Posner's Three-Stage Model – model of learning that asserts learning consists of three stages: cognitive, associative, and autonomous

cognitive stage – the first stage of Fitts and Posner's Three-Stage Model of learning

associative stage – the second stage of Fitts and Posner's Three-Stage Model of learning

autonomous stage – the third stage of Fitts and Posner's Three-Stage Model of learning

Gentile's Two-Stage Model – model of learning that proposes learning progresses through two stages: "getting the idea of the movement" and fixation/diversification

"getting the idea of the movement" – the first stage of the Gentile Two-Stage Model of learning

fixation – the refinement of the movement pattern of a closed skill which occurs during the second stage of the Gentile Two-Stage Model of learning

diversification – during the second stage of the Gentile Two-Stage Model of learning, the learner's acquirement of the ability to adjust the movement pattern of an open skill, based on the environmental characteristics

learning-memory theory – theory that suggests learning occurs through three memory processing stages

ability – a trait or capacity that underlies an individual's skilled performance

general motor ability hypothesis – supports that different motor abilities within an individual are highly related and can be characterized as one homogeneous motor ability.

specificity of motor abilities hypothesis – suggests that different motor abilities that an individual possesses are independent from one another

Chapter Content Outline

I. Fitts and Posner's Three-Stage Model of Learning

II. Gentile's Two-Stage Model of Learning

III. The Learning-Memory Theory

IV. The General Versus Specific Motor Ability Hypothesis

V. Summary

VI. Questions for Discussion

VII. Class Activities

VIII. References

Fitts and Posner's Three-Stage Model of Learning

Objective 10.1: Explain Fitts and Posner's Three-Stage Model of learning.

One of the most influential models that has been proposed to describe the stages that humans go through as they learn a motor skill is **Fitts and Posner's Three-Stage Model**. This model of learning asserts that motor learning consists of three distinct stages. The stages, however, should be thought of as a continuum rather than abrupt changes from one stage to the next. Transition of learning is gradual, and the model allows instructors to identify the general characteristics and needs of a particular individual (Fitts and Posner, 1967).

The first stage is called the **cognitive stage**. The main task of the learner during this stage is to understand the goal of the task, movements to accomplish the goal, and the strategy that will produce the desired movements. The main tasks of the teacher during the cognitive stage are to assist the learner to comprehend the task, through demonstrations, verbal descriptions, and manual guidance. Once the learner begins to practice a skill, appropriate feedback must be provided by the instructor. During the cognitive stage, the learner may make many large errors and be inconsistent from trial to trial. While beginners may be aware of the errors, they generally do not understand what needs to be done to make corrections (Schmidt, 1991).

The second stage of Fitts and Posner's model, the **associative stage**, is a period in which movements begin to fuse into well-coordinated movement patterns. An individual acquires the basic fundamentals and mechanics of a skill, and makes fewer gross errors. The associative stage is also referred to as a "refining" stage, because the focus of the learner is on performing a skill correctly and consistently. Also, individuals become able to identify and detect their own errors. Feedback and movement analysis by instructors, and mental practice can enhance learning during this stage (Magill, 2001).

The third and final stage of Fitts and Posner's model of learning, the **autonomous stage,** is a period in which a motor skill becomes habitual and almost automatic. Many individuals during this stage do not need to consciously think about the skill during performance. This allows the performer to execute another task simultaneously. For example, a skilled juggler may have the ability to juggle five bowling pins, while performing a dance. During the autonomous stage, the learner develops motor programs of increased length, complexity, and integration. The main role of instructors of highly skilled performers is to organize practice so that learning continues. This can be done by providing appropriate feedback and motivation, and assistance with tactics and strategies. Many skilled performers are also able to utilize mental practice effectively to enhance skill proficiency (Magill, 2001).

Gentile's Two-Stage Model of Learning

Objective 10.2: Describe the elements of Gentile's Two-Stage Model of learning.

Another popular learning model is **Gentile's Two Stage Model.** This model proposes that learning progresses through two stages. The distinction of each stage is based on the goal of the learner during the particular stage (Gentile, 1972).

In the first stage of the Gentile model, the goal of the learner is **"getting the idea of the movement."** The "idea" is described as the appropriate movement coordination pattern required to achieve the goal of the skill. A beginner learning how to pass a football must learn the proper grip, the appropriate hand and arm coordination required, and the necessary footwork involved. An individual in Gentile's first stage of learning must also learn to discriminate between environmental features that may or may not influence the performance. These features are referred to as "regulatory" and "nonregulatory conditions." Regulatory conditions are environmental features that affect the performance of a skill. The size, shape, and location of a baseball are regulatory conditions that a batter must take into consideration when learning how to strike. Nonregulatory conditions are irrelevant environmental conditions to the performance of a skill. Examples of nonregulatory conditions to striking a baseball are the color of the ball and crowd noise. During Gentile's first stage, an individual will experiment with different movement patterns through trial and error. Practice is focused on movements that are successful. Individuals also engage in cognitive problem solving to learn how to achieve the goal of the action. At the end of the first stage, a learner has established the fundamental movement coordination pattern that allows for success, but performance remains inconsistent (Gentile, 1972).

In the second stage of the Gentile model, the learner develops the ability to adapt the movement pattern to different performance situations. In addition, consistency improves, and the execution of a skill requires less effort. Gentile describes the goals of the learner in the second stage as **fixation** or **diversification**, depending on what type of skill is being learned (Magill, 2001).

Fixation refers to the refinement of the movement pattern of closed skills, so that performance is correct, consistent, and efficient. Practice of closed skills during this stage must allow the learner to "fixate" the movement pattern, so that performance becomes consistent, requiring little conscious effort. **Diversification** refers to the learner's acquisition of the ability to adjust the movement pattern of an open skill, based on the environmental characteristics. Performers of open skills must have the ability to adapt to changing regulatory conditions that are presented. Thus, an individual must learn how to monitor environmental conditions, rather than simply learn how to automatically perform a skill. A skilled racquetball player is able to adjust the basic forehand stroke to a variety of different situations, based on the speed and location of the ball (Magill, 2001).

Consideration of the differences between open and closed skills when planning a practice regimen are important. Closed skills, such as bowling, allow the performer to prepare for the movement with little time constraints. The environment of open skills, such as returning a volleyball, strictly limit the time a player has to prepare for the execution of a skill. Thus, practice of open skills should facilitate the ability to quickly monitor environmental characteristics, so that changes can be anticipated, and performance will be successful.

The Learning-Memory Theory

Objective 10.3: Explain the learning-memory theory.

Complex motor behavior must be learned, and one of the ways to understand how motor skills are acquired is to examine memory aspects of motor behavior. Learning is a neural change that is the result of experiences with environmental stimuli. The **learning – memory theory** has attempted to explain how memory is involved in learning (Schmidt, 1991).

The learning-memory theory suggests that learning occurs through three memory processing stages. In the first stage, environmental stimuli are transduced and coded in the form of nerve impulses and transmitted to the brain. Second, this activity becomes recoded in short-term memory, which has the capacity to hold up to 10 items or stimuli. The "hold" time for items in short-term memory can vary from a few seconds to over one hour. Gradually, the neural representation of the stimulus event is transformed into a structural change in the brain. This change represents the third stage, and it is characterized by the neural activity being transformed into consolidated long-term memory. If the short-term memory process is disrupted, the long-term process cannot take place, and the stimulus event cannot be recalled. Current research does not provide a definitive explanation of long-term memory, but some researchers suggest that molecular changes occur in neurons whenever an individual learns something. The molecules most frequently identified as being involved in long-term memory are ribonucleic acid and protein. Learning-memory theorists believe that long-term memory for movements is superior to long-term memory for verbal abilities. The theory also suggests that continuous motor skills, such as running, are retained better than serial or discrete skills (Schmidt, 1991).

The General Versus Specific Motor Ability Hypothesis

Objective 10.4: Define ability, and differentiate between the general motor ability hypothesis and the specificity of motor abilities hypothesis.

An **ability** is a trait or capacity that underlies an individual's skilled performance. Abilities are generally inherited and affect the potential of an individual to perform at a certain level. Motor abilities vary considerably among individuals. If two people have the same training in snow skiing, but differ in their abilities required to perform the skill, the individual with the greater ability has the potential to perform at a higher level (Magill, 2001).

The **general motor ability hypothesis** is one of the viewpoints that has attempted to explain the motor ability phenomenon. This hypothesis states that different motor abilities within an individual are highly related and can be characterized as one homogeneous motor ability. The hypothesis supports that the level of the general motor ability has a major influence on how well an individual will perform any motor skill. Thus, if an individual is a proficient performer of one skill, then that person has the potential to be good at any motor skill. The reasoning behind this theory is that there is one general motor ability. The general motor ability hypothesis is a popular anecdotal explanation of why some individuals outperform others with various skills, but there is little research evidence to support this hypothesis (Schmidt, 1991).

An alternative to the general motor ability hypothesis is the **specificity of motor abilities hypothesis**. This viewpoint suggests that different motor abilities that an individual possesses are independent of one another. Thus, one would not necessarily expect a skilled track athlete to have the same potential to be an accurate dart thrower. The hurdle for the specificity hypothesis is the notion of the "all-around athlete," a person who is skilled at a variety of physical tasks. The explanation offered by the specificity view is that abilities fall along a range of low, average, and high amounts among individuals. Thus, there are individuals who have many abilities at an average level, and there are those who have a majority of abilities at the high or low end of the scale.

According to the specificity view, the "all-around athlete" is someone who has high levels of a large number of motor abilities (Magill, 2001).

Summary

Two influential models of learning are Fitts and Posner's Three-Stage Model and Gentile's Two-Stage Model. The Fitts and Posner model asserts that learning consists of three distinct stages: the cognitive, associative, and autonomous stages. Gentile's model consists of two separate stages. The goal of the learner in the first stage is "getting the idea of the movement." The goal in the second stage is fixation or diversification, depending if the skill is open or closed. The stages of these two models should be thought of more as a continuum rather than abrupt changes from one stage to the next.

One of the accepted theories of the relationship of memory and learning is the learning-memory theory. This theory suggests that learning occurs through three memory processing stages. First, environmental stimuli are coded in the form of nerve impulses to the brain. Second, the neural impulses are briefly stored in short-term memory. Finally, a structural change takes place in the brain, and the neural activity is consolidated into long-term memory.

An ability is a trait or capacity that underlies an individual's skilled performance. The general and specific motor ability hypotheses have attempted to explain this phenomenon. The general motor ability hypothesis supports that different motor abilities within an individual are highly related and can be characterized as one homogeneous motor ability. The specificity of motor abilities hypothesis suggests that different motor abilities that an individual possesses are independent from one another.

Questions for Discussion

1. What are the major differences between the type of practice conditions that should be employed for an open and closed skill in Gentile's second stage of learning?

2. What are some of the explanations for the phenomenon of the "all-around athlete?"

Class Activities

1. Have students get into groups of three or four, and assign each group a different skill. Instruct each group to write down the general performance characteristics of the skill in each phase of Fitts and Posner's Three-Stage Model of learning.

2. Split the class in half, and assign one group to become experts on the general motor ability hypothesis and one group to become experts on the specificity of motor abilities hypothesis. Give each group a chance to defend its hypothesis in a formal debate.

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Chapter Eleven

Feedback and Practice

Chapter Objectives

11.1 Explain the difference between **task-intrinsic** and **augmented feedback**, and differentiate between **knowledge of results** and **knowledge of performance.**

11.2 Describe the importance of practice variability in learning motor skills.

11.3 Explain how the distribution of practice can affect motor learning.

11.4 Discuss the basis for practicing skills in wholes or in parts.

11.5 Describe the effects of mental practice on motor performance.

Definitions of Key Terms

feedback – the information an individual receives as a result of performing a skill

task-intrinsic feedback – the sensory information provided by the visual, auditory, proprioceptive, and tactile receptors

augmented feedback – any type of feedback that is provided by an external source besides the individual performer

concurrent feedback – feedback given during a performance

terminal feedback – feedback given after a performance

knowledge of results – the category of augmented feedback that provides information about the outcome of a performance

knowledge of performance – a category of augmented feedback that provides information about the characteristics of the movement that led to the outcome of a performance

practice variability – the degree to which movement and content characteristics vary while practicing a skill

contextual interference – a beneficial procedure of practicing variations of a skill within a practice

practice distribution – the spacing of practice

massed practice – a practice schedule with very short rest periods between sessions or trials

distributed practice – a practice schedule with relatively long rest periods between sessions or trials

organization – the relationship among a skill's components

fractionization – practicing separate components of the whole skill that do not depend on the other parts

segmentation – separating a skill into parts and then practicing each part in turn

simplification – reducing the difficulty of a whole skill

mental practice – a practice procedure in which the performer imagines successful action without any overt practice

internal mental practice – mentally rehearsing what the performer sees and feels during the actual performance of a skill

external mental practice – imagining watching oneself perform, from a spectator's perspective

Chapter Content Outline

I. Types of Feedback
   A. Task-intrinsic feedback
   B. Augmented feedback

II. Practice Variability

III. Practice Distribution

IV. Whole Versus Part Practice

V. Mental Practice

VI. Summary

VII. Questions for Discussion

VIII. Class Activities

IX. References

Types of Feedback

Objective 11.1: Explain the difference between task-intrinsic and augmented feedback, and differentiate between knowledge of results and knowledge of performance.

Task-Intrinsic Feedback

Feedback is the information an individual receives as a result of performing a skill. The three main functions that feedback serves are to provide information, motivation, and reinforcement. There are two general categories of feedback: **task-intrinsic feedback** and **augmented feedback. Task-intrinsic feedback** is the sensory information provided by the visual, auditory, proprioceptive, and tactile receptors. A golfer is provided a plethora of sensory feedback when striking a ball. Visual information about the flight of the ball, the sound of the contact of the club and ball, kinesthetic information about the velocity and location of body limbs, and tactile information through the grip of the club, all give the golfer clues to the performance of the swing (Schmidt, 1991).

Augmented Feedback

A second category of feedback is **augmented feedback.** Augmented feedback is any type of feedback that is provided by an external source besides the individual performer. The term "augmented" means "enhanced"; thus, this type of feedback is used to enhance the task-intrinsic feedback that is naturally provided through the perceptual modalities. A golfer's task-intrinsic feedback would be augmented by a coach who could tell a right-handed performer something about the movement of the hips that led to the outcome of the ball hooking off to the left. There are various ways in which augmented feedback can be given. If the feedback is given during the movement, it is called **concurrent feedback**. An example of concurrent feedback is a strength and conditioning coach instructing a lifter to slow down a movement during a repetitive exercise. Any augmented feedback given after a performance is called **terminal augmented feedback**. An example of terminal augmented feedback is a coach providing information to a gymnast about the judges' scores. Regardless of the time period in which the feedback is provided, augmented feedback is divided into two categories: **knowledge of results** and **knowledge of performance** (Magill, 2001).

Knowledge of results refers to the category of augmented feedback that provides information about the outcome of a performance. An example of knowledge of results is a coach telling a sprinter his or her time after running a 100 meter dash. This provides the athlete with information about the quality of the performance (Magill, 2001).

Knowledge of performance is a category of augmented feedback that provides information about the characteristics of the movement that led to the outcome of a performance (Schmidt, 1991). A track coach may tell a sprinter that during a run, he or she displayed horizontal arm movements that contributed to a slower time. This feedback would enhance any proprioceptive feedback the sprinter was given during the run. Knowledge of performance is not always given verbally. Other ways to provide knowledge of performance are videotaped performances and computer-generated movement analyses.

Practice Variability

Objective 11.2: Describe the importance of practice variability in learning motor skills.

One of the most effective ways to enhance the learning of motor skills is by varying the practice. **Practice variability** is the degree to which movement and content characteristics vary while practicing a skill. The type or amount of practice variability to use depends on the future situation in which the skill will be performed, and the type of skill being learned. For closed skills that do not involve intertrial variability for the regulatory conditions, such as shooting a free throw, regulatory conditions should remain constant, but nonregulatory conditions should vary. Conditions that should remain constant include the size of the basketball, the distance of the goal from the free throw line, and the height of the goal. Nonregulatory conditions that should be varied, because they vary in games, include number of free throws to be taken, importance of the free throw to the outcome of the game, and crowd noise. For closed skills that have intertrial variability, such as a golf shot with a nine iron, both regulatory and nonregulatory conditions should be varied, because they are both likely to be novel in a performance situation. In golf, regulatory conditions that can vary include the goal of the shot, distance required for the shot, and the location of the ball. Nonregulatory conditions that could vary include the hole number being played, the number of strokes an individual is ahead or behind, weather conditions, or the importance of a particular shot. For open skills, regulatory and nonregulatory conditions should always be varied because performance situations are usually always different (Schmidt, 1991).

One way to organize varied practice is to apply **contextual interference**, a beneficial procedure of practicing variations of a skill within a practice. A high degree of contextual interference involves random arrangements of trials in which all variations of a task are practiced within one session. A random practice schedule for a volleyball team might include a random series of drills for all overhand, underhand, and sidearm shots. Low contextual interference involves each task variation practiced in its own block, or time period. A volleyball team may spend an entire practice session working only on overhand shots. Researchers have found that increased interference (i.e. random practice) is more effective than low interference (i.e. blocked practice) in most motor skill learning situations of beginners and skilled performers (Magill, 2001).

Practice Distribution

Objective 11.3: Explain how the distribution of practice can affect motor learning.

The spacing of practice is referred to as **practice distribution**. Two types of practice, **massed** and **distributed practice**, are relevant to this issue. **Massed practice** refers to a practice schedule with very short rest periods between sessions or trials. **Distributed practice** refers to a practice schedule with relatively long rest periods between sessions or trials. Research supports that practice that is too long and too infrequent does not lead to optimal learning. People generally learn better in a large number of shorter sessions. The length of the period between trials also has a major impact on learning. Researchers have found that the optimal intertrial interval length varies depending on the type of skill. Distributed practice schedules appear to be more effective with continuous skills, and massed practice schedules are more effective with discrete skills (Magill, 2001).

Whole Versus Part Practice

Objective 11.4: Discuss the basis for practicing skills in wholes or in parts.

The decision to practice a motor skill as a whole or in parts should largely be based on the skill's complexity and **organization**. Complexity refers to the number of parts or components and the information processing demands of a skill. **Organization** refers to the relationship among the skill's components. A skill requiring a high degree of organization, such as shooting a jump shot, is one in which each part of the skill is dependent on the other. A skill with a low degree of organization, such as a dance routine, is one in which each part of the skill is independent of the other. Generally, if a skill is low in complexity and high in organization, it is best to practice that skill as the whole skill. On the other hand, a skill that is high in complexity and low in organization should be practiced in parts (Schmidt, 1991).

There are three effective methods for dividing skills into parts. One of these is **fractionization**, practicing separate components of the whole skill that do not depend on the other parts. With fractionization, parts of the skill that are dependent are combined as a unit and practiced together. For example, independent parts of the tennis serve are the grip, stance, backswing, and toss. Dependent parts of the tennis serve are the forward swing, ball contact, and a follow through. **Segmentation**, a second method of practicing a skill in parts, is the process of separating a skill into parts and then practicing each part in turn. Each independent part progressively joins a larger part, and as practice continues, the learner eventually practices the skill as a whole. A placekicker using segmentation could practice passing the ball off of the foot, kicking the ball with no step, kicking the ball with one step, and finally kicking the ball with two steps. A third method for practicing skills in parts, **simplification**, involves reducing the difficulty of the whole skill. One way to reduce the difficulty of a skill is to reduce the difficulty of objects. An individual learning how to juggle three balls may use scarves first. Another way to simplify is to provide auditory accompaniment. For individuals with gait disorders, a metronome can be used to assist the rhythmic component of walking. A third method of simplification is to reduce the speed of the movement (Magill, 2001).

Mental Practice

Objective 11.5: Describe the effects of mental practice on motor performance.

Mental practice has been an increasingly prevalent topic in the motor learning literature. Numerous studies have been done in this century to examine what effect covert rehearsal has on learning and performance. **Mental practice** is defined as a practice procedure in which the performer imagines successful action without any overt practice. Mental rehearsal, conceptualization, ideational functioning, introspection, imaginary practice, and imagery practice are all terms used synonymously with mental practice. Mental practice should be distinguished, however, from "mental preparation," which includes other mental techniques such as positive imagery, psyching-up strategies, attention focusing, relaxation, and other types of cognitive and emotional preparation (Schmidt, 1991).

Different forms of mental practice include rehearsing the perfect performance of a skill, observing other highly skilled athletes, reviewing and correcting one's performance, and developing strategy. Mental practice can be **internal** or **external**. **Internal mental practice** refers to rehearsing what the performer sees and feels during the actual performance of a skill. **External mental practice** is performed by imagining watching oneself from a spectator's perspective. Mental practice can also be guided by an instructor step by step, or can be undirected, giving the performer the freedom to use his or her own technique (Magill, 2001).

Mental practice should be considered as a supplement to normal physical training. Mental practice has not been proposed as a substitute for physical practice. To become truly proficient at a motor skill, some overt practice must be done. Mental practice is effective in crowded facilities, with limited available equipment, with tasks that are too dangerous to train for physically, or when there are few opportunities for overt practice. Covert rehearsal allows a person to enter scenes which can never be fully duplicated by simulated practice. An athlete can imagine performing in a stadium filled with 100,000 people, or a downhill skier can visualize a new course by having only looked at a map. Mental practice can be done almost anywhere, but probably works best with the learner seated. Some athletes, however, are able to visualize while moving. Some gymnasts are able to visualize upcoming moves while walking through a floor routine.

Three theories that attempt to explain why mental practice has a positive effect on performance are as follows: the psychoneuromuscular theory, the pseudomotivational theory, and the cognitive/symbolic theory. The psychoneuromuscular theorists believe mental practice causes tiny contractions in the musculature used to perform a skill. This provides kinesthetic feedback which strengthens a motor program. Research shows there is an increase in the electrical activity in skeletal muscles when subjects imagine performing a skill. Some theorists believe that the motor program is "run off" to a smaller scale during mental practice, to prepare the musculature for action. Pseudomotivational theorists describe mental practice as an "epiphenomenon." In many studies, a mental practice group is compared to a control group. This suggests a "Hawthorne effect," meaning the mental practice group improved simply because it did something as opposed to nothing. The cognitive/symbolic theory supports the notion that mental practice is effective with skills which are more cognitive in nature. However, measuring the degree of mental activity involved in a skill is difficult (Schmidt, 1991).

Certain factors play a role in determining the effectiveness of mental practice. One of these is the type of task being performed. The more a task involves cognitive elements, the stronger the effects seem to be. Also, the retention interval is influential. The time between the last practice and the posttest, can affect the results. As the retention interval increases, the positive effects of mental practice begin to deteriorate. Another factor is the experience level. Novice subjects tend to benefit more from mental practice when the task is more cognitive in nature, while more experienced subjects benefit equally from mental practice on cognitive or physical tasks. The duration of practice is another factor. As the length of mental practice sessions increases, the beneficial effects begin to decrease (Lamirand and Rainey, 1994). Twenty minutes has been suggested for implementing mental practice. A final factor affecting the effectiveness of mental practice is a performer's ability to visualize. The ability to control and vividly see an image varies among individuals (Mendoza and Whichman, 1978). If a learner is unable to vividly imagine the correct performance, it is unlikely that mental practice will be effective. Some believe the ability to visualize skills improves with practice.

Summary

Two general categories of feedback are task-intrinsic and augmented feedback. Task-intrinsic feedback is the sensory information provided by the visual, auditory, proprioceptive, and tactile receptors. Augmented feedback is any type of feedback that is provided by an external source besides the individual performer. Knowledge of results is a type of augmented feedback that provides information about the outcome of a performance. Knowledge of performance is a type of augmented feedback that provides information about the characteristics of the movement that led to the outcome of a performance.

Practice variability is the degree to which movement and content characteristics vary while practicing a skill. Random practice is usually more effective than blocked practice in motor learning situations. Distributed practice is more effective with continuous skills, and massed practice is more effective with discrete skills. The decision to practice a motor skill as a whole or in parts should be based on the skill's complexity and organization. If a skill is low in complexity and high in organization, it is best to practice that skill as a whole. A skill that is high in complexity and low in organization should be practiced in parts. Three effective methods for practicing skills in parts include fractionization, segmentation, and simplification.

Mental practice is a practice procedure in which the performer imagines successful action without any overt practice. Internal mental practice refers to mentally rehearsing what the performer sees and feels during the actual performance of a skill. External mental practice is performed by imagining watching oneself from a spectator's perspective. Factors that determine the effectiveness of mental practice on performance include the type of task, the retention interval, experience level, duration of practice, and the ability to visualize.

Questions for Discussion

1. What are some examples of augmented feedback that could be given to a young child learning how to strike?

2. How could an individual use segmentation to practice a tennis serve?

3. Do you think internal or external mental practice would be more effective in learning a skill like pole vaulting?

Class Activities

1. Acquire three scarves and three tennis balls for each student. Demonstrate the concept of simplification by having everyone practice juggling three scarves for a 15-minute block. Next, have every other student try juggling three balls. Notice how many beginners are able to successfully juggle the balls.

2. Conduct an experiment to test the effectiveness of mental practice. On day one, have every student shoot 10 free throws, and record the successful number of shots made for each student. Next, divide your students in half, and assign one half of the class to a control group and one half of the class to a mental practice group. Instruct the mental practice group to spend three 15-minute sessions over the next two days mentally rehearsing successful free throw shots. Instruct each group not to physically practice any free throw shooting before a posttest is administered. Finally, administer a posttest, and note the differences between the groups' free throw percentages.

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APPENDIX A

Chapter Format

I. Chapter Objectives

II. Definitions of Key Terms

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APPENDIX B

Recommended Motor Behavior Course Outline (15 week course)

Weeks 1 – 2	I. Introduction to Motor Behavior
	Week one: General terminology
	Week two: History of motor behavior research
Weeks 3 – 7	II. Motor Development
	Week three: Lifespan development
	Week four: Physical development
	Week five: Physiological development
	Week six: Phases of motor development
	Week seven: Review/exam one
Weeks 8 – 11	III. Motor Control
	Week eight: The nervous system
	Week nine: Information processing
	Week ten: Motor control theories and laws
	Week eleven: Review/exam 2
Weeks 12 – 15	IV. Motor Learning
	Week twelve: Classifying motor skills
	Week thirteen: Motor learning theories
	Week fourteen: Feedback and practice
	Week fifteen: Review/exam three

GLOSSARY

ability – a trait or capacity that underlies an individual's skilled performance

action – a class of movements that is goal-directed

afferent fibers – type of peripheral nerve fibers that send information into the spinal cord and brain from the periphery of the body

age of viability – the age at which the fetus has matured enough that it would have a 50% chance of survival outside of the womb; approximately the 28th prenatal week

ambidexterity – the ability to use either limb in equal proficiency

arteries – blood vessels that carry oxygen-rich blood from the heart

associative stage – the second stage of Fitts and Posner's Three-Stage Model of learning

atrophy – a decrease in size of cells

attention – the conscious or unconscious ability to engage in mental concentration or readiness

attentional focus – the ability to direct attention to specific characteristics of a performance or environment

augmented feedback – any type of feedback that is provided by an external source besides the individual performer

automaticity – the ability to execute a movement with little or no demand on attention capacity

autonomic nervous system – part of the peripheral nervous system that controls the regulation of smooth muscles of the internal organs

autonomous stage – the third stage of Fitts and Posner's Three-Stage Model of learning

axon – the part of a neuron that carries information away from the cell body

basal metabolic rate – the measure of the amount of heat produced by the body at rest

behavior – performance

bimanual control – the ability to coordinate both hands together

binocular vision – vision with both eyes

blood volume – amount of blood in the body

body awareness – the awareness of the name and location of body parts, their relationship to one another, and their abilities and limitations

brain – the command center of the nervous system

brainstem – the part of the brain responsible for controlling involuntary functions

capillaries – small interconnecting blood vessels

cardiac output – quantity of blood ejected by the heart per minute

cardiorespiratory system – the cardiovascular (heart and blood vessels) and the respiratory (lungs) systems collectively

catching – a manipulative skill in which an object is tracked and gained control of with the hands

central nervous system – the brain and spinal cord

cephalocaudal – growth and development that begins toward the head of the body and progress downward

cerebellum – the part of the brain responsible for determining coordinated sequences of muscle contractions during complex movements

cerebral cortex – the outermost layer of the cerebrum composed of 75% of the total neurons in the central nervous system

cerebrum – the part of the brain responsible for controlling voluntary motor function

climbing – ascending or descending the body using the hands and feet

closed motor skill – a skill that is executed in a predictable environment

closed-loop control system – motor control model that proposes that the initial commands to the efferent nerves only initiate a movement, but the execution and completion of a movement is dependent on feedback information

cognitive stage – the first stage of Fitts and Posner's Three-Stage Model of learning

conception – the beginning of the prenatal period; when the sperm unites with the egg

concurrent feedback – feedback given during a performance

contextual interference – a beneficial procedure of practicing variations of a skill within a practice

continuity – the view that development involves gradual and cumulative changes

continuous motor skill – a skill which has arbitrary beginning and end points

corpus callosum – myelinated tissue connecting the two hemispheres of the brain

crawling – locomotion in a prone position with the abdomen dragging the ground

creeping – locomotion on the hands and knees with the abdomen clear of the ground

critical period – an optimal time for the emergence of certain developmental processes and behaviors

dendrites – finger-like nerve fiber projections which receive information from other neurons

depth perception – the ability to judge the distance of an object from oneself

development – a change in the level of functioning

diastolic blood pressure – the lowest pressure on the blood vessel walls during filling and relaxation of the heart

differentiation – process by which behavior becomes more specialized

directional awareness – the awareness of the two sides of the body, and the ability to recognize movements through various planes

discontinuity – the view that development is stage-like

discrete motor skill – a skill which has a clearly defined beginning and end point

distributed practice – a practice schedule with relatively long rest periods between sessions or trials

diversification – during the second stage of the Gentile Two-Stage Model of learning, the learner's acquirement of the ability to adjust the movement pattern of an open skill, based on the environmental characteristics

dribbling – a manipulative skill in which a ball is bounced with the hand

dynamic balance – the ability to maintain posture while in motion

dynamic systems theory – motor control theory that emphasizes the role of environmental information and the dynamics of the body and limbs

dynamic tripod – writing grip in which the thumb, index finger, and middle finger are used to hold a writing utensil

Educational Testing Service – professional organization that provides tests and other services to states to use as part of their teacher certification process

efferent fibers – type of peripheral nerve fibers that channel information from the central nervous system to the periphery

embryonic period – the period lasting approximately two to eight weeks after conception

endocardium – inner layer of the heart

environment – the circumstances, objects, or conditions by which one is surrounded

external mental practice – imagining watching oneself perform, from a spectator's perspective

feedback – the information an individual receives as a result of performing a skill

fetal period – the period lasting approximately eight weeks prenatal to birth

figure-ground perception – the ability to recognize an object as separate from the background

fine motor skill – a skill which requires the control of small musculature

Fitts and Posner's Three-Stage Model – model of learning that asserts learning consists of three stages: cognitive, associative, and autonomous

Fitts' Law – a mathematical law describing the "speed-accuracy trade-off" in human movement

fixation – the refinement of the movement pattern of a closed skill, which occurs during the second stage of the Gentile Two-Stage Model of learning

flexibility – the range of motion possible at a joint

forgetting – the loss of the ability to retrieve specific information from memory

fractionization – practicing separate components of the whole skill that do not depend on the other parts

galloping – step and leap combination locomotor skill

general motor ability hypothesis – supports that different motor abilities within an individual are highly related and can be characterized as one homogeneous motor ability

generalized motor program – a class of actions with common characteristics stored in memory

Gentile's Two-Dimensional Taxonomy – a two-dimensional motor skill classification system that takes into consideration the environmental context in which a skill is performed and the function of the action

Gentile's Two-Stage Model – model of learning that proposes learning progresses through two stages: "getting the idea of the movement" and fixation/diversification

germinal period – the period lasting approximately 14 days after conception.

"getting the idea of the movement" – the first stage of the Gentile Two-Stage Model of learning

Golgi tendon organs – kinesthetic receptor site located at the muscle-tendon junction

gross motor skill – a skill in which the large musculature is primarily involved to produce the movement

growth – an observable physical change in size

heart rate – number of heart beats per minute

hemoglobin – compound of blood that helps carry oxygen to the tissues of the body

heredity – the characteristics or qualities passed from parent to offspring

Hick's Law – law of motor control that states that reaction time increases logarithmically as the number of stimulus-response choices increases

hopping – a repeated jump in which there is a transfer of weight from one foot to the same foot or both feet to both feet

hormone – a chemical messenger secreted into the bloodstream in response to conditions in the body that require regulation

hyperplasia – increase in number of cells

hypertrophy – increase in size of cells

integration – coordinated interaction of opposing muscle groups or limbs

internal mental practice – mentally rehearsing what the performer sees and feels during the actual performance of a skill

isometric – refers to a muscle action in which there is no change in the length of the muscle

isotonic – refers to a muscle action in which there is change in the length of the muscle

joint receptors – kinesthetic receptor site located in the capsules and ligaments of many joints

jumping – a transfer of weight from one or both feet to one or both feet

kinesthesis – sense of movement awareness

kinesthetic acuity – the ability to detect differences or likenesses with respect to location, distance, weight, velocity, and acceleration

kinesthetic memory – the ability to remember and reproduce movements

knowledge of performance – a category of augmented feedback that provides information about the characteristics of the movement that led to the outcome of a performance

knowledge of results – the category of augmented feedback that provides information about the outcome of a performance

leaping – type of jump in which there is a transfer of weight from one foot to the opposite foot

learning – a relatively permanent change in performance

learning-memory theory – theory that suggests learning occurs through three memory processing stages

lifespan perspective – the examination of development from conception to death

locomotor reflex – reflex that is a precursor to voluntary locomotion

locomotor skill – a basic motor skill involving a change of the position of the feet or the body's direction

long-term memory – the component of memory that stores information in a relatively permanent area

manipulation – ability to skillfully use the hands

manipulative skill – a movement which involves the control of objects

massed practice – a practice schedule with very short rest periods between sessions or trials

maturation – the qualitative functional changes that occur with age

maximal oxygen uptake – the maximum amount of oxygen that can be taken in, transported, and utilized by the body

memory – the capacity to store and process past experiences

menarche – a female's first menstruation

mental practice – a practice procedure in which the performer imagines successful action without any overt practice

midgrowth spurt – a brief growth spurt that occurs at about age seven

motoneurons – neurons that innervate a muscle fiber

motor – the biological and mechanical factors that influence movement

motor area – a small strip of the cerebral cortex responsible for the control of all voluntary movements

motor behavior – sub-discipline of the study of human movement, emphasizing the investigation of the principles of human movement behavior

motor control – the study of the neural, physical, and behavioral aspects of movement

motor development – specialized study of human movement behavior which emphasizes the associated biological changes in human movement across the lifespan, the underlying processes of these changes, and the factors that affect them

motor learning – the study of the processes involved in attaining and perfecting motor skills

motor program – a memory representation of a coordinated movement sequence

motor program-based theory – motor control theory that proposes that movement patterns are stored in memory as an abstract representation of the information needed to carry out the action

motor skill – a movement which depends on experience or practice to be performed; a skill requiring voluntary movement to achieve a goal

motor unit – a neuron and the muscle fiber it innervates

movement – a characteristic or component of an action or skill

muscle spindle receptors – kinesthetic receptor site located between skeletal muscle fibers

muscular endurance – the ability of a muscle or muscle group to perform repeated contractions against a light load

muscular strength – the maximal amount of force that a muscle or muscle group can generate

myelin – a fatty, insulating material located around axons

myocardium – middle muscular layer of the heart

nerve conduction velocity – the speed of a nerve impulse

neuron – a nerve cell

neurophysiology – the study of the functioning of the nervous system

nonlocomotor skill – movements of the body performed with a relatively stable base of support

object permanence – the awareness that objects exist even when they are no longer in view

ontogenetic – behavior that is specific to the environment by which one is surrounded

open motor skill – a skill that is performed in an unstable environment

open-loop control system – motor control model that contends that all of the information needed to carry out a planned action is contained in the brain

organization – the relationship among a skill's components

ossification – the process by which cartilage is replaced by bone

osteoporosis – loss of bone mass in which the bone becomes porous and fragile

perception of movement – the ability to detect and track moving objects

pericardium – outer layer of the heart

peripheral nervous system – the network of nerves covering the entire body

peripheral vascular resistance – the resistance to blood flow offered by the blood vessels

peripheral vision – an individual's entire field of vision when the eyes are fixated

phase – a part of a sequence of qualitative transitions over time, not affixed to specific age levels

phylogenetic – behavior that tends to appear automatically and in a predictable sequence

pincer grasp – a true thumb opposition grasp involving the thumb and index finger

plasticity – the dramatic capacity for change in response to positive or negative life experiences

postural balance – the ability to maintain upright posture, hold the head erect, sit, and stand

postural reflex – reflex which helps an infant to maintain posture when presented with a change in the environment

power grip – writing grip in which all four fingers and the thumb are wrapped around the implement

practice distribution – the spacing of practice

practice variability – the degree to which movement and content characteristics vary while practicing a skill

Praxis I – an academic skills assessment designed to measure general academic skills of college students

Praxis II – a subject assessment designed to measure a teaching candidate's knowledge of the subject in which certification is desired

Praxis Series – a program developed by the Educational Testing Service to provide tests and other services to states for use as a part of the teacher certification process

prehension – ability to grasp

prenatal period – the lifespan period from conception to birth

primitive reflex – reflex associated with an infant's instinct for protection and survival

proximodistal – growth and development that begins in the center of the body and moves toward the periphery

psychomotor slowing – decrease in neuron activity and excitability with aging due to deterioration of neural structures

puberty – period of accelerated physical growth and maturation occurring in early adolescence

reflex – involuntary movement initiated by a stimulus

rhythmic awareness – the ability to create and maintain a pattern or rhythm during movement

running – an extension of walking where the body is propelled into "flight," with no base of support by either leg

segmentation – separating a skill into parts and then practicing each part in turn

sensitive period – a time in the lifespan when individuals may be especially sensitive to certain influences

serial motor skill – a skill which involves a series of discrete skills

short-term memory – the component of memory that temporarily stores and uses recently processed information

simplification – reducing the difficulty of a whole skill

size constancy – the ability to perceive constant size

skill – an action or task with a specific goal

skipping – step and hop combination locomotor skill

soma – the cell body of a neuron

somatic nervous system – part of the peripheral nervous system that controls skeletal muscles during voluntary contraction

somatotype – classification of body physique

spatial awareness – the ability to recognize objects in three-dimensional space in relation to the body's space and position

spatial orientation – the ability to perceive an object in three-dimensional space

specificity of motor abilities hypothesis – suggests that different motor abilities that an individual possesses are independent from one another

spinal cord – the pathway for nerve impulse transmission

spontaneous movement – involuntary movement that appears in the absence of a stimulus

stage – age period in which common developmental milestones occur

standing long jumping – a type of jump with the desired goal being distance

static balance – the ability to maintain posture when the body is stationary

striking – a manipulative skill in which an object is contacted by a part of the body or an implement

stroke volume – the quantity of blood ejected per heartbeat

synapse – the space between neurons

systolic blood pressure – the highest pressure on the blood vessel walls during contraction of the heart

tactile perception – the ability to detect and interpret information through the skin

task-intrinsic feedback – the sensory information provided by the visual, auditory, proprioceptive, and tactile receptors

teratogens – substances from the environment that can cause birth defects or can be fatal to the unborn child

terminal feedback – feedback given after a performance

throwing – a manipulative skill in which one or two arms are used to propel an object away from the body

thumb opposition – ability to use the thumb in opposition to the fingers while manipulating an object

transitional fiber – type of skeletal muscle fiber that can become type I or type II depending upon training

type I muscle fiber – type of skeletal muscle fiber which is resistant to fatigue and associated with endurance activities

type II muscle fiber – type of skeletal muscle fiber which is associated with rapid, forceful, or explosive movements

veins – blood vessels that carry oxygen-poor blood toward the heart

vertical jumping – a type of jump with the desired goal being height

vestibular apparatus – kinesthetic receptor site located inside of the inner ear

vestibular awareness – the ability to establish and maintain balance

visual acuity – the clearness of vision

visual-motor coordination – the ability to coordinate visual functions with movement

vital capacity – total amount of air that can be voluntarily expired after a maximal inspiration

walking – locomotion by means of alternating weight from one foot to the other with at least one foot in contact with the ground at all times

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