UNIT THREE
Attention and Memory

CHAPTER 9 Attention as a Limited Capacity Resource

Concept: Preparation for and performance of motor skills are influenced by our limited capacity to select and attend to information.

After completing this chapter, you will be able to

- Define the term *attention* as it relates to the performance of motor skills
- Discuss the concept of *attention capacity,* and identify the similarities and differences between fixed and flexible central-resource theories of attention capacity
- Describe *Kahneman's model of attention* as it relates to a motor skill performance situation
- Describe the differences between central- and multiple-resource theories of attention capacity
- Discuss *dual-task techniques* that researchers use to assess the attention demands of performing a motor skill
- Explain the different types of *attentional focus* a person can employ when performing a motor skill
- Define *visual selective attention* and describe how it relates to attention-capacity limits and to the performance of a motor skill
- Discuss how skilled performers engage in visual search as they perform open and closed motor skills

APPLICATION

When you are driving your car on an open highway that has little traffic, it is relatively easy for you to carry on a conversation with a passenger in the car or on a cell phone (although it is illegal in many states in the United States and countries) at the same time. But what happens when the highway you are driving on becomes congested with other traffic? Isn't it difficult to carry on a conversation with your passenger or on your phone while driving under these conditions?

Consider some other examples in which doing more than one activity at a time may or may not be a problem. A skilled typist can easily carry on a conversation with someone while continuing to type—but a beginner cannot. A child learning to dribble a ball has difficulty dribbling and running at the same time, whereas a skilled basketball player does these two activities and more at the same time. A physical therapy patient tells the therapist not to talk to her while she is trying to walk down a set of stairs.

These examples raise an important human performance and learning question: Why is it easy to do more than one thing at the same time in one situation, but difficult to do these same things simultaneously in another situation? The answer to this question comes from the study of *attention* as it relates to the performance of multiple activities at the same time.

Another aspect of attention occurs when you need to visually select and attend to specific features of the environmental context before actually carrying out an action. For example, when you reach for a cup to drink the coffee in it, you visually note where the cup is and how full it is before you reach to pick it up. When you put your door key into the keyhole, you first look to see exactly where it is. When you need to maneuver around people and objects as you walk along a corridor, you look to see where they are, what direction they are moving in, and how fast they are going. To drive your car, you also must visually select information from the environment so that you can get safely to your destination.

In sports activities, visual attention to environmental context information is also essential. For example, visually selecting and attending to ball- and server-based cues allows the player to prepare to hit a return shot in tennis or racquetball. Skills such as determining where to direct a pass in soccer or hockey, or deciding which type of move to put on a defender in basketball or football, are all dependent on a player's successful attention to the appropriate visual cues prior to initiating action.

In the following discussion, you will be introduced to the concept of attention as it relates to the types of motor skill performance situations we have just considered. As you will see here, and in the remaining chapters in this book, the concept of attention is involved in important ways in the learning and performance of motor skills. Although the specific definition of this concept is difficult to identify, there is general agreement that the definition of the term "attention," as we use it in this book, refers to both our limited capability to engage in multiple cognitive and motor activities simultaneously (commonly referred to as "multitasking") and our need to selectively focus on specific performance related environmental context features when we perform motor skills.

Application Problem to Solve Describe a motor skill that you perform that requires you to do more than one thing at the same time. Describe how you can simultaneously perform these multiple activities by identifying what you think about, what you do not think about, and what you visually focus on as you perform these activities.

DISCUSSION

When the term is used in the context of human performance, **attention** refers to several characteristics associated with perceptual, cognitive, and motor activities that establish limits to our performance of motor skills. A common view of attention is that it relates to consciousness or awareness. When used in this way, attention refers to what we are thinking about (or not thinking about), or what we are aware of (or not aware of), when we perform activities. A related view extends the notion of attention to the amount of cognitive effort we put into performing activities. We will use both meanings of *attention* in the first part of this chapter as they relate to the types of situations described in the introduction.

For example, detecting performance-related information in the environment as we perform a skill can be an attention-demanding activity. We observe and attend to the environment in which we move to detect features that help us determine what skill to perform and how to perform it. Although this observation and detection activity demands our attention, it does not always require that we are consciously aware of what we observe and detect that directs our actions.

Since the earliest days of investigating human behavior, scholars have had a keen interest in the study of attention. For example, as early as 1859, Sir William Hamilton conducted studies in Britain dealing with attention. Around the same time, William Wundt, generally acknowledged as the "father of experimental psychology," investigated the concept of attention at the University of Leipzig in Germany. In America, William James at Harvard University provided one of the earliest definitions of

attention in human performance, characteristics associated with consciousness, awareness, and cognitive effort as they relate to the performance of skills. Of particular interest are limitations associated with these characteristics on the simultaneous performance of multiple skills and the detection of relevant information in the performance environment.

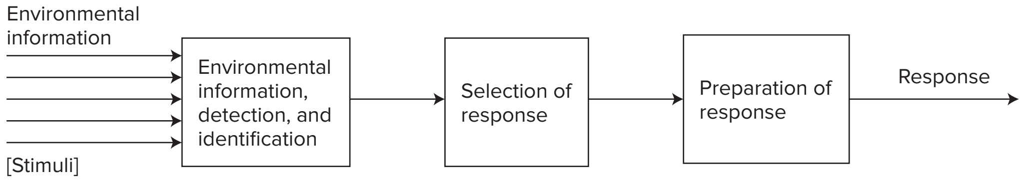


FIGURE 9.1 A generic information-processing model on which filter theories of attention were based. The figure illustrates the several stages of information processing and the serial order in which information is processed. Filter theories varied in terms of the stage at which the filter occurred. Prior to the filter, the system could process several stimuli at the same time. In the model illustrated in this figure, the filter is located in the detection and identification stage, which creates a "bottleneck" for further processing.

attention in 1890, describing it as the "focalization, concentration, of consciousness."

Unfortunately, this late-nineteenth- and early-twentieth-century emphasis on attention soon waned, as those under the influence of behaviorism deemed the study of attention no longer relevant to the understanding of human behavior. A renaissance in attention research occurred, however, when the practical requirements of World War II included the need to understand human performance in a variety of military skills. Researchers were interested in several attention-related areas, such as the performance of more than one skill at the same time; the selection of, and attention to, relevant information from the performance environment; the performance of tasks where people had to make rapid decisions when there were several response choices; and the performance of tasks where people had to maintain attention over long periods of time. The discussion in this chapter will address two of these issues: the simultaneous performance of multiple activities, and the detection of, and attention to, relevant information in the performance environment.

ATTENTION AND MULTIPLE-TASK PERFORMANCE

Scientists have known for many years that we have attention limits that influence performance when we do more than one activity at the same time. In fact, in the late nineteenth century, a French physiologist named Jacques Loeb (1890) showed that the maximum amount of pressure that a person can exert on a hand dynamometer actually decreases when the person is engaged in mental work. Other researchers in that era also pointed out this multiple-task performance limitation (e.g., Solomons & Stein, 1896). Unfortunately, it was not until the 1950s that researchers began to try to provide a theoretical basis for this type of behavioral evidence.

Attention Theories

The most prominent among the first theories addressing attention limitations[1] was the *filter theory* of attention, sometimes referred to as the *bottleneck theory*. This theory, which evolved into many variations, proposed that a person has difficulty doing several things at one time because the human information-processing system performs each of its functions in serial order, and some of these functions can process only one piece of information at a time. This means that somewhere along the stages of information processing, the system has a *bottleneck*, where it filters out information not selected for further processing (see figure 9.1). Variations of this theory were based on the processing stage in which the bottleneck occurred. Some contended it existed very early, at the stage of detection of environmental information (e.g., Broadbent, 1958; Welford, 1952, 1967), whereas others argued that it occurred later, after information was perceived or after it had been processed cognitively (e.g., Norman, 1968).

[1]For an excellent review and discussion of the history and evolution of attention theories, see Neumann (1996).

This type of theoretical viewpoint remained popular for many years, until it became evident that the filter theories of attention did not adequately explain all performance situations. The most influential alternative proposed that information-processing functions could be carried out in parallel rather than serially, but attention limits were the result of the *limited availability of resources* needed to carry out those functions. Just as you have limited economic resources to pay for your activities, we all have limited attentional resources to do all the activities that we may attempt at one time.

Theories emphasizing attentional resource limits propose that we can perform several tasks simultaneously, as long as the resource capacity limits of the system are not exceeded. However, if these limits are exceeded, we experience difficulty performing one or more of these tasks. Theorists who adhere to this viewpoint differ in their views of *where the resource limit exists.* Some propose that there is one central-resource pool from which all attentional resources are allocated, whereas others propose multiple sources for resources.

Finally, more recent attention theories have moved away from the concept of a central capacity limit to one that emphasizes the selection and integration of information and activities associated with the various functional aspects of human performance, such as those depicted in figure 9.1. The primary focus of these theories has been in the area of visual selective attention, which will be discussed later in this chapter.

Central-Resource Capacity Theories

According to some attention theories, there is a central reservoir of resources for which all activities compete. Following the analogy of your economic resources, these **central-resource theories of attention** compare human attention capacity to a single source from which all activities must be funded. To illustrate this view, consider a rather simplistic analogy in which the available attentional resources exist within one large circle, like the one depicted in figure 9.2. Next, consider as smaller circles the specific tasks that require these resources, such as driving a car (task A) and talking with a friend (task B).

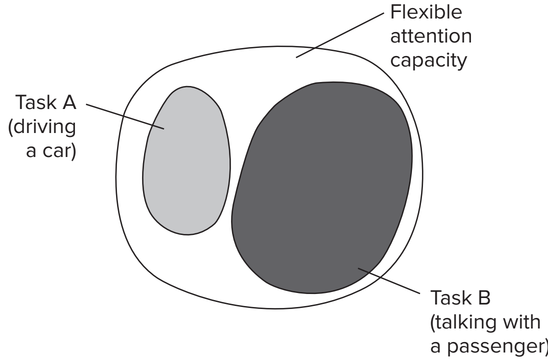


FIGURE 9.2 Diagram showing that two tasks (A and B) can be performed simultaneously (e.g., driving a car while talking with a passenger) if the attention demanded by the tasks does not exceed the available attention capacity. Note that the amount of available capacity and the amount of attention demanded by each task to be performed may increase or decrease, a change that would be represented in this diagram by changing the sizes of the appropriate circles.

Each circle by itself fits inside the larger circle. But for a person to successfully perform both tasks simultaneously, both small circles must fit into the large circle. Problems arise when we try to fit into the large circle more circles than will fit.

Kahneman's attention theory. A good example of a central-resource theory is one proposed by Nobel laureate Daniel Kahneman (1973). Although this theory was originally presented many years ago, it continues to influence our present views about attention (e.g., Tombu & Jolicoeur, 2005). And although some researchers (e.g., Neumann, 1996; Wickens, 2008) have pointed out shortcomings in Kahneman's theory in terms of accounting for all aspects of attention and human performance, it continues to serve as a useful guide to direct our understanding of some basic characteristics of attention-related limits on the simultaneous performance of multiple activities.

central-resource theories of attention attention-capacity theories that propose one central source of attentional resources for which all activities requiring attention compete.

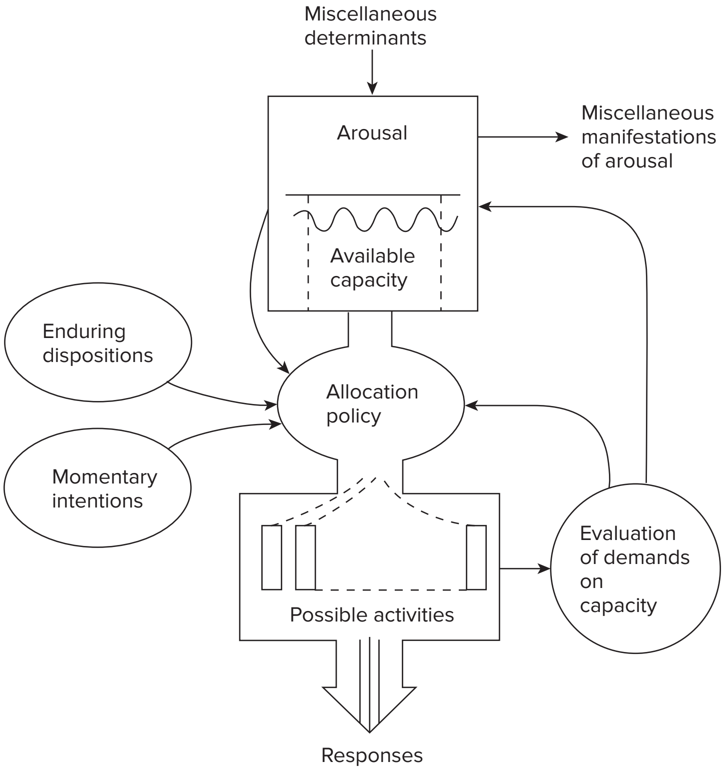


FIGURE 9.3 Kahneman's model of attention. *Source:* From Kahneman, D. (1973). *Attention and Effort,* 1973, p. 10. Reprinted by permission of the author.

Kahneman views attention as *cognitive effort,* which he relates to the mental resources needed to carry out specific activities. The location of the source of these resources is central, which means the CNS; furthermore, there is a limited amount of these resources available for use at any given time. In Kahneman's model (see figure 9.3), the single source of our mental resources from which we derive cognitive effort is presented as a "central pool" of resources (i.e., available capacity) that has a *flexible capacity*. This means that the amount of available attention (i.e., mental resources) can vary depending on certain conditions related to the individual, the tasks being performed, and the situation. To relate this view to the illustration in figure 9.2, this flexible central-capacity theory states that the size of the large circle can change according to certain personal, task, and situation characteristics.

Kahneman views the *available* attention that a person can give to an activity or activities as a general *pool of effort*. The person can subdivide this pool so that he or she can allocate attention to several activities at the same time. Allocation of attentional resources is determined by characteristics of the activities and the allocation policy of the individual, which in turn is influenced by situations internal and external to the individual.

Figure 9.3 depicts the various conditions that influence the amount of available resources (i.e., attention capacity) and how a person will allocate these resources. First, notice that the central pool of available resources (i.e., available capacity) is represented as a box at the top of the model. The wavy line indicates that the capacity limit for the amount of attention available is flexible. Notice also that within this box is the word "Arousal." Kahneman included this word to indicate that the arousal level of the person significantly influences that person's available attention capacity at any given time. More specifically, a person's attention capacity will increase or decrease according to his or her *arousal level.* **Arousal** is the general state of excitability of a person, reflected in the activation levels

A CLOSER LOOK

An Attention-Capacity Explanation of the Arousal-Performance Relationship

A widely held view of the relationship between arousal and performance is that it takes the form of an inverted U. This means that when we graph this relationship, placing on the vertical axis the performance level ranging from poor to high, and placing on the horizontal axis the arousal level ranging from very low to very high, the plot of the relationship resembles an inverted U. This type of relationship indicates that arousal levels that are either too low or too high will result in poor performance. However, between these extremes is a range of arousal levels that should yield high performance levels. This relationship is often referred to as the Yerkes-Dodson law, which is named after two Harvard researchers who initially described this relationship in 1908 by investigating the relationship between stress and learning (Yerkes & Dodson, 1908; see also Brothen, 2012). Although the original research involved rats, many subsequent studies established its relevance to humans. It is now widely accepted as a common characteristic of human behavior.

If, as Kahneman's model indicates, arousal levels influence available attention capacity in a similar way, we can attribute some of the arousal level–performance relationship to available attention capacity. This means that arousal levels that are too low or too high lead to poor performance, because the person does not have the attentional resources needed to perform the activity. When the arousal level is optimal, sufficient attentional resources are available for the person to achieve a high level of performance.

of the person's emotional, mental, and physiological systems. If the person's arousal level is too low or too high, he or she has a smaller available attention capacity than he or she would if the arousal level were in an optimal range. This means that *for a person to have available the maximum attentional resources, the person must be at an optimal arousal level.*

Second, another critical factor determining whether the amount of available attention capacity is sufficient for performing the multiple tasks is the *attention demands, or requirements, of the tasks to be performed.* This factor is represented in Kahneman's model in figure 9.3 as the *evaluation of demands on capacity.* The important point here is that tasks differ in the amount of attention they demand. As a result, the person must evaluate these demands to determine if he or she can do them all simultaneously or if he or she will not be able to perform some of them.

Finally, *three general rules influence how people allocate attentional resources. One rule* is that we allocate attention to ensure that we can complete one activity. It is important to note here that completing one activity may not always be possible. Kahneman indicated that an activity may not be performed successfully if there is not enough capacity to meet the activity's demands or because the allocation of available attention was directed toward other activities.

A *second rule* is that we allocate attentional resources according to our *enduring dispositions.* These are the basic rules of "involuntary" attention, which concern those things that seem to naturally attract our attention (i.e., distract us). We typically will "involuntarily" direct our attention to (or be distracted by) at least *two types of characteristics of events* in our environment, even though we may be attending to something else at the time. An example of one of these types of characteristics is that the event is *novel* for the situation in which it occurs. These events can be visual or auditory. In terms of novel visual events, think about why fans at a basketball game who sit behind the basket like to stand and wave objects in the air while a player is attempting to shoot free throws. Or, consider why you become distracted while driving your car when a ball rolls onto the street in front of you. That we spontaneously and involuntary allocate our visual attention to novel events such as these

arousal the general state of excitability of a person, involving physiological, emotional, and mental systems. Terms such as *anxiety* and *intensity* are sometimes used synonymously in psychological contexts.

This bicycle rider, who can drink water, steer the bike, pedal the bike, maintain balance, see ahead to determine where to go and how to avoid road hazards, etc., demonstrates the simultaneous performance of multiple activities.

Lothar Schulz/Getty Images

is well supported by research evidence (see Cole, Gellatly, & Blurton, 2001; and Pashler & Harris, 2001, for excellent reviews of this evidence).

Unexpected noise also presents a novel event that spontaneously and involuntarily attracts our attention. For example, how many times have you directed your attention away from the person teaching your class to one of your classmates when he or she sneezes very loudly or drops a book on the floor? Consider a different type of example. Why is a professional golfer who is preparing to putt distracted by a spectator talking, when a basketball player who is preparing to shoot a free throw is not distracted by thousands of spectators yelling and screaming? The most likely reason is that the golfer does not expect to hear someone talking while preparing to putt, but for the basketball player, the noise is a common part of the game. As a result, the noise is novel in one situation but not in the other.

The second characteristic of events that will involuntarily direct our attention is the *meaningfulness* of the event to us personally. A classic example of this characteristic is known as the *cocktail party phenomenon,* which was first described in the 1950s (Cherry, 1953). Undoubtedly, you have experienced this phenomenon yourself. Suppose you are at a party in a room filled with people. You are attending to your conversation with another person. Suddenly you hear someone near you mention your name in a conversation that person is having with other people. What do you do? You probably redirect your attention away from your own conversation to the person who said your name. Why did you do this? The reason relates to the meaningfulness of your name to you. Even though you were attending to your own conversation, this meaningful event caused you to spontaneously shift your attention. In sports, it is not uncommon to hear athletes say that while they are performing, the only person they hear saying something to them is the coach. Why? In this competitive situation, the person's coach is very meaningful to the athlete.

The *third rule* governing our allocation of attention relates to a person's *momentary intentions.* This phrase means that a person allocates attention in a situation according to his or her specific intentions. Sometimes, these intentions are self-directed, which means the person has personally decided to direct attention to a certain aspect of the situation. At other times, momentary intentions result from instructions given to the person about how or where to direct his or her attentional resources. For example, if a physical therapist tells a patient to "pay close attention to where you place your foot on the stair step," the patient has the "momentary intention" to allocate his or her attention according to the therapist's instruction.

Multiple-Resource Theories

Multiple-resource theories provide an alternative to theories proposing a central-resource pool of attention resources. Multiple-resource theories contend that we have several attention mechanisms,

A CLOSER LOOK

Attention and Cell Phone Use while Driving

A common concern throughout the world is the use of cell phones by people who are driving motor vehicles. Many countries, and some cities and states in the United States, have passed laws that prohibit cell phone use while driving. In some instances, the laws prohibit the use of both handheld and hands-free cell phones, while in other cases, laws allow hands-free cell phone use. The following information, taken from an article by Strayer and Johnston (2001), provides some basis for concern.

- A study by the United States Department of Transportation indicated that as many as half of the motor vehicle accidents in the United States can be related to driver inattention and other human error.
- A survey of cell phone owners reported that approximately 85 percent use their phones while driving, and 27 percent of those use the phones on half of their trips (Goodman et al., 1999; a summary of their report is available online at http://www.nhtsa.dot.gov).
- A study of cell phone records of 699 people who had been involved in motor-vehicle accidents reported that 24 percent were using their cell phones within the 10 min period before the accident (Redelmeier & Tibshirani, 1997).

Although research evidence supports a relationship between cell phone use and motor vehicle accidents, the issue of cell phone use as the cause of accidents remains unsolved. However, researchers who have investigated this issue, in either car simulators or simulated driving situations in laboratories, report evidence that indicates an attention-related basis for driving accidents. In their article, Strayer and Johnson reported a series of experiments in which participants engaged in a simulated driving task in a laboratory. The results indicated these things:

- Participants missed two times more simulated traffic signals when they were engaged in cell phone conversations; and, when they responded correctly to the signals (i.e., red lights), their reaction time (RT) was significantly slower than when they were not using the cell phone.
- No significant differences were found between handheld and hands-free cell phone use for the number of missed traffic signals and RT (a result that is problematic for a multiple-resource theory of attention). (It is worth noting that a study by Treffner and Barrett [2004] found critical problems with movement coordination characteristics when people were using a hands-free mobile phone while driving.)
- The generation of phone conversations influenced the number of missed traffic signals and RT more than did listening to the radio or to a section of a book on audiotape.

Comparisons of conversations on cell phones and conversations with car passengers have consistently found that cell phone conversations are related to more driving errors than are passenger conversations. For example, in a comparison of driving performance while conversing on a cell phone, conversing with a passenger, and having no conversation, researchers at the University of Utah found that when drivers engaged in cell phone conversations, they increased their driving errors (Drews, Pasupathi, & Strayer, 2008). The conversation characteristics were distinctly different, which the researchers contended influenced the results. The primary difference was that passenger conversations would change as traffic situations changed, which led to a shared awareness of traffic characteristics. Cell phone conversations did not reflect this shared awareness. More recently, Strayer and colleagues (Strayer et al., 2015) have shown that using a speech-to-text system to receive and send texts and emails is even more distracting than conversing on a cell phone. It is notable that a review of more than 60 research studies by Lipovac et al. (2017) found agreement with the conclusion that the use of both hand-held and hands-free mobile phones typically results in driving performance decrements.

each having limited resources. Each resource pool is specific to a component of performing skills. Using a government analogy, the resources are available in various government agencies, and competition for the resources occurs only among those activities related to the specific agencies. The most

multiple-resource theories theories of attention proposing that there are several attentional resource mechanisms, each of which is related to a specific information-processing activity and is limited in how much information it can process simultaneously.

LAB LINKS

Lab 9 in the Online Learning Center Lab Manual provides an opportunity for you to experience the dual-task procedure to assess attention-capacity demands of two tasks performed simultaneously.

prevalent of the multiple-resource theories were proposed by Navon and Gopher (1979), Allport (1980), and Wickens (1980, 1992, 2008).

Wickens proposed what has become the most popular of these theories. He stated that resources for processing information are available from three different sources. These are the *input and output modalities* (e.g., vision, limbs, and speech system), the *stages of information processing* (e.g., perception, memory encoding, response output), and the *codes of processing information* (e.g., verbal codes, spatial codes). Our success in performing two or more tasks simultaneously depends on whether those tasks demand our attention from a common resource or from different resources. When two tasks must be performed simultaneously and share a common resource, they will be performed less well than when the two tasks compete for different resources.

For example, the multiple-resource view would explain variations in the situation involving driving a car while talking with a passenger in the following way. When there is little traffic, driving does not demand many resources from any of the three different sources. But when traffic gets heavy, resource demand increases from these two sources: input-output modalities and stages of information processing. These are the same two sources involved in providing attentional resources for carrying on a conversation with a friend. As a result, to maintain safe driving, the person must reduce the resource demand of the conversation activity.

An advantage of multiple-resource theories is their focus on the types of demands placed on various information-processing and response outcome structures, rather than on a nonspecific resource capacity. The resource-specific attention view provides a practical guide to help us determine when task demands may be too great to be performed simultaneously. For example, if one task requires a hand response and one requires a vocal response, a person should have little difficulty performing them simultaneously, because they do not demand attention from the same resource structure. Conversely, people have difficulty performing two different hand responses simultaneously because they both demand resources from the same structure. (For a more in-depth discussion of the multiple-resource view see Hancock, Oron-Gilad, & Szalma, 2007.)

THE DUAL-TASK PROCEDURE FOR ASSESSING ATTENTION DEMANDS

A common experimental procedure used to investigate attention-limit issues is the **dual-task procedure**. The general purpose of experiments using this technique is to determine the attention demands and characteristics of the simultaneous performance of two different tasks. Researchers typically determine the attention demands of one of the two tasks by noting the degree of interference caused on that task while it is performed simultaneously with another task, called the *secondary task.*

The *primary task* in the dual-task procedure is typically the task of interest, whose performance experimenters are observing in order to assess its attention demands. Depending on the purpose of the experiment, the performer may or may not need to maintain consistent primary-task performance, when performing that task alone compared to performing it simultaneously with the secondary task.

If instructions in the experiment require the participant to pay attention to the primary task so that it is performed as well alone as with the secondary task, then secondary-task performance is the basis researchers use to make inferences about the attention demands of the primary task. On the other hand, if the experiment does not direct the person to attend primarily to either task, performance on both tasks is compared to performance when each task is performed alone. You will see a variety of examples of the use of the dual-task procedure in this chapter and others in this book.

A CLOSER LOOK

Dual-Task Techniques Used to Assess Attention Demands of Motor Skill Performance

Researchers typically have used one of two dual-task techniques in their investigations of the attention demands associated with the preparation and performance of motor skills. Each technique relates to a specific attention-demand issue.

Continuous Secondary-Task Technique

Purpose. To determine if attention capacity is required *throughout* the performance of a motor skill.

Procedure. A person performs the primary and secondary tasks separately and simultaneously. When the person performs both tasks simultaneously, he or she is instructed to concentrate on the performance of the primary task while continuously performing the secondary task.

Rationale. If the primary task demands full attention capacity, performance will be poorer on a secondary task while performing it together with the primary task than when performing only the secondary task. If attention capacity can be shared by both tasks, simultaneous performance should be similar to that of each task alone.

Example. As a person walks from one end of a hallway to the other, he or she must listen to words spoken through earphones; when the person hears each word, he or she must repeat the word that was spoken just prior to that word (i.e., the secondary task is a short-term memory task that involves interference during the retention interval).

Secondary-Task Probe Technique

Purpose. To determine the attention demands required by the *preparation* of a skill, by the performance of *specific components* of a skill, or at *specific times* during the performance of a skill.

Procedure. A person performs the primary and secondary tasks separately and simultaneously. The secondary task (a discrete task) is performed at predetermined times before or during primary-task performance (i.e., the secondary task "probes" the primary task).

Rationale. If a probed site of the primary task demands full attention capacity, performance will be poorer on a secondary task while performing it together with the primary task than when performing only the secondary task. If attention capacity can be shared by both tasks at the probed site, simultaneous performance should be similar to that of each task alone.

Example. As a person reaches for and grasps a cup of water to drink from it, he or she must listen through earphones for a "beep" sound at any time just before or during the performance of the activity. As soon as the person hears the "beep" he or she says "bop" into a microphone (i.e., the secondary task is a simple auditory-reaction time task that requires a vocal response).

FOCUSING ATTENTION

In addition to having to allocate attention among several activities, people also direct attention to specific features of the environment and to action preparation activities. This attention-directing process is known as **attentional focus**. As opposed to attentional demands, which concern the allocation of attentional resources to various tasks that need to be performed simultaneously, attentional focus concerns the marshaling of available resources in

dual-task procedure an experimental procedure used in the study of attention to determine the amount of attention required to perform an action, or a part of an action; the procedure involves assessing the degree of interference caused by one task when a person is simultaneously performing another task.

attentional focus the directing of attention to specific characteristics in a performance environment, or to action-preparation activities.

A CLOSER LOOK

Using the Dual-Task Procedure to Study the Attention Demands of Gait in People with Parkinson's Disease

A study by O'Shea, Morris, and Iansek (2002) provides a good example of the use of the dual-task procedure to study attention demands of activities, and an opportunity to consider the relationship between movement disorders and attention demands as it relates to multiple-task performance.

Participants: 15 people (mean age = 68.3 yrs) with Parkinson's disease (PD) and 15 comparison people (mean age = 67.7 yrs) without PD. The people with PD were in a self-determined "on" phase of their medication cycle.

Walking tasks:

1. Walk 14 m at a self-selected speed (single task: free walking)
2. Walk while transferring as many coins as possible from one pocket to another on their opposite side (motor secondary task: manual object manipulation)
3. Walk while counting backward aloud by threes from a three-digit number (cognitive secondary task: subtraction)

Standing tasks: Perform the coin transfer task and the digit subtraction task while standing

Results:

Walking tasks change from walking only to walking while performing a secondary task:

	Walking Speed		Stride Length	
	PD Group	No–PD Group	PD Group	No–PD group
With Coin Task:	−18.5%	−7.4%	−15.4%	−7.4%
With Subtraction Task:	−18.7%	−6.9%	−18.7%	−6.9%

Secondary tasks change from performing it while standing to performing it while walking:

	PD Group	No–PD Group
Coin task (coins/min rate)	−17.4%	0.0%
Subtraction task (responses/min rate)	−4.7%	+13.1%

Conclusions: People with PD showed

- a greater amount of deterioration in their walking gait characteristics when they had to simultaneously perform a manual object-manipulation task and cognitive task involving subtraction than comparably aged people who did not have PD
- a slower rate of performing a manual object-manipulation task and a cognitive task involving subtraction when they had to perform these tasks while walking than when they performed them while standing

order to direct them to specific aspects of our performance or performance environment.

We can consider attentional focus in terms of both width and direction of focus. *Width* indicates that our attention can have a *broad or narrow* focus on environmental information and mental activities. *Direction* indicates that our attentional focus can be *external or internal:* attention may be focused on cues in the environment or on internal thoughts, plans, or problem-solving activities. Nideffer (1993) showed that the broad and narrow focus widths and the external and internal focus directions interact to establish four types of attention-focus situations that relate to performance.

Individuals in performance situations require specific types of attentional focus to achieve successful performance. For example, a person needs a broad/external focus to walk successfully through a crowded hallway, but a narrow/external focus to catch a ball. Sometimes, situations require us to shift the type of attentional focus and the object of that attention. We do this by engaging in what is referred to as *attention switching*. It is an advantage to switch attentional focus rapidly among environmental and situational pieces of information when we must use a variety of sources of information for rapid decision making. For example, a football quarterback may look to decide if the primary receiver is open; if not, he must find an alternate receiver. In the meantime, the quarterback must make decisions related to whether or not he is about to be tackled or kept from delivering a pass. Each of these activities requires attention and must be carried out in the course of a few seconds. To do this, the player must rapidly switch attention between external and internal sources of information.

However, certain kinds of attention switching can be a disadvantage in the performance of some activities. For example, a person performing a skill that requires a rapid, accurate series of movements, such as typing, piano playing, or dancing, will be more successful if he or she focuses attention on a primary source of information for extended periods of time. Problems can arise if the person's attention is switched too frequently between appropriate and inappropriate sources of information. For example, if a pianist is constantly switching visual attention from the written music to the hands and keys, he or she will have difficulty maintaining the precise timing structure required by the piece being played.

Focusing Attention on Movements versus Movement Effects

If, as we just discussed, it is best for people to narrow their attentional focus while performing certain skills, a relevant question concerns the specific location of the attentional focus. Although Nideffer presented the direction options of internal and external to represent the location, there is an alternative way to use these terms when referring to the performance of a specific skill. Is it preferable to focus attention on one's own movements (*internal focus*) or on the effects of one's own movements (*external focus*)? This question has intrigued scientists for many years, which we can see if we look at the classic and influential work of William James (1890). He raised this same question more than a century ago and offered as an answer that the directing of attention to the "remote effects" (i.e., outcome of a movement, or movement effects) would lead to better performance than attention to the "close effects" (i.e., the movements). He presented an example of a reaching/aiming movement to illustrate his point: "Keep your eye at the place aimed at, and your hand will fetch [the target]; think of your hand, and you will likely miss your aim" (p. 520).

The German scholar Wolfgang Prinz (1997) formalized this view by proposing the **action effect hypothesis** (Prinz, 1997), which proposes that actions are best planned and controlled by their intended effects. The theory basis for this hypothesis relates to how we code sensory and motor information in memory. Prinz contends that we represent both in memory in a common code, which argues against the separation of perception and action as unique and distinct events. Without going further into the theory issues involved, the *common coding view* predicts that actions will be more effective when they are planned in terms of their intended outcomes rather than in terms of the movement patterns required by the skill.

An interesting application of this hypothesis was reported in an article in *The New Yorker* magazine (Acocella, 2003) about the great ballerina Suzanne Farrell. Although retired from performing, she teaches ballet to experienced students and

action effect hypothesis the proposition that actions are best planned and controlled by their intended effects. When related to attentional focus, this hypothesis proposes that the learning and performance of skills are optimized when the performer's attention is directed to the intended outcome of the action rather than on the movements themselves.

A CLOSER LOOK

An External Focus of Attention Benefits Standing Long Jump Performance

A study by Porter, Ostrowski, Nolan, and Wu (2010) provides an excellent example of the comparison between an external and internal focus of attention when performing a sport skill.

Rationale and hypothesis for the study: A previous study by the first author (Porter, Wu, & Partridge, 2009) found that experienced track and field coaches of elite athletes typically provide instructions during practice and competition that emphasize the athletes' use of an internal focus of attention. Because of the abundance of research showing the performance benefit of an external focus of attention for numerous motor skills, the authors hypothesized that an external focus of attention would yield longer jumps than an internal focus for the standing long jump.

Participants: 120 undergraduate student volunteers, who had no formal training in the standing long jump.

Task and performance environment: The participants performed the standing long jump indoors on a black rubber composite floor mat from a start line clearly marked at one end.

Procedures: All participants performed five consecutive jumps, with a seated two minute rest between jumps. The distance jumped was recorded at the end of each jump from the back of the heel that was closest to the start line. Participants were randomly assigned to either an external or internal focus of attention group. These groups read different instructions before their first jump:

> ***External focus:*** "When you are attempting to jump as far as possible, I want you to focus your attention on jumping as far past the start line as possible."
>
> ***Internal focus:*** "When you are attempting to jump as far as possible, I want you to focus your attention on extending your knees as rapidly as possible."

Results: The distance jumped by the *external focus group* averaged 10 cm longer (187.4 cm) than the *internal focus group* (177.3 cm).

Conclusion and application: The results support the benefit of an external focus of attention for performing the standing long jump. The authors indicate that these results should encourage strength and conditioning professionals as well as coaches to provide instructions that focus an athlete's attention externally rather than internally.

professional dancers. In her teaching, she emphasizes that the dancers concentrate on the effect they want to create with movements rather than on the movements themselves.

When researchers have investigated the action effect hypothesis, they have reported strong support with evidence based on a variety of laboratory and sports skills and physical rehabilitation activities (e.g., Wulf, 2013; Wulf & Lewthwaite, 2016; Wulf & Prinz, 2001). One of the research methods for investigating this hypothesis has been to study the effects of attentional focus on motor skill performance and learning. The results of this research have been remarkably consistent in showing that when performers direct their attentional focus to the movement effects, they perform the skill at a higher level than when their attentional focus is on their own movements. It is important to note here that research has shown that the focus of attention is also relevant for the learning of motor skills. We will discuss the influence of focus of attention on the learning of skills in more detail in chapter 14 when we discuss verbal instructions and their effects on skill learning.

The reason an external focus of attention results in better skill performance has been the subject of some debate (see Wulf, 2013; Wulf & Lewthwaite, 2016; and Wulf & Prinz, 2001, for a discussion of the various issues in this debate). However, the most commonly accepted reason is the *constrained action hypothesis,* which was proposed by Wulf and her colleagues (e.g., McNevin, Shea,

& Wulf, 2003; Wulf, McNevin, & Shea, 2001). According to this hypothesis an internal focus “constrains” the motor system because the performer consciously attempts to control it, which results in a disruption of the automatic motor control processes that should control performance of the skill. But when the performer engages in an external focus of attention, the automatic (i.e., nonconscious) processes control performance. Research support for this view has come from several studies that involved a variety of techniques, including dual-task probe reaction times and EMG assessment (see Wulf, 2013; Zachry, Wulf, Mercer, & Bezodis, 2005; and Gray, 2011, for brief reviews of these studies).

It is important to note that other researchers have a slightly different explanation for why focusing externally leads to better performance. For example, Beilock and colleagues (e.g., Beilock, Bertenthal, McCoy, & Carr, 2004; Beilock, Carr, MacMahon, & Starkes, 2002) distinguish between *skill-focused* attention, which is directed to any aspect of the movement, and *environmental-focused* attention, which is directed away from the execution of the skill (and not necessarily on anything relevant to the skill itself). In contrast to Wulf and colleagues, Beilock argues that the appropriate focus of attention is determined by the performer’s skill level. Because beginners tend to consciously control many of the details associated with performance, she believes that a skill-focused attention is appropriate early in learning. On the other hand, because highly skilled individuals have proceduralized most aspects of performance and execute skills automatically with little conscious attentional monitoring, she believes that an environmental focus of attention is better in the later stages of learning.

Like Wulf and colleagues, Beilock proposes that skilled individuals suffer when they focus on controlling the skill because of interference with automatic control processes. Performance deteriorates because the skilled individual reverts to an earlier, less automatic form of movement control. The interference that results from consciously monitoring proceduralized aspects of performance has been referred to as the *deautomatization-of-skills* hypothesis (Ford, Hodges, & Williams, 2005). It is also thought to be the basis for what is commonly referred to as *choking* under pressure (Beilock, 2010; Beilock & Carr, 2001). Evidence to support the idea that novices perform better under skill-focused instructions and experts perform better when distracted from focusing on the skill itself has been provided for the skills of golf putting (Beilock et al., 2004) and soccer dribbling (Beilock et al., 2002; Ford et al., 2005). In summary, researchers agree that focusing attention on movements leads to poor performance of well-learned skills because attention to movement details interferes with automatic control processes. However, researchers disagree about whether beginners should focus their attention externally or on aspects of the movement.

ATTENTION AND AUTOMATICITY

Automaticity is an important concept in our understanding of attention and motor skill performance. The term **automaticity** is commonly used to indicate that a person performs a skill or engages in an information-processing activity with little or no demands on attention capacity. We briefly considered the attention-capacity demands of a skill in the discussion of the evaluation of the task demands component of Kahneman’s model of attention. Some examples of these activities include (a) the visual search of the environment to assess the environmental context regulatory characteristics associated with performing a skill; (b) the use of *tau* when moving toward an object to make or avoid contact with it, or when an object is moving toward a person who needs to catch or strike it; (c) the storing of information in memory and the retrieval of information from memory; (d) the selection of an action to perform and the movement characteristics that must be applied to carry out the action; and (e) the actual production of an action. From an attention point of view, the question of interest here

automaticity the term used to indicate that a person performs a skill, or engages in certain information-processing activities, with little or no demands on attention capacity.

concerns the demand, or need, for some amount of attention capacity for each activity.

Kahneman's (2011) most recent views of automaticity are presented in his best-selling book, *Thinking, Fast and Slow*. Although his book focuses primarily on problem solving and decision making as they relate to cognitive operations, it also presents concepts relevant to many of the perceptual and motor issues discussed throughout our book. With respect to automaticity and attention, Kahneman proposes two systems that operate differently but interactively, to help us solve problems, of which we have included performing a motor skill. *System 1* operates automatically and quickly with little or no effort or sense of voluntary control. For example, this system operates when we detect that one object is more distant from us than another, or when we drive a car on an empty road. *System 2,* on the other hand, allocates attention to the various activities that demand attention, such as preparing for the starter gun in a race, and maintaining a faster walking speed than is normal for a person. From this perspective, automaticity relates to attention as it allows us to perform certain activities without effortful mental activity, especially when we engage System 1. This system enables us to solve certain problems (mental, perceptual, and motor) by relying on intuition that has developed through learning, which typically results from experience and practice. But, some problems require more effort to solve; they require effortful mental activities that are also influenced by experience and practice.

Logan (1985, 1988; Logan, Taylor, & Etherton, 1999), who has produced some of the most important research and thinking about the concept of automaticity and motor skill performance, views automaticity as an acquired skill that should be viewed as a continuum of varying degrees of automaticity. This means that rather than considering the attention-capacity demand of an activity in terms of "yes, it demands capacity," or "no, it doesn't demand capacity," the continuum view considers automaticity as related to demanding varying amounts of attention capacity. Logan proposes that, as with skill, people acquire automaticity with practice. As a result, the degree of automaticity for a skill or information-processing activity may be only partially automatic when the attention demand of the activity is assessed.

According to both Kahneman's and Logan's perspectives, a complex motor skill could involve activities that require a range of attention demands. For example, the movement component of passing a soccer ball may require no attention capacity because the kicking of the ball can be performed automatically, but the preparation for making the pass (recall the discussion related to decision making in action preparation in chapter 8) may demand full attention capacity.

The neural components associated with automaticity as it relates to motor skill performance have also been investigated. For example, Poldrack and his associates (Poldrack et al., 2005) used fMRI procedures to show that different brain areas are active in the following situation. When performance of each of the two tasks in a dual-task situation [is] compared to when the secondary task does not interfere with performance of the primary task, which would indicate performance automaticity of the primary task. Their results indicated that the supplementary motor area (SMA) and putamen/globus pallidus regions are more involved with automaticity than when each of the two tasks demand attention, in which case the prefrontal regions are more active. (For a more extensive discussion of the neural characteristics associated with automaticity of motor skill performance see Lohse, et al. 2014.)

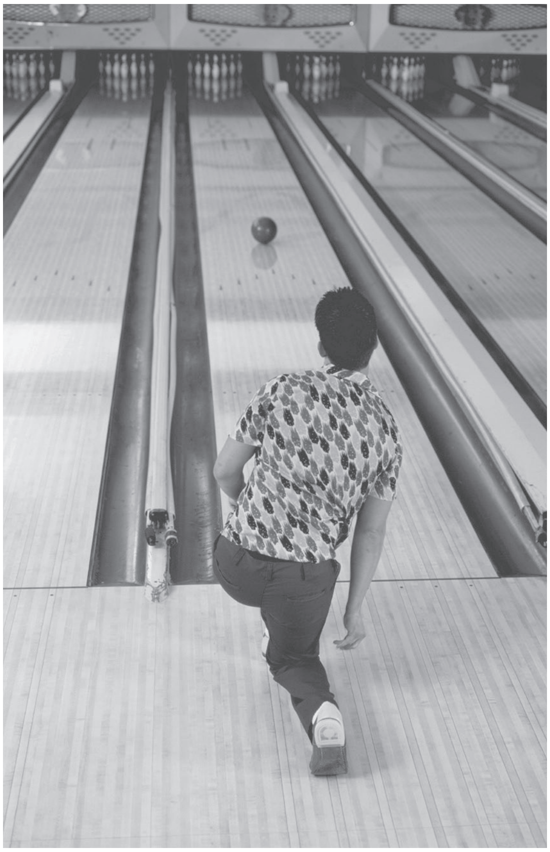
VISUAL SELECTIVE ATTENTION

In addition to the capacity limits of attention, the selection of performance-related information in the environment is also important to the study of attention as it relates to the learning and performance of motor skills. This area of study is commonly referred to as **selective attention**. Of particular interest to researchers has been *visual selective attention,* which concerns the role of vision in motor skill performance in directing visual attention to environmental information (sometimes referred to as "cues") that influences the preparation and/or the performance of an action. Because the use of vision in this way is primarily an attention issue, it is included here rather than in chapter 7 where we discussed the roles vision plays in the control of several motor skills. (For a discussion of the neural basis of selective attention, see Tyler et al., 2015 and Yantis, 2008.)

Researchers have disputed since the end of the nineteenth century about whether visual selective attention is active or passive (sometimes phrased as “top-down or bottom-up,” or “goal directed or stimulus driven”). In terms of the information-processing model in figure 9.1, the basis for this dispute concerns how we select information from the environmental context to process in the first stage. Do we visually select relevant environmental cues according to our action intentions and goals, or do we visually attend to environmental cues because of their distinctiveness or meaningfulness in the situation? In their review of the visual attention research literature, Egeth and Yantis (1997) concluded that these two types of visual attention control “almost invariably interact” (p. 270). This means that in most performance situations, our intentions and goals as well as certain characteristics in the environment influence our visual attention. In other words, although we may actively seek environmental cues based on our action intentions and goals, we may also attend to certain cues because of their distinct characteristics. You will see evidence of this active-passive visual attention throughout this discussion.

The term **visual search** is used to describe the process of directing visual attention to locate relevant environmental cues. During the preparation process for performing many skills, people carry out visual search to select from the environment those cues that are relevant for the performance of a skill in a specific situation. In the following sections, we consider the actual process of selecting appropriate information from the environment, and give examples from various sport and everyday skills to illustrate how visual search is an important component of the performance of both open and closed motor skills.

As you read the following sections, you may find it helpful to refer back to chapter 6, where we discussed various procedures researchers have used to investigate the role of vision in motor control. You will find that researchers who study visual selective attention have used these same procedures.



Visual selective attention plays an important role in bowling.

Ryan McVay/Getty Images

Eye Movements and Visual Selective Attention

As you read in chapter 6, eye movement recordings track the location of central vision while people observe a scene. However, an important question

selective attention in the study of attention as it relates to human learning and performance, the term used to refer to the detection and selection of performance-related information in the performance environment.

visual search the process of directing visual attention to locate relevant information in the environment that will enable a person to determine how to prepare and perform a skill in a specific situation.

arises concerning how well this procedure assesses visual selective attention. The rationale for the use of the procedure is that what a person is looking at (i.e., the point of gaze) should give researchers insight into what information in the environment the person is attending to. But there is an important research question here: Is this a valid assumption? Can we validly relate eye movements to visual attention?

Two characteristics of the use of eye movement recordings provide an answer. First, research evidence has shown consistently that *it is possible to give attention to a feature in the environment without moving the eyes to focus on that feature* (see Henderson, 1996; Zelinsky et al., 1997; and Brisson & Jolicoeur, 2007, for reviews of this evidence). This would mean that peripheral vision was the source of picking up the relevant information. However, it is *not* possible to make an eye movement without a corresponding shift in attention. Second, because eye movement recordings are limited to the assessment of central vision, they do not assess peripheral vision. Research evidence has shown that peripheral vision is involved in visual attention in motor skill performance (see Bard, Fleury, & Goulet, 1994 for a brief review of this research). As a result of these two factors, eye movement recordings cannot provide a complete picture of the environmental features to which the person is directing visual attention. Therefore, eye movement recordings typically *underestimate* what a person is visually attending to. However, even with these limitations, the recording of eye movements is a useful technique to provide reasonable estimates of those features in the environment that a person directs visual attention to as he or she prepares and performs a motor skill.

How We Select Visual Cues

Theories concerning how we select certain cues in the environment address the selection of cues for nonmoving as well as moving objects. Both situations are important for the performance of motor skills. For example, visual search for regulatory conditions associated with stationary objects is critical for successful prehension actions. Without detection of these conditions a person would not have the information needed to prepare and initiate movement to reach for and grasp a cup, or any stationary object.

Visual search and intended actions. The visual search for regulatory conditions in the performance environment is an active search that a person engages in according to the action he or she intends to perform. This means that the performer looks for specific cues in the performance environment that will enable him or her to achieve a specific action goal. For example, if a person intends to pick up a cup to drink from it, he or she will visually search for features of the cup and environment that will indicate the movement characteristics to implement. This search could include looking to see how full the cup is, what type of liquid is in it, the location of the cup in terms of distance from the person, and whether or not there may be obstacles between the person and the cup. By actively looking for these features, the person can prepare the movement characteristics to reach for, pick up, and drink from the cup. This view of a visual search process fits well with the research evidence you saw in chapter 7 that showed the influence of various object and environment features on prehension movement kinematics.

Research evidence also supports the view that we actively visually search the performance environment according to action intentions. For example, Bekkering and Neggers (2002) demonstrated that the focus of initial eye movements differed when participants in their experiment were told to point to or grasp an object. The intention to grasp an object directed participants' visual search to the spatial orientation of an object, whereas the intention to point to the object did not. The authors concluded that a specific action intention enhances the visual detection of those regulatory conditions that are relevant to the intended action.

It is also important to note that visual search does not always mean that a person performing a motor skill is actively seeking cues in the environment to respond to. On the contrary, there are times when a person detects cues as he or she performs

A CLOSER LOOK

Visual Search and Attention Allocation Rules

If the key to successful selection of environmental information when performing motor skills is the distinctiveness of the relevant features, an important question is this:

What Makes Certain Features More Distinctive than Others?

Insight into answering this question comes from the attention allocation rules in Kahneman's theory of attention (1973), which we discussed earlier in this chapter:

- **Unexpected features attract our attention.** You can see this in your own daily experience. While concentrating on your professor during a lecture, haven't you been distracted when a classmate has dropped some books on the floor? Undoubtedly, you switched your visual attention from the professor to search for the source of the noise. When the environment includes features that typically are not there, their distinctiveness increases. The result is that people have a tendency to direct visual attention to them.
- **We allocate attention to the most meaningful features.** In the performance environment, the most meaningful cues "pop out" and become very evident to the performer. Meaningfulness is a product of experience and instruction. As a person experiences performing in certain environments, critical cues for successful performance are invariant and increase in their meaningfulness, often without the person's conscious awareness. Instruction also plays a part in the way certain features of cues become more meaningful than others.

a skill. These cues get attended to, but rather than having been actively searched for, they were detected by the performer as relevant to the situation, which then influenced the performer's movements accordingly.

The feature integration theory. Although researchers have proposed several theories to account for the characteristics of how we select certain cues in the environment and ignore others (see Neumann, 1996, for a review of these theories), one of the more popular theories is the *feature integration theory* proposed by Treisman in the 1980s (e.g., Treisman, 1988; Treisman & Gelade, 1980; see also Chan & Hayward, 2009). This theory indicates that during visual search, we initially group stimuli together according to their unique features, such as color or shape. This grouping occurs automatically. These groups of features form "maps" related to the various values of various features. For example, a color map would identify the various colors in the observed scene, whereas a shape map would indicate which shapes are observed. These maps become the basis for further search processes when the task demands that the person identify specific cues. For further processing, we must use attention, and must direct it to selecting specific features of interest. The features of interest in an environmental context have a degree of *salience* to them, which means they have a specific amount of meaningfulness because of their presence in the situation. For example, the rotation characteristics of a pitched baseball are highly meaningful to a batter in a game situation. As a result the batter visually attends to the ball's rotation because of its salience as a visual cue about the type of pitch. (To learn more about the salience of visual cues in movement situations, read the Introduction in the article by Zehetleitner, Hegenloh, & Müller, 2011.)

The selection of features of interest occurs when a person focuses the *attentional spotlight* on the master map of all features. People can direct attention over a wide or a narrow area, and it appears that the spotlight can be split to cover different map areas. If the person's task is to search for a target having a certain distinct feature, then the target will "pop out" as a result of this search process, because the feature is distinct among the groupings of features. Thus, the more distinctive the feature is that identifies the target of the visual search, the more quickly the person can identify and locate the target. If the distinctive feature is a part of several cues, the search slows as the person assesses each cue in terms of how its characteristics match those of the target. (See Wolfe, 2014 and Hershler & Hochstein, 2005, for an extended discussion of feature integration theory and factors that influence the "pop out" effect.)

For movement situations, McLeod, Driver, Dienes, and Crisp (1991) proposed a *movement filter* in the visual system that would allow visual attention to be directed at just the moving items in the person's environment. They suggested that this movement filter mechanism can be related to Treisman's feature integration theory's emphasis on the importance of grouping in visual search by operating as a subsystem to a group's common movement characteristics. In light of this view it is interesting to note that Abernethy (1993) described research evidence to demonstrate that in sports involving fast ball action, such as racquet sports, skilled players visually search the playing environment for the *minimal essential information* necessary to determine an action to perform. This information is an invariant perceptual feature of the performance context. We described one of these invariant features in chapter 7 when we discussed the importance of the use of time-to-contact information to catch a ball, contact or avoid an object while walking or running, and strike a moving ball.

Abernethy indicated that another essential source of information to detect is the kinematics of an opponent's action, which specify what he or she is going to do next. This information is contained in the grouping of joint displacements that define an opponent's pattern of coordination. As a person becomes more skillful, his or her visual attention becomes increasingly more attuned to detecting the important kinematic features, which provides the skilled player an advantage over the less-skilled player in anticipating the opponent's action in a situation. In effect then, this minimal essential information "pops out" for the skilled player and directs the player's visual attention as he or she prepares an appropriate action to respond to his or her opponent's action.

In addition to detecting essential information from an individual player, skilled athletes in dynamic team sports, such as basketall and soccer, visually select patterns of play, similar to what chess masters do while playing chess. For example, in a series of experiments by Williams, Hodges, North, and Barton (2006), skilled soccer players were quicker and more accurate than less-skilled players in recognizing familiar and unfamiliar game action sequences presented on film, as point-light displays, and with event and people occluded conditions on film.

VISUAL SEARCH AND MOTOR SKILL PERFORMANCE

Visual search picks up critical cues that influence three parts of the action control process: *action selection, constraining of the selected action* (i.e., determining the specific movement features for performing the action), and *timing of action initiation.* By influencing these processes, the visual system enables a person to prepare, initiate, and execute the movements of an action that conform to the specific requirements of the performance context.

Research investigating visual search in performance situations has produced evidence about what is involved in these important preparation and performance processes. The following research examples illustrate how researchers have investigated a variety of sports and everyday skills, and provide a sense of what we currently know about the characteristics of visual search processes related to the performance of open and closed motor skills.

Visual Search in Open Motor Skills

Returning a badminton serve. The experiments by Abernethy and Russell (1987) described earlier in chapter 6 provide the best example of research investigations of visual search by expert badminton players. They found that the time between the initiation of the badminton server's backswing and the shuttle's hitting the floor in the receiver's court is approximately 400 msec (0.4 sec). Within that time period, there appears to be a critical time window for visually picking up critical cues predicting

A CLOSER LOOK

Two Examples of Severe Time Constraints on Visual Search

There are some situations in sport in which researchers can determine the actual amount of time a person has to engage in visual search and to prepare an action. Two of these are returning a serve in tennis and hitting a baseball. In each of these situations, it is clearly to the player's advantage to detect the information needed as early as possible in order to prepare and initiate the appropriate action.

Preparing to Return a Tennis Serve

A serve traveling at 90 to 100 mi/hr (145 to 161 km/hr) allows the receiver only 0.5 to 0.6 sec to hit the ball. This means that the person must search as soon as possible for the cues that will provide information about the direction, speed, landing point, and bounce characteristics of the ball so that he or she can select, organize, and execute an appropriate return stroke.

Preparing to Hit a Baseball

When a pitcher throws a ball at a speed of 90 mi/hr, it will arrive at home plate in approximately 0.45 sec. Suppose that it takes 0.1 sec for the batter to get his or her bat to the desired point of ball contact. This means that the batter has less than 0.35 sec after the ball leaves the pitcher's hand to make a decision and to initiate the swing. If the pitcher releases the ball 10 to 15 ft in front of the rubber, the batter has less than 0.3 sec of decision and swing initiation time.

where the shuttle will land. This window, which lasts from about 83 msec before until 83 msec after racquet-shuttle contact, provides information about racquet movement and shuttle flight that seems to resolve uncertainty about where the served shuttle will land. Experts use the 83 msec period prior to racquet-shuttle contact more effectively than novices. As a result, experts have more time to prepare their returns. The racquet and the arm are the primary sources to visually search for the anticipatory cues needed to prepare the return. In a series of experiments that extended the Abernethy and Russell study, Abernethy, Zawi, and Jackson (2008) found similar time-based characteristics distinguishing expert from nonexpert badminton players. In addition, they found that the expert players visually focused on different kinematic information of their opponents than the nonexperts.

Returning a tennis serve. Results from two experiments by Goulet, Bard, and Fleury (1989) demonstrate how critical visual search strategies are to preparing to return tennis serves. Expert and novice tennis players watched a film showing a person serving and were asked to identify the type of serve as quickly as possible. The authors recorded the participants' eye movements as they watched the film. Three phases of the serve were of particular interest: the "ritual phase" (the 3.5 sec preceding the initiation of the serve); the "preparatory phase" (the time between the elevation of the arm for the ball toss and the ball's reaching the top of the toss); and the "execution phase" (from the ball toss to racquet-ball contact).

As illustrated in figure 9.4, during the ritual phase, the expert players focused mainly on the head and the shoulder/trunk complex, where general body position cues could be found. During the preparatory phase, they directed visual search primarily around the racquet and ball, where it remained until ball contact. An interesting note was that the experts also looked at the server's feet and knees during the preparatory phase. The important difference between experts and novices was that the visual search patterns of the expert players allowed them to correctly identify the serve sooner than novices could.

More recent research has supported the results of the Goulet et al. (1989) study in which the ball and the server's arm and racquet are the visual focus of attention for skilled tennis players preparing to return a serve. For example, Jackson and Morgan (2007) used an event occlusion procedure similar to the one described in chapter 6. Their results

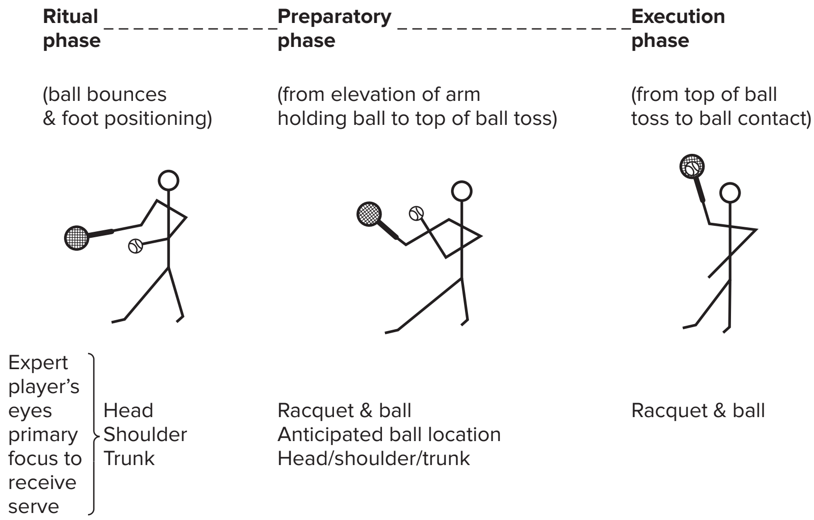


FIGURE 9.4 Illustration showing where expert tennis players in the Goulet, Bard, and Fleury experiment were looking during the three phases of a tennis serve. *Source:* Based on discussion in Goulet, C. et al. (1989). Expertise differences in preparing to return a tennis serve: A visual information processing approach. *Journal of Sport and Exercise Psychology, 11,* 382–398.

showed that when skilled tennis players could not see the server's arm and racquet or the ball prior to ball-racquet contact, their predictions of the service court in which the ball would land were much worse than when they could see these components.

In an effort to investigate the visual search characteristics of expert players in a more realistic setting, Singer et al. (1998) assessed the eye movement behaviors of five nationally ranked university male and female tennis players as they returned ten serves on a tennis court. Interestingly, all five players did not use the same visual search strategies. During the phases of the serve that Goulet et al. (1989) called the ritual and preparatory phases, the two highest-ranked players fixated primarily on the arm-racquet-shoulder region of the server, whereas two fixated on the racquet and expected ball toss area. All the players included head fixations during these phases. The players demonstrated more individual variation during the ball toss phase of the serve. Two players visually tracked the ball from the server's hand to the highest point of the toss, one player made a visual jump from the server's hand to the highest point of the toss, one player fixated only on the predicted highest point of the toss, and one player did not fixate on the ball toss but only on the racquet. Differences again were found for the visual search strategies used by the players after the server hit the ball. The two highest-ranked players visually tracked the ball to its landing location, two players did not track the ball after contact but visually jumped to the predicted landing location, and one player used a combination of these two strategies to return serves.

Baseball batting. An example of research describing characteristics of the visual search processes involved in baseball batting is a study by Shank and Haywood (1987). They recorded eye movements for college and novice players as they watched a videotape of a right-handed pitcher as if they were right-handed batters. For each of twenty pitches, the players indicated whether the pitch was a fastball or a curve. The expert players correctly identified almost every pitch, whereas the novices were correct only about 60 percent of the time. Participants in both groups did not begin to track the ball until about 150 msec after the ball had left the pitcher's hand. During the windup, experts fixated on the release point, whereas novices tended to shift fixations from the release point to the pitcher's head.

More recently, Takeuchi and Inomata (2009) investigated the eye movements of expert baseball batters as they viewed the pitcher's motion during fastball pitches. The distribution of eye movement fixations indicated, in results similar to those of Shank and Haywood, the batters' visual attention was directed at the pitcher's release point just prior to the pitcher's release of the ball.

Soccer actions. To determine whether to shoot, pass, or dribble in soccer, the player must use visual search that is different from that involved in the situations described above. The soccer situation involves many players in the visual scene that must be searched for relevant cues. An experiment by Helsen and Pauwels (1990) provides a good demonstration of visual search patterns used by experienced and inexperienced male players to determine these actions. Participants acted as ball handlers as they viewed slides of typical attacking situations. For each, the person indicated as quickly as possible whether he would shoot at the goal, dribble around the goalkeeper or opponent, or pass to a teammate. The experts took less time to make the decision. Eye movement recordings showed that the experts gained this time advantage because they fixated on fewer features of the scene and spent less time at each fixation.

Another visual search situation in soccer involves anticipating where a pass will go. Williams, Davids, Burwitz, and Williams (1994) showed that experienced players and inexperienced players look at different environmental features to make this determination. Results based on subjects' eye-movement characteristics while watching an actual soccer game showed that the experienced players fixated more on the positions and movements of other players, in addition to the ball and the ball handler. In contrast, inexperienced players typically fixated only on the ball and the ball handler. More recently, Roca, Ford, McRobert, and Williams (2013) showed that skilled and less skilled soccer players employ different visual search strategies when the ball is in the offensive (far) versus defensive (near) half of the field.

Finally, Williams and Davids (1998) reported a comprehensive investigation of visual selective attention and search strategies of experienced and less-experienced soccer players in three-on-three and one-on-one situations. Among the many results in this study, two are especially noteworthy. One is that in the one-on-one situations, the experienced players visually fixated longer on the opponent's hip region more than the less-experienced players, which indicated their knowledge of the relevant information to be acquired from the specific environmental feature. The other is that in the three-on-three situations, the experienced players used peripheral vision to select relevant information more than the less-experienced players. Evidence for the use of peripheral vision came from the results of the spatial occlusion procedure, in which the masking of areas of the video scene surrounding the ball and the player with the ball had a more negative effect on the performance of the experienced players.

Shooting a basketball. When a basketball player shoots a jump shot, when does the player visually search for and detect the relevant information needed to determine when and how to make the shot? To address this question, some researchers have used the temporal occlusion procedure to investigate expert basketball players shooting a jump shot (See, for example, Oudejans, van de Langenberg, & Hunter, 2002). The researchers established a simulated game situation in which the players watched a scene on a video projected in front of them. The players performed jump shots at a basket on the basis of the actions of the defensive players in the video. The players saw all, none, or only parts of the video. The results indicated that the players' shooting performance was less successful when they could not observe the scene just before they released the ball. The researchers concluded that to successfully shoot a jump shot, players determine their final shooting movement characteristics by visually searching for and using information detected until they release the ball. In agreement with and extending this conclusion, de Oliveira, Oudejans, and Beek

(2008) showed that visual information was continuously being detected and used until the ball release, which demonstrated a closed-loop basis for control of shooting the ball.

Driving a car. Driving a car is a nonsport performance situation in which vision provides information to select and constrain action. In a study that was done many years ago, but continues to be preferred as a demonstration of this role for vision, Mourant and Rockwell (1972) had novice and experienced drivers drive a 2.1 mile neighborhood route and a 4.3 mile freeway route. The novices were students in a driver education class. The results of the eye movement recordings showed that novice drivers concentrated their eye fixations in a small area more immediately in front of the car. More experienced drivers visually searched a wider area that was farther from the front of the car. This broader scanning range increases the probability for the detection of important cues in the environment. On the freeway, the novices made pursuit eye movements, whereas the experienced drivers made specific eye fixations that jumped from location to location. That is, the experienced drivers knew which cues were important and specifically searched for those cues. The experienced drivers looked into the rear- and side-view mirrors more frequently than the novices, whereas the novices looked at the speedometer more than the experienced drivers did.

In an extension of these findings, Chapman and Underwood (1998) monitored eye movements of novice and experienced drivers as they watched various driving-related scenes that included at least one dangerous situation. In these situations, both types of drivers narrowed their visual search and increased the durations of their eye movement fixations. But the more experienced drivers tended to fixate for shorter amounts of time on specific parts of the scene than the novice drivers. This result indicates that more experienced drivers require less time to detect and process the information obtained from a fixation, which gives them an advantage in determining the appropriate driving action to take in the situation. In addition, the experienced drivers tended to be less variable in where they fixated their eye movements while watching the driving scenes, which, in agreement with the findings of Mourant and Rockwell (1972), indicates their greater knowledge of which environmental cues to look at to obtain the most relevant information. The results of these two studies have been replicated in several other studies (see Falkmer & Gregerson, 2005, for a review of this research).

The relationship between attentional resources allocation and eye movements was demonstrated in research by Mackenzie and Harris (2017). Drivers who more successfully attended to relevant driving environment areas showed more effective eye movements related to scanning the roadway and relevant driving related tasks, such as looking at the vehicle's mirrors and speedometer. These results add to those already discussed that establish the important role visual selective attention plays in driving safety.

Prehension while walking. When a person must walk to a table to pick up an object, such as a pen or book, visual search plays an important role in setting into motion the appropriate action coordination. An experiment by Cockrell, Carnahan, and McFayden (1995) demonstrated this role for visual search. Participants were required to walk 3.75 m to a table and pick up an aluminum can or a pencil as they walked by. Results showed that before they began any prehensive action, their eyes moved to fixate on the target. Head movement also preceded the initiation of reaching movements. Thus, the eyes' searching of the environment to determine the location and characteristics of the object started a chain of events to allow the participants to grasp the object successfully.

Locomoting through a cluttered environment. Walking and running through a cluttered environment can occur in everyday situations—we walk around furniture in the house or walk through a crowded mall—and in sport situations: a player runs with a football or dribbles a basketball during a game. People's ability to maneuver through environments like these indicates that they have detected relevant cues and used them in advance to avoid collisions. Visual search is an important part of this process.

According to research by Cutting, Vishton, and Braren (1995), the most important cues involved in avoiding collision in these situations come from the relative location or motion of objects around the object the person needs to avoid. When visually fixating on the object he or she needs to avoid, the person uses relative-displacement and/or velocity information about both the object to be avoided and other objects in front of or behind the object. It is important to note that this decision making is done automatically by the visual system and provides the basis for appropriate action by the motor control system. The key practical point here is that the person needs to visually fixate on the object or objects that he or she wishes to avoid. (See Basili et al., 2013, for a more extensive discussion of this point and related research; and Elder, Grossberg, & Mingolla, 2009, for a proposed neural model to explain how we avoid objects during locomotion.)

Visual Search in Closed Motor Skills

Basketball free throw. Vickers (1996) reported an experiment in which she recorded the eye movements of elite Canadian women basketball players as they prepared to shoot, and then shot, free throws. Two results are especially noteworthy. First, the "experts" (they had made an average of 75 percent of their free throws during the just-completed season) looked directly at the backboard or hoop for a longer period of time just prior to shooting the ball than did the "near experts" (they had made an average of 42 percent of their free throws during the just-completed season). This was especially the case for the final eye movement fixation just prior to the release of the ball which Vickers referred to as the "quiet eye." Second, as can be seen in figure 9.5, the amount of time devoted to the final fixation prior to releasing the ball was related to the shooting success of the experts. They fixated on the backboard or hoop for just over 1.4 sec for shots they made, but almost 0.2 sec less for shots they missed. It is interesting to note that the final fixation duration for the near experts was just the opposite, with a longer fixation time on shots they missed than on shots they made. Vickers interpreted this finding as evidence that the near experts did not fixate long enough just prior to the release of the ball for the shots they made or missed to allow them to attain the shooting

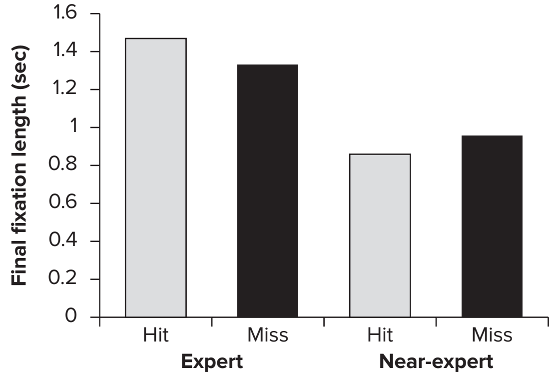


FIGURE 9.5 Results from Vickers (1996) showing expert and near-expert basketball players' mean duration of their final eye movement fixations just prior to releasing the ball during basketball free throws for shots they hit and missed. These final fixations were on the backboard or hoop. *Soruce:* Modified figure 6 (p. 348) in Vickers, J. (1996). Visual control when aiming at a far target. *Psychology: Human Perception and Performance, 22,* 342–354.

percentage of the experts. For a comprehensive review of research related to the quiet eye and sports performance, see LeBeau et al. (2016).

Putting a golf ball. In another experiment by Vickers (1992), she reported eye movement data for lower-handicap golfers (0 to 8 handicaps) and higher-handicap golfers (10 to 16 handicaps). In golf, the lower-handicap golfers are more skilled than those with higher handicaps. Vickers reported that during a series of putts, several differences were found between these two groups during the interval of time just after the golfer completed positioning the ball and just before the initiation of the backswing of the putter (i.e., the preparation phase). First, this time interval was shorter for the low-handicap golfers (approximately 3.7 sec) than for the high-handicap golfers (approximately 4.8 sec). Second, the low-handicap golfers directed more eye movement fixations to the ball during this phase than the high-handicap golfers, who directed more fixations to the putter. Third, there was a relationship between the eye movement fixation during the preparation phase and the success of a putt. Fixations on the club led to more missed putts, whereas fixations on the ball led to more successful putts.

A CLOSER LOOK

The "Quiet Eye"—A Strategic Part of the Visual Search Process for Performing Motor Skills

Research by Joan Vickers and her colleagues discovered an important characteristic of visual search that is associated with successful motor skill performance. This characteristic, which they called the "quiet eye," occurs for both closed and open skills. The research evidence for the "quiet eye" is based on the use of eye movement recording technology, which was discussed in chapter 6. These recordings showed that when people search the performance environment, they typically fixate their gaze on a specific location or object for a certain amount of time (approximately 100 ms) *just before* initiating performance of the activity. This final gaze fixation is the "quiet eye" (i.e., the "quiet" portion of the visual search process). In terms of attention processes involved in motor skill performance, the "quiet eye" characteristic of visual search demonstrates the importance of the visual focus of attention.*

Four Common Characteristics of the "Quiet Eye" (*see McPherson & Vickers, 2004*):
- It is directed to a critical location or object in the performance context
- It is a stable fixation of the performer's gaze
- Its onset occurs just before the first movement common to all performers of the skill
- Its duration tends to be longer for elite performers

These four characteristics indicate the "need for an optimal focus on one location or object prior to the final execution of the skill" (McPherson & Vickers, 2004, p. 279).

The "Quiet Eye" for Closed Skills
For the successful performance of a closed skill the final gaze fixation, just prior to performing the skill, is typically located on the goal object in the performance environment. For example, golfers fixate on the ball, free-throw shooters in basketball fixate on the rim of the basket, walkers fixate on stepping stones along a pathway, etc.

- *Specific closed skills demonstrations of the "quiet eye."* Research has shown the relationship between the "quiet eye" and performance for: golf putting; basketball free-throw shooting; walking on stepping stones; rifle target shooting; dart throwing; laparoscopic surgery; potting billard balls; football penalty shooting; and line walking.

The "Quiet Eye" for Open Skills
Open skills involve moving objects that must be visually tracked, which makes the visual search process different from that used for closed skills. The final gaze fixation (i.e., the "quiet eye") during the performance of open skills is on the moving object, which the eye then tracks for as long as possible before initiating the required movement. For example, batters in baseball or receivers of serves in tennis, table tennis, and volleyball fixate on the oncoming ball and track it to a specific location in space just prior to initiating movement to respond to the oncoming ball.

- *Specific open skills demonstrations of the "quiet eye."* Research has shown the relationship between the "quiet eye" and performance for: batters in baseball; softball umpires; receivers of serves in tennis, table tennis, and volleyball; ice hockey goal tenders; skeet shooters; and soccer goalkeepers attempting saves.

*For specific references and summaries of the research demonstrating the "quiet eye" for these skills, see Wilson, Causer, and Vickers (2015) and Vickers (2007).

Vickers also described an interesting point that is relevant to our discussion on visual attention. She noted that golfers generally are not consciously aware of eye movements during putting. Golfers tend to associate visual attention with head position, which means they consider a change in visual attention to be related to a change in head movement. However, their head movement to shift visual attention from one location to another is generally initiated by eye movement.

A study by Campbell and Moran (2014) noted that the research by Vickers and others tended to investigate eye movements and gaze during the act of putting a ball and not during the planning of the putt, which would occur prior to the initiation of the putting movement. In their study, Campbell and Moran tracked gaze behavior of three skill levels of golfers (professional, elite amateurs, and club level) as they approached putting a ball on a green. The results showed that the professional golfers had fewer fixations of longer duration than the other two groups of golfers. The fixations were directed toward halfway between the ball and the hole, from behind the hole towards the ball, and from behind the ball towards the hole.

TRAINING VISUAL SEARCH STRATEGIES

Each of the motor skill performance examples discussed in the preceding section had in common the characteristic that people with more experience in an activity visually searched their environment and located essential information more effectively and efficiently than people with little experience. Therefore, we know that as people become more experienced and skilled in an activity, they acquire better visual search skills. How do people acquire this capability? In many cases, experience alone is the key factor in the acquisition of effective visual search strategies. These strategies are often acquired without specific training and without the person's conscious awareness of the strategies they use. But is it possible to facilitate the acquisition of effective search strategies by teaching novices to use strategies that experts use? A positive answer to this question would provide teachers, coaches, and physical rehabilitation therapists with guidance about how to more effectively design practice and intervention strategies.

Researchers have demonstrated the benefits of providing novices with instructions concerning what to look for and attend to, along with giving them a sufficient amount of practice implementing these instructions. A result of this type of intervention strategy is an increase in the probability that important environmental cues will "pop out" when the person is in the performance situation (see Czerwinski, Lightfoot, & Shiffrin, 1992).

However, Abernethy, Wood, and Parks (1999) emphasized that it is essential for this type of training to be specific to an activity. They pointed out that research evidence has demonstrated the lack of benefit derived from generalized visual training programs, such as those often promoted by sports optometrists (e.g., Wood & Abernethy, 1997). The problem with a generalized training approach to the improvement of visual attention is that it ignores the general finding that experts recognize specific patterns in their activity more readily than do novices.

Several examples of effective visual search training programs have been reported (e.g., Abernethy, Wood, & Parks, 1999; Causer, Holmes, & Williams, 2011; Farrow et al., 1998; Haskins, 1965; Singer et al., 1994; Vera et al., 2008; Vickers, 2007; Wilson, Causer, & Vickers, 2015). Most of these programs are sport specific. Some of them are video-based simulations and have shown the effectiveness of this type of program for the self-paced training of athletes outside of their organized practice time. However, one caution is that many of the studies that have reported the effectiveness of these programs have not tested their efficacy in actual performance situations or in competition environments (see Williams, Ward, Smeeton, & Allen, 2004, for an extensive review and critique of these studies).

It is interesting to note, however, that studies by Green and Bavelier (2003, 2006) found that highly experienced players of action video games exhibited better visual selective attention capabilities than nonplayers. And, after training nonplayers on an action-video game, the trained nonplayers demonstrated distinct improvement in their visual attention skills. However, more recent research has demonstrated not only these positive effects but also several negative effects (Trisolini, Petilli, & Daini, 2018).

SUMMARY

We have considered the concept of attention as it relates to human motor skill performance in two ways: the simultaneous performance of multiple activities, and the visual selection of performance-relevant information from the environment.

In the discussion of attention and the simultaneous performance of multiple activities, we discussed the following:

- People have a limited availability of mental resources, which was described as a *limited attention capacity* for performing more than one activity at the same time.
- *Kahneman's attention theory* is an example of a centrally located, flexible limited capacity view of attention. His theory proposes that our attention capacity is a single pool of mental resources that influences the cognitive effort that can be allocated to activities to be performed. The amount of available resources (i.e., attention capacity) can increase or decrease according to the general arousal level of the performer. The allocation of resources is influenced by several factors related to the person and the activities.
- *Multiple-resource theories* provide an alternative view of a limited capacity view of attention by proposing that several different resource pools exist from which attention can be allocated. The resources are specific to a component of performing a skill. Wickens' model describes these components.
- The most common experimental procedure used to investigate the attention demands of motor skill performance is called the *dual-task procedure.*
- *Attentional focus,* which refers to where a person directs his or her attention in a performance situation, can be considered in terms of its width (i.e., broad or narrow) and direction (i.e., internal or external) or in terms of whether attention is focused on the movements or the movement effect.
- *Automaticity* is an important attention-related concept that relates primarily to skill performance in which the performer can implement knowledge and procedures with little or no demand on attention capacity.

In the discussion of attention and the visual selection of performance-relevant information from the environment, we discussed the following:

- *Visual selective attention* to performance-relevant information in the environment is an important part of preparing to perform a motor skill.
- The performer usually engages in an active *visual search* of the performance environment according to the information needed to prepare and perform an intended action, although sometimes the environmental information attended to provides the basis for selecting an appropriate action.
- The *feature integration theory* of visual selective attention is one of the more popular explanations of how people visually select and attend to certain cues in the performance environment and ignore others.
- We looked at research related to the visual search involved in the performance of several different open and closed motor skills. Each skill provided evidence that effective visual search strategies are distinctly specific to the requirements of the action and to the skill level of the performer.
- Activity-specific training programs facilitate the use of effective visual search strategies more successfully than general-vision training programs.

POINTS FOR THE PRACTITIONER

- The capability to do more than one activity simultaneously when performing a motor skill can be situation-specific. This means that a person may have more success in some situations than in others. Note these differences and use them as the basis for designing further instruction and practice.
- People will be more likely to be distracted while preparing to perform, or performing, a motor skill

when events occur in the performance environment that are not usually present in this environment.

- Skilled individuals will be more likely to perform at their best when their arousal or anxiety levels are optimal for performing the skill in the situation they will experience.
- People will perform motor skills better when they focus their conscious attention (i.e., what they "think about") on the intended outcome of the movement rather than on their own movements.
- You can enhance a person's visual selective attention in performance situations by providing many opportunities to perform a skill in a variety of situations in which the most relevant visual cues remain the same in each situation.
- Provide training for people to visually focus on the most relevant cue in the performance environment and then maintain visual contact with that cue just prior to initiating movement.

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STUDY QUESTIONS

1. (a) Discuss the similarities and differences between fixed and flexible central-resource theories of attention capacity. (b) Discuss the differences between central- and multiple-resource theories of attention capacity.
2. Describe a motor skill situation in which two or more actions must be performed simultaneously, and then discuss how Kahneman's model of attention could be applied to the situation to explain conditions in which all the actions could be performed simultaneously and when they could not be.
3. Discuss two different dual-task techniques that researchers use to assess the attention demands of performing a motor skill. Give an example of each.
4. (a) Describe the width and direction of attention-focus options a person has when performing a motor skill. (b) For each type, describe a motor skill situation in which that focus option would be preferred.
5. Discuss whether a person should focus attention on his or her own movements or on the movement effects. Give an example.
6. What is the meaning of the term *automaticity* as it relates to attention and the performance of motor skills? Give an example.
7. (a) What is the meaning of the term *visual selective attention,* and how does it relate to the study of attention? (b) Describe how researchers study visual selective attention as it relates to the performance of motor skills. Give an example.
8. Discuss how skilled performers engage in visual search in the performance of four different types of motor skills.

Specific Application Problem:
You are working in your chosen profession. Describe a situation in which you are helping people learn a skill that involves performing more than one activity at a time (e.g., dribbling a basketball while running and looking for a teammate to pass to). Describe how you would help people acquire the capability to perform this multiple-activity skill beginning with their not being able to do all the activities simultaneously. Indicate how you would take the concept of attention capacity into account in designing this instructional strategy.