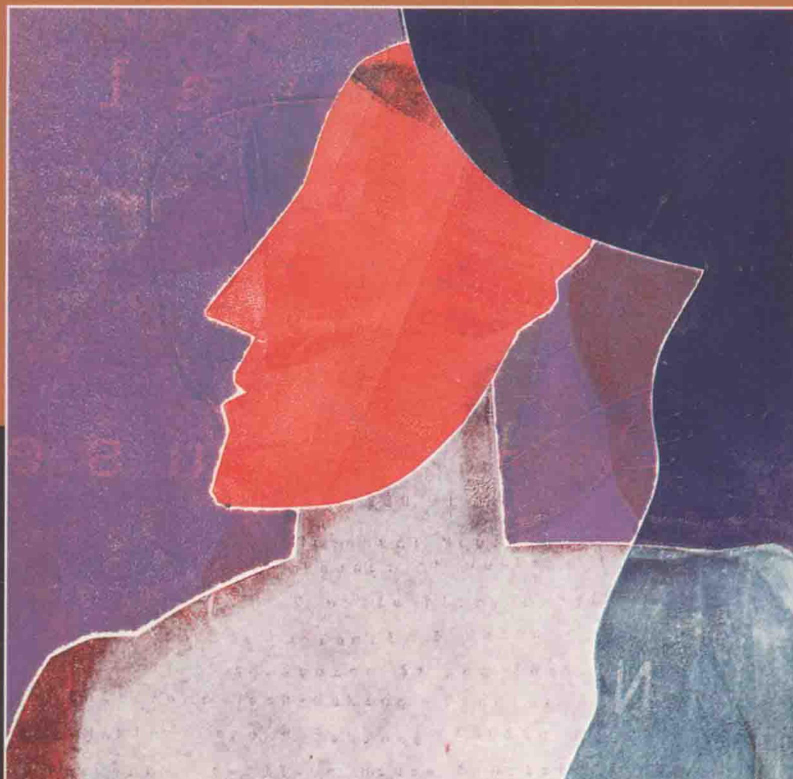
READINGS FROM THE
AMERICAN PSYCHOLOGICAL SOCIETY

CURRENT DIRECTIONS IN COGNITIVE SCIENCE



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Overview of the Book

Picking articles for this reader was, in many ways, a pleasure. As we looked back through the years of *Current Directions* to find articles relevant to cognitive science, we were struck by how many were interesting, well-written, or both. The hard part then was how to narrow down the selection to the 20-25 for the reader.

We assumed that most users of this book would be concurrently taking a course in cognitive psychology or cognitive science. Thus, we decided not to pick articles that were on issues likely to be well-covered in the textbooks for those courses. This decision also led to another decision—not to pick articles that were more than 6 years old. For one thing, such topics were likely to already be in the textbooks; for another, the reader is titled *Current* (not *Historic*) *Directions.*

Beyond that, the reader reflects our shared views as to topics that are particularly timely in cognitive psychology and topics that are applicable beyond cognitive psychology. Indeed, over the past years we have each had reason to answer the question: What are the current trends in cognitive psychology and where do you see the field going? In sum we would say that the directions are micro, macro, and down under. By "micro" we mean the current interest in neuroscience: What is the relation between mind and brain? As the tools for looking at the brain get better, we can learn more about how the mind works. But as Miller and Keller (2000) point out, don't be fooled, one is not reducible to the other. By "macro" we mean two things: first, ties to systems bigger than our individual minds (e.g., to evolution and culture) and second, to human affairs such as law, business, and economics, whose practioners increasingly look to cognitive scientists for information about how people think and behave in the "real world" outside the laboratory. And by "down under" we mean that interest in the unconscious and the role of emotion and affect in influencing cognition is booming. We find all of these directions very exciting and have tried to select articles that illustrate them and, we hope, bring the excitement to you.

Textbooks are good for explaining the theories in a field and for detailing a few central research findings. These articles give you a chance to read recent reviews by experts that will show you something beyond the basics, by taking you to the cutting edge of the field. We hope that these readings will expand your understanding of what cognitive science is and can do. Enjoy.

Contents

Readings from *Current Directions in Psychological Science*

Visual Perception

Cognitive psychology can be frustrating because it seems so splintered. Beginning students study perception, then attention, then working memory, and so on. They have the sense that each researcher has fenced off a small domain of the mind for study, and scarcely cares or even acknowledges that the mind performs other functions, let alone that these functions might have some influence on the researcher's cherished domain.

There is a grain of truth in this perception. Cognitive psychologists do believe that progress can be made by examining cognitive processes in isolation, because they believe that it is useful to consider the mind as *modular*. That means that the mind is composed of processes, each of which performs a particular cognitive function (e.g., calculating the motion of objects, or maintaining auditory information in working memory). The modules are not entirely independent of one another—they communicate—but they have a certain independence in that their function does not radically change based on what other modules are doing. In addition, most introductory cognitive psychology books don't discuss interaction because it is a more advanced topic—you need to know the basics before discussing how the basics interact. This section includes three articles that consider the interaction of visual perception with other cognitive processes: attention, imagery, and other perceptual systems.

Our intuition tells us that attention increases the processing of visual information, but vision still proceeds to some extent without the benefit of attention. For example, suppose you had walked past a painting in a museum but your friend told you that it was her favorite, so you went back and inspected it more closely. You would likely say that you had *seen* the painting when you first passed it, but had not noticed many of the details until you had directed attention to it. This observation indicates that attention enables deeper or more complex visual perception, but that some perceptual processes operate independently of attention. These processes allow you to know that it's a painting on a wall, and not a mirror or a window. Research reviewed by Mack in "Inattentional Blindness: Looking Without Seeing" suggests that our intuition is not quite right, and that visual perception is more dependent on attention than we would guess. It appears that we do not see objects to which we don't attend. But the interesting twist is that this generalization holds true only for conscious perception. Visible objects can and do affect behavior, although we may not be aware of how they influence us.

Attention relates to perception by making certain types of perception possible. Perception has an altogether different relationship to visual imagery. Again using our intuition as a guide, we might guess that the two have something in common. When asked "does the Statue of Liberty hold her torch in her right hand or her left hand?" most people report that they answer this question by generating a mental picture of the Statue and then inspecting it. This mental picture seems to have something in common with perception—it entails a visual experience—but further reflection reveals important differences between perception and visual imagery. Pause from your reading for a moment and image a tiger. Once you have done so, try to count the number of stripes on the tiger's torso. Most people find this task impossible, although you could of course complete the task if you were perceiving a tiger. Images are less detailed than percepts. Is imagery a watered-down version of perception? No, but it is now known that there is considerable overlap in the two systems. In "The Mind's Eye Mapped onto the Brain's Matter", Behrmann describes in detail the current knowledge of what these systems have in common, and how they differ.

It is easy for us to appreciate how vision and mental imagery overlap; it is more difficult to imagine significant overlap of vision and other sensory systems, such as audition. One might describe the tone of Stan Getz's saxophone as "warm" or even refer to it as "golden" but we mean that as a metaphor, not literally. "Synesthesia: Strong and Weak" by Martino and Marks reports on the small number of people for whom such descriptions are not metaphoric. Synesthetes experience cross talk among the senses such that stimulation of one sensory modality (e.g., a sound) leads to a strong sensation in another modality (e.g., a visual image). Although true synesthesia is rare, it can inform us about basic mechanisms of how perceptions are coded.

The articles in this section illustrate the intricate relationships among cognitive processes. Although we may speak of processes such as "attention" as though they operate in isolation, cognitive psychologists are mindful that this is a convenient simplification, and that even as we study individual cognitive processes we must bear in mind how they interact.

Inattentional Blindness: Looking Without Seeing

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Abstract

Surprising as it may seem, research shows that we rarely see what we are looking at unless our attention is directed to it. This phenomenon can have serious life-and-death consequences. Although the inextricable link between perceiving and attending was noted long ago by Aristotle, this phenomenon, now called inattentional blindness (IB), only recently has been named and carefully studied. Among the many questions that have been raised about IB are questions about the fate of the clearly visible, yet unseen stimuli, whether any stimuli reliably capture attention, and, if so, what they have in common. Finally, is IB an instance of rapid forgetting, or is it a failure to perceive?

Keywords

inattention; perception; awareness

Imagine an experienced pilot attempting to land an airplane on a busy runway. He pays close attention to his display console, carefully watching the airspeed indicator on his windshield to make sure he does not stall, yet he never sees that another airplane is blocking his runway!

Intuitively, one might think (and hope) that an attentive pilot would notice the airplane in time. However, in a study by Haines (1991), a few experienced pilots training in flight simulators proceeded with their landing when a clearly visible airplane was blocking the runway, unaware of the second airplane until it was too late to avoid a collision.

As it turns out, such events are not uncommon and even may account for many car accidents resulting from distraction and inattention. This is why talking on cell telephones while driving is a distinctly bad idea. However, the pervasive assumption that the eye functions like a camera and our subjective impression of a coherent and richly detailed world lead most of us to assume that we see what there is to be seen by merely opening our eyes and looking. Perhaps this is why we are so astonished by events like the airplane scenario, although less potentially damaging instances occur every day, such as when we pass by a friend without seeing her.

These scenarios are examples of what psychologists call inattentional blindness (IB; Mack & Rock, 1998). IB denotes the failure to see highly visible objects we may be looking at directly when our attention is elsewhere. Although IB is a visual phenomenon, it has auditory and tactile counterparts as well; for example, we often do not hear something said to us if we are "not listening."

INATTENTIONAL BLINDNESS

The idea that we miss a substantial amount of the visual world at any given time is startling even though evidence for such selective seeing was first reported in the 1970s by Neisser (1979). In one of several experiments, he asked participants to view a video of two superimposed ball-passing games in which one group of players wore white uniforms and another group wore black uniforms. Participants counted the number of passes between members of one of the groups. When the participants were subsequently asked to report what they had seen, only 21% reported the presence of a woman who had unexpectedly strolled though the basketball court carrying an open umbrella, even though she was clearly in view some of the time. Researchers recently replicated this finding with a study in which a man dressed in a gorilla costume stopped to thump his chest while walking through the court and remained visible for between 5 and 9 s (Simons & Chabris, 1999).

Although it is possible that some failures to see the gorilla or the umbrella-carrying woman might have resulted from not looking directly at them, another body of work supports the alternative explanation that the observers were so intent on counting ball passes that they missed the unexpected object that appeared in plain view. Research I have conducted with my colleagues (Mack & Rock, 1998) conclusively demonstrates that, with rare exceptions, observers generally do not see what they are looking directly at when they are attending to something else. In many of these experiments, observers fixated on specified locations while simultaneously attending to a demanding perceptual task, the object of which might be elsewhere. Under these conditions, observers often failed to perceive a clearly visible stimulus that was located exactly where they were looking.

INATTENTIONAL BLINDNESS OR INATTENTIONAL AMNESIA?

Not surprisingly, there is a controversy over whether the types of failures documented in such experiments are really evidence that the observers did not see the stimulus, or whether they in fact saw the stimulus but then quickly forgot it. In other words, is IB more correctly described as *inattentional amnesia* (Wolfe, 1999)? Although this controversy may not lend itself to an empirical resolution, many researchers find it difficult to believe that a thumping gorilla appearing in the midst of a ball game is noticed and then immediately forgotten. What makes the argument for inattentional amnesia even more difficult to sustain is evidence that unseen stimuli are capable of priming, that is, of affecting some subsequent act. (For example, if a subject is shown some object too quickly to identify it and is then shown it again so that it is clearly visible, the subject is likely to identify it more quickly than if it had not been previously flashed. This is evidence of priming: The first exposure speeded the response to the second.) Priming can occur only if there is some memory of the stimulus, even if that memory is inaccessible.

UNCONSCIOUS PERCEPTION

A considerable amount of research has investigated unconscious, or *implicit*, perception and those perceptual processes that occur outside of awareness. This work has led many researchers to conclude that events in the environment, even if not consciously perceived, may direct later behavior. If stimuli not seen because of IB are in fact processed but encoded outside of awareness, then it should be possible to demonstrate that they prime subsequent behavior.

The typical method for documenting implicit perception entails measuring reaction time over multiple trials. Such studies are based on the assumption that an implicitly perceived stimulus will either speed up or retard subsequent responses to relevant stimuli depending on whether the priming produces facilitation or inhibition.[2] However, because subjects in IB experiments cannot be made aware of the critical stimulus, unlike in many kinds of priming studies, only one trial with that stimulus is possible. This requirement rules out reaction time procedures, which demand hundreds of trials because reaction time differences tend to be small and therefore require stable response rates that can be achieved only with many trials. Fortunately, an alternate procedure, stem completion, can be used when the critical stimuli are words. In this method, some observers (experimental group) are exposed to a word in an IB procedure, and other observers (control group) are not. Then, the initial few letters of the unseen word are presented to all the observers, who are asked to complete the string of letters with one or two English words. If the members of the experimental group complete the string with the unseen word more frequently than do the members of the control group, this is taken as evidence that the experimental group implicitly perceived and encoded the word.

IB experiments using this method have demonstrated significant priming (Mack & Rock, 1998), as well as other kinds of evidence that visual information undergoes substantial processing prior to the engagement of attention. For example, evidence that aspects of visual processing take place before attention is allocated has been provided by a series of ingenious IB experiments by Moore and her collaborators (e.g., Moore & Egeth, 1997). This work has shown that under conditions of inattention, basic perceptual processes, such as those responsible for the grouping of elements in the visual field into objects, are carried out and influence task responses even though observers are unable to report seeing the percepts that result from those processes. For example, in one study using a modification of the IB procedure, Moore and Egeth investigated the Müller-Lyer illusion, in which two lines of equal length look unequal because one has outgoing fins, which make it look longer, and the other has ingoing fins, which make it look shorter. In this case, the fins were formed by the grouping of background dots: Dots forming the fins were closer together than the other dots in the background. Moore and Egeth demonstrated that subjects saw the illusion even when, because of inattention, the fins were not consciously perceived. Whatever processes priming entails, the fact that it occurs is evidence of implicit perception and the encoding of a stimulus in memory. Thus, the fact that the critical stimulus in the IB paradigm can prime subsequent responses is evidence that this stimulus is implicitly perceived and encoded.

When Do Stimuli Capture Attention and Why?

That unconsciously perceived stimuli in IB experiments undergo substantial processing in the brain is also supported by evidence that the select few stimuli able to capture attention when attention is elsewhere are complex and meaningful (e.g., the observer's name, an iconic image of a happy face) rather than simple features like color or motion. This fact suggests that attention is captured only after the meaning of a stimulus has been analyzed. There are psychologists who believe that attention operates much earlier in the processing of sensory input, before meaning has been analyzed (e.g., Treisman, 1969). These accounts, however, do not easily explain why modest changes, such as inverting a happy face and changing one internal letter in the observer's name, which alter the apparent meaning of the stimuli but not their overall shape, cause a very large increase in IB (Mack & Rock, 1998).

Meaning and the Capture of Attention

If meaning is what captures attention, then it follows axiomatically that meaning must be analyzed before attention is captured, which is thought to occur at the end stage of the processing of sensory input. This therefore implies that even those stimuli that we are not intending to see and that do not capture our attention must be fully processed by the brain, for otherwise their meanings would be lost before they had a chance of capturing our attention and being perceived. If this is the case, then we are left with some yet-unanswered, very difficult questions. Are all the innumerable stimuli imaged on our retinas really processed for meaning and encoded into memory, and if not, which stimuli are and which are not?

Although we do not yet have answers to these questions, an unpublished doctoral dissertation by Silverman, at New School University, has demonstrated that there can be priming by more than one element in a multielement display, even when these elements cannot be reported by the subject. This finding is relevant to the question whether all elements in the visual field are processed and stored because up to now there has been scarcely any evidence of priming by more than one unreportable element in the field. The fact of multielement priming begins to suggest that unattended or unseen elements are processed and stored, although it says nothing about how many elements are processed and whether the meaning of all the elements is analyzed.

One answer to the question of how much of what is not seen is encoded into memory comes from an account of perceptual processing based on the assumption that perception is a limited-capacity process and that processing is mandatory up to the point that this capacity is exhausted (Lavie, 1995). According to this analysis, the extent to which unattended objects are processed is a function of the difficulty of the perceptual task (i.e., the perceptual load). When the perceptual load is high, only attended stimuli are encoded. When it is low, unattended stimuli are also processed. This account faces some difficulty because it is not clear how perceptual load should be estimated. Beyond this, however, it is difficult to reconcile this account with evidence suggesting that observers are likely to see their own names even when they occur among the stimuli that must be ignored in order to perform a demanding perceptual task (Mack, Pappas, Silverman, & Gay, 2002). It should be noted, however, that these latter results are at odds with a published report (Rees, Russell, Firth, & Driver, 1999) I describe in the next section.

EVIDENCE FROM NEURAL IMAGING

Researchers have used magnetic imaging techniques to try to determine what happens in the brain when observers fail to detect a visual stimulus because their attention is elsewhere. Neural recording techniques may be able to show whether visual stimuli that are unconsciously perceived arouse the same areas of the brain to the same extent as visual stimuli that are seen. This is an important question because it bears directly on the nature of the processing that occurs outside of awareness prior to the engagement of attention and on the difference between the processing of attended and unattended stimuli.

In one study, Scholte, Spekreijse, and Lamme (2001) found similar neural activity related to the segregation of unattended target stimuli from their backgrounds (i.e., the grouping of the unattended stimuli so they stood out from the background on which they appeared), an operation that is thought to occur early in the processing of visual input. This activation was found regardless of whether the stimuli were attended and seen or unattended and not seen, although there was increased activation for targets that were attended and seen. This finding is consistent with the behavioral findings of Moore and Egeth (1997), cited earlier, showing that unattended, unseen stimuli undergo lower-level processing such as grouping, although the additional neural activity associated with awareness suggests that there may be important differences in processing of attended versus unattended stimuli.

In another study, Rees and his colleagues (Rees et al., 1999) used functional magnetic resonance imaging (fMRI) to picture brain activity while observers were engaged in a perceptual task. They found no evidence of any difference between the neural processing of meaningful and meaningless lexical stimuli when they were ignored, although when the same stimuli were attended to and seen, the neural processing of meaningful and meaningless stimuli did differ. These results suggest that unattended stimuli are not processed for meaning. However, in another study that repeated the procedure used by Rees et al. (without fMRI recordings) but included the subject's own name among the ignored stimuli, many subjects saw their names, suggesting that meaning was in fact analyzed (Mack et al., 2002). Thus, one study shows that ignored stimuli are not semantically processed, and the other suggests that they are. This conflict remains unresolved. Are unattended, unseen words deeply processed outside of awareness, despite these fMRI results, which show no evidence of semantic neural activation by ignored words? How can one reconcile behavioral evidence of priming by lexical stimuli under conditions of inattention (Mack & Rock, 1998) with evidence that these stimuli are not semantically processed?

NEUROLOGICAL DISORDER RELATED TO INATTENTIONAL BLINDNESS

People who have experienced brain injuries that cause lesions in the parietal cortex (an area of the brain associated with attention) often exhibit what is called unilateral visual neglect, meaning that they fail to see objects located in the visual field opposite the site of the lesion. That is, for example, if the lesion is on the right, they fail to eat food on the left side of their plates or to shave the left half of their faces. Because these lesions do not cause any sensory deficits, the apparent blindness cannot be attributed to sensory causes and has been explained in terms of the role of the parietal cortex in attentional processing

(Rafal, 1998). Visual neglect therefore seems to share important similarities with IB. Both phenomena are attributed to inattention, and there is evidence that in both visual neglect (Rafal, 1998) and IB, unseen stimuli are capable of priming. In IB and visual neglect, the failure to see objects shares a common cause, namely inattention, even though in one case the inattention is produced by brain damage, and in the other the inattention is produced by the task. Thus, evidence of priming by neglected stimuli appears to be additional evidence of the processing and encoding of unattended stimuli.

ATTENTION AND PERCEPTION

IB highlights the intimate link between perception and attention, which is further underscored by recent evidence showing that unattended stimuli that share features with task-relevant stimuli are less likely to suffer IB than those that do not (Most et al., 2001). This new evidence illustrates the power of our intentions in determining what we see and what we do not.

CONCLUDING REMARKS

Although the phenomenon of IB is now well established, it remains surrounded by many unanswered questions. In addition to the almost completely unexplored question concerning whether all unattended, unseen stimuli in a complex scene are fully processed outside of awareness (and if not, which are and which are not), there is the question of whether the observer can locate where in the visual field the information extracted from a single unseen stimulus came from, despite the fact that the observer has failed to perceive it. This possibility is suggested by the proposal that there are two separate visual systems, one dedicated to action, which does not entail consciousness, and the other dedicated to perception, which does entail consciousness (Milner & Goodale, 1995). That is, the action stream may process an unseen stimulus, including its location information, although the perception stream does not. An answer to this question would be informative about the fate of the unseen stimuli.

The pervasiveness of IB raises another unresolved question. Given that people see much less than they think they do, is the visual world a mere illusion? According to one provocative answer to this question, most recently defended by O'Regan and Noe (2001), the outcome of perceptual processing is not the construction of some internal representation; rather, seeing is a way of exploring the environment, and the outside world serves as its own external representation, eliminating the need for internal representations. Whether or not this account turns out to be viable, the phenomenon of IB has raised a host of questions, the answers to which promise to change scientists' understanding of the nature of perception. The phenomenon itself points to the serious dangers of inattention.

Recommended Reading

Mack, A., & Rock, I. (1998). (See References)
Rensink, R. (2002). Change blindness. *Annual Review of Psychology*, 53, 245–277.

Simons, D. (2000). Current approaches to change blindness. *Visual Cognition*, 7, 1–15.
Wilkens, P. (Ed.). (2000). Symposium on Mack and Rock's *Inattentional Blindness. Psyche,* 6 and 7. Retrieved from http://psyche.cs. monash.edu.au/psyche-indexv7.html#ib

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Notes

1. Address correspondence to Arien Mack, Psychology Department, New School University, 65 Fifth Ave., New York, NY 10003.

2. An example of a speeded-up response (facilitation, or positive priming) has already been given. Negative, or inhibition, priming occurs when a stimulus that has been actively ignored is subsequently presented. For example, if a series of superimposed red and green shapes is rapidly presented and subjects are asked to report a feature of the red shapes, later on it is likely to take them longer to identify the green shapes than a shape that has not previously appeared, suggesting that the mental representation of the green shapes has been associated with something like an "ignore me" tag.

References

Haines, R.F. (1991). A breakdown in simultaneous information processing. In G. Obrecht & L.W. Stark (Eds.), *Presbyopia research* (pp. 171–175). New York: Plenum Press.
Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 21*, 451–468.
Mack, A., Pappas, Z., Silverman, M., & Gay, R. (2002). What we see: Inattention and the capture of attention by meaning. *Consciousness and Cognition, 11*, 488–506.
Mack, A., & Rock, I. (1998). *Inattentional blindness.* Cambridge, MA: MIT Press.
Milner, D., & Goodale, M.A. (1995). *The visual brain in action.* Oxford, England: Oxford University Press.
Moore, C.M., & Egeth, H. (1997). Perception without attention: Evidence of grouping under conditions of inattention. *Journal of Experimental Psychology: Human Perception and Performance,* 23, 339–352.
Most, S.B., Simons, D.J., Scholl, B.J., Jimenez, R., Clifford, E., & Chabris, C.F. (2001). How not to be seen: The contribution of similarity and selective ignoring to sustained inattentional blindness. *Psychological Science*, *12*, 9–17.
Neisser, U. (1979). The control of information pickup in selective looking. In A.D. Pick (Ed.), *Perception and its development: A tribute to Eleanor Gibson* (pp. 201–219). Hillsdale, NJ: Erlbaum.
O'Regan, K., & Noe, A. (2001). A sensorimotor account of vision and visual consciousness. *Behavioral and Brain Sciences*, 25, 5.
Rafal, R. (1998). Neglect. In R. Parasuraman (Ed.), *The attentive brain* (pp. 489–526). Cambridge, MA: MIT Press.
Rees, G., Russell, C., Firth, C., & Driver, J. (1999). Inattentional blindness versus inattentional amnesia. *Science*, 286, 849–860.
Scholte, H.S., Spekreijse, H., & Lamme, V.A. (2001). Neural correlates of global scene segmentation are present during inattentional blindness [Abstract]. *Journal of Vision*, *1*(3), Article 346. Retrieved from http://journalofvision. org/1/3/346
Simons, D.J., & Chabris, C.F. (1999). Gorillas in our midst: Sustained inattentional blindness for dynamic events. *Perception*, 28, 1059–1074.
Treisman, A. (1969). Strategies and models of selective attention. *Psychological Review*, 76, 282–299.
Wolfe, J. (1999). Inattentional amnesia. In V. Coltheart (Ed.), *Fleeting memories* (pp. 71–94). Cambridge, MA: MIT Press.

Critical Thinking Questions

1. This article notes that some traffic accidents may well be caused by inattentional blindness, but you have likely had the experience of daydreaming as you drove without incident. In fact, your inattention may be so complete that you might drive to a familiar destination (e.g., your home) and feel surprised when you arrive. Does this phenomenon mean that the low-level processing that occurs with inattention is sufficient to support successful driving?

2. This article describes evidence that priming is supported by low-level processes that occur even in the absence of attention. When attention is directed to stimuli, you are aware of them. Other than awareness, what cognitive processes do you think are possible only with attention?

3. Mack cites the neurological phenomenon of unilateral neglect as sharing important similarities with inattentional blindness. Neglect patients fail to process stimuli in *all* modalities, not just vision. Do you think that lack of attention yields "blindness" in other modalities? In other words, if you are not attending, will you not hear an auditory stimulus? Will you not feel a tactile stimulus such as someone touching you?