Change Blindness

Theory and Consequences

Daniel J. Simons and Michael S. Ambinder

University of Illinois at Urbana-Champaign

ABSTRACT—*People often fail to notice large changes to visual scenes, a phenomenon now known as* **change blindness**. *The extent of change blindness in visual perception suggests limits on our capacity to encode, retain, and compare visual information from one glance to the next; our awareness of our visual surroundings is far more sparse than most people intuitively believe. These failures of awareness and the erroneous intuitions that often accompany them have both theoretical and practical ramifications. This article briefly summarizes the current state of research on change blindness and suggests future directions that promise to improve our understanding of scene perception and visual memory.*

KEYWORDS—*change blindness; change detection; visual representation; attention; perception; consciousness; awareness; memory*

Would you notice if a person you were talking to were surreptitiously replaced by a different person during a brief interruption? Do you think you would readily notice if two people in a photograph exchanged heads while you shifted your eyes from one part of the photo to another? If you are like most people, and you have not heard of change blindness before, you might confidently answer "yes" to both questions. Yet in studies involving just such scenarios, 50% of observers missed these changes (Grimes, 1996; Simons & Levin, 1998)! In fact, even when actively searching for changes, observers often struggle to find them. For example, when an original and changed photograph alternate repeatedly, separated by a brief blank screen, observers often require dozens of alternations to spot large changes (e.g., the disappearance of an airplane engine; Rensink, O'Regan, & Clark, 1997). Although change detection is quite good when the change signal is clearly visible (i.e., when the shift from the original version to the changed version is instantaneous and visible as it happens) and when no other distractions draw attention away from it, people are surprisingly inept at change detection whenever the change signal is masked or hidden from view. This failure to detect changes, or *change blindness*, has developed from a laboratory curiosity into a central phenomenon in the field of visual cognition, and has both theoretical and practical implications. It has been used to motivate conclusions about the nature of visual memory, the role of attention in scene perception, and even the mechanisms underlying conscious awareness of our visual world.

A BRIEF OVERVIEW OF CHANGE-BLINDNESS RESEARCH

Interest in change blindness has surged since the mid-1990s, but the phenomenon itself has much older roots. The use of change-detection tasks and experimental evidence for change blindness appeared sporadically in the literature beginning as early as the 1950s, with most studies revealing failures to detect changes to simple, sequentially presented arrays of dots or letters when they were separated by a brief blank interval (e.g., Di Lollo, 1980). Change blindness also surfaced in studies exploring the integration of information across eye movements (saccades), with subjects failing to detect changes that occurred while the eyes were moving. Although these early studies documented the existence of change blindness, more recent studies have illustrated the extent of our blindness to large changes in contexts more closely approximating real-world perception.

The most prominent task used to study change detection was developed by Ron Rensink and his colleagues in the 1990s (Rensink et al., 1997). The task was inspired by the finding that changes introduced during eye movements (known as saccade-contingent changes) often go undetected. One explanation for such change blindness is that the mechanisms that generate an eye movement actively suppress perception during the eye movement, a phenomenon known as saccadic suppression. Alternatively, rapid movement of the eye produces blur on the retina, and it might be this blurring itself that masks the change signal. If it is motion blur that masks changes, then other

The authors contributed equally to this manuscript. Address correspondence to Daniel J. Simons, Department of Psychology & Beckman Institute, University of Illinois, 603 E. Daniel St., #807, Champaign, IL 61820; e-mail: dsimons@uiuc.edu.

disruptions should mask them as well. In Rensink's *flicker* task, an original and changed image alternate repeatedly, separated by a blank screen, until observers detect the change (see Fig. 1). The blank screen produces a luminance change everywhere in the image, which serves to mask the signal produced by the change—that is, observers cannot see the change to the object while it happens. While performing this task, observers know something is changing but simply cannot find it. In most saccade-contingent change-detection tasks, changes typically occur only once; observers do not experience the "struggle" of change detection. This flicker task contributed to interest in change blindness by allowing audience members at talks or in classes to experience the phenomenon for themselves.

Change blindness has been observed in many other tasks, all of which disrupt or hide the localizable signal that would otherwise accompany an immediate change (see Rensink, 2002, for a recent review). For example, observers fail to notice changes introduced during a blank screen, a blink, an eye movement, or a motion-picture cut or pan. Similarly, they fail to notice a change that is accompanied by other visual signals that distract attention from the change location or a change that occurs gradually over a period of several seconds so that the change signal is not sufficiently strong to draw attention. The extent of change blindness is particularly striking, with remarkably large changes going unnoticed when the change is unexpected and incidental to the observer's task.

WHAT WE KNOW AND WHAT REMAINS TO BE DETERMINED

The change-blindness literature has converged on a core set of findings: First, change blindness occurs whenever attention is diverted from the change signal. Second, changes to objects that are central to the meaning of the scene or changes to visually distinctive objects are detected more readily than other changes, presumably because observers focus attention on important objects (Rensink et al., 1997). Third, attention may be necessary for change detection, with changes to unattended objects going unnoticed. Fourth, attention to a changing object may not be sufficient for change detection; observers frequently fail to detect changes to the central actors in motion pictures and to real-world conversation partners even though these people clearly are attended (Levin & Simons, 1997; Simons & Levin, 1998), suggesting that change detection requires observers to encode the changing features before and after the change and compare them (see Fig. 2).

Although these core conclusions are fairly well established in the change-detection literature, a number of open issues remain. For example, more research is needed to establish what draws attention to some scene elements and not others in a change-detection task. Image features might attract attention by virtue of their distinctiveness, or expectations about a scene might drive attention to an object. Few studies have examined

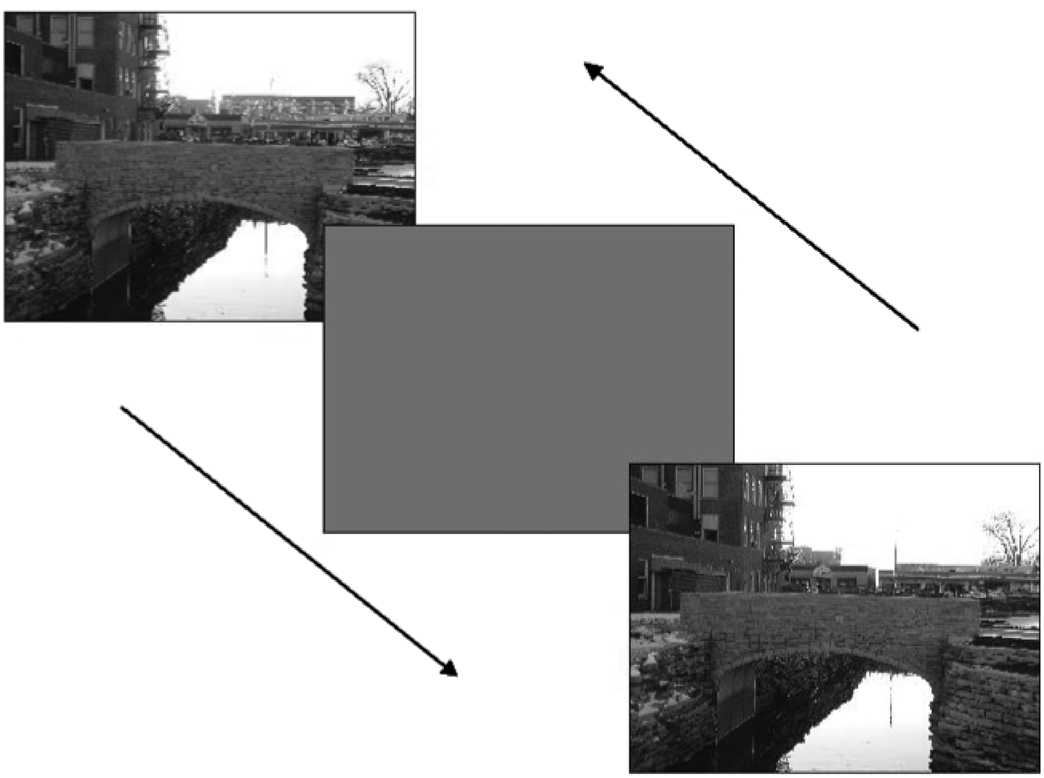

Fig. 1. Schematic illustration of the flicker task. In this task, an original and modified image alternate repeatedly, separated by brief blank displays, until observers find the change. Even large changes can go unnoticed for many seconds. In this image, the change is the appearance and disappearance of a building in the background.

Fig. 2. Frames from a video of a subject (the white-haired man) failing to notice a change in the person he was speaking with. Frames a through c show the sequence of the switch. Note that in Frame b, two people carrying a door pass between the experimenter and the subject, and during this interruption, the experimenter in Frame a is replaced by the experimenter in Frame c. Frame d shows the two experimenters side by side. Approximately 50% of subjects failed to notice that they were talking to a different person after the switch. Reprinted from ''Failure to Detect Changes to People in a Real-World Interaction,'' by D.J. Simons and D.T. Levin, 1998, *Psychonomic Bulletin & Review*, *5*, p. 646. Copyright 1998 by the Psychonomic Society. Reprinted with permission.

the combined contributions of visual distinctiveness and expectations to change detection.

Another topic that has been underexplored involves how individual differences in knowledge, personality, or expectations influence change detection as a function of the semantic content of a scene. Studies of experts and novices do reveal differences in change-detection performance. For example, experts in American football are better able to detect meaningful changes to football scenes than are people who are completely unfamiliar with American football (Werner & Thies, 2000). Expertise presumably guides the focus of attention when someone is looking at images, thereby enhancing change detection for semantically meaningful changes. Given that the same images are shown to experts and novices in these studies, the differences in change detection can be attributed to knowledge and expectations, rather than to image properties. The study of individual differences and their relationship to change detection and attention is an exciting new direction for the field; studies of the effects of aging, cultural differences, expertise, and practice on change-detection performance hold promise for a better characterization of the mechanisms of attention and visual memory.

WHAT CAN WE INFER FROM CHANGE BLINDNESS?

The phenomenon of change blindness has inspired strong claims about visual attention, visual memory, and awareness. For example, some researchers have argued that change blindness implies that internal visual representations are completely absent (O'Regan & Noë, 2001), and others have suggested that it implies that our representations of visual scenes are sparse or incomplete (Rensink et al., 1997; Simons & Levin, 1997). These conclusions are intriguing because they run counter to traditional models of perception, in which a complete representation or internal model of a scene is constructed from multiple views of it. Instead, these conclusions rely on the idea that there is no need to form internal representations in normal scene perception because the world can serve as a "memory store." However, recent thinking about the possible causes of change blindness shows that change blindness does not constrain the extent of completeness of our visual representations; change blindness could still occur even if our representations were rendered with infinite precision. Successful change detection requires both a representation of the scene before the change and a comparison of that representation with the scene after the change, and change blindness could occur because of a failure of this comparison process rather than (or in addition to) a failure to represent the prechange scene. Consequently, although representations are needed in order to detect a change, the failure to detect change does not imply the absence of a representation.

Given that observers do detect some changes, they must have some visual representations, so the strongest form of the no-representations view must be wrong. Moreover, several recent studies suggest that observers do have preserved visual information even when they fail to notice changes. For example, observers successfully recognize a previously attended object on a memory test even when they have failed to notice a change to that object (Hollingworth & Henderson, 2002). They can even recognize both the prechange and the postchange object at better-than-chance levels when they have failed to detect the change (Mitroff, Simons, & Levin, 2004). These findings suggest that change blindness sometimes occurs not because of a failure to represent the visual information, but because of a failure to successfully compare information from before and after the change.

An additional argument against sparse representations is that the preserved information might not be of a form or format that could be used for conscious change perception. In recent years, a number of studies have addressed this issue directly by examining whether changes are ever detected in the absence of awareness of the change. For example, can observers guess the change location even if they report no awareness of anything changing? Or will their performance show evidence of change detection (e.g., slowed responses in the presence of a change) when they report no awareness of it? If such implicit measures reveal change detection even when observers report no awareness of a change, then the observers must have represented some visual information from the scene and compared it with their perception of the scene after the change. However, the representations used for such implicit change detection might differ from those used for conscious change perception. The support for the existence of implicit change detection is equivocal, with some investigators claiming that the data support the existence of change detection without awareness (e.g., Fernandez-Duque & Thornton, 2000), and others arguing that all change detection can be explained without any implicit detection (Mitroff, Simons, & Franconeri, 2002).

Rensink (2004) has recently argued that some people can sense changes without actually seeing them, a phenomenon he named *mindsight*. In a subset of trials in the flicker task, some observers report that they sense something changing before they are able to visually identify the change. This finding could indicate the operation of a different change-detection mechanism, one not subject to the same constraints and limitations typically resulting in change blindness. If so, mindsight implies that observers represent information from the scene and compare it, perhaps without focused attention to the changing region. This strong claim that mindsight arises from a previously unknown attention mechanism merits scrutiny. If true, it would suggest an operation akin to a "sixth sense" in some subjects on some trials. However, more mundane explanations are also possible. For example, the effect might be due to the demands of the task itself or to the tendency to verify (or not) the detection of a change before responding.

Regardless of whether or not mindsight and implicit change detection exist, care must be taken not to overstate the conclusions drawn from change-blindness research. A failure of conscious change detection need not imply the absence of visual representations, and it might not reflect the absence of all forms of change detection. So what can we conclude from change blindness? Although change blindness does not imply the absence of representations, it does imply that whatever representations are maintained do not contribute to conscious change perception. Such failures could result from limitations on the capacity of attention: Even if we have sufficient representations to potentially detect a change, the change will go unnoticed if we do not attend to the changing object. Or the failures could imply limitations on the comparison mechanism used for change detection: Unless we explicitly compare the changed information before and after the change, it will go unnoticed regardless of how much information we represent. The contribution of these different mechanisms to both change detection and change blindness remains an open and important area of exploration. Regardless of which mechanisms contribute to change blindness, the phenomenon itself is still theoretically significant—our conscious awareness of our visual environment is sparse even if our representations of it might not be.

In addition to its theoretical implications, change blindness has practical consequences. Particularly for incidental and unexpected changes, people vastly overestimate their ability to detect changes in their environment (Levin, Momen, Drivdahl, & Simons, 2000), and this error reflects a misunderstanding of the mechanisms of attention—people incorrectly assume that important events automatically draw attention and are noticed. This *change blindness blindness* could have dire practical consequences when we perform tasks that require vigilance (e.g., driving a car or monitoring a warning display). It also likely affects the cognitive strategies we use in performing real-world tasks. For example, drivers might assume that important events, such as a pedestrian stepping into the street in front of them, will automatically draw their attention and be noticed. The widespread use of cell phones—an attention-demanding task—in cars reveals the extent of this assumption. Even if people know that cell-phone conversations require attention, they still believe that they will notice anything important in their visual environment. However, studies of change blindness show that even large changes in the environment may go unnoticed if they are not the focus of attention.

CONCLUSION

Change blindness is a striking phenomenon, one that reveals limits on conscious awareness and accentuates the discrepancy between what we see and what we think we see. Even if change blindness is a pervasive and unavoidable aspect of visual processing, making people more aware of their mistaken beliefs about attention and perception may lead to increased vigilance for important changes. People can experience change blindness for themselves, and doing so can highlight their erroneous beliefs. Increased knowledge of change blindness might then help them to override these erroneous beliefs, so that they are more vigilant for changes and better understand the consequences of dividing attention. Ongoing and future change-detection research will help clarify the role of attention, expectations, experience, and beliefs in producing change blindness. For example, studies of individual differences in change-detection performance will help determine how variations in attention and memory capacity affect the encoding and retention of the information in complex scenes. Furthermore, longitudinal studies of change detection using controlled displays can examine how change detection develops and improves with practice, and also whether change-detection training can transfer to real-world, attention-demanding tasks. Such studies hold promise for better theoretical models of visual memory and attention, as well as for understanding and eliminating the practical consequences of failures of awareness.

Recommended Reading

Rensink, R.A. (2002). (See References)

Simons, D.J. (Ed.). (2000). Change blindness and visual memory [Special issue]. *Visual Cognition*, *7*(1/2/3).

Simons, D.J., & Levin, D.T. (2003). What makes change blindness interesting? *The Psychology of Learning and Motivation*, *42*, 295–322.

REFERENCES

Di Lollo, V. (1980). Temporal integration in visual memory. *Journal of Experimental Psychology: General*, *109*(1), 75–97.

Fernandez-Duque, D., & Thornton, I.M. (2000). Change detection without awareness: Do explicit reports underestimate the representation of change in the visual system? *Visual Cognition*, *7*, 323–344.

Grimes, J. (1996). On the failure to detect changes in scenes across saccades. In K. Akins (Ed.), *Vancouver studies in cognitive science: Vol. 5. Perception* (pp. 89–110). New York: Oxford University Press.

Hollingworth, A., & Henderson, J.M. (2002). Accurate visual memory for previously attended objects in natural scenes. *Journal of Experimental Psychology: Human Perception and Performance*, *28*, 113–136.

Levin, D.T., Momen, N., Drivdahl, S.B., & Simons, D.J. (2000). Change blindness blindness: The metacognitive error of overestimating change-detection ability. *Visual Cognition*, *7*, 397–412.

Levin, D.T., & Simons, D.J. (1997). Failure to detect changes to attended objects in motion pictures. *Psychonomic Bulletin & Review*, *4*, 501–506.

Mitroff, S.R., Simons, D.J., & Franconeri, S.L. (2002). The siren song of implicit change detection. *Journal of Experimental Psychology: Human Perception and Performance*, *28*, 798–815.

Mitroff, S.R., Simons, D.J., & Levin, D.T. (2004). Nothing compares two views: Change blindness can occur despite preserved access to the changed information. *Perception & Psychophysics*, *66*, 1268–1281.

O'Regan, J.K., & Noë, A. (2001). A sensorimotor account of vision and visual consciousness. *Behavioral and Brain Sciences*, *24*, 939–1031.

Rensink, R.A. (2002). Change detection. *Annual Review of Psychology*, *53*, 245–277.

Rensink, R.A. (2004). Visual sensing without seeing. *Psychological Science*, *15*, 27–32.

Rensink, R.A., O'Regan, J.K., & Clark, J.J. (1997). To see or not to see: The need for attention to perceive changes in scenes. *Psychological Science*, *8*, 368–373.

Simons, D.J., & Levin, D.T. (1997). Change blindness. *Trends in Cognitive Sciences*, *1*, 261–267.

Simons, D.J., & Levin, D.T. (1998). Failure to detect changes to people in a real-world interaction. *Psychonomic Bulletin & Review*, *5*, 644–649.

Werner, S., & Thies, B. (2000). Is 'change blindness' attenuated by domain-specific expertise? An expert-novices comparison of change detection in football images. *Visual Cognition*, *7*, 163–174.