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Forming and updating object representations without awareness: evidence from motion-induced blindness

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Abstract

The input to visual processing consists of an undifferentiated array of features which must be parsed into discrete units. Here we explore the degree to which conscious awareness is important for forming such object representations, and for updating them in the face of changing visual scenes. We do so by exploiting the phenomenon of motion-induced blindness (MIB), wherein salient (and even attended) objects fluctuate into and out of conscious awareness when superimposed onto certain global motion patterns. By introducing changes to unseen visual stimuli *during* MIB, we demonstrate that object representations can be formed and updated even without conscious access to those objects. Such changes can then influence not only how stimuli reenter awareness, but also *what* reenters awareness. We demonstrate that this processing encompasses simple object representations and also several independent Gestalt grouping cues. We conclude that flexible visual parsing over time and visual change can occur even without conscious perception. Methodologically, we conclude that MIB may be an especially useful tool for studying the role of awareness in visual processing and vice versa.

Keywords: Visual perception; Motion-induced blindness; Gestalt grouping; Segmentation; Consciousness

1. Introduction

We perceive the world in terms of discrete objects and events, and their interactions. The raw input to visual processing, in contrast, consists of an undifferentiated array of features. Accordingly, a considerable amount of visual processing—and of research in vision science—focuses on the formation of object representations. This work has proceeded on many fronts, involving several types of segmentation and grouping cues (for recent reviews, see Kimchi, Behrmann, & Olson, 2003; Palmeri & Gauthier, 2004; Scholl, 2001). Despite this extensive literature, the underlying nature of segmentation and visual-object formation still remains unclear in several respects. One especially important issue is the role of conscious visual awareness in the formation of object representations (and vice versa). While some earlier work argued that unit formation via perceptual grouping cues required attention and awareness (e.g. Mack, Tang, Tuma, Kahn, & Rock, 1992; Rock, Linnet, Grant, & Mack, 1992), more recent work has demonstrated that in some cases grouping can occur even outside awareness (e.g. Chan & Chua, 2003; Driver, Davis, Russell, Turatto, & Freeman, 2001; Mack & Rock, 1998; Moore & Egeth, 1997).

In a recent study of inattentional blindness (Moore & Egeth, 1997), for example, observers had to compare the length of two lines which on each trial were

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superimposed onto a background of black and white discs (which were irrelevant to the task). On a 'critical trial' the discs of one luminance were arranged coherently around the lines to form the classic Ponzo or Müller-Lyer illusions. Observers reported no conscious awareness of the unexpectedly-coherent grouping, but the illusions nevertheless affected the line-length judgments, illustrating a type of grouping without awareness which still affected other aspects of conscious perception.

Inspired by the fact that real-world perception consists of a constantly shifting array of visual input, the experiments reported here explore a related question: can object representations not only be formed but also *updated* in the face of changing dynamic scenes without awareness? To our knowledge, no previous studies have addressed this question. Here we present not only unseen objects, but also unseen *changes* to these unseen objects, which fundamentally alter how the scenes are parsed—for example, connecting two objects into one, or splitting one into two outside of awareness. We thus ask not only whether object representations can be formed outside of awareness, but also whether representations can be *re-formed* and updated in response to unseen visual changes.

We ask these questions by exploiting motion-induced blindness (MIB), wherein salient (and even attended) objects fluctuate into and out of conscious awareness when superimposed onto certain global motion patterns (Bonneh, Cooperman, & Sagi, 2001). This phenomenon does not require any particular expectations, sudden disruptions, or attentional manipulations: instead, MIB gives rise to the striking phenomenology wherein you actually see objects fade away from awareness even while you are looking at them. Whereas previous studies have explored the underlying nature and causes of MIB (e.g. Bonneh et al., 2001; Carter & Pettigrew, 2003; Funk & Pettigrew, 2003; Graf, Adams, & Lages, 2002), here we simply exploit it as a tool for studying object representations. [1]

Two recent studies suggest that other types of visual processing occur during episodes of MIB. In one study, one of two gabor patches was physically removed after observers reported that both had faded from awareness. The remaining gabor, even though unseen, still produced orientation-specific adaptation effects (Montaser-Kouhsari, Moradi, Zandvakili, & Esteky, 2004). In another study, more salient objects were physically removed after perceptually disappearing during MIB. Surprisingly, such disappearances were still detected: in some cases, an image of the object momentarily flashed back into awareness, and this sudden burst of conscious access reflected small changes such as rotation that occurred outside of awareness (Mitroff & Scholl, in press).

In the current experiments, we ask whether a particularly important type of visual processing (the formation and updating of object representations) still occurs with a particularly critical type of visual change (to the underlying segmentation of the stimuli).

2. Experiment 1: Updating object representations

To study object updating during MIB, we utilize the fact that multiple objects tend to fluctuate into and out of awareness independently, whereas parts of a single object leave and reenter awareness together (Bonneh et al., 2001). We explore such differences using a particularly direct manipulation, involving *dumbbells*: based on previous work we expect (and actually find, as described below) that two discs will undergo MIB independently, but that two discs connected into a dumbbell—by a single-pixel line—will tend to undergo MIB together. The primary questions we then ask in this experiment are: (1) When a dumbbell disappears due to MIB, and the connecting line between the discs then physically fades away outside of awareness, will the two discs still reenter awareness together (see Fig. 1a)? (2) Similarly, when two discs eventually disappear perceptually due to MIB, and a connecting line between them physically fades in outside of awareness, will the two discs still reenter awareness independently (see Fig. 1b)?

2.1. Method

Five observers from neighboring laboratories participated. Stimuli were presented on a Macintosh iMac computer using custom software written with the VisionShell graphics libraries (Comtois, 2004). Viewing distance was approximately 40 cm but was unrestricted. The displays contained a central fixation point of two concentric white circles (0.89° and 0.45° in diameter), a grid of blue crosses (13.76° across) which continuously rotated counterclockwise at 470 deg/s, and a bright yellow target object (see Fig. 1). In the *shrinking block*, the target object began as a 'dumbbell'—two yellow discs (0.89° in diameter, 2.98° above fixation, with their centers 1.49° from the vertical midline) connected by a single pixel line. In the *growing block*, the target object was the same except the outermost 0.74° of each side of the line was not drawn, leaving an 'unconnected'

[1] MIB allows us to ask questions that other popular paradigms do not, and may thus prove to be an especially useful tool for studying dynamic aspects of visual awareness. Unlike repetition blindness (e.g. Kanwisher, 1987) and the attentional blink (e.g. Shapiro, Arnell, & Raymond, 1997), for example, MIB does not impose strict timing constraints: targets can remain present for extended periods of time, and undergo dynamic changes. Unlike change blindness (e.g. Rensink, 2002; Simons, 2000), MIB allows observers to indicate their awareness of particular attended objects which can disappear from awareness multiple times. And unlike inattentional blindness (e.g. Mack & Rock, 1998; Most, Scholl, Clifford, & Simons, in press), observers can be tested on more than a single critical trial.