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The path of least persistence: Object status mediates visual updating

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Abstract

On what basis does the visual system use recently sampled information to update existing representations of the world? One possibility is that representations are updated through an image-based point-for-point replacement process. An alternative possibility is that representations are updated on the basis of perceptually organized units that reflect objects in the scene rather than locations within the visual field. We report a new effect involving a modulation of visible persistence that seems to support this alternative possibility. In particular, we show that a moving stimulus leaves a visible trace of itself when it undergoes an abrupt and transient change in size but does not do so when the stimulus does not change. Further we show that this effect is substantially reduced when a scene-based reason for the abrupt change in size is provided (i.e., the object is shown to be passing behind an occluding surface that has a very small window in it through which the stimulus shows briefly). We suggest that the visible persistence in the face of change reflects a disruption of the normal updating process which is object-based and disrupted because of the discontinuity of the object. Providing a scene-based reason for the discontinuity allows the object representation to be maintained, and thus does not result in a disruption of the updating process.

Keywords: Visual updating; Object representations; Object files; Motion deblurring; Visible persistence

1. Introduction

The visual system samples information more-or-less continually. As a consequence it is faced with the problem of how to use newly sampled information to update existing representations of the world. One possibility is that representations are updated through a point-for-point image-based process, whereby each "pixel" of the representation is updated independently. Such a mechanism would, by definition, be blind to the organization of the scene, such as what objects are in the scene, where they are relative to each other, and whether or not they are moving. Alternatively, representations may be updated through an object-based process, such that the perceptual organization of the scene is taken into account, and changes to the representation are made only insofar as they are perceived as occurring to a particular object within the represented scene. The distinction between image-based and object-based updating is analogous to differences between pixel-based "paint" programs and object-based "draw" programs for computer graphics. In an image-based paint program, editing something on one object can inadvertently alter another object. In contrast for draw programs, objects are selected and edited independently. Objects other than the one that is selected are protected from changes that are made to the selected object, even if the two objects overlap each other in the image space.

Boundary conditions can be placed on likely answers to the question of how visual representations are updated, which differ depending on the level of representation in question. At one extreme is the registration of new light information on the array of photoreceptors in the retina; here updating is almost certainly image based. At another extreme is the registration of changes to long-term representations like changes in the appearance of a friend whom you are seeing for the first time in many years; here,

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updating is almost certainly object based. For dynamic online vision like viewing a ball roll across the floor and pass behind a table leg, however, the answer is less obvious.

Image-based solutions are appealing because they can be computationally simple and because they can be implemented easily within models that embody the retinotopic registration of information in different brain areas. The theoretical appeal of image-based updating is evidenced by the fact that it has been incorporated into many models of visual processing, ranging from those concerned with perceptual interference between stimuli (e.g., Breitmeyer & Ganz, 1976; Breitmeyer, Ro, & Ogmen, 2004; Growney, Weisstein, & Cox, 1977; Keysers & Perrett, 2002; Kovacs, Vogels, & Orban, 1995; Scheerer, 1973; Spencer & Shuntich, 1970), perceptual integration over time (e.g., Coltheart, 1980; Di Lollo, 1980), spatial attention (e.g., Eriksen & St-James, 1986; Posner, 1980), object recognition and visual memory (e.g., Logan, 1988; Tarr & Bülthoff, 1998), and within models of *motion deblurring*, the apparent reduction of visible persistence that accompanies objects in motion (Anderson & van Essen, 1987; Hammett, Georgeson, & Gorea, 1998).

Despite the appeal of image-based updating, this alternative would carry considerable cost for later, higher-order processing. Because such updating would occur without regard to the organization of the scene in terms of surfaces and objects, many important distinctions would be lost with each resampling cycle. Image-based updating would fail, for example, to maintain region assignments to figure vs. ground, edge assignments to luminance change vs. surface orientation, as well as associations between discontinuous regions of a surface caused by occlusion. Given the importance of organized representations for disambiguating the retinal image, image-based updating cannot be the only solution to the problem of representational updating within the visual system.

Here, we report evidence that even at apparently early levels of representation, visual representations are updated on the basis of the perceived organization of the scene, a process we call *object-mediated updating*. The general idea is that, if currently sampled information is perceived as deriving from an object that is already represented in the scene, then it will be used to update that object representation. In contrast, if it is perceived as deriving from a different object, then the original object representation will be 'spared' from updating and will remain unchanged in the face of new sensory information. Finally, if the information is perceived as deriving from a new object, then it may elicit the establishment of a new component object of the represented scene. Notice that in any given sampling cycle, an old object could be in a new location and a new object could be in a location where an old object had been before. In this way, object-mediated updating is dissociable from image-based updating.

Evidence for object-mediated updating derives in part from an effect called *change-related persistence*. The basic phenomenon was reported by Moore and Enns (2004) and is illustrated in Fig. 1a. When a moving stimulus undergoes an abrupt change in some attribute, such as size, it can cause the perception of two objects, leading to the simultaneous appearance of the original, unchanged object and the changed object (a demonstration is available at http://viplab.psych.psu.edu/cathleen/demos.htm). We interpret this effect as indicating that the abrupt change was too great for the perceptual system to tolerate as having occurred within a single object over the given period of time. To accommodate the abrupt change, therefore, a new object representation is established. Because the new object is different from the original, the representation of the new object is spared from updating (i.e., it is not

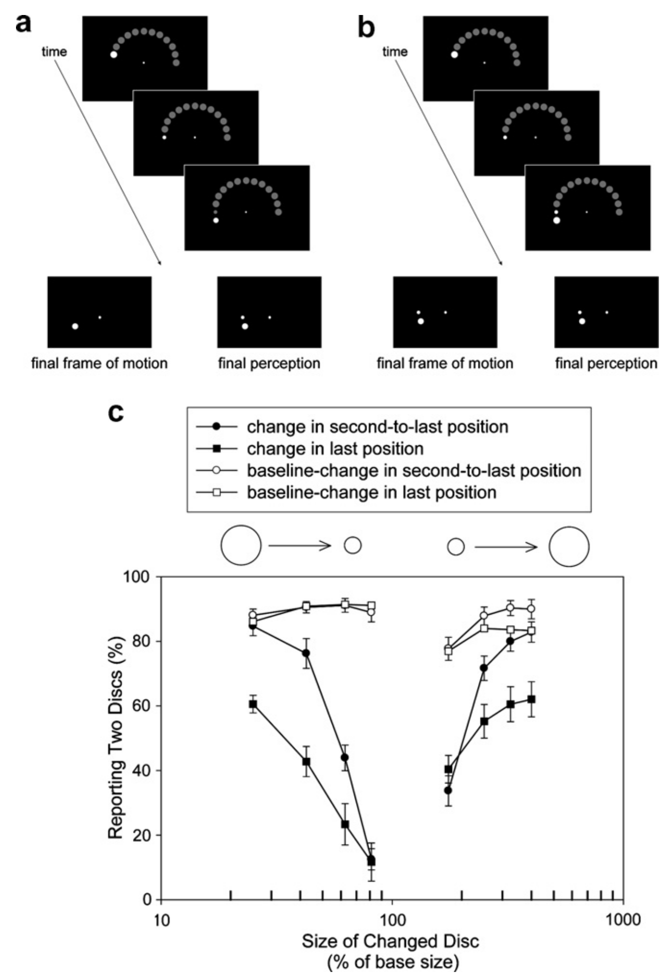

Fig. 1. (a) Illustration of change displays in Experiment 1. Observers fixated the central fixation dot. (b) Illustration of baseline displays in Experiment 1. (c) Data from Experiment 1 for the small-to-large group (left) and large-to-small group (right) separately. Error bars indicate the standard error of the means. Change-related persistence is reflected in the difference between the filled symbols and the corresponding open symbols. The conditions in which they are closer together (i.e., the conditions of greater size change), shows that observers were more likely to report having seen two discs when there was only one present (filled symbol). For those conditions in which the filled and corresponding open symbols are the same, it indicates that observers could not distinguish between the illusory presence of two discs (filled symbol) and the physical presence of two discs (open symbol).