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Brief article

Object representations maintain attentional control settings across space and time

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A R T I C L E I N F O

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A B S T R A C T

Previous research has revealed that we create and maintain mental representations for perceived objects on the basis of their spatiotemporal continuity. An important question is what type of information can be maintained within these so-called object files. We provide evidence that object files retain specific attentional control settings for items presented inside the object, even when it disappears from vision. The objects were entire visual search displays consisting of multiple items moving into and out of view. It was demonstrated that search was speeded when the search target position was repeated from trial to trial, but especially so when spatiotemporal continuity suggested that the entire display was the same object. We conclude that complete spatial attentional biases can be stored in an object file.

1. Introduction

Visual attention is the mechanism by which we select relevant information from a rich visual world. Evidence so far indicates that attention can be directed not only to specific locations (Posner, Snyder, & Davidson, 1980) or features (e.g. Wolfe, 1994), but also to entire objects (see Scholl (2001), for a review). In most of the classic studies on object-based selection, objects were presented abruptly on the screen and, either after a set time or after a response, disappeared instantly. Researchers then assume that each trial provides an independent performance measurement of the condition at hand. In the real world, objects often behave quite differently. Rather than covering a well-defined instance in time, objects typically appear and disappear gradually (e.g. by occlusion, moving in and out of the periphery, or looming). In other words, objects have a history across space and time. The present study investigates the effect of this spatiotemporal history of an object on the attentional selection settings applied to that object. More specifically, it addresses the question as to whether an object representation includes the way in which attention has previously treated that object, and whether this information is then preserved across space and time, even when an object temporarily disappears from vision.

Theorists have argued that for an object representation to be preserved across space and time, some type of indexing or tokenization of objects is necessary (e.g. Pylyshyn, 2001). A token is an episodic representation that allows the observer to refer to "*that* object, *then* and *there*" and thus to track it across space and time (Pylyshyn & Storm, 1988). Kahneman, Treisman, and Burkell (1983) referred to such temporary episodic representations as *object files*. Evidence for object files comes from the object reviewing paradigm (Kahneman, Treisman, & Gibbs, 1992), in which observers typically are presented with a preview of two objects, each containing a letter. The letters disappear and the objects then move to a new position, after which one of the initial letters re-emerges in either one of the objects. The task is to identify the letter. Identification is speeded when the target letter emerges in the same object as it did before, even though this object has now changed position. This effect was referred to as "the object-specific preview benefit", and we refer to it here as the *same object benefit*.

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An important question is what information about an object is maintained across space and time. In other words, what properties are bound to an object file or index? Pylyshyn and co-workers (Pylyshyn, 2001) have argued that indexes are primitive and preconceptual, and should thus contain little information on specific object features, as long as spatiotemporal continuity is preserved (see also Mitroff & Alvarez, 2007). However, Flombaum and Scholl (2006) demonstrated that, when a moving object is briefly occluded by another display element, a change to the object's color or shape is better detected when the object moves in a spatiotemporally coherent fashion, suggesting a link between spatiotemporal and object feature representations. In addition, the same object benefit in the classic object file studies imply that information about the identity of the response feature (the letter inside the object) must have been preserved across the object's translation (Gordon & Irwin, 1996, 2000; Kahneman et al., 1992).

In the present study, we investigate the possibility that entire attentional selection settings as applied to a specific object are maintained in its mental representation. Imagine the case when only a part of an object is relevant to an observer, for example the door handle when approaching one's car, or one's favorite flavor when presented with a tray of different tea bags. If a certain part or feature of an object has been selected before, do these selection settings then survive with the object across subsequent spatiotemporal changes, and affect attention later on? So far, this question has been largely unexplored. Object reviewing studies have typically used displays with only a single response-related feature inside the specified target object. This means that there was no competition for selection in these displays, and hence no way of testing whether specific selection settings were preserved with the object. In fact, in many object reviewing studies the previewed and target-defining features were identical to the response features, such that same object benefits may have been response-based rather than perceptual in nature (although this was certainly not the case for all object file studies, see Kruschke & Fragassi, 1996; Noles, Scholl, & Mitroff, 2005).

In our experiment, the objects of interest consisted of entire visual search displays containing more than one item, but only one target. Thus, there was competition between multiple elements within the object, and hence the need for selection (of the search target). Fig. 1 illustrates the procedure. Within a trial, one of two search displays gradually emerged from behind one of four walls on each side of the screen, and, after response, moved back to a random unoccupied location behind one of the walls. Crucially, the search display could emerge from the same side as it disappeared to on the previous trial and would thus constitute the same object in terms of spatiotemporal continuity, or it could come from a different side and would thus constitute a different object. A potential *same object benefit* on selection was then measured through repeating the target position. Following the object reviewing logic, if observers selected a certain location within a search display on trial n, they may be inclined to select the same location again on trial $n + 1$, especially so if the search display is perceived as being the same object as before. If so, intertrial repetitions of the target location should result in greater performance benefits when the spatiotemporal dynamics suggest that the search display is the same object as that appeared the trial before.

The rationale for this manipulation was inspired by Yi et al. (2008). They asked participants to respond to particular faces while measuring fMRI activity in the fusiform face area (FFA). The faces appeared from pillars on either side of the screen. They found that if the same face was repeated from one trial to the next, FFA activity was reduced, in line with general habituation effects. The important finding was that this reduction was greater when the repeated face appeared from behind the pillar where it had disappeared on the previous trial. In other words, FFA activity was modulated by the spatiotemporal history of

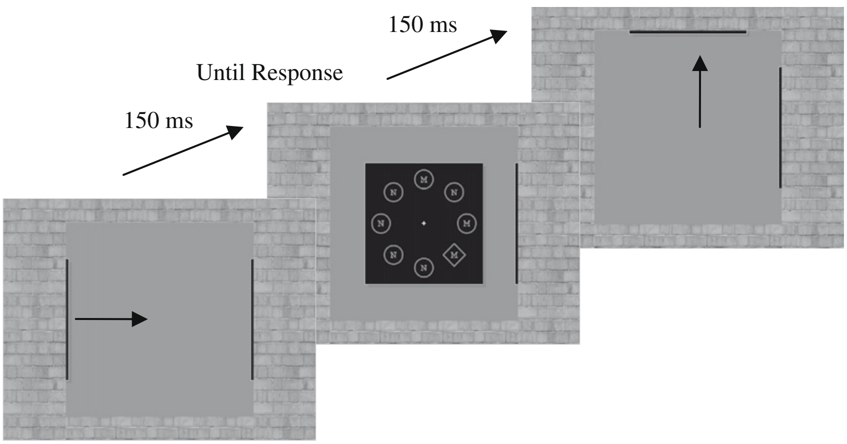

Fig. 1. Example of stimulus display for a typical trial in Experiment 1. For printing purposes, these images were converted to black and white, but the walls were brick-colored and the search elements were green or red. A typical trial started with a screen with both search displays hidden behind the walls for 1000 ms. Then, over a time course of 150 ms, one of the search displays slid to the center of the screen, and with this exposed the search array. Participants were to report the identity of the letter in the diamond shape. When the participant had given a response, the search display shifted back behind one of the unoccupied walls (within another 150 ms).