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Exploring the relationship between object realism and object-based attention effects

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ABSTRACT

Visual attention prioritizes processing of locations in space, and evidence also suggests that the benefits of attention can be shaped by the presence of objects (object-based attention). However, the prevalence of object-based attention effects has been called into question recently by evidence from a large-sampled study employing classic attention paradigms (Pilz et al., 2012). We conducted two experiments to explore factors that might determine when and if object-based attention effects are observed, focusing on the degree to which the concreteness and realism of objects might contribute to these effects. We adapted the classic attention paradigm first reported by Egly, Driver, and Rafal (1994) by replacing abstract bar stimuli in some conditions with objects that were more concrete and familiar to participants: items of silverware. Furthermore, we varied the realism of these items of silverware, presenting either cartoon versions or photo-realistic versions. Contrary to predictions, increased realism did not increase the size of object-based effects. In fact, no clear object-based effects were observed in either experiment, consistent with previous failures to replicate these effects in similar paradigms. While object-based attention may exist, and may have important influences on how we parse the visual world, these and other findings suggest that the two-object paradigm typically relied upon to study object-based effects may not be the best paradigm to investigate these issues.

The dynamic visual environments we navigate everyday contain far too much information for our visual system to process fully at any one moment. Mechanisms of visual attention help to ensure that relevant objects and events receive prioritized access to visual processing resources while task-irrelevant, distracting information is processed minimally. A major goal of attention research has been to uncover the visual and cognitive factors that control the movement of attention during search, scene viewing, and other goal-directed behaviors (e.g., Carrasco, 2011; Evans et al., 2011; Theeuwes, 2010). However, a more fundamental question is the level at which attentional selection operates. That is, when information is selected in a scene for prioritized processing, is it selected solely based on the location of that information in space (e.g., pure X, Y coordinates of an image)? Or does selection take into account that our goals are often related to our interactions with objects? If so, there should be evidence that when a cue draws attention to an object, facilitation spreads within that object's boundaries (see Chen, 2012 for review).

Classic findings in the attention literature suggest that in some situations selection can indeed be object-based. For example, Egly, Driver, and Rafal (1994) created a target detection task in which two objects (either horizontally or vertically arranged rectangles on either side of a fixation cross) were displayed on screen. Participants pushed a button as soon as a target stimulus appeared at either end of the two rectangles. A non-predictive cue preceded the target display and could occur at the same location as the upcoming target, within the same object (but at a different location), or within the non-cued object. Reaction times were fastest when the cue appeared at the same location as the upcoming target (Valid trial). This benefit represents a space-based effect. However, when the cue was invalid, response times were still faster when the target appeared within the same object as the cue but at a different location within the object (Invalid-Same), compared to when the target and cue appeared within different objects (Invalid-Different). This benefit is assumed to represent an object-based attention effect. When an object is cued, the attentional facilitation associated with the cue spreads throughout that object.

While a number of object-based effects can be found in the literature (e.g., Brown & Denney, 2007; Duncan, 1984; Hollingworth, Maxcey-Richard, & Vecera, 2012; Kramer & Jacobson, 1991; Marino & Scholl, 2005; Shapiro, Hillstrom, & Husain, 2000; Zhang & Fang, 2012), it should be noted that object effects are not always robust and may depend on how attention is cued, the shape of the objects cued, strategic influences, and trial history (Avrahami, 1999; Cepeda & Kramer, 1999; Davis & Holmes, 2005; Lee, Mozer, Kramer, & Vecera, 2012; Macquistan, 1997). A particularly notable failure to observe object-based effects, presented by Pilz, Roggeveen, Creighton, Bennett,

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and Sekuler (2012), used a modified version of the Egly, Driver and Rafal paradigm. For both a detection task in which participants made a speeded response to a letter (irrespective of its identity) and for a discrimination task in which participant's made a speeded identification of a letter (T or L), no overall object-based effects were observed (though a robust space-based effect was observed in each case). One experiment included one hundred and twenty participants and was powered to detect even a small object-based effect. Of particular note, the authors looked at whether each participant reliably demonstrated a space or object-based cuing effect. At the participant level, almost all participants demonstrated space-based effects that were significant. In contrast, about 5% of participants demonstrated a significant object-based effect, and about 3% of participants demonstrated an *anti*-object effect.

Pilz et al. (2012) found no overall object-based effect. However, in some conditions the two rectangles in the display were arranged horizontally and in some conditions they were arranged vertically. Response times were consistent with an object-based effect only in the horizontal conditions, which they explain by attention being more easily allocated along the horizontal meridian (across the vertical meridian), and note the consistency of this pattern with similar findings in the visual search and change blindness literatures (e.g., Carrasco, Talgar, & Cameron, 2001; Mackeben, 1999; Tse, Sheinberg, & Logothetis, 2003). If attention is more easily allocated along the horizontal meridian, then this should result in an apparent "anti-object" effect when the two objects in the display are presented vertically, with one object to the left and right of fixation. This is exactly what was found in Experiment 1 (discrimination task) and Experiment 2 of the studies reported by Pilz et al. (significantly faster RTs on Invalid-Different trials compared to Invalid-Same trials). Rather than interpret effects in the horizontal object conditions as the result of object-based attention, in light of the observed anti-object effects in the vertical object conditions, Pilz and colleagues solely attributed effects to the increased ease with which attention can be shifted along the horizontal meridian.

Using the two-object paradigm, some studies appear to find significant object-based effects and some studies do not. What could moderate this effect? We propose that the concreteness and realism of objects depicted in the display may play an important role. Rather than abstract bar-shaped stimuli, displays in the experiments reported here sometimes featured cartoon-like or photorealistic depictions of silverware. The motivation for our chosen manipulation and choice of stimuli was shaped by several factors. (1) The visual system evolved to recognize and interact with concrete, 3D, and often familiar objects rather than 2D, abstract bar stimuli. We propose that since the visual system evolved to process real-world objects, evidence for object-based attentional selection is most likely to be observed when observers view more realistic objects. (2) Hollingworth et al. (2012) reported particularly robust object-based effects in studies featuring displays in which shaded 3D objects (tubes) were presented to participants. Their motivation for the use of these stimuli was based on the assumption that 3D cues would encourage object-based attention by helping to segment objects from the background and from one another. Similarly, Atchley and Kramer (2001) presented participants with displays containing 3D pipes and multiple depth cues and found large object-based effect. (3) We also reasoned that most of our participants would likely have had interactions with silverware almost daily for many years. Top-down representations associated with these every day interactions should, in a way similar to pictorial cues, help facilitate their distinctness from the background and each other (e.g., see Bravo & Farid, 2003; Eger, Henson, Driver, & Dolan, 2007; for evidence of top-down facilitation of object perception and segmentation). It should be noted that Pilz et al. (2012) did not observe object-effects using wrench-like objects as stimuli. However, these flat, 2D, cartoon-like representations lacking shading and photorealism still differed significantly from the 3D objects most participants might have been accustomed to interacting with, and from the types of 3D objects the visual system evolved to process. This led to the prediction that as the number of pictorial cues in the display increased suggesting that objects depicted concrete, real objects, object-based attention effects would be more likely to be observed. Of primary interest is whether object-based effects replicate, and whether object-based effects increase with the realism and concreteness of objects.

1. Experiment 1

1.1. Methods

1.1.1. Participants

One hundred and thirty-four undergraduate students with self-reported normal or corrected-to-normal vision at Florida State University participated in exchange for course credit. This sample had an average age of 19 years ($SD = 1.31$).

1.1.2. Materials

A PsychoPy (v 1.76; Peirce, 2007) program presented stimuli on a 19-inch color monitor (1024×768 resolution) and response latency and accuracy were collected using a standard keyboard. For the photorealistic condition, a digital photograph was taken of a spoon with a Canon T1i DSLR camera. The image of the spoon was then trimmed away from the background and de-saturated to remove any color. For the vector condition, this image was imported into Adobe Illustrator CS5 and a proportional vector image was created using the pen tool. A gradient was then applied to the vector image, mimicking the black and white shading from the photo. For the rectangular bar condition, a rectangle with the same shading as the vector spoon was created in Adobe Illustrator, with the width equal to the handle of the spoon at its thickest point (5.3°), and a height matching the height of the photo (22.6°). For more explanation of the varying degrees of realism, refer to Fig. 1. Note that Experiment 1 presented displays containing two spoons, while Experiment 2 presented participants with displays of one spoon and one fork.

Displays contained two parallel objects that were arranged either vertically or horizontally, with 18.6° between each cue/target location (except when the cue and target were diagonal — Fig. 2). This resulted in a perfect square (18.6° × 18.6°) connecting the four possible cue/target locations, meaning that the distance between the cue and the target in the Invalid-Same and Invalid-Different conditions was equidistant. These objects were present throughout the entire trial and never disappeared (i.e., no blank screen was inserted between trials, objects were always visible). The cue for this experiment was a red square (RGB: 255, 0, 0) appearing at one of four locations at the end of one of the objects in the display. The target letter was a T or L, with a font color of cyan (RGB: 0, 255, 255). The target letter measured 1.6° and the cue measured 1.9°.

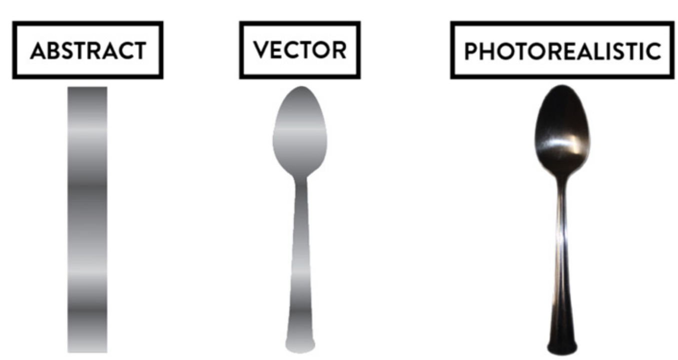

Fig. 1. Abstract, vector, and photorealistic objects used in Experiment 1.