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# Action influences figure–ground assignment

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Our ability to segregate objects from one another in a scene is a fundamental perceptual mechanism. Central to this process is figure–ground assignment, or the segregation of candidate objects from their backgrounds. Although hierarchical models of vision (e.g., Julesz, 1984; Pylyshyn, 1999) posit that figure–ground assignment occurs prior to higher level visual processing such as focal attention, a recent study demonstrated that attention can influence which regions of a scene are assigned figural status (Vecera, Flevaris, & Filapek, 2004). As a result, it has been posited that figure–ground segregation is an interactive process, in which both bottom-up and top-down cues compete to bias which items in a scene are perceived as figures and grounds (Vecera et al., 2004; Vecera & O'Reilly, 1998).

Such an interactive account raises the possibility that other high-level factors can influence figure–ground segregation. Specifically, it is possible that *acting* upon an object can increase the likelihood that it will be assigned figural status. In other words, action may act as a cue to figure–ground assignment. Such a possibility is suggested by the presence of populations of bimodal visuotactile neurons that respond exclusively to tactile and visual

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stimulation in peripersonal space around the hand (di Pelligrino, Làdavas, & Farnè, 1997; Graziano & Gross, 1993). It has been posited that such bimodal representations are responsible for integrating visual and tactile space, supporting the control of reaching/grasping and visual processing of objects near the hand (Làdavas, di Pellegrino, Farnè, & Zeloni, 1998; Reed, Grubb, & Steele, 2006). It is possible that the presence of such bimodal representations may complement the unimodal visual representations provided by early visual processing, and as a result may have the effect of biasing or strengthening perceptual processing of objects near the hand. The focus of the current study was to determine whether such bimodal representations exert an effect on figure–ground assignment, a process typically thought to rely on preattentive, unimodal visual processing.

## EXPERIMENT 1

Twenty-four observers performed a figure-memory task in which they viewed ambiguous figure–ground displays and then performed a matching task where they were asked which of two probe regions matched one presented in the initial display (see Vecera et al., 2004; Figure 1a). A visual anchor, either the observer's hand or a wooden dowel (manipulated between subjects), was present in one region of the bipartite display allowing us to compare the effects of actively reaching towards one region of the display with those of simply having a visual anchor present in one region.

Critically, on half of the trials the matching probe region had contained the visual anchor during the presentation of the figure–ground display. If reaching towards an object increases its likelihood of being seen as figure, we would expect faster RTs to matching probes that had contained the hand during presentation of the figure–ground display. Participants were told anchor position would not predict which region would be tested, and were told to focus on the contour at fixation to maximize their ability to recognize the shape of the matching region during the memory task. Eye position was monitored to ensure that observers did not preferentially fixate either region of the display.

Analyses revealed a significant interaction between anchor type (hand vs. dowel) and region probed (anchor present vs. anchor absent), $F(1, 22) = 5.9$, $p = .03$. Planned comparisons showed that the interaction was driven by significantly faster reaction times in the "hand" anchor condition when the probe matched the region containing the observer's hand, $t(11) = 2.7$, $p = .02$, whereas there was no such difference in the dowel anchor condition, $t(11) = 0.38$, $p = .90$ (see Figure 1c). Neither main effect was significant, all $F$s $< 1.8$, $p$s $< .22$. Analyses of accuracy data revealed no significant main effects or interactions, all $F$s $< 1$, $p$s $> .73$. Thus, it appears that when
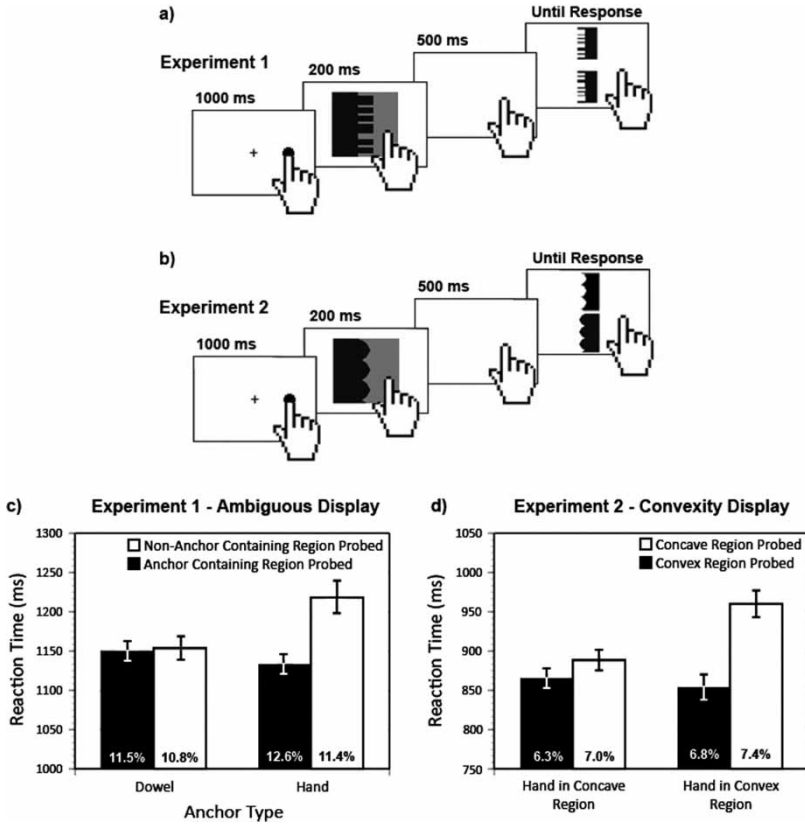
**Figure 1.** Task sequence and reaction time data. (a) Trial sequence for Experiment 1. (b) Trial sequence for Experiment 2. (c) Mean reaction times to probe trials in Experiment 1. (d) Mean reaction times to probe trials in Experiment 2. Error bars represent 95% confidence intervals, and error rates are present in white at the base of each bar.

image-based cues to figure–ground assignment are absent, the presence of an observer's outstretched hand influences figure–ground assignment.

# EXPERIMENT 2

A follow-up experiment was performed with 12 new participants to examine whether the position of an observer's hand can compete with image-based, configural cues to figure–ground assignment when both are present in a scene. This experiment was identical to Experiment 1, but instead of using ambiguous figure–ground displays we used displays with strong convexity cues known to influence figural assignment (Kanisza & Gerbino, 1976; see Figure 1b). Typically, when observers view such displays they are more likely

to see the convex region as figure. Participants were asked to place their outstretched hand into either the convex figure or the concave ground on a given trial, allowing us to see whether the presence of a hand in a region could compete with a strong image-based cue to figure–ground assignment.

Analyses revealed a significant main effect of region probed (convex vs. concave), $F(1, 11) = 14.9$, $p = .001$, with participants responding faster overall to convex probes. Critically, we also observed a significant interaction between hand region (convex vs. concave) and region probed, $F(1, 11) = 4.9$, $p = .04$. As can be seen in Figure 1b, the difference in RTs to convex and concave probes was reduced when the hand was placed in the concave region of the display, indicating that this region was better able to compete for figural status when an observer's hand was located within it. The main effect of hand region was not significant, $F(1, 11) = 3.2$, $p = .10$ (Figure 1d). Analyses revealed no significant main effects or interactions in the accuracy data, $Fs < 1$, $ps > .65$.

## DISCUSSION

Our results suggest that bimodal neural representations can act as a cue to figure–ground assignment, interacting with image-based cues to bias the assignment of figural status to regions near the hand. The fact that objects of action are more likely to be perceived as figures suggests that other early visual processes may also be influenced by action, and that neural systems involved in the bimodal visuotactile representation of scenes can exert effects on unimodal perceptual processing.

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# Controlling stimulus variability reveals stronger face-selective responses near the average face

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The past decade of fMRI research has identified face-selective regions in the human ventral stream that respond more strongly when people observe faces than other objects and are thought to be critically involved in face perception and recognition (Grill-Spector, Knouf, & Kanwisher, 2004; Kanwisher, McDermott, & Chun, 1997). However, the underlying neural representations that subserve humans' remarkable ability to recognize thousands of individual faces are not well understood. A basic question is whether responses in face-selective regions increase or decrease as faces deviate from the average face. In one view, face-selective neural responses are anchored on the average (or mean) face, suggesting responses should increase as faces deviate from the mean face in particular directions (or angles) away from the mean (Leopold, Bondar, & Giese, 2006; Loffler, Yourganov, Wilkinson, & Wilson, 2005). An alternative view posits that neurons are tuned to particular stored exemplar faces, and responses decrease as faces deviate from the preferred face exemplar. Because the distribution of faces is thought to be centrally dense, the latter view predicts higher responses near the mean face. Electrophysiological and fMRI research shows that responses are reduced, or adapted (Grill-Spector et al., 1999; Li, Miller, & Desimone, 1993) to repetitions of similar faces, and thus assessing the strength of responses to faces blocked by their distance from the mean requires the control of stimulus variability within each block. Here, we use a parameterized space of face silhouettes (Davidenko, 2007) and high-resolution fMRI (HR-fMRI) to measure responses in face- and object-selective regions as we manipulate distance from the mean face and control in two ways the variability of stimuli at each distance from the mean.

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