Journal Club

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Strategic Control of Attention to Objects and Locations

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Review of Martinez et al. (http://www.jneurosci.org/cgi/content/full/27/30/7963)

Humans have a highly developed expertise to selectively process sensory input that is relevant to their goals, an ability known as attention. Visual attention to spatial locations modulates the activity of retinotopically organized neurons within visual cortex. However, attention can also be allocated selectively to relevant objects, even when they are superimposed with irrelevant objects. Object-based attention yields a behavioral and neural advantage when discriminating between parts of the same object versus parts of different objects. This same-object advantage is found even when distances between relevant parts are equated. Because locations and objects are more or less relevant depending on one's current goals, it is important to examine how and when processing resources are allocated to these different types of information. In their recent *The Journal of Neuroscience* paper, Martinez et al. (2007) provide a window into the temporal profiles and the functional neuroanatomical correlates of space-based and object-based attention. They measured event-related potentials (ERPs), two components of which index attention: the P1 component (a positive deflection 80–130 ms after stimulus presentation) and the N1 component (a negative deflection 150–200 ms after stimulus presentation).

Subjects fixated the center of a display containing either a whole square [intact-object (IO) condition] or a square fragmented into four rectangles [fragmented-object (FO) condition] [Martinez et al. (2007), their Fig. 1 (http://www.jneurosci.org/cgi/content/full/27/30/7963/F1)]. A central arrow cued one of the four outermost corners of the display throughout each 20 s block. A target (convex) or nontarget (concave) corner offset appeared for 100 ms at a randomly chosen outermost corner every 400–600 ms, with a target/nontarget ratio of 1:4. Importantly, subjects were instructed to respond only to convex offsets that appeared at the cued location.

Subjects correctly discriminated >90% of cued targets, suggesting that they successfully attended to the cued location when stimuli appeared there. Additionally, neither accuracy nor reaction time differed by object configuration (presumably because subjects were instructed not to respond to uncued stimuli). A small false alarm rate did not vary by condition (A. Martinez, personal communication).

Martinez et al. (2007) predicted a same-object neural advantage such that uncued stimuli would evoke larger neural responses in the IO condition than in the FO condition, because only in the IO condition did uncued stimuli occur on an object having a cued corner. This prediction was borne out in the N1 component: cued, uncued IO, and uncued FO stimuli evoked the largest, medium, and smallest amplitudes, respectively. The amplitude difference between IO and FO conditions indicates that, even when it is irrelevant, object information can guide the allocation of processing resources. Meanwhile, the amplitude difference between cued and uncued stimuli reflects a concurrent space-based attentional modulation. However, the earlier P1 component indicated a purely space-based modulation: cued stimuli evoked the largest amplitude, but there was no effect of object configuration [Martinez et al. (2007), their Fig. 3 (http://www.jneurosci.org/cgi/content/full/27/30/7963/F3)]. Accordingly, Martinez et al. (2007) concluded that "spatially mediated selection began earlier than the object-selective effects."

N1-component source analysis localized a combined object-based and space-based attentional modulation of neural activity to the lateral occipital complex (LOC) contralateral to the offset-stimulus hemifield. In a separate fMRI experiment, the authors found that a region near LOC was the only area reflecting both space-based and object-based attentional modulation in their paradigm [Martinez et al. (2007), their Fig. 5 (http://www.jneurosci.org/cgi/content/full/27/30/7963/F5)]. These are intriguing findings because LOC is thought to be one of the first points in the ventral visual processing stream where object representations are formed; thus, it is a prime candidate for the confluence of space-based and object-based selection mechanisms. However, as mentioned above, the ERP analysis indicated that space-based attentional modulation (which might have been driven by a

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source outside of LOC) began before object-based modulation in LOC.

The difference between ERP amplitudes to cued and uncued stimuli observed in both the P1 and N1 components reflects a space-based allocation of attention. Unlike most object-based attention paradigms, however, subjects were instructed not to respond to stimuli appearing at uncued locations. As a result, subjects should have been especially motivated to ignore stimuli appearing at any uncued location and, thus, to focus attention very narrowly at the cued location. Nevertheless, the difference in ERP amplitude between IO and FO conditions reflects a persistent same-object neural advantage.

The prevailing view of object-based selection (Vecera and Farah, 1994) is that when attention is directed to a location on an object, all points on that object gain attentional priority. However, the data of Martinez et al. (2007) are also consistent with an alternative hypothesis that subjects have flexible, albeit limited, control over the degree to which object information in the visual environment is permitted to guide attention. For instance, one may be able to bias neural resources toward the processing of locations over objects. In the task used by Martinez et al. (2007), because only one location was relevant in each trial block, subjects may have suppressed object processing while attending to the cued location. This account is consistent with the proposal that P1 indexes visual suppression (Luck, 1995) and would explain both the space-based attentional modulation and the lack of object-based attentional modulation in LOC immediately after stimulus presentation.

However, a failure to prevent the influence of objects on attentional allocation could arise from salient changes in object information (e.g., when a new object appears) and/or from momentary loss of attentional control [e.g., when attention is captured by a sudden onset (Yantis and Hillstrom, 1994)]. In Martinez et al.'s (2007) study, attention may have been captured when a stimulus appeared at an uncued location because the subject anticipated a sudden-offset target (possibly consistent with the observation of false alarms). This momentary loss of attentional control could have provided an opportunity for object processing to subsequently receive neural resources that were previously withheld. It is also possible that because the particular target and nontarget stimuli used in this study changed the shape of the object on which they appeared, a new object representation might have been formed after corner offset. This object representation could have modulated the top-down, space-based attentional bias toward the cued location. Moreover, the same-object neural advantage may have arisen during the N1 time period because the newly formed object representation encompassed the cued location in the IO condition only. Conversely, in the FO condition, the newly formed object representation did not overlap the cued location, resulting in an attenuation of the N1 component. Thus, the combined effects of voluntary space-based attention and failed suppression of object processing might underlie the N1 modulations observed in LOC.

The particular hypothesis outlined above is predicated on our general notion of voluntary control over the influence of object representations on visual attention. The delayed object-based attentional modulation of LOC activity in the face of persistent objects suggests that humans can filter out objects, or isolate object representations from space-based attentional selection processes, when those objects are not relevant to current goals. Consistent with this possibility, recent studies have shown that 100% valid cues indicating the location of a target appearing within an object eliminate the same-object behavioral advantage (Shomstein and Yantis, 2002; Greenberg et al., 2006). Future studies will contribute to a better understanding of how attention is flexibly allocated to objects and locations as a function of one's goals, motivation, and environment.

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