



Editorial: Beyond Space-Based or Feature-Based Selection: Mechanisms of Object-Based Attention

Vivian M. Ciaramitaro^{1*} and Gene R. Stoner²

¹ Department of Psychology, University of Massachusetts Boston, Boston, MA, USA, ² The Vision Center Laboratory, Salk Institute for Biological Studies, Systems Neuroscience, La Jolla, CA, USA

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Editorial on the Research Topic

Beyond Space-Based or Feature-Based Selection: Mechanisms of Object-Based Attention

Our senses are constantly bombarded by an overwhelming amount of information, yet, our brain has a limited computational capacity and can fully process only a small fraction of that information at any given time. By selectively attending to information we overcome this limited capacity, prioritizing the processing of behaviorally relevant sensory information to the detriment of behaviorally irrelevant sensory information.

Mechanisms underlying attentional selection and the prioritization of select locations in space or select features, such as visual color or motion, have been investigated in considerable detail (e.g., Carrasco, 2011). Our perceptual experience, however, is not one of disjoint features at disparate spatial locations, but of unified representations, objects, which can serve as the goal of our actions. Relative to our understanding of space- and feature-based selection, much less is known regarding object-based selection (see Chen, 2012 for review). In object-based selection, the object is the unit of selection such that if one feature of an object is attended, other task irrelevant features of that object are also prioritized (e.g., Duncan, 1984; O'Craven et al., 1999). How object-based mechanisms might differ from other forms of feature-based selection is poorly understood. For example, in global feature-based attention, selecting a feature prioritizes processing of this feature across the visual field, irrespective of location (e.g., Boynton et al., 2006; Liu and Mance, 2011; reviewed in Treue and Martinez-Trujillo, 2007).

The definition of a perceptual object has long been the focus of both philosophical and empirical inquiry. Our ability to perceive visual objects is present from early in development (e.g., Spelke, 1990; Leslie et al., 1998 offers a comparison of the object concept in development and object-based attention). Our perception of objects is, in part, based on mechanisms of perceptual grouping, such as Gestalt principles, and attention can be, in turn, influenced by this grouping (e.g., Harms and Bundesen, 1983; Driver and Baylis, 1989; Kramer and Jacobson, 1991; Baylis and Driver, 1992).

One fundamental question is whether or not attention does automatically spread across all features and locations delineated by object boundaries. Given that the spreading of attention across an entire object may not always be optimal and may not be mandatory, another fundamental question is how subsets of an object might be prioritized and enhanced, while task-irrelevant subsets of an object might be suppressed. Whereas, some studies have considered a more "pure" form of object-based selection, trying to control for the confounds of space- or feature-based selection (e.g., Mitchell et al., 2003, 2004; Ciaramitaro et al., 2011), other studies have focused on how space- or feature-based selection are constrained by objecthood (e.g., Shomstein and Yantis, 2004; Shomstein and Behrmann, 2008).

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Elizabeth B. Torres,
Rutgers University, USA

*Correspondence:

Vivian M. Ciaramitaro
vivian.ciaramitaro@umb.edu

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Several of the contributions to our research topic consider the diverse factors that can influence the allocation of attention within and between visual objects. *Spatial uncertainty* can play a role in re-allocating spatial attention within object boundaries. To decouple the influence of space- and object-based attention, Drummond and Shomstein present a cue with either high or low certainty within an object and sample behavior at several time points following cue presentation. They find that as spatial uncertainty decreases, spatial information guides selection and objects are filtered out. *Reward history* can also determine the allocation of attention. Sali et al. find that inconsistent vs. consistent rewarding based on a feature, such as color, can bias which of multiple objects are attended. *Behavioral relevance* also plays a role. Lim and Sinnett study *attention set*, a proxy for behavioral relevance, and find that the influence of a peripheral cue on a central task varies depending on whether peripheral cues and central targets contain objects from the same category or shared features. *Hierarchical internal representation* of a visual object may also influence how attention is allocated to an object. Valdés-Sosa et al. find that attention may act at different levels of the object hierarchy and that spatial frequency information structures the organization of object hierarchy. Another key element is that of *perceptual grouping*. Freeman et al. focus on the fate of task-irrelevant features when perceptually grouped as belonging to an object vs. ungrouped. They find that neuronal mechanisms of object-based attention, as assessed by fMRI, are not purely facilitatory and do not automatically spread across hemifields for objects delineated via perceptual grouping. They argue that suppression of task-irrelevant stimuli may depend on how effectively they compete with task-relevant stimuli, with greater competition when relevant and irrelevant features or locations belong to the same object.

Two other contributions consider models that allow for the selection of behaviorally relevant visual objects amongst a crowd of irrelevant objects, exploring the influence of emotion and categorization (Chang et al.), and delineating a new model of visual crowding that can account for object-level crowding (Chaney et al.).

Sensory modality is another key dimension in object-based attention. While the majority of contributions to our research topic focus on visual objects, perceptual objects are also present in other sensory domains, such as audition (e.g., Griffiths and Warren, 2004; Bizley and Cohen, 2013). Much less is understood about the processing of such non-visual objects. Bharadwaj et al. highlight that whereas the visual steady-state response is clearly modulated by visual attention, studies examining the auditory analog, the auditory steady-state response, have found inconsistent effects from auditory attention. Using naturalistic auditory objects and methodological advances, they resolve some of the inconsistencies from previous findings and provide evidence that the two forms of selection may act similarly. Specifically, they find that the auditory steady-state brain response can be selectively enhanced for attended objects and suppressed for unattended objects as has been found for visual objects and the visual steady-state response.

Finally, the origins and development of different mechanisms of attention are still poorly understood. One contribution to our research topic addresses how *emotional or social salience* can guide attentional selection, considering such influences early in development, not simply in adulthood. Valenza et al. examine this influence for the unique case of faces. They find differences in adults vs. infants, suggesting that experience with select objects may influence object-based selection.

To conclude, the diverse contributions offered here reveal the multi-faceted nature of attending within and between objects and point the way to further explorations of those facets, especially in domains where our understanding is more limited, such as considerations of objects in other sensory domains and the development of many of these select mechanisms of attention.

AUTHOR CONTRIBUTIONS

All authors listed, have made substantial, direct and intellectual contribution to the work, and approved it for publication.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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