How Humans Efficiently Search Complex Scenes by Learning about their Spatial and Object Contexts

How do humans use predictive contextual information to facilitate visual search? Tsung-Ren Huang and Stephen Grossberg in the CELEST Science of Learning Center have developed a neural model to explain how people encode the spatial layout and object associations of a typical scene into memory and how such context memory can be used later to quickly find a target in a scene. For example, when we are looking for a friend in a beach picture (see Figure 1), we direct our eyes right away to the bottom sand part rather than the top sky part. Such knowledge of the spatial layout of a scene is named spatial contextual cueing. However, such spatial information is not always available in a new environment. For instance, when we are seeking beverages in a friend’s refrigerator for the very first time, we may not even know where the kitchen is situated until seeing some related objects such as an oven or a microwave (see Figure 2). In this scenario, object contextual cueing plays a role in suggesting the existence of a refrigerator in the kitchen context. This neural model explains challenging psychophysical data on positive vs. negative, spatial vs. object, and local vs. global cueing effects during visual search. The model also clarifies data from neuroanatomy, neurophysiology, and neuroimaging concerning the role of subregions in prefrontal cortex, medial temporal lobe, and visual cortices during visual search. In particular, model cells in dorsolateral prefrontal cortex prime possible target locations in posterior parietal cortex based on bottom-up activation of a representation of scene gist in parahippocampal cortex. Model ventral prefrontal cortex cells prime possible target identities on temporal-occipital areas based on the history of viewed objects represented in perirhinal cortex. Through simulations, the model illustrates the dynamic processes of evidence accumulation in visual search, which incrementally integrates available spatial and object constraints to limit the search space, and offers new insights on the complex interplay among the What and Where cortical areas which orchestrate scene perception and scene memory.

Figure 1. A typical beach scene is organized into the sky, sea, and sand regions.

Figure 2. Objects that often co-occur in a spatially kitchen scene become associated with each other in memory.