Is object search mediated by object-based or image-based representations?

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Abstract—Recent research suggests that visually specific memory representations for previously fixated objects are maintained during scene perception. Here we investigate the degree of visual specificity by asking whether the memory representations are image-based or object-based. To that end we measured the effects of object orientation on the time to search for a familiar object from amongst a set of 7 familiar distractors arranged in a circular array. Search times were found to depend on the relative orientations of the target object and the probe object for both familiar and novel objects. This effect was found to be partly an image matching effect but there was also an advantage shown for the object’s canonical view for familiar objects. Orientation effects were maintained even when the target object was specified as having unique or similar shape properties relative to the distractors. Participants’ eye movements were monitored during two of the experiments. Eye movement patterns revealed selection for object shape and object orientation during the search process. Our findings provide evidence for object representations during search that are detailed and share image-based characteristics with more high-level characteristics from object memory.

Keywords: Object search; object representations; orientation-dependent search; scene perception.

INTRODUCTION

When searching for an object in the real world, the target object is generally located amongst a set of random non-targets in a complex scene. In many cases, the precise image characteristics of the target object will be unknown. Therefore, search may need to use a more general, non-specific representation in order to be prepared for unexpected situations such as changes in illumination, viewing distance or orientation relative to the observer. It is not known, however, whether object representations used for search are generally invariant to or sensitive to such incidental changes. The question we specifically address in this paper is whether,
under free viewing conditions, orientation affects the time to search for a familiar object. We use tasks in which shape information is required to distinguish between a target object and distractor objects.

Many studies on visual search specify bottom-up principles for search performance, based on low-level image characteristics (Duncan and Humphreys, 1989; Treisman and Sato, 1990; Wolfe, 1994). According to the Feature Integration Theory, for example, object properties are coded preattentively from a visual scene and attention is required to bind these features into object files (Treisman and Gelade, 1980; see also Wolfe and Bennett, 1997). Such pre-attentive features mainly consist of the product of early visual processing such as colour (Treisman and Gelade, 1980), orientation (Julesz and Bergen, 1983), and stereoscopic depth (Nakayama and Silverman, 1986) although some higher level features, such as 3D orientation of objects (Enns, 1992; Enns and Rensink, 1991) are also coded preattentively. Other image-based factors, such as the degree of inter-item similarity between the target and the distractors have also been shown to affect search performance (Duncan and Humphreys, 1989). Thus, these models predict efficient search performance when the target is specified by a unique, (or sufficiently dissimilar), feature. Search is less efficient when the target is defined by, for example, feature conjunctions since attention is required to correctly bind features for target identification. Although these studies provide evidence for the role of attention in search based on the image characteristics of the scene content (e.g. display size, number of features present, inter-item similarity) they do not account for more high-level factors affecting search performance (e.g. scene or target familiarity).

Very few studies have investigated more higher-level principles for search, such as the role of object-based representations in search. In general, the representations of objects in scenes are considered coarse or ephemeral (Biederman et al., 1988; Rensink, 2000; Simons and Levin, 1997). Notable exceptions to this are the recent studies reported by Henderson and colleagues (for a review see Henderson and Hollingworth, 1999). Typically they use a change detection paradigm where a target object is changed during the execution of a saccade (either towards or away from a target). They manipulate the relationship of the changed object relative to the initial target object in order to investigate the nature of the representation of the target prior to change. For example, if a target object is represented as a content-free ‘presence’, then target deletion would be easily detected. On the other hand, if some aspect of the identity of the target is represented, then any change to its identity (token change) or semantic category (type change) would also be detected. Finally, if the contents of a visual scene are not represented (unless previously attended), or are coarsely represented then any change would probably go unnoticed (as predicted by proponents of the ‘change blindness’ model, e.g. Rensink, 2000; Simons and Levin, 1997). In a series of studies, Henderson, Hollingworth and colleagues have reported that visually specific representations are preserved during scene perception, such that target deletion, type and token changes are detected (Henderson and Hollingworth, 1999, 2003; Hollingworth and Henderson, 2002; Hollingworth et