Investigating the role of spatial location in surface-feature binding: The retrieval of features and objects as a function of their spatial proximity

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Introduction

Recent investigations of feature binding in working memory (WM) have explored the role of spatial location, drawing parallels with the perception literature (Treisman & Gelade, 1980; Treisman, 1993; Treisman, 1998). These studies converge in their observations that spatial location appears to be critical to the binding of visual (surface) features in WM, at least during the initial phases of memory (Treisman & Zhang, 2006; Treisman, 2006; Logie et al., 2011), coming along 'for free' when visual information is relevant and attended (e.g., Jiang et al., 2000; Olson & Marshuetz, 2005). Our study investigated whether the ‘spatial distance’ between stored objects in memory influences the retrieval of object features.

Retrieving information from WM

Several theoretical accounts of WM suggest the retrieval function is served by an internal focus of attention, that brings memorized information back into conscious awareness for further processing (Cowan, 1988; Oberauer, 2002). According to the Concentric Model (Oberauer, 2002; 2007) the focus of attention is limited in capacity to just one item, as demonstrated by switch costs associated with reorienting the attentional focus to a new stored item in memory (e.g., Garavan, 1998; Oberauer, 2002).

Rationale

Based on the observation that: a) surface-feature bindings are processed with obligatory reference to their spatial positions in WM; and b) the focus of attention can only select one item at a time for further processing; we investigated whether the cost of switching attention between objects stored in memory (consisting of color and shape features) varied as a function of their spatial proximity.

Method

Participants saw displays of four colored shapes in distinct locations (2000ms), followed by a visual mask (50ms) a retention interval (450ms) and finally a central single probe item (Figure 1).

Task: to indicate if the single probe represented both a color and shape from the memory display, regardless of original pairing.

• Intact probes: a repetition of a color and shape combination from the original display (surface-feature binding preserved).
• Switch-near probes: Features from spatially proximal objects switch to form the probe.
• Switch-far probes: Features from spatially distant objects switch to form the probe.

Hypotheses

A binding effect: predicts superior performance in the intact condition relative to the two switch conditions.

A distance effect: Predicts greater switch costs associated with the switch-far condition relative to the switch-near condition.

Results (N = 48)

Only RT data are reported below (no differences were observed in error data, see Figure 2).

Binding effect. Data for the intact and switch conditions were subjected to a one-way ANOVA for repeated measures, that indicated a significant binding effect, F (1, 47) = 15.07, MSE = 4641.05, p < .001, ηp² = .26 (faster responses to intact relative to switch probes).

Distance effect: Data for the switch-near and far conditions were subjected to a one-way ANOVA for repeated measures that indicated a significant distance effect, F (1, 47) = 4.59, MSE = 4006.47, p < .05, ηp² = .09, with responses faster in the switch-near condition.

Discussion

Our results indicated the presence of both a binding effect and a distance effect. The binding effect suggests that participants stored the color and shape features present in the memory display as bound objects, as demonstrated elsewhere (e.g., Allen et al., 2006; Luck & Vogel, 1997). The distance effect (the greater cost associated with retrieving spatially distant features relative to spatially proximal features from WM) supports earlier work suggesting that surface-features are stored in WM with reference to their spatial positions (Treisman & Zhang, 2006; Logie et al., 2011), even when when spatial location is not relevant for task completion.

Feature Retrieval and Spatial Proximity

Our results can be reconciled under the Concentric Model of WM (Oberauer, 2002; 2007) according to which, a single-item focus of attention retrieves information back into conscious awareness for further processing from an activated subset of WM (the region of direct access). The binding effect may manifest as a consequence of the requirement to shift the focus of attention between two stored items to match the features of the probe to features stored in memory in the switch conditions which was not necessary in the intact condition (where both probe features belonged to single object). The distance effect may be thought of as a time cost associated with bringing two spatially distant locations into the focus of attention, relative to two spatially proximal locations. Drawing parallels with the visual selective attention literature, this finding hints at the notion that the focus of attention may shift in an analogue (rather than discrete) manner across the contents of WM in this task (Shulman et al., 1979; Tsai, 1983).

Conclusions

Outwardly, the internal focus of attention bears close resemblance to the space-based window of visual selective attention. Indeed, Oberauer and Bialkova (2009) observe that “Selection of representations from WM bears many similarities to selection from perceptual input, and therefore it is likely that similar, if not the same mechanisms are involved in both selection functions.” (Oberauer & Bialkova, 2009, p. 64). The present study provides evidence for one point of similarity between the two selection mechanisms.

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