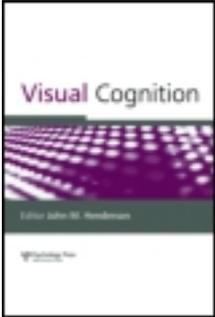


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Hybrid search in context: How to search for vegetables in the produce section and cereal in the cereal aisle

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Imagine you are browsing the supermarket for any of several items on your memorized shopping list. To get items into your cart, you must coordinate visual search of the aisle with memory search through your list ("Hybrid Search"; Wolfe, 2012). Wolfe (2012) found that reaction times (RT) increase logarithmically with the memory set size (the grocery list) for memory sets of up to 100 items. Such large memory sets cannot be held in working memory, nor are they simply held in undifferentiated long-term memory. Rather, they seem to be held in an "activated" partition of LTM ("activated long-term memory"—ALTM; Cowan, 1995). In a preliminary study, we tracked eye movements during Hybrid Search. Again, RTs rose logarithmically with memory set size. The percentage of objects fixated during search was strongly modulated by memory set size, from 23% when searching for memory set 1 to 73% when searching for memory set 100. Dwell time on fixated items also increased with memory set size, suggesting that a memory search was occurring for each fixated item (Drew & Wolfe, 2013).

Returning to the supermarket, it seems likely that the visual context will shape the memory search. For example, if we need lettuce, tomatoes, buns, and hamburgers, only lettuce and tomatoes will be relevant in the produce section. Experiment 1 was designed to test the hypothesis that observers could restrict their memory search to items from the relevant group.

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EXPERIMENT 1

Methods

Observers memorized two sets of eight arbitrary items, each group associated with a different background. Items were photorealistic objects. If Background A was present on a search trial, only items from List A were correct targets. Targets were present on 50% of trials. Visual set size was always 16. On an uncorrelated 50% of trials, an irrelevant target from List B replaced a distractor. If selected, this “lure” would be considered a false alarm.

Results

Dwell time on lures (589 ms) was significantly higher than on distractors (272 ms), $t(11) = 6.055$, $p < .001$. In addition, observers were more likely to fixate the lures than distractors (82% of lures fixated vs. 69% of distractors), $t(11) = 9.15$, $p < .001$. Mean RT was 5505 ms for search through 8 currently relevant items out of 16. This is comparable to RT for memory set size 8 as predicted by the log curve from previous data, and much faster than memory set size 16 data (6064 ms; [Figure 1A](#)). Thus, observers behave as if able to restrict memory search to relevant subset even though, when encountered, lure items exacted a cost.

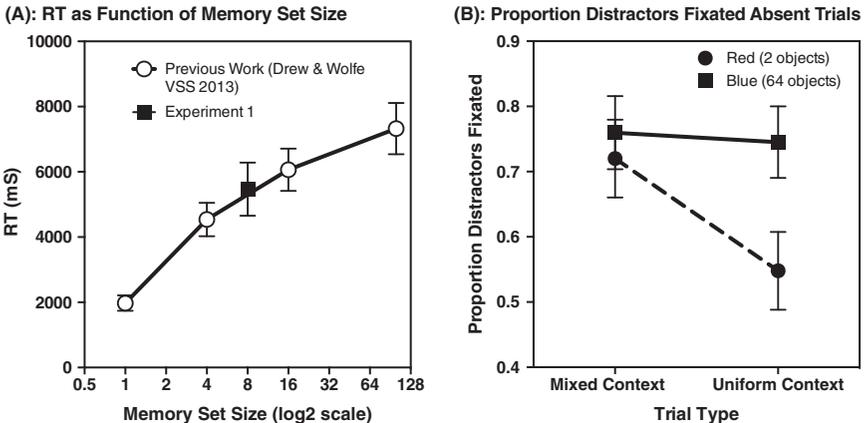


Figure 1. (A) The overall response times for absent trials in Experiment 1 is plotted along with the data from a previous experiment with comparable conditions (Drew & Wolfe VSS 2013). Here we clearly see observers search times more closely resemble what we would expect for a memory set size of eight compared to the 16 total items they have in memory. (B) In Experiment 2 there is a significant interaction between trial type and colour for the proportion of distractors fixated. This indicates we are able to successfully limit our memory search, although there is a notable cost during the mixed context trials.

EXPERIMENT 2

Methods

Experiment 2 tested the hypothesis that observers could switch from one memory set within a trial if multiple contexts were present in the same scene. Observers first memorized two groups of arbitrary objects. The “red” group contained two objects and the “blue” group contained 64 objects. Each trial was either of mixed or uniform context. On mixed context trials, the screen was split into four quadrants (red, blue, purple, and green). Only red group targets appeared in the red section. Only blue group targets appeared in the blue section. Either red or blue targets could appear in the purple section. No targets appeared in the green section. On uniform context trials, a single solid colour background was presented (red, blue, or purple), specifying the relevant memory set(s) with the same constraints. Each trial contained zero or one target and observers were asked to localize that target or click “no target” as quickly and accurately as possible.

Results

Using eye tracking, we found that the dwell time on distractors increased with the memory set size associated with a given context regardless of whether a trial had one or multiple contexts, $F(1, 10) = 31.51, p < .001$. Thus, on mixed trials, observers spent less time looking at distractors in the red area (304.7 ms) compared with the blue (347 ms), $t(10) = 6.34, p < .001$. Although, this difference appeared more pronounced in the uniform context conditions (red 274 ms vs. blue 343 ms), $t(10) = 3.62, p = .004$, the interaction was not significant, $F(1, 10) = 1.697, p = .2219$.

A more dramatic pattern emerges in the percentage of distractors fixated (Figure 1B). We no longer see a significant difference within the mixed trials (red 72%, blue 76%), $t(10) = 1.933, p = .08$. However, the uniform conditions show a significant difference (red 54%, blue 74%), $t(10) = 5.7, p < .001$, and these factors interacted significantly, $F(1, 10) = 36.83, p < .001$. This suggests that there is some cost to switching memory groups; a cost made visible when switches must be made within a trial. As in our previous work, fewer distractors were fixated in the lower set size areas; an effect that was stronger when context was presented alone.

GENERAL DISCUSSION

First, as memory set size increases, dwell times and percentages of fixated distractors increase. The longer dwell time is consistent with the need to perform a more extensive memory search for each selected item. The greater percentage

of fixated items suggests that fewer distractors can be rejected without fixation when the memory set is large.

Second, observers appear to be capable of trial-by-trial switching between different memory sets that are associated with specific, arbitrary contexts. That is, rather than searching through an entire grocery list of items, Experiment 1 suggests the observers were able to constrain their memory search to the relevant items in a given context. Furthermore, they were able to ignore lure items with minimal cost to overall search efficiency.

Third, our data suggests that there is some cost to switching between different partitions of activated long-term memory within the same trial. If observers could switch freely between partitions of ALTM, we would expect no difference between the mixed context and uniform context trials in Experiment 2. However, this difference appeared in both dwell times on distractors as well as percentage of distractors fixated.

Returning the grocery store, given a list with multiple items in multiple categories, it will be possible to limit hybrid search on the basis of context (e.g., the cereal aisle). There will be some cost to switching to different subsets of your list, but that cost will be small relative to the time required to get to the next aisle.

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