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RESEARCH ARTICLE

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Abstract The localized attentional interference (LAI) effect was investigated in a visual search task requiring participants to simultaneously monitor two spatially separated features from the same or different dimensions. In Experiment 1, the search type was blocked and targets were defined by [illegible]

of neural coding, inducing stronger competition and interference among them. The resource allocation account would make the same prediction, as the difficulty of discerning the target from the distractors would increase when more items are placed in a fixed spatial region. With more distractors competing for limited attentional resources, there would be less spare resources in the surrounding region for the target to borrow from, inducing a stronger interference effect.

Given these open issues, this study re-examined the LAI effect in a visual search paradigm in which participants were asked to search for two simultaneously presented feature targets defined in separable dimensions: color and shape. The critical manipulation was whether the two features were spatially CLOSE to or DISTANT from each other in the two-feature search task. If the LAI works both with targets from the same dimension and with targets from different dimensions, one would expect to find slower RTs when the two features are CLOSE to, rather than DISTANT from, each other. Moreover, this pattern of interference effects could be modulated by the density of items in the search display: larger LAI effects would be obtained with an increased number of items within a given region. In Experiment 1, the type of search task and the distance between the two critical features were blocked, and the feature values of the targets were pre-specified and kept constant (e.g., search for a yellow target plus a circle target) for each block of trials. In Experiment 2, participants were required to perform singleton search with the precise featural values of the targets in the color and shape dimensions varying randomly across trials. Experiment 3 directly compared the LAI effect for cross-dimension targets with that for intra-dimension targets to examine whether additional processes in visual search contribute to the LAI effect. In all the experiments, the search set size (i.e., the item dens randomly at the 24 possible grid locations, with the fixation marker occupying the central position of the grid. Each item subtended 0.6° × 0.6° of visual angle. The viewing distance was held constant at 66 cm by using a chinrest. Participants were instructed to respond as quickly and as accurately as possible to the presence versus absence of the target(s). A blank screen was presented for 1,800 ms after the search display. Before the main experiment, each participant received four practice blocks of 20 trials for each type of search task.

Results

Incorrect responses were excluded from the analyses of RTs. Furthermore, RTs more than three standard deviations above or below the mean in each experimental condition were discarded as “outliers” (1.1% of responses in total). Mean RTs and response error percentages are reported in Table 2 for each experimental condition. Figure 1 depicts RTs in the CLOSE and DISTANT conditions relative to the averaged RTs in the two baseline conditions.

Preliminary data analyses had revealed no significant effect of set size on RTs in the baseline conditions (see Table 2). Therefore, the subsequent analyses of RTs in CLOSE and DISTANT conditions were based on the differ-

would have had to backtrack to the specific dimensional map to discern the possible targets after finding the peak signals on the master map, with focal attention consuming attentional resources. It is then reasonable to assume that, in DISTANT condition, the two peak signals did not interfere with each other because they could borrow enough resources in their respective sub-regions. However, when numbers of trials for the four levels of set size and for target presence/absence. All other methodological details were the same as in Experiment 1.

Results

Incorrect responses were excluded from the RT analysis. Furthermore, RTs more than three standard deviations above or below the mean in each experimental condition were discarded as “outliers” (0.9% of responses in total). Mean RTs and response error percentages are reported in Table 4 for each experimental condition. Figure 2 depicts the RTs in CLOSE and DISTANT conditions relative to the averaged RTs in the two baseline conditions.

A 2 (search type) × 4 (set size) × 2 (target presence) ANOVA on the RT data revealed a significant main effect of set size, $(3, 51) = 10.46$, < 0.001, but no main effect of search type, $(1, 17) = 3.03$, $= 0.1$, and target presence, $(1, 17) < 1$. Importantly, the set size × target presence and the search type and set size interactions were function of set size for CLOSE condition, $(3, 51) = 9.46$, < 0.001, but was unaffected by the set size for DISTANT condition, $(3, 51) = 1.17$, > 0.1. Planned tests comparing the miss rates between CLOSE and DISTANT conditions at the various sizes showed that, while the differences at set sizes 6, 10, and 16 items were not significant, $(17) < 1$, $(17) = 1.19$, > 0.1, and $(17) < 1$, respectively, the miss rate at set size 20 items was larger in CLOSE, relative to DISTANT, condition, $(17) = 3.65$, < 0.05.

took part in Experiment 3. They were all right handed and had normal or corrected-to-normal vision. They gave their informed consent to take part in the experiment and were paid for their participation.

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Experiment 3 used a 2 (target dimension) × 2 (search type) × 4 (set size) × 2 (target presence) design, with participants being instructed to perform the two-singleton search. Two singleton targets were either from the same dimension or from different dimensions, and they were either CLOSE or DISTANT; the search set size was 6, 10, 16, or 20 items, and the targets were either both present or only one was present. In addition, there were one-target color singleton and shape singleton search conditions which served as baselines for the two-target CLOSE and DISTANT conditions. The combinations of target and distractors in each block are illustrated in Table 5. In the baseline conditions, participants were asked to search for a color or, respectively, a shape singleton. In CLOSE and DISTANT conditions, participants were instructed to search for two singletons from whatever dimensions. Cross-dimension target trials were mixed with intra-dimension target trials; the intra-dimension trials consisted of displays with either two color targets or two shape targets (each 50% of the trials).

The search type was blocked, with three testing blocks for each search type. Testing blocks consisted of either 96 trials (one-target search baselines) or 192 trials (two-target CLOSE and DISTANT conditions). Within each block, there were equal numbers of trials for the four levels of set size and for target presence/absence. All other methodological details were the same as in Experiment 2.

Results

Incorrect responses were excluded from the RT analysis, and RTs more than three standard deviations above or below the mean in each experimental condition were discarded as “outliers” (0.9% of responses in total). Mean RTs and response error percentages are reported in Table 6 for each experimental condition and Fig. 3 depicts the RTs for CLOSE and DISTANT conditions relative to the averaged RTs in the two baseline conditions.

A 2 (cross- versus intra-dimension) × 2 (CLOSE versus DISTANT) ×

were present. This was further supported by the significant three-way interaction between target presence, search type, and target dimension, $(1, 19) = 10.54$, < 0.005.

To analyze the interactions further, separate target dimension × set size × search type ANOVAs were performed for the target-present and -absent trials. For targetfindings are consistent with the hypothesis that the LAI effect is modulated by the distance between the two targets and by switch of dimensions when searching for two sin-

resources and, thus, leave fewer resources available for a particular target. When the set size is small, there would be enough spare attentional resources to process the targets, whether the targets are CLOSE to or DISTANT from each other, so that the RTs would be comparable for CLOSE and DISTANT conditions. However, when the set size is large, there would be few spare attentional resources available for the processing of each target, which has to borrow resources from the neighboring region. If the two targets are close to each other, they may cause interference by drawing upon limited attentional resources from the same region, leading to the delay in processing the two targets.

However, the above two accounts seem to be more descriptive rather than explanatory in relation to the set size eVect. Perhaps a more “mechanistic” account may be derived from saliency-based models such as Guided Search (Wolfe 1994), according to which feature contrast values would be computed not only for the targets, but also, in parallel, for the distractors. The saliency value of a distractor, signaling the