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Visuospatial Attention Is Guided by Both the Symbolic Value and the Spatial Proximity of Selected Arrows

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There is considerable evidence that overlearned symbols, especially arrows, can orient attention to peripheral locations. In 2003, Pratt and Hommel showed that when 1 arrow is selected from a set of arrows, based on an attentional control setting for a specific target color, the selected arrow determines the orientation of attention. Recently, Leblanc and Jolicoeur (2010) reexamined this finding, and concluded that spatial proximity of the arrow to the target, not the symbolic value of the arrow, determines the orienting of attention. Here, we manipulated both the symbolic value of the cue (direction arrows or directionless circles) and the proximity of the cue to the peripheral target location (near or far), and found that although proximity does play a role in the orienting of attention (larger cuing effects were found with far cues than near cues), the symbolic content of the cue also plays an important role (larger cuing effects were found with arrows than circles). Thus, both the symbolic value and the spatial proximity of cues affect the orienting of attention.

Keywords: attention, symbols, top-down control

There is now considerable evidence that various types of symbolic information presented at, or near, fixation are capable of generating shifts of attention to specific peripheral locations. Such symbolic information includes directional words (e.g., *left*, *right*; Hommel, Pratt, Colzato, & Godijn, 2001), time words (e.g., *tomorrow*, *yesterday*; Weger & Pratt, 2008), words related to concrete concepts (e.g., *cowboy–hat*; Estes, Verges, & Barsalou, 2008), words relating to abstract concepts (e.g., *god*, *devil*; Chasteen, Burdzy, & Pratt, in press), letters (Dodd, Van der Stigchel, Leghari, Fung, & Kingstone, 2008), and numbers (Fischer, Castel, Dodd, & Pratt, 2003). Perhaps the most effective centrally presented symbolic information is nonverbal: Hommel et al. (2001) have shown that uninformative arrows shown at fixation tend to orient attention to peripheral locations indicated by the direction of the arrows. Since this initial finding, several other studies have successfully used centrally presented arrows to allocate attention to specific portions of the peripheral visual field (e.g., Friesen, Ristic, & Kingstone, 2004; Gibson & Bryant, 2005; Tipples, 2002).

Following up their initial findings, Pratt and Hommel (2003) then asked the question of how one arrow can be selected to orient attention when several arrows are present in the visual field. They performed a series of experiments that required people to find a specific colored target, and then presented a set of colored arrows at fixation (one of which appeared in the target color) before the onset of the target. They found that responses were facilitated if the target appeared at a location pointed to by the target-colored arrow. This occurred even though the target location and the direction of the target-colored arrow were unrelated. Pratt and Hommel further found that even when color was irrelevant to the specification of the target, the color feature of the target held in working memory was sufficient to select one arrow from a set of arrows.

Recently, Leblanc and Jolicoeur (2010) presented a potential problem with the conclusions of Pratt and Hommel (2003). In examining the experimental design of Pratt and Hommel, Leblanc and Jolicoeur noted that the target-colored arrow, which radiated out from fixation along with the other uninformative arrows, was closer in proximity to the peripheral target than the other arrows. Thus, it is possible that it was the proximity of the selected arrow to the target, not the symbolic information of the direction of the arrow, that produced the facilitation effects found by Pratt and Hommel. To test this notion, Leblanc and Jolicoeur conducted a set of experiments that disentangled the potential proximity and directional effects of the arrows: They presented arrows halfway between fixation and the peripheral target locations, but with the arrows pointing diagonally to an adjacent peripheral location from the location closest to the arrow. For example, when participants were searching for a blue target, four arrows would appear with the blue arrow closest to the left target location but pointing to the top target location, creating a condition where cuing by proximity would conflict with cuing by arrow direction. Likewise, in another experiment, the arrows were clustered around fixation but their arrowheads were pointed inward, such that an arrow placed to the left of fixation would point to the right peripheral target. Across these experiments, Leblanc and Jolicoeur consistently found cuing effects based on the spatial proximity of the cues and targets and

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not the direction of the arrows. They concluded that the Pratt and Hommel findings were driven by the proximity of selected arrow and target location and not the symbolic (direction) information contained by the selected arrow.

It should be noted that Leblanc and Jolicoeur (2010) agree with one of Pratt and Hommel's (2003) major tenets that cues that feature overlap with stimulus events held in working memory automatically attract visuospatial attention, even if the overlap refers to a task-irrelevant feature (e.g., if a blue square is held in working memory and shape is the task-relevant feature, the task-irrelevant color will still guide attention). Moreover, Pratt and Hommel's approach by no means denies that this attraction can facilitate the processing of stimuli appearing close to the cue, nor does it claim or imply that the symbolic content of cues must have a stronger impact on attention than proximity has. And yet, the Leblanc and Jolicoeur study brings up an important point regarding the need to separate attentional effects due to the spatial proximity of cues and those due to symbolic content of cues. Indeed, Leblanc and Jolicoeur quite rightly note that this separation was not possible in the design used by Pratt and Hommel. There is reason to believe, however, that the design of the Leblanc and Jolicoeur study may not provide the best possible test of proximity and symbolic information either. In particular, there are three potential issues with their study.

The first potential issue is that the arrow cues in both experiments of Leblanc and Jolicoeur (2010) were presented halfway between fixation and the peripheral target location. As visual resolution diminishes with distance from foveal vision, the arrowheads of these cues may not have been especially successful in communicating directional information. In other words, the placement of cues may have biased proximity effects over symbolic effects. Second, the location of these cues away from fixation may have induced eye movements, which were not controlled for, and the effects found may have been due to overt, not covert, shifts of attention. Third, with respect to their "anti-arrow cue" experiment, where the arrowheads pointed inward to fixation, it is unknown whether symbolic cues are capable of generating shifts of attention across attentional meridians. Indeed, previous research has shown that whereas attention can be moved around quite successfully within a visual hemifield, it is very difficult to orient endogenously across visual meridians and into other hemifields (Rizzolatti, Riggio, Dascola, & Umiltá, 1987). Thus, although Leblanc and Jolicoeur bring up an interesting and important point with regards to proximity and symbolic orienting effects, the design of their study may by biased toward finding proximity effects over symbolic effects of the arrow cues.

The present experiment attempts to find a common ground between the Pratt and Hommel (2003) and the Leblanc and Jolicoeur (2010) studies by independently manipulating factors that test proximity and symbolic cuing effects. The basic paradigm is similar to the previous studies; participants are given the color of the target they need to find, then two differentially colored cues appear (one on each side of fixation), followed by the peripheral target in one of two possible target locations. Thus, participants should select one of the two arrows on the basis of their attentional set for the colored target. To examine the role of symbolic cuing effects, the cues would either be two differentially colored arrows (pointing into the periphery in their respective hemifields) or two differentially colored circles. To examine the role of proximity cuing effects, the cues would appear either immediately beside the fixation point (near cues) or halfway between fixation and the peripheral target locations (far cues). If arrows direct attention to peripheral locations, larger cuing effects should be found for arrow cues than for circle cues. If spatial proximity directs attention, larger cuing effects should be found for far cues than for near cues. To rule out confounds due to overt attentional shift, participants' gaze location was monitored via a closed circuit camera.

Method

Participants

Sixteen undergraduates (mean age = 23.3 years; 10 women and six men) from the University of Toronto participated in this experiment in exchange for course credit. All had normal or corrected-to-normal vision and were naïve to the purposes of the study.

Apparatus and Procedure

The experiment was conducted in a dimly lit, sound attenuated room on a PC computer and a CRT monitor. Participants used a chin rest to maintain viewing distance at 48 cm, and a closed circuit camera, directed at the eyes of the participants, was located directly underneath the monitor. Participants received warnings if they failed to remain fixated.

Each trial began with an initial display consisting of a black background on which a white central fixation point (0.2°) and two peripheral white boxes (1° wide, centered 5.5° from fixation) appeared (see Figure 1). Following a foreperiod of either 500, 1,000, or 1,500 ms, the target color (the word *GREEN* or *RED*, drawn in white letters), appeared at fixation for 500 ms, which was followed by a 500-ms delay. The two cues were then presented, one green and one red. On half the trials, the cues were arrows that pointed into the periphery in their respective visual field; on the other half of the trials, the cues were filled-in circles (both subtended an area 1° in diameter). Also, on half the trials the cues appeared immediately to the left and right of fixation, and on the other half of trials, the cues appeared halfway between fixation and the placeholders. The cues remained visible for 500 ms, and on their disappearance, a green or red target appeared in one of the placeholders. Participants were instructed to read the target color word and then press the spacebar as quickly as possible if the target matched that color. If the target did not match the target color word, they were instructed to withhold making a response. An error tone sounded if they made an incorrect response (no response to a match target, response to a mismatch target) or if they responded too quickly (<100 ms) or too slowly (>1,500 ms). Following the responses, there was an intertrial interval of 1,000 ms.

Design

On any given trial, it was equally likely that (a) the color target word was *GREEN* or *RED*, (b) the cues would be arrows or circles, (c) the proximity of the cues would be near or far, (d) the green cue would appear on the left or right (and vice versa for the red cue), (d) the target would appear in the left or right placeholder, and (e) the target would be green or red. There were a total of 640 trials,

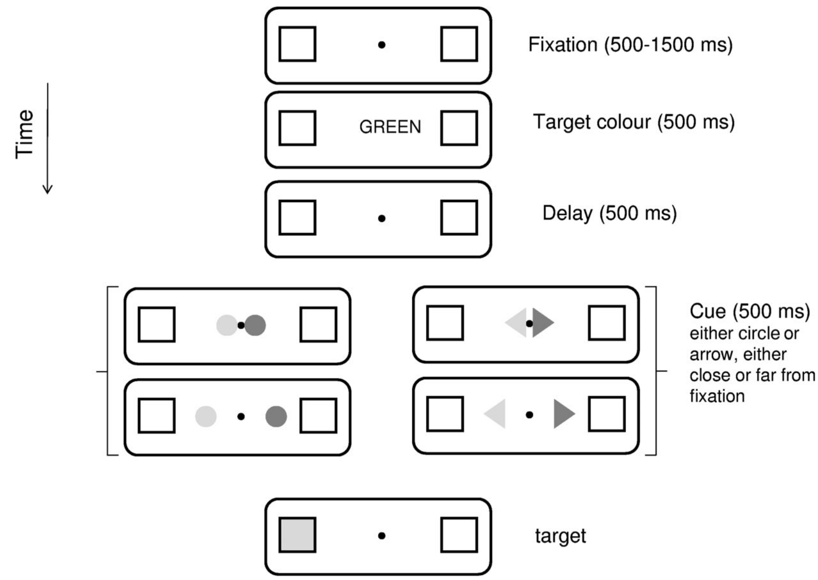

Figure 1. Sample trial sequence used in the experiment (see the text for details). The light grey and dark grey cues and targets were green and red in the actual experiment.

of which half (320) would invoke a response as the color target word would match the color of the peripheral target.

Results

The mean response times (RTs) of the correct responses were analyzed with a 2 (cue type: arrow or circle) × 2 (cue proximity: near or far) × 2 (trial type: cued or uncued) analysis of variance (see Figure 2). A main effect of trial type was found, $F(1, 15) = 89.1$, $MSE = 147.7$, $\eta^2 = .856$, $p < .0001$, as RTs for cued trials (365 ms) were shorter than for uncued trials (385 ms). There was also a main effect of cue proximity, $F(1, 15) = 5.46$, $MSE = 259.8$, $\eta^2 = .267$, $p < .035$, with longer RTs with near cues (379 ms) than far cues (372 ms). Cue type also showed a main effect, $F(1, 15) = 14.58$, $MSE = 14.6$, $\eta^2 = .493$, $p < .002$, with shorter RTs for arrow cues (373 ms) than circle cues (379 ms). Two important two-way interactions were found. First, the cue type by trial type interaction was significant, $F(1, 15) = 6.7$, $MSE = 105.5$, $\eta^2 = .308$, $p < .025$, as arrow cues (25 ms) produced larger cuing effects than circle cues (16 ms). Second, the cue proximity by trial type interaction, $F(1, 15) = 4.8$, $MSE = 98.3$, $\eta^2 = .243$, $p < .05$, indicated that far cues produced larger cuing effects (24 ms) than near cues (17 ms). The interaction of cue type and cue proximity and the three-way interaction were not significant (Fs < 1).

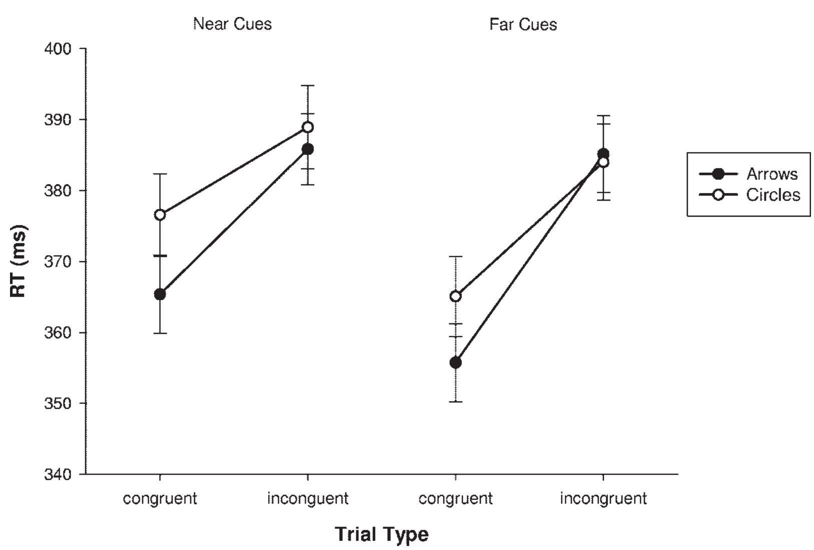

Figure 2. Mean response times for the arrow and circle cue conditions in the experiment (error bars are 95% confidence intervals).

Very few errors were made, with only 93 trials (0.018%) removed for RTs above or below the cutoffs and 42 trials (0.008%) removed for an incorrect response.

Discussion

In 2003, Pratt and Hommel asked the question of whether or not one arrow from a set of irrelevant arrows would be spontaneously selected because of a top-down attentional control setting. This was accomplished by having people search for a specific color target, and then seeing whether responses were faster when the target appeared at the location pointed to by the same color arrow than when the target appeared at locations pointed to by other color arrows. Pratt and Hommel assumed that once an arrow was selected, the facilitated response was due to attention being oriented into the periphery by the symbolic information of the arrow. Recently, Leblanc and Jolicoeur (2010) suggested that the faster responses were due to the proximity of the selected arrow to the target location and not to the directional information of the arrow. The present experiment, which manipulated both the symbolic content of the cue and the proximity of the cue to the target, shows that although proximity does play a role in the orienting of attention (larger cuing effects were found with far cues than near cues), the symbolic content of the cue also plays an important role (larger cuing effects were found with arrows than circles).

The finding that arrows are capable of orienting attention, above and beyond their proximity to a peripheral location, is consistent with a large number of studies that have found cuing effects with centrally presented arrow cues (e.g., Friesen et al., 2004; Gibson & Bryant, 2005; Hommel et al., 2001; Tipples, 2002). Indeed, the fact that Leblanc and Jolicoeur (2010) were unable to find any effects of this type of symbolic cue seems somewhat out of place with the literature. Their design, which emphasized the proximity of the cue to the target, may not have been especially sensitive to symbolic cuing effects. Their combination of arrow cues with long shafts but small heads, and located in the periphery, likely contributed to the lack of symbolic cuing. Although the present study also had arrow cues in the periphery on some trials, the arrows were essentially all head, making the symbolic information more salient.

In addition to the saliency of the symbolic information in the arrow cues, the Leblanc and Jolicoeur (2010) study also suggests that arrow cues suffer the same fate of other attentional cues: Once attention is brought to one hemifield, it is difficult to reorient it across the visual meridians (Rizzolatti et al., 1987). Indeed, in addition to the symbolic number cues used by Rizzolatti et al. (1987), where certain numbers were assigned certain spatial locations, other researchers have shown that inhibition of return tends to be bounded by meridians (e.g., Tassinari, Aglioti, Chelazzi, Marzi, & Berlucchi, 1987), even when cued objects extend across two visual fields (Weger, Al-Aidroos, & Pratt, 2008). In the Leblanc and Jolicoeur study, the arrows pointing to locations in different hemifields simply may have had their effects muted by the visual meridians.

In summary, the results of the present study show that although the proximity of a cue to a target location does influence the magnitude of cuing effects, so does the symbolic direction information provided by arrow cues. Thus, when a direction symbol is selected from a set of symbols, both the symbolic information and the location of the symbol will determine the allocation of attention in the visual field.

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