Short Report

The Effect of Practice on Location Cueing and Visual Search

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Abstract Location cueing can facilitate response times when target-detection tasks are performed. A target-detection experiment was conducted with inexperienced participants to determine whether or not the magnitude of facilitative location cueing effects would change as a function of practice. Over the course of five test sessions, these effects attenuated. This suggests that practice decreases the influence of location cues on visual search performance and attentional processing. We propose that when participants perform cued visual search experiments and become familiar with potential target locations as a result of extended practice and automaticity, these locations are encoded in spatial memory by an operation called spatial indexing.

Résumé Le repérage de l'emplacement peut réduire le temps de réaction lors de tâches consistant à détecter des cibles. Une expérience de détection de cibles à laquelle ont participé des personnes inexpérimentées a été menée pour déterminer si les effets facilitateurs du repérage de l'emplacement changeaient avec l'entraînement. Au fil des cinq séances, ces effets se sont atténués, ce qui laisse présumer que l'entraînement diminue l'influence des repères sur la recherche visuelle et l'attention nécessaire. Nous croyons que, lorsque les participants à des expériences de recherche visuelle avec repères se sont familiarisés avec l'emplacement de cibles potentielles par suite d'un long entraînement et d'une automatisation, l'emplacement de ces cibles est encodé dans la mémoire spatiale par une opération appelée répertoriage spatial.

When target detection tasks are performed, location cues can facilitate or inhibit response times (RTs) depending on whether the cue is a valid indicator of the impending target's location or not (e.g., Posner, Snyder, & Davidson, 1980). A direct or peripheral cue (e.g., a bar-marker, underline, or box), if valid, is typically presented at or near the target's location and, if invalid, at a nontarget location (e.g., Posner, 1980). This technique is sometimes called exogenous cueing. Previous research indicates that, in most cases, when the delay between cue and target onset is 100 ms, valid direct cues have their strongest effect on RTs and, when this cue-target-onset-asynchrony (CTOA) is increased from 100 to 200 ms, cue effectiveness attenuates (Müller & Findlay, 1988; Müller & Rabbitt, 1989; Shepard & Müller, 1989; Weichselgartner & Sperling, 1987). In other words, the facilitative effect of direct cues appears to be transient and to last about 200 ms. If two successive direct cues are presented 200 ms apart at different locations, then the facilitative effect of the first cue not only attenuates, but changes to an inhibitory effect on detection RTs for targets presented at this location 300 ms or more after cue onset (e.g., Posner & Cohen, 1984; Posner, Rafal, Choate, & Vaughan, 1985; Possamai, 1985; Rafal, Egly, & Rhodes, 1994; Tipper, Driver, & Weaver, 1991; Tipper & Weaver, 1998; Tipper, Weaver, & Houghton, 1994; Wright & Richard, 1998). Posner and Cohen (1984) called this effect inhibition-of-return and proposed that it occurs to increase visual search efficiency by biasing search away from previously inspected locations and toward novel locations. Thus, the effect of location cues on target-detection RTs appears to change as a function of the delay between cue and target onset.

The efficiency of visual search can also increase as observers gain experience with the particular target-detection task at hand. For example, search for a target positioned among distractor items can become more rapid with practice, and can even reach the point at which *automatic* processes are said to mediate search performance (Czerwinski, Lightfoot, & Shiffrin, 1992; Kahneman & Treisman, 1984; Logan, 1988; Logan & Compton, 1998; Schneider, Dumais, & Shiffrin, 1984). As demonstrated by Treisman, Vieira, and Hayes (1992), an automatic process differs from a low-level, preattentive process in the sense that it becomes more efficient with repeated execution. A preattentive process, on the other hand, is more primitive, reflexive, and encapsulated from practice effects. In the attention literature, it is commonly assumed that increased visual search efficiency with practice is an indication that the processes involved are becoming automatized.

The fact that uncued visual search can become more efficient with practice raises questions about whether or not the same is true of *cued* visual search. We conducted the current experiment to determine the extent to which practice would influence location-cue effectiveness during visual search over the course of several experimental sessions.

Cues were presented at two successive locations, as is commonly done when studying inhibition-of-return. This allowed us to examine the duration of location-cue effectiveness more directly than is possible with a single-cue procedure. In particular, the onset of a second cue reduced the likelihood that observers would continue to attentionally monitor the first cued location. As mentioned previously, when two locations are cued in succession 200 ms apart, RT facilitation for targets presented at the first-cued location is usually followed 300-400 ms later by response inhibition. On the other hand, when only a single location is cued, it is possible for RT facilitation to be prolonged beyond a 300-ms CTOA (Cheal & Lyon, 1991). In the latter case, the duration of facilitation appears to be longer if participants expect a relevant stimulus event to occur at the single-cued location. The presentation of a second successive cue in the current experiment, however, reduced the likelihood that participants would continue to monitor the first-cued location. We expected that, over the course of the study, there would be a gradual attenuation of location-cue effectiveness as search became more efficient.

Method

PARTICIPANTS

Participants were four Simon Fraser University students with normal or corrected-to-normal vision who had no experience with visual search or location cueing studies of this type in the past. Participants with no experience performing RT tasks were tested so that their initial performance could be used as a baseline with which to compare performance after practice.

MATERIALS AND PROCEDURE

Experimental control, timing, and data collection were carried out with a microcomputer interfaced to a response button.The screen displayed three boxes (left, centre, and right), which remained partially visible throughout the experiment. In particular, their vertices were always visible on a black (unlit) computer screen and the other parts of each box were then filled in when the box served as a location cue. The display was viewed at a distance of 100 cm and the boxes were presented in a horizontal array in the centre of the computer screen. The target could appear at any of these three locations. Each trial began with a filling in of the rest of the parts of either the box 8° (7 cm) to the left of the display centre or the box 8° to the right of it (see Figure 1). This was the first cue. Cues were white (1.14° × 1.14°) square outline boxes presented at the *three potential* target locations. After a 50-ms delay, the first cue's component lines disappeared with the exception of the vertices that were initially visible, and then the central cue's component lines were filled in. As is the convention in studies involving sequential cue presentation (e.g., Posner & Cohen, 1984), this filled-in box at the centre location was always the second cue. As seen in Figure 1, after a further 50-ms delay, the centre cue's component lines disappeared with the exception of the vertices that were initially visible. Then the target was presented either within the vertices at the first cued location, within the vertices at the uncued location on the opposite side of centre, or within the vertices at the centre cued location. Thus, the delay between the onset of the first cue and the target was 100 ms. The target was a filled (0.38° × 0.38°) white square that was equally likely to appear at each of the three locations. Trial presentation order was completely random. Therefore, participants had no incentive to "aim" their attention at a cued location prior to target onset.

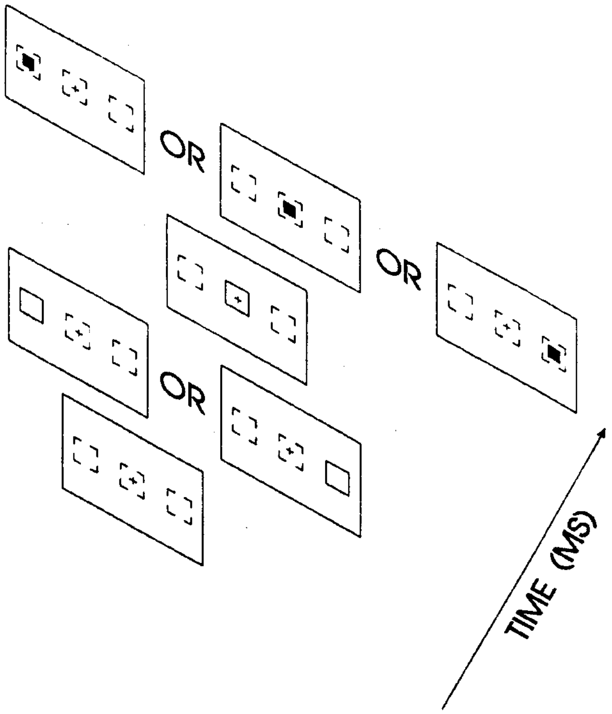

Figure 1. Stimulus display used in the experiment. The CTOA was 100 ms and, on each trial, the target was equally likely to appear at the First-Cued location, the Second-Cued location, or the Uncued location.

We used a 100-ms CTOA between the first cue and target because it has reliably elicited target detection RT facilitation in previous studies regardless of cue validity (e.g., Shepard & Müller, 1989) and regardless of participants' experience (Wright & Richard, 1998). CTOAs shorter than 100 ms (e.g., 50 ms) elicit less reliable effects of cueing on RTs. And, when the two-cue presentation paradigm is used, CTOAs longer than 200 ms either have no effect or elicit an inhibitory effect on RTs (e.g., Posner & Cohen, 1984; Wright &

Richard, 1999). Thus, a 100-ms CTOA was most suitable for studying the extent to which the facilitation would attenuate with practice. Moreover, this CTOA was short enough to preclude the occurrence of eye movements after cue onset but before target onset (e.g., Fischer, 1998; Fischer & Weber, 1993).

All participants fixed their eyes at the centre of the display and were required to press a button as quickly as possible when they detected the onset of the target. Participants took part in five blocks of testing sessions separated by at least one day. Each testing session involved 40 practice trials followed by 1,152 data trials with an additional 576 catch trials (1,500 ms CTOA) randomly interspersed among them to reduce response anticipation errors. The frequency of the catch trials (every third trial on average), and the considerably longer delay between cue and target onsets on these trials (relative to the data trials) were sufficient to virtually eliminate the participants' tendency to make anticipatory responses — a common problem in simple-detection RT experiments.

Results

All RTs less than 100 ms or greater than 1,000 ms and all RTs three standard deviations greater than or less than the mean RT for a particular condition were removed as outliers. Less than 2% of all trials were treated this way and their removal did not vary across conditions or sessions. RT facilitation scores were calculated for each test block by subtracting the mean RT for trials on which the target appeared at the first-cued location from the mean RT for trials on which the target appeared at the uncued location (see Table 1). This measure is also commonly used in inhibition-of-return studies (e.g., Posner & Cohen, 1984; Tipper et al., 1991; Wright & Richard, 1996).

A 3 × 5 repeated measures ANOVA was carried out on the mean first-cued, second-cued, and uncued RTs over the five testing sessions. The results indicated that the location of the cue preceding the target's onset affected target-detection RTs, $F(2,6) = 39.1$, $MSE = 321$, $p < .01$. However, not all participants showed a decrease in RTs over the course of the five testing sessions. Participant 2 appeared to show an increase. Thus, the ANOVA indicated that there was no significant effect of practice on RTs, and no significant interaction effect between the location of the cue preceding the target's onset and the amount of practice that the participant had performing the task. Note, however, that the measure of interest was not whether there was a decrease in RTs with practice, but, instead, whether there was a decrease in the magnitude of the location-cue facilitation effect with practice.

To examine this facilitation effect more directly, a 2 × 5 ANOVA was carried out on the mean first-cued and uncued RTs over the five testing sessions. The mean second-cued RTs were left out of the analysis because they were not used to compute the location-cue facilitation scores. The results indicated that there was no significant difference between the mean uncued RT and the mean cued RT. As seen in Figure 2, however, there was an interaction between the location of the cue and the amount of practice that the participant had, $F(4,12) = 4.1$, $MSE = 25$, $p < .05$. In the first three sessions, the mean uncued RTs were greater than the mean cued RTs. But in the last two sessions, the mean uncued RTs were less than the mean cued RTs.

TABLE 1
Mean Detection RTs (in Milliseconds) Across Sessions for Targets Presented at Cued, Uncued, and Central Distractor Locations

	SESSION NUMBER				
	One	Two	Three	Four	Five
Participant 1					
Cued	348	368	325	323	334
Uncued	369	366	332	320	326
Centre	308	308	284	288	289
Uncued - Cued	21	-2	7	-3	-8
Participant 2					
Cued	378	376	400	422	394
Uncued	389	387	400	414	398
Centre	324	333	349	367	359
Uncued - Cued	11	11	0	-8	4
Participant 3					
Cued	307	266	283	310	290
Uncued	317	264	266	295	281
Centre	265	241	252	276	279
Uncued - Cued	10	-2	-17	-15	-9
Participant 4					
Cued	392	398	349	351	334
Uncued	402	414	368	355	341
Centre	372	327	299	299	290
Uncued - Cued	10	16	19	4	7
All Participants					
Uncued - Cued	13	6	2	-6	-2

Note: Mean RT facilitation score is determined by uncued RT minus cued RT.

In order to determine the effect of practice on the cued and uncued RTs respectively, Newman-Keuls paired comparisons of the 2 × 5 ANOVA means were carried out. The Newman-Keuls critical difference for the 10 means in Figure 2 ranged from 7.7 to 13.5 ms at the $p < .05$ level, and from 10.8 to 17.1 ms at the $p < .01$ level. The results indicated that both cued RT and uncued RT decreased significantly with practice. More specifically, participants' mean cued RT for the first session was significantly greater than that for the third ($p < .05$) and fifth ($p < .01$) sessions. Likewise, their mean cued RT for the second session was significantly greater than that for the fifth ($p < .05$) session. Similarly, participants' mean uncued RT for the first session was significantly greater than that for the third ($p < .01$), fourth

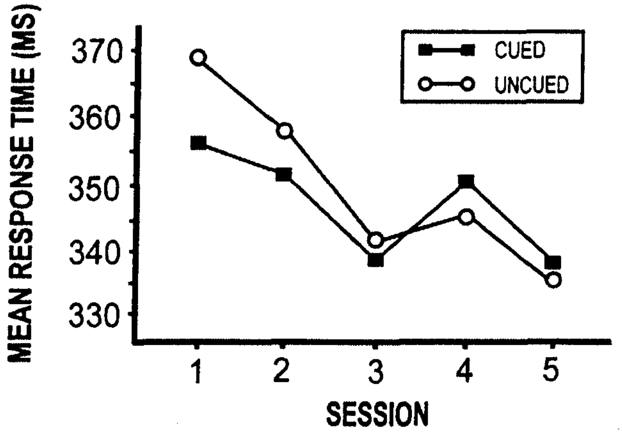

Figure 2. Mean RTs for detecting targets presented at the first-cued location and at the uncued location over the course of the five experimental sessions.

($p < .01$), and fifth ($p < .01$) sessions. Their mean uncued RT for the second session was significantly greater than that for the third ($p < .05$) and fifth ($p < .05$) sessions. In other words, both the mean cued RT function and the mean uncued RT function decreased significantly over sessions.

Newman-Keuls paired comparisons of these means also indicated that the mean uncued RT was significantly greater than the mean cued RT in the first session ($p < .05$), but that no significant facilitation effect occurred in the sessions that followed. As seen in Figure 2, the mean uncued and cued RTs were separated by 3 ms or less in the third and fifth sessions.

In order to determine whether the change in magnitude of the facilitation effect over the course of the five sessions was linear, we carried out a trend analysis using the mean facilitation scores for each participant across sessions. As seen in the final row in Table 1, these scores decreased from 13 ms in the first session to -2 ms in the fifth session. The results of the analysis indicated that the change in facilitation magnitude across sessions showed a significant linear trend, $F(1,12) = 13.9, MSE = 51, p < .001$.

Discussion

This experiment was conducted to determine whether or not location-cued visual search performance would become more efficient with practice. The results indicated that, over the course of the five test sessions, the benefit of location cueing on target-detection RTs attenuated. This benefit was based on a comparison of mean cued RTs and mean uncued RTs. Both decreased with practice, and significant location-cue facilitation occurred only in the first session.

Why should an RT advantage at the cued location versus the uncued location disappear after a period of practice? We suggest that, as participants become more familiar with potential target locations, these locations are encoded in spatial memory. This may be particularly true with a small number of possible target locations, such as in the current experiment. And with repeated exposure to targets at these locations, participants may become more sensitive to subsequent stimulus onsets there. As a result, target-detection response times may become faster, even at uncued locations, because all three locations may be spatially indexed.

This proposal is consistent with the fact that focused attention is not always required to encode locations in visual space. We have argued elsewhere that when a direct cue appears at a peripheral location 100 ms before the expected target, some visual analysis of the cue must be non-attentional (Wright & Richard, 1997; Wright, Richard, & McDonald, 1995; Wright & Ward, 1998). In particular, processing of the cue's onset that signals its presence to the observer, and some primitive encoding of the cue's location must precede attentional analysis. As a result, the cue can trigger an alignment of the attentional focal point to its location once the cue onset is detected. This processing, in turn, provides spatial coordinates required for determining the destination to which the attentional focal point will be shifted. Notice the flaw in the counter-argument that "attention is required to determine the spatial coordinates of the destination to which attention is to be directed." In order for attention to be directed to a cued location, the spatial coordinates must first be available through non-attentional processing. This non-attentional encoding of location information is sometimes called spatial indexing.

Over the course of the five test sessions, the location-cue facilitation measure showed a trend towards inhibition. In particular, as seen in Table 1, the mean uncued RT minus the mean cued RT in Session 4 was -6 ms. Although this difference between the means was not significant, it suggests that continued task performance over more test sessions could have led to inhibition-of-return. This would be consistent with reports that practice affects inhibition-of-return magnitude (Richard, Wright, & McDonald, 1994; Tipper & Weaver, 1998; Wright & Richard, 1998). And it would indicate that, with practice, perhaps location cueing can elicit inhibition-of-return at much shorter CTOAs than the 300-400 ms traditionally thought to be necessary (e.g., Posner & Cohen, 1984; Possamai, 1985; Wright & Richard, 1996).

More generally, the result warrants further study because it raises concerns about future investigations of cued visual search. In particular, it suggests that researchers should consider the effect of extended practice on the performance of target-detection tasks when designing experiments involving only a small number of possible target locations and a large number of experimental trials.

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