Orienting of attention without awareness is affected by measurement-induced attentional control settings

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McCormick (1997) concluded that peripheral cues presented below a threshold of awareness could nevertheless attract attention because they facilitated target processing near the cue shortly after its presentation. Yet, whereas an exogenous shift of attention typically exhibits a biphasic pattern (initial facilitation followed by inhibition of return [IOR]), at late cue-target onset asynchronies, IOR was not observed by McCormick. In our study, targets requiring a detection response were preceded by masked and nonmasked, uninformative cues presented under two conditions: one in which the cue was ignored (no report) and one in which the cue was detected and localized following the response to the target (cue report). When participants were required to make cue judgments at the end of each trial, we replicated McCormick's pattern, finding facilitation (but not IOR) following both masked and nonmasked cues. When there was no requirement to judge the presence or location of the cues, IOR was present with and without masks, whereas facilitation was observed only when the cues were not masked. That the assessment of cue awareness increases attentional facilitation and prevents (or delays) the onset of IOR is attributed to attentional control settings put in place to perform the cue-awareness assessments in the cue-report condition.

Keywords: attention, inhibition of return, awareness, consciousness, masking, cueing

Introduction

Attention is the means by which a particular region of space and the objects that occupy this region receive further or enhanced processing. Generally, it is thought that attention traverses space in at least two modes (Jonides, 1981; Posner, 1980): *Endogenous* shifts of attention are slow and largely under volitional control; *exogenous* shifts of attention are rapid and thought to occur automatically. The spatial-cueing paradigm, in which targets are preceded by cues that may or may not provide information regarding the spatial location of a forthcoming target, has been used extensively to explore both modes of orienting attention. Whereas endogenous orienting is studied with predictive cues (e.g., a central arrow predicts with 80% validity which of two locations will contain the target), exogenous orienting is studied with noninformative peripheral cues (e.g., a sudden onset stimulus that does not predict which of two locations will contain the target [i.e., 50% validity]). A peripheral cue with predictive validity may engender both exogenous and endogenous modes of attention. A shift of exogenous attention to the location occupied by the cue, or a shift of endogenous attention to the location indicated by the cue, is inferred when responses are faster and/or more accurate to targets presented at the cued location than to targets at an otherwise equivalent, uncued location.

Empirically, the distinctions between endogenous and exogenous shifts of attention, using predictive central cues and peripheral noninformative cues, respectively, are well established (for a review, see Klein & Shore, 2000). One difference between endogenous and exogenous orienting is apparent in the time course of their processing effects. Posner and Cohen (1984) were the first to report a biphasic pattern of results from exogenous cues. At short stimulus-onset asynchronies (SOAs), target detection performance is generally better at the cued than at the uncued location, reflecting the benefit of attending to a location. However, at longer SOAs (>250 ms), performance is worse at the cued location. This later inhibitory effect, now called inhibition of return (IOR), is generally thought to be caused by oculomotor programming (Rafal, Calabresi, Brennan, & Sciolto, 1989; Taylor & Klein, 1998) and to have widespread effects on information processing (slowing perceptual, attentional, and response stages of processing; for a review, see Klein, 2000). For the purpose of this investigation, it is important to note that IOR is a hallmark of exogenous cues; it is not observed following orienting in response to predictive, central endogenous cues (Posner & Cohen, 1984; Rafal et al., 1989).

If exogenous cues automatically capture attention, then attention might be captured without one being aware of the cue. In an important study aimed at testing this hypothesis, McCormick (1997) used exogenous cues that were salient or inconspicuous, and he followed the general recommendations of Dixon (1971) and Holender (1986) by assessing both the locus of attention (as

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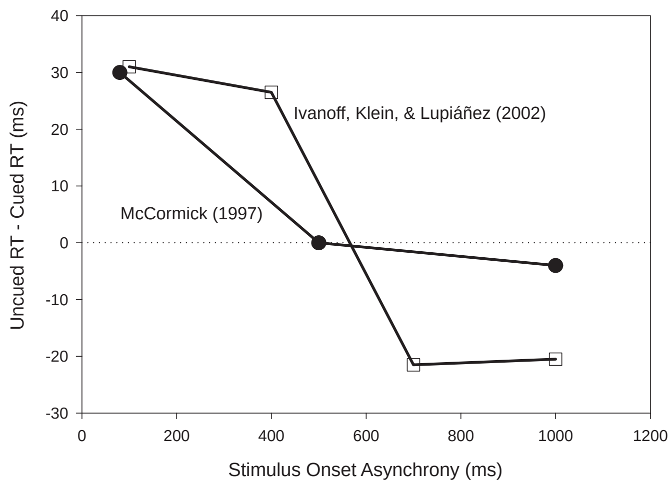

Figure 1. Time course of facilitation (positive values on the ordinate) and IOR (negative values) for McCormick's (1997) orienting without awareness condition in his third experiment and the results from a recent meta-analysis of exogenous orienting, using supra-threshold cues, by Ivanoff et al. (2002). In this figure (and subsequent figures), the ordinate reflects the mean uncued RT minus cued RT difference.

reflected in target reaction time) and cue awareness on every trial. In addition, by reversing the validity of the peripheral cue, McCormick implemented a version of Jacoby's (1991) process-dissociation procedure in which conscious and unconscious processes are placed in opposition. That is, the cue and target rarely (15%) appeared at the same location, so that if the cue was consciously localized, it would be to the observer's advantage to endogenously reorient attention away from it to the opposite location where targets were likely (85%) to be presented. As expected, when participants were aware of the cue, responses to the target were faster at the uncued location (the one likely to contain the target) than at the cued location. When participants reported that they were not aware of the cue, responses were faster to targets at the cued location than at the uncued location. McCormick concluded by noting that his study supports Posner's (1980) distinction between orienting and detecting. Posner suggested that the alignment of attentional resources with a signal (orienting) is a pre-requisite for awareness of the signal (detection). Converging with the finding of orienting without awareness in patients with blindsight (Weiskrantz, 1986) and extinction (Danziger, Kingstone, & Rafal, 1998), McCormick's results with normal observers showed that "Exogenous orienting appears to occur before and at lower thresholds than detection and does not require conscious awareness (p. 179)."

Although McCormick (1997) convincingly demonstrated early facilitation when participants were unaware of the cue, three issues warrant reexamination. First, McCormick's clever application of the process-dissociation approach required the unconventional use of peripheral cues that were informative to elicit unconscious exogenous orienting. It is possible, therefore, that the shift of attention that occurred without awareness in his work was somehow contingent on the establishment of an attention set to endogenously orient attention away from the cue. Thus, we will determine if we can generalize McCormick's important finding of unconscious orienting using uninformative peripheral cues.

Providing a second impetus for this work is the fact that when McCormick (1997) tested cue-target SOAs ranging from 80 ms to 1,000 ms (Experiment 3), IOR did not follow the early facilitation that was obtained when the cue was not noticed. Instead, at the longer SOAs (500 and 1000 ms), there were no significant cueing effects. The time course of the cueing effects from the unaware condition of McCormick's Experiment 3 are compared to a recent analysis of the time course of facilitation (Figure 1; based on over 200 participants) and IOR in discrimination tasks (by Ivanoff, Klein, & Lupiáñez, 2002) following purely exogenous cues. The crux is that without awareness (i.e., McCormick, 1997), there is very little evidence of IOR, whereas IOR is clearly evident when cues are presented above the threshold of awareness (e.g., Ivanoff et al., 2002).[1]

There are at least four reasons why McCormick (1997) did not observe IOR in the unaware condition in his third experiment. First, perhaps IOR is present following peripheral cues that attract attention unconsciously, but McCormick failed to find it because of insufficient statistical power: there were only eight participants in his Experiment 3. Because our experiment will have 21 participants, it will provide an assessment of this possibility. Second, if IOR and facilitation are the result of distinct mechanisms (Danziger & Kingstone, 1999; Klein, 2000, see Figure c, Box 1), then perhaps only exogenous attention occurs without awareness. For example, if IOR were the result of a conscious strategy to orient toward novel locations, then it would not be observed when participants are not aware of the cue. Although the time course of IOR has been shown to change with endogenous strategies (e.g., Lupiáñez & Milliken, 1999; Klein, 2000), currently there is no direct evidence that IOR is an endogenous process. A third possibility is that IOR was not observed with unaware cues because of demands related to the cue. Unlike a typical exogenous cueing study, McCormick uses a process-dissociation approach that requires participants to actively search for the cue on every trial because they were instructed to attend the location opposite the cue that was more likely to contain targets. In addition, at the end of every trial, participants reported whether or not they had detected the cue. These requirements may have established an attentional control setting (ACS) (Folk, Remington, & Johnston, 1992) to detect and localize the cues, which might have encouraged attention to remain engaged at the cued location. This would increase the overall attentional facilitative effect and eliminate or delay the appearance of IOR. This hypothesized effect upon IOR could occur whether IOR begins when attention is removed from the cued location or begins with the cue's onset but is masked by facilitation until attention is removed (for evidence of this latter possibility, see Danziger & Kingstone, 1999; Klein, Munoz, Dorris, & Taylor, 2001). An interesting aspect of this explanation is that the ACS, an endogenous process, might modify a nonconscious mental process (for an example of the influence of endogenous factors influencing the assessment of awareness, see Snodgrass, Shevrin, & Kopka, 1993, and Van Selst & Merikle, 1993). This possibility will be assessed by exploring two conditions. In one, participants provided reports of cue detection and localization following each trial (cue-report condition); in the other, no reports of cue awareness were made (no-report condition). The ACS hypothesized to discourage attention from orienting away from cues that capture it unconsciously ought to be present in the cue-report condition. This ACS should prevent the observation of the IOR effect. However, the ACS should not be activated when no-cue reports are required. If this explanation for the absence of IOR in McCormick's study is correct, then IOR will be observed when cue reports are not required.

A fourth possibility, suggested by an anonymous reviewer, is that the facilitation McCormick (1997) observed in his unaware condition might reflect a form of luminance summation (e.g., Sachs, Nachmias, & Robson, 1971; Watson & Nachmias, 1980) rather than orienting, and that without exogenous orienting, IOR might not be expected to occur. For McCormick's Experiments 1 and 2, this challenge might be rebutted by noting that the 500-ms cue-target SOA was too long, and the 1 deg of spatial separation (between cue and target) was too far for either temporal or spatial summation to be operating. In Experiment 3, however, for which the SOA was 80 ms, temporal summation might have contributed to the facilitation that was observed. We think this is unlikely because the effect McCormick observed was larger than might be expected in this experiment (30 ms for unaware cues), considering that the task was form (X vs. 0) discrimination. Nevertheless, the third feature of the present study is that it can address this alternative explanation for McCormick's finding (serendipitously, we must add, as we were unaware of the summation alternative until after the research was conducted). If we obtain IOR at the longer SOAs, then this will provide indirect evidence that an exogenous shift of attention was responsible for the facilitation at the shorter ones.

Method

Subjects

Twenty-one undergraduate participants from Dalhousie University participated in the experiment as part of a course.

Apparatus and Stimuli

All stimuli were presented in black and gray on the white background on iMac computers using SuperLab software. The fixation point was a plus sign (+) measuring 0.7 cm by 0.7 cm. The cue was a hollow circle measuring 1 cm in diameter presented 4.5 cm from fixation (to the innermost part of circle). The mask consisted of two hollow, 1.4-cm diameter circles presented to the left and right of fixation. The two-circle mask was positioned so that it would overlap a cue perfectly (about 4.3 cm from fixation to the innermost part of the circle) without actually occupying the same space. The space between the cue and the mask was just 1 pixel. This was a meta-contrast masking procedure (Breitmeyer, 1984). The go target was a single filled black circle measuring 0.8 cm that could be presented 4.9 cm to the left or right of fixation. The no-go target was exactly like the go target except that it was dark gray.

In the condition for which cue-awareness assessments were made, at the end of the trial, a "report-cue display" was shown, illustrating the nine left-most letters on a QWERTY keyboard (q, w, e, a, s, d, z, x, c) along with instructions for responding. Each letter was presented inside a small square. The letters were arranged as they are on the keyboard (in a 3 x 3 matrix shaped like a rhombus). Above the letter matrix, the words "LEFT," "ABSENT," and "RIGHT" were in the left, center, and right columns, respectively. Along the right side of the matrix of letters were the labels "HIGH CONFIDENCE," "SOME CONFIDENCE," and "NO CONFIDENCE" for the top, middle, and bottom row, respectively. The display was accompanied by instructions for the participant to report whether, and if so where, a single unfilled circle (i.e., the cue) had been presented.

Procedure

Each participant took part in the experiments in the same classroom, which was equipped with 20 iMac computers. In two "sittings," subjects participated in the experiment at the same time as other subjects. There were 17 participants in the first sitting and 4 in the second. Participants were seated approximately 50 to 60 cm away from the screen. At this viewing distance, 1 cm on the screen corresponded to approximately 1 deg of visual angle.

There were two conditions: no report and cue report. All participants completed the no-report condition before the cue-report condition, so that there would be no carry-over effects when participants performed without reporting cue awareness from having done the reporting previously. The two conditions were separated by approximately 15 min, during which time the instructions for the cue-report condition were explained.

No-Report Condition

Every trial started with the presentation of a blank screen for 600 ms. The central fixation point was then presented alone for 900 ms. Following this, no cue, a left cue, or a right cue was added to the fixation display for 15 ms. There were equal numbers of trials without a cue, with a left cue, and with a right cue. The cue (if presented) was removed and the central fixation point was presented alone for 15 ms. On one half of the trials, the two-circle meta-contrast mask was presented for 30 ms; on the other one half of the trials, the fixation point alone was presented for the 30 ms. Following this, the fixation point was presented alone for 45 ms (for the 105-ms SOA) or for 945 ms (1005-ms SOA). The target (go or no-go) was then presented for 900 ms or until a response was made. The cue's location did not predict the location of the target (i.e., the validity of a cue was 50%). Responses were made with the right hand using the "." key.

It was emphasized to the participants that every trial has the following structure: a fixation point; a single brief cue (an unfilled circle presented alone) may or may not appear to the left or right of fixation (left, right, and absent are equally probable); two circles (the mask) may or may not appear; and the go or no-go target. An illustrative example of the procedure was drawn on a chalkboard for the participants. It was explained to the participants that the mask (the two circles) would appear only 50% of the time and that the cue (circle presented alone) would not appear, appear to the left, or appear to the right 33% of the time. They were instructed to press the "." key quickly with their right index finger whenever the black-filled circle (go target) appeared, but to withhold responding when the circle was gray (no-go target). Participants were instructed to place their left hand over the left side of the keyboard with the heel of the palm placed on the desk. However, they did not need to make a response with this hand.

There were three blocks of 96 trials. Within each block, one half of the trials were devoted to the short (105 ms) SOA and one half were devoted to the long (1,005 ms) SOA; and at each SOA, one half of the trials were masked and one half were unmasked. There were equal numbers of trials without a cue, with left cues, and with right cues. Finally, in each block, 25% of the trials were no-go targets. If a response was made to a no-go trial, this was counted as a false alarm. Feedback was not provided.

Cue-Report Condition

In the cue-report condition, the procedure was the same as the no-report condition with the following two exceptions. First, a display appeared at the end of each trial prompting the participants to make a report regarding the presence and location of the single unfilled circle (i.e., the cue). If they believed that the cue was not shown (irrespective of whether the mask appeared), they were to press the "w," "s," or "x" keys, depending on whether they had high confidence, some confidence, or no confidence in their decision, respectively. If they believed that a cue had been present, they were to press the "q," "a," or "z" key if the cue was on the left or the "e," "d," or "c" key if the cue was on the right. Again, they were to press the "q"/"e," "a"/"d," or "z"/"c," depending on their confidence of their cue report (high, some, or none, respectively). They were instructed that the post-target cue reports were nonspeeded and that they were to make their decision as accurately as they could. Second, there were 4 blocks of 96 trials, rather than 3.

Results

Although the no-report condition was run first, the results will be reported in the opposite order because the report condition is more comparable to McCormick's (1997), and it is important to first establish whether we have replicated McCormick's finding of early facilitation without a subsequent IOR effect from masked cues.

Cue-Report Condition

RTs less than 150 ms and greater than 900 ms were excluded from the analysis. RTs greater than 900 ms were not recorded because the target disappeared, and the trial ended 900 ms after the onset of target. This RT criterion excluded 10% of the trials. Most of the excluded RTs were greater than 900 ms; only 0.25% of the RTs were less than 150 ms.

The RTs are presented in Table 1. RTs from trials with cues[2] were entered into a 2 (cueing: cued and uncued) x 2 (SOA: 105 ms and 1,005 ms) x 2 (mask: present and absent) repeated measures ANOVA. The effects of cueing [$F(1,20)=10.13$, $p < .005$], SOA [$F(1,20)=72.40$, $p < .001$], SOA x cueing [$F(1,20)=20.17$, $p < .001$], and SOA x cueing x mask [$F(1,20)=20.87$, $p < .001$] were all significant. To break down the three-way interaction, cueing effects (mean uncued RTs minus cued RTs) were examined at each level of mask and SOA (see Figure 2). At the 105-ms SOA, there was a 20-ms advantage for cued RTs over uncued RTs, when the cues were masked [$t(20)=2.22$, $p < .05$] and a 57-ms facilitation effect when they were not masked [$t(20)=5.97$, $p < .001$]. The uncued minus cued difference was significantly greater for nonmasked cues than it was for masked cues

Table 1. Mean Response Times and Percentage of False Alarms in the Cue-Report Condition

	Cueing condition		
Stimulus-onset asynchrony	No cue	Uncued	Cued
		Mask	
105 ms	574 (8.93%)	585 (15.48%)	565 (9.52%)
1,005 ms	474 (12.50%)	485 (12.50%)	476 (12.50%)
		No Mask	
105 ms	522 (3.57%)	606 (7.14%)	549 (7.14%)
1,005 ms	493 (5.36%)	452 (20.83%)	473 (11.31%)

[$t(20)=3.58$, $p < .005$]. At the 1,005-ms SOA, there was a 21-ms advantage for the uncued condition (i.e., an IOR effect) when there was no mask [$t(20)=2.17$, $p < .05$]. The uncued RT minus cued RT difference (an 8-ms advantage for the cued location) was not significant when there was a mask ($p > .25$).

The false alarm rates were entered into the same analysis as were the RTs. The main effect of cueing [$F(1,20)=6.83$, $p < .05$], the mask x SOA interaction [$F(1,20)=8.65$, $p <$ 001], and the SOA x cueing x mask interaction [$F(1,20)=5.12$, $p < .05$] were significant. We examined the three-way interaction by examining cueing effects as a function of mask and SOA. There were 9.5% more false alarms for targets at the uncued location than at the cued location [$t(20)=2.32$, $p < .05$] at the 1,005-ms SOA when there was no mask. No other differences were significant (*ps* >.10).

The ability of participants to correctly perceive (i.e., detect and localize) the cues was assessed using the information transmitted (Ht) metric. As described by Miller (1956), Ht measures the correlation between the stimulus (cue on left, cue on right, and no cue) and the subject's responses (left, right, and none). With three equally likely alternative stimulus states, the maximum amount of information that could be transmitted in this situation is 1.585 bits. Participants' cue reports transmitted 0.996 bits of information when there was no mask and only 0.107 bits when there was a mask, a difference that was highly significant [$t(20)=9.019$, $p <$ .0001). Using the more common percent correct measure, performance was 44.4% correct in the mask condition and 83.4% correct in the no-mask condition (note 33.3% correct is the "chance" level).

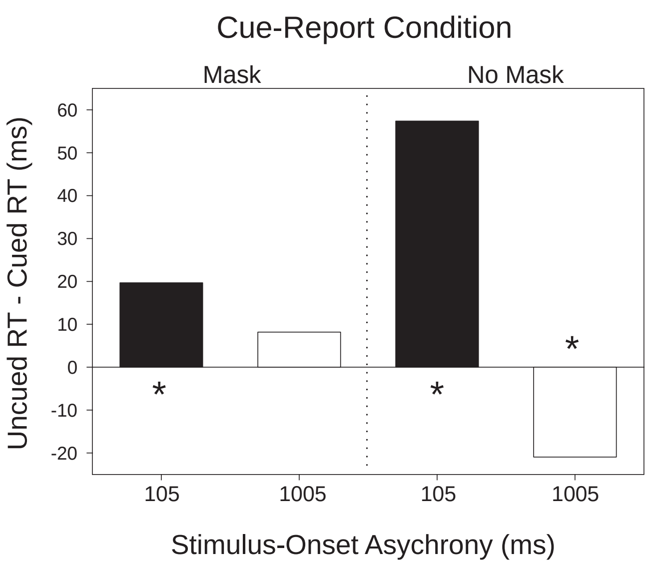

Figure 2. Mean RT differences (uncued RTs minus cued RTs) for each masking condition and cue-target stimulus-onset asynchrony in the cue-report condition. An asterisk indicates that the indicated uncued-cued difference is statistically significant from 0 ($p < .05$).

A bootstrapping procedure, using the same number of observations as obtained in this study, was employed to determine the mean and variance of information transmitted under the assumption of random responding. This procedure allows us to note that the performance of over one half of the participants in the mask condition could not be distinguished from chance performance, whereas this was true for only one subject in the no-mask condition. Because the overall level of cue-report performance was so close to chance when the mask was presented, we are confident that on the vast majority of masked trials, the signal strength of the cues was at or below the objective threshold of awareness. To ensure that the inclusion of participants with significantly better than chance cue report performance in the mask condition was not contaminating our pattern of findings, two groups were formed (chance and above chance), and the RT and false alarm data were subjected to a mixed ANOVA with group (chance and above chance) as a between-subject variable and cueing, SOA, and mask as the within-subject variable. The critical three-way interaction between cueing, SOA, and mask described above and illustrated in Figure 2, was unaffected by group in this analysis [i.e., the four-way interaction between group, SOA, cueing, and mask was not significant; RT: $F(1,19)=1.07$, $p > .30$, power=0.16; false alarms: $F(1,19)=0.20$, $p > 0.65$, power=0.07] supporting our decision to treat the participants homogeneously.

We suspected that the confidence ratings were not well understood by our participants, as the average rating by our participants for the masked condition was 2.3 and the average rating for the unmasked condition was 2.7.

Table 2. Mean Response Times and Percentage of False Alarms in the No-Report Condition

Stimulus-onset asynchrony	No cue	Uncued	Cued
		Mask	
105 ms	418 (13.5%)	406 (7.9%)	405 (10.3%)
1,005 ms	398 (9.5%)	387 (14.3%)	398 (6.3%)
		No Mask	
105 ms	426 (4.8%)	417 (9.5%)	405 (6.3%)
1,005 ms	424 (7.9%)	383 (17.5%)	406 (8.7%)

Although this difference was significant [t(20)=4.55, $p < .001$], we will not consider the analysis of confidence ratings too seriously.

No-Report Condition

RTs faster than 150 ms and slower than 750 ms were excluded from the analysis. This response window criterion (shortened from that used in the more difficult cue-report condition because of the faster RTs here in the absence of the cue-report requirement) excluded 2.1% of the trials.

The mean RTs are shown in Table 1. Mean RTs from trials with cues were entered into a 2 (cueing: cued and uncued) x 2 (SOA: 105 ms and 1,005 ms) x 2 (mask: present and absent) repeated measures ANOVA. The main effect of SOA [F(1,20)=5.34, $p < .05$], the interaction between cueing and SOA [F(1,20)=15.99, $p < .001$], and the three-way interaction between SOA, mask and cue [F(1,20)=5.20, $p < .05$] were significant. To examine the three-way interaction, the cueing effects (uncued RTs minus cued RTs) were examined at each level of SOA and mask (see Figure 3). When the cues were masked, there was 1 ms of nonsignificant facilitation at the short SOA and −11 ms of significant IOR [t(20)=2.56, $p < .05$] at the longer SOA. When the cues were not masked, there was 12 ms of significant facilitation [t(20)=2.21, $p < .05$] at the short SOA and −23 ms of significant IOR [t(20)=5.82, $p < .0001$] at the long SOA. The difference between the IOR effect for masked and nonmasked cues was marginally significant [t(20)=1.83, $p = .0823$].

No-Report Condition

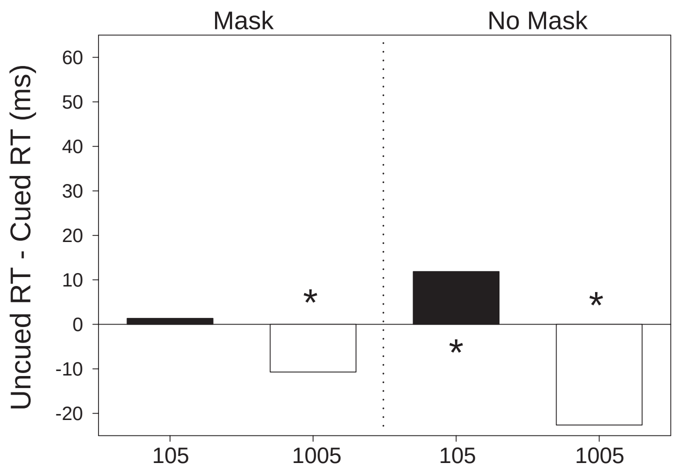

Figure 3. Mean RT differences (uncued RTs minus cued RTs) for each masking condition and cue-target stimulus-onset asynchrony in the no-report condition. An asterisk indicates that the indicated uncued-cued difference is statistically significant from 0 ($p < .05$).

The percentage of false alarms was entered into the same analysis applied to the RTs. The mean percentage of false alarms is shown in Table 2. The main effect of cueing was the only significant effect [F(1,20)=4.66, $p < .05$]. Previous work has shown that the IOR effect, as measured with RTs, is characterized by fewer false alarms for cued than for uncued targets (Ivanoff & Klein, 2001). Thus, despite the nonsignificant cueing x SOA interaction, cued and uncued false alarms were compared at each level of SOA. At the short SOA, the difference between cued and uncued was not significant, but at the longer SOA, there were 8.3% more false alarms at the uncued than at the cued location [t(20)=2.69, $p < .05$].

Discussion

When the cue was not masked, the results clearly duplicated one typical pattern in the literature: at the early SOA (105 ms), responses were facilitated when the target appeared at the same location as the cue. This attentional facilitation effect was modified by the instructions to report the cue. The 57-ms attentional facilitation effect in the cue-report condition was significantly [t(20)=4.76, $p < .001$] larger than the 12-ms attentional facilitation effect in the no-report condition. This enhancement may be due to the engagement of an attentional set to detect and localize the cue. The purpose of this set is to extract and maintain enough information regarding the cue to make an accurate report after the target's disappearance. As a result of this attentional set, the cue's power to attract and hold attention would be greatly enhanced. Our results support this idea.

At the longer SOA (1,005 ms), when the cues were not masked, we found the usual IOR effect. Interestingly, the IOR effect for the cue-report condition (M=-21 ms) did not differ from that in the no-report condition (M=-23 ms). Apparently, attention had been withdrawn from an unmasked cued location about 1 s after the cue, irrespective of whether or not a cue report was required, allowing IOR to be observed. Supporting the RT results, the false alarm analysis reveals the tell-tale excess of false alarms for uncued targets than for cued targets that is associated with IOR (Ivanoff & Klein, 2001). Although this difference was significant only in the cue-report condition, it is also the case that the cued minus uncued differences for false alarms in the cue-report and no-report conditions were not significantly different from each other [$t(20)=0.10$, $p > .90$). Thus, IOR was not significantly altered by the ACS to detect and localize the cue. This provides converging evidence for a nonattentional component to the IOR effect (Ivanoff & Klein, 2001; Ivanoff et al., 2002; Klein & Taylor, 1994).

The cue-report condition with the masked cues is the one that closely resembles the conditions of McCormick's (1997) experiment where his participants were unable to detect the cues. Supporting this comparison is the fact that the general pattern of results is similar in McCormick's study and ours. McCormick found evidence of early attentional facilitation without evidence of later IOR. Likewise, in our comparable experimental condition (i.e., the cue-report condition with masked cues), we found evidence of attentional facilitation and no IOR (see Figure 2). Indeed, the direction of the effect at the late SOA was opposite to that expected if there was an IOR effect. Thus, McCormick's finding was replicated and extended to a situation in which the peripheral cues were unpredictive.

A tempting interpretation of this result is that IOR is not found when the cue is not consciously perceived. This conclusion would be incorrect because in the no-report condition, there was 11 ms of IOR (that was accompanied by 7.9% more false alarms for uncued targets than for cued targets). Thus, the appearance of the IOR effect is not contingent on one's awareness of the cue. That the IOR effect is not different between the cue-report and no-report conditions for nonmasked cues suggests that the ACS, by itself, does not eliminate IOR. However, the combined influence of the ACS with cues that are nonconsciously perceived does eliminate the IOR effect (in both RT and false alarms). Our interpretation of this pattern of results is that when there is an ACS to process the cue (for cue report), and when the cue captures attention unconsciously (cue is masked), participants may fail to consciously disengage attention from the cue on a substantial proportion of trials just because they are not aware of its capture in the first place. With a mixture of facilitation from attention and IOR when attention is finally disengaged, the net result is a nonsignificant difference between cued and uncued RTs.

We have interpreted our pattern of results with masked cues in terms of the orienting of attention toward the location of unconsciously perceived cues. As outlined in the "Introduction," some of McCormick's (1997) findings might be explained by spatial or temporal luminance summation. Summation provides an unsatisfactory account of our pattern of findings for two reasons: First, if summation were occurring. facilitation should have been observed whether or not participants were reporting the cue, yet in the no-report condition, early facilitation was absent. Second, IOR is an aftermath of orienting, hence its presence in the no-report condition provides converging evidence that, when observed, the early facilitation was due to orienting.

Conclusions

When cue awareness was assessed, our results replicate and extend McCormick's (1997) finding that a peripheral cue, presented below the threshold of awareness, facilitates target processing at early SOAs and does not show the expected IOR effect at later SOAs. In contrast to McCormick's study, which used a process-dissociation procedure, our method could have obtained evidence for IOR, yet like McCormick's, it did not. Thus, unconscious peripheral cues attract exogenous attention, without showing IOR, when there is an ACS to try to detect and localize the cues. However, when the ACS is absent, because no cue report is required, the early facilitation following a masked cue is virtually eliminated and the IOR effect that normally follows exogenous orienting is obtained. It thus appears that the experimenter's attempt to measure cue awareness on a trial-by-trial basis (as recommended by many scholars) alters the processing that the cue elicits. This finding is reminiscent of the uncertainty principle in quantum physics: Two properties of a particle, position and momentum, cannot be measured with precision simultaneously (see Cassidy, 1998; http://www.aip.org/history/heisenberg/p01.htm). As in Heisenberg's gamma-ray microscope "thought experiment," wherein the effort to measure the position of a particle results in a shift in its position, in our work, the temporal dynamics or magnitude of exogenous attention is altered when awareness of the cues is assessed. A solution to this measurement conundrum will depend on clever scientists developing methods for assessing awareness that will not engender an attentional control setting that modifies the effects of cues below the threshold of awareness.

We were able to obtain IOR when the cue was not consciously perceived so long as there was no attentional set to search for the cue. This is consistent with the proposals that IOR will be seen only if attention is disengaged from the cue and that disengagement is unlikely when attention to the cue is encouraged by the requirement to provide cue-awareness reports and participants are unaware of the cue. Although attention is more strongly attracted to a consciously perceived cue when cue reports are required than when they are not, awareness of this attraction permits attentional disengagement (because the cue does not predict the likely location of the target) and the subsequent appearance of IOR.. The absence of early facilitation combined with the subsequent appearance of IOR when cue reports are not required and cues are masked can be explained by assuming that under these conditions, attention (and/or the oculomotor system) has been attracted to the cue (thus causing IOR), but disengagement occurs so rapidly (as in Danziger & Kingstone, 1999) that the early facilitation is combined with early IOR leaving no net facilitation.

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Footnotes

[1] Because of his use of cues with a reverse meaning, McCormick's own data from aware trials cannot serve as the comparison. Indeed, it is ironic that even if an IOR effect had been observed in McCormick's (1997) third experiment, it would have been compromised by the conscious attentional set to reorient attention away from the cue. If some participants incorrectly responded that they were unaware of the cue when in fact they were aware of the cue, then any effect resembling IOR might actually be due to the endogenous reorienting of attention away from the cue or IOR, or some combination of the two.

[2] The no-cue condition was excluded from the statistical analyses because it does not constitute a fair neutral condition with the cued and uncued trials. The presence of the cue acts like a warning stimulus and, thus, may deflate RTs.

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