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Attending to objects: Endogenous cues can produce inhibition of return

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Inhibition of Return (IOR) is effective in a wide range of experimental settings but has proven elusive under conditions of volitional (endogenous) attentional control. This result may be due to a continuing attentional bias towards the cued location. Here we ask whether IOR can be unmasked under endogenous cueing conditions when a predictive cue prevents such a bias. In Experiment 1, a central arrow directed attention endogenously to one end of a rectangular object. Attention initially radiated to an unpredicted location in the object but IOR later impaired target detection at that location. In Experiment 2, attention was directed endogenously to a dynamic object. While target detection was facilitated at a subsequent (and predicted) location of the rotating object, detection-latencies at its original location were slowed. Together the results show that it is possible to produce IOR using endogenous cues.

An important aspect of efficient attentional processing is the ability to prioritize novel information and avoid repetitive selection of previously attended locations or objects. One well-studied phenomenon thought to contribute to the efficient allocation of attention is inhibition of return (IOR; Posner & Cohen, 1984; Posner, Rafal, Choate, & Vaughan; see Klein, 2000, for an overview). In a standard IOR task, a cue appears at a peripheral

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location, attracting attention at that location. Following a delay, a target then appears at the cued location, or an uncued location, with an equal likelihood (i.e., the cue is uninformative). When the stimulus–onset asynchrony (SOA) between the cue and the target is short, targets are detected faster at the cued location relative to the uncued location. If the cue–target SOA is long enough (typically 200 ms or longer; see McAuliffe & Pratt, 2005), however, inhibition occurs at the cued location such that target detection at that location is now slowed relative to the detection of a target at an uncued location.

Inhibition of return has been observed under a wide range of experimental conditions. It has been shown, for instance, that IOR can be tagged to both locations and objects (Abrams & Dobkin, 1994; Tipper, Driver, & Weaver, 1991); that it occurs in the visuospatial as well as the auditory modality (Mondor, Breau, & Milliken, 1998); that it is evident in both detection and identification tasks (e.g., Pratt & Abrams, 1999); and that it generalizes to other response modes such as eye or limb movements (Abrams & Dobkin, 1994; Klein & McInnes, 1999; Roelofs, van Galen, Eling, Keijsers, & Hoogduin, 2003).

Despite these diversities, there are some criteria for IOR that appear to be more restrictive. In particular, IOR is generally thought to occur only under exogenous (bottom-up), and not endogenous (top-down, volitional), attentional orienting. Exogenous cueing has often been considered a signature feature of IOR, and has assumed axiomatic status since the early years of IOR research. Indeed, two of the most influential IOR studies failed to find inhibition following “classic” endogenous cues—central arrows that provided information regarding the most likely location of an upcoming target (Posner & Cohen, 1984; Rafal, Calabresi, Brennan, & Sciolto, 1989). As a result, several researchers have used the presence of IOR as a test of exogenous orienting (Pratt, Hillis, & Gold, 2001; Theeuwes & Godijn, 2002). It should be noted, however, that there is some evidence that endogenous processing may not be totally at odds with the generation of IOR. Lupianez et al. (2004) found IOR with informative exogenous cues (peripheral onsets) that predicted target locations at the cued or uncued location and inhibition occurred in the former case. It is unclear, however, to what extent their finding represents endogenous IOR in a traditional sense, as cues were still peripheral onsets and there was also no intervening stimulus that would have pulled attention away from the periphery. Taylor and Klein (2000) found IOR with uninformative central arrows that did not predict target locations. Earlier studies have suggested, however, that arrow cues, similar to face cues with a gaze pointing to the side, direct attention involuntarily (Hommel, Pratt, Colzato, & Godijn, 2001; Pratt & Hommel, 2003). The present work was designed to extend the arrow cue paradigm (Experiment 1) and replace it with a word-cue prime (Experiment 2) to minimize this problem.

In examining if IOR only occurs at exogenously cued locations, and not endogenously attended locations, Danzinger and Kingstone (1999) found that IOR can occur at much shorter SOAs than previously thought. In two experiments, they dissociated *cued* and *predicted* target locations and thereby "unmasked" IOR, revealing inhibition at the cued location with an SOA of only 50 ms. In their experiment, an exogenous cue appeared at one of four peripheral locations that were centralized around the fixation cross. In the critical condition, the cue predicted the target to appear one location clockwise from the cued location. After SOAs of 50 or 950 ms, the target appeared at the predicted location with a likelihood of 67%, and with a likelihood of 11% each at the three remaining locations (including the cued location). Target detection was fastest at the predicted location while it was significantly slowed in the cued location relative to a neutral baseline in both the 50 and 950 ms SOA conditions. From this latter finding, Danzinger and Kingstone concluded that in standard IOR paradigms (i.e., using uninformative exogenous cues), attention continues to be directed to the cued location beyond the offset of the cue, thus masking the inhibition generated by the cue. When attention is directed to a different location (in their case, the position clockwise to the cue), only the inhibition remains at the cued location, thus unmasking IOR.

In the current experiments we used a similar logic to investigate whether IOR can be "unmasked" under conditions of endogenous cueing. Endogenous attentional orienting is more slow-moving than exogenously guided attention (Theeuwes, Godijn, & Pratt, 2004; Wolfe, Alvarez, & Horowitz, 2000), providing a possible explanation for why attention is less effectively disengaged from an endogenously cued location, thus masking IOR. In the study by Theeuwes et al. (2004), for instance, attentional dwell-times were found to be about 10 times larger in an endogenous cueing paradigm as compared to an exogenous cueing situation (a visual search task). Moreover, endogenous orienting has been shown to reduce the effect of exogenous cues (Mueller & Rabbitt, 1989), which could limit the efficiency with which the central fixation cross disengages attention from the cued location. As such, it is possible that previous studies have failed to show IOR with endogenous cues because attention is more slowly reallocated at the centre and continues to be biased towards the cued location.

Our first experiment employed an object-cueing paradigm in which one end of an object was cued by a central arrow. Earlier studies have shown that facilitatory as well as inhibitory attention radiates through an object following a peripheral (exogenous) cue (Egly, Driver, & Rafal, 1994; Leek, Reppa, & Tipper, 2003). Here we sought to confirm earlier findings that facilitatory attention can spread to uncued locations of the object following central arrow cues (Abrams & Law, 2000); and to investigate whether such an arrow-induced spreading of attention is followed by IOR. Our second experiment uses symbolic cues (words) to further establish the existence of IOR under endogenous cueing conditions.

EXPERIMENT 1

Experiment 1 pursued two goals. First, we sought to corroborate previous findings that attentional radiation can occur under endogenous cueing conditions (Abrams & Law, 2000). To this end we used a variant of a paradigm by Egly et al. (1994) who investigated the spreading of attention through an object. Egly et al. showed that when one end of an oblong object is cued by a peripheral luminance increment, target detection will be facilitated not only at the cued location, but also throughout the cued object. In particular, participants will be faster to detect a target in the uncued end of a cued object compared to a target located the same distance from the cue but on a different object. Thus, attention appears to spread or radiate over the surface of an object following an attentional cue to another part of that object.

We used a variant of the Egly et al. (1994) cueing paradigm, the critical modification being that an endogenous (central arrow) cue was used instead of the standard exogenous cue. If attentional radiation occurs with endogenous cues in the Egly et al. cueing paradigm, facilitation is expected to occur at an uncued location in the cued object relative to an equidistant uncued location in the uncued object. No such difference would be expected if attentional radiation is confined to exogenous cues in the Egly et al. paradigm.

Our second, and more important, goal was to study the effect of endogenous cues at later SOAs (up to 2500 ms; see Frischen & Tipper, 2004) where IOR is usually observed in exogenous cueing tasks. The spreading of IOR through an object has already been shown in previous research (Leek et al., 2003), but in those experiments, peripheral cues were used.

Following Danzinger and Kingstone's (1999) study, IOR may not occur when attention is not properly disengaged from a cued location. When predictive cues were used that encouraged such disengagement, IOR was observed with very short SOAs. If lack of attentional disengagement is also the reason for why IOR has not been obtained with endogenous cues, we expect IOR to occur when a predictive cue promotes such disengagement.

Once attention has radiated across the object, we expected the predictive validity of the cue to withdraw attention from a cued but unpredicted location and to redirect and refocus it at the predicted location. Similar to Danzinger and Kingstone's (1999) "clockwise predicted condition", facilitation would now be expected at the predicted location while IOR should occur at the remainder of the cued object.

The arrow in the current experiment cued one end of one of two oblong rectangles indicating that an upcoming target had a greater than 70% chance of appearing there. The high validity of the cue was expected to motivate participants to maintain attention at the cued location until the target arrives. Targets appeared after one of several cue–target delay intervals. Importantly, the target sometimes appeared at one of two uncued locations: A location on the cued object, or a location on the uncued object. Of interest is the time needed to detect an uncued target as a function of both the object upon which it appeared and the cue–target delay.

Method

Participants. Eleven undergraduates participated as paid volunteers in a single, 1-hour session. They all had normal, or corrected to normal vision, and were naïve as to the purposes of the experiment.

Procedure and stimuli. Testing was conducted in a dimly lit, sound attenuated room. Participants were seated in front of a computer monitor and their heads were steadied with a chinrest. The sequence of events during a trial is shown in Figure 1 and was as follows: At the beginning of each trial the fixation display was shown. This display consisted of a central fixation and was flanked by two $11.4^{\circ} \times 1.7^{\circ}$ rectangles. The rectangles were either vertically oriented and to the left and right of fixation, or they were horizontally oriented and above and below it.

One second after the onset of the display, the fixation plus was replaced with an arrow cue which pointed toward one of the four rectangle ends and remained visible for 300 ms. The size of the arrow was such that it would fit inside a $1.1^{\circ} \times 1.0^{\circ}$ box. Either 600 ms after offset of the arrow (900 ms cue–target interval), or after a 1400 ms delay (1700 ms cue–target interval), or after a 2200 ms delay (2500 ms cue–target interval), the target, a grey 0.9° square, was presented inside and near the end of one of the rectangles. The target could appear at the cued location, in the uncued end of the cued object (uncued same-object condition) or in the end of the uncued object closest to the cue (uncued different-object condition) The target remained visible until the participant responded. The participant's task was to press a key as soon as they detected the appearance of the target. At the end of the trial a blank screen was displayed for 250 ms and then the next trial began. Participants were provided with performance feedback and an opportunity to take a short rest after every 64 trials.

Eye movement monitoring. Participants wore a scleral-reflectance eye-movement monitor mounted on a spectacles frame (Applied Science Laboratories, Model 210). Output from the eye movement monitor was

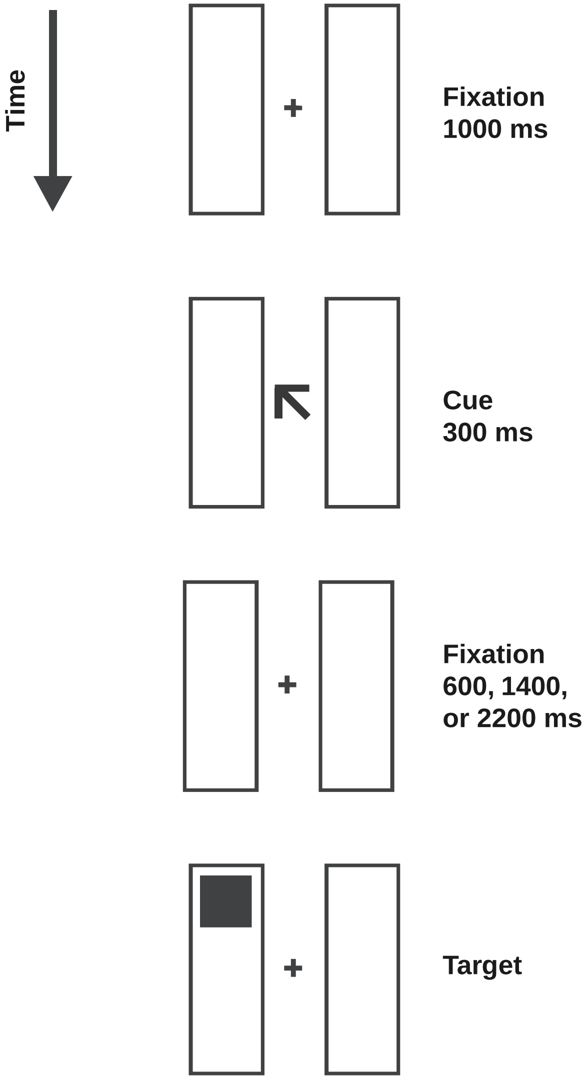

Figure 1. Sequence of events during a trial. The actual stimuli were white against a black background, except for the target which was grey.

sampled during the fixation period prior to cue presentation, and during the interval between cue presentation and the keypress response, using methods similar to those that we have used previously (Abrams & Dobkin, 1994). The trial did not begin until the participant's gaze was within 1.5° of fixation; the trial was excluded from analysis if the participant produced a saccade during the trial.

Design. At the beginning of each session a practice block of 20 trials was presented, these trials were randomly selected from among the possible conditions. Two experimental blocks each comprised of 168 trials followed the practice block. Of these trials, 120 (71.4%) were cued trials, 24 uncued same-object, and 24 were uncued different-object trials. An equal number of trials in each cue condition were presented at each cue–target interval. A 3 (cue-type: Cued, uncued same-object, uncued difference object) × 3 (SOA: Short, medium, long) was conducted for overall effects. Post hoc tests were two-sided *t*-tests.

Results

Mean reaction times for the three cueing conditions at each cue–target interval are shown in Figure 2. There was a main effect of type of cue, $F(2, 20) = 7.6, p < .01$. As seen in the figure, cued trials were generally fastest, reflecting the predictive validity of the (endogenous) cue. There was also a main effect of cue-target interval, $F(2, 20) = 17.4$, $p < .01$, and importantly, the type of cue interacted with cue–target interval, $F(4, 40) = 3.6$, $p < .05$. The interaction can be described as follows. At the shortest cue–target interval (900 ms), there was an object-advantage with detection latency being 33 ms faster in the uncued same-object condition

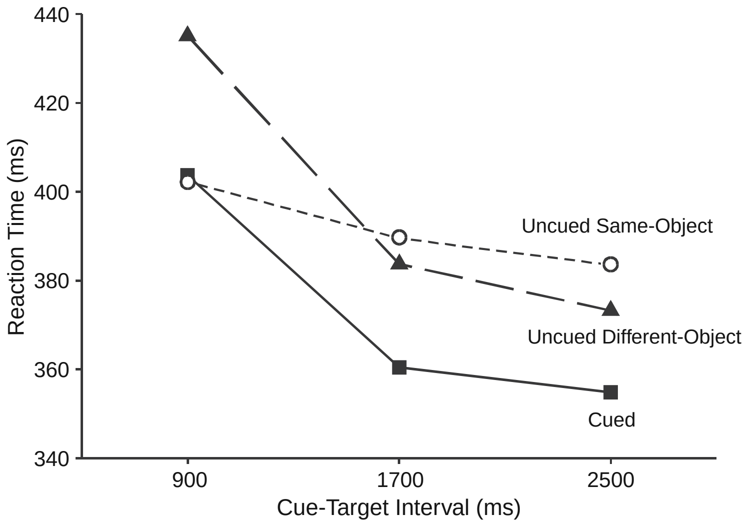

Figure 2. Mean reaction times for each cue–target interval. Faster latencies in the uncued same-object condition compared to the uncued different-object condition are evidence of an object advantage (e.g., at the 900 ms SOA). Faster latencies in the uncued different-object condition compared to the uncued same-object condition are evidence of object-based inhibition.

compared to the uncued different-object condition, $t(10) = 2.2$, $p < .05$. This facilitation disappeared at the medium (1700 ms) cue–target interval, $t(10) = 0.6$, $p > .05$. And at the longest (2500 ms) cue–target interval there was a significant object disadvantage: Detection in the uncued same-object condition was 11 ms *slower* than in the uncued different-object condition, $t(10) = 2.4$, $p < .05$. Note that this latter cost was observed at the uncued end of the cued object at the same time that facilitation was present at the cued location.

Discussion

The current results clearly demonstrate that attentional radiation can occur with endogenous cues. Target detection at the uncued-same object location yielded a clear advantage over the uncued-location uncued-object condition, at least at the 900 ms SOA. In fact, it is quite remarkable that the cued location and the uncued-same object location yielded similar reaction-time benefits, as compared to the uncued-object condition. At the longer SOA, the same object advantage was eliminated and eventually followed by an inhibitory aftereffect, IOR. In other words, at a sufficiently long SOA, it is possible to observe IOR following endogenous cues in an object-based attention paradigm. Earlier research with gaze cues have shown IOR to emerge at comparably long SOAs (Frischen & Tipper, 2004).

In the current experiment, it is important to note that attention was never directly deployed at the location that later yielded IOR. Earlier research has suggested, however, that similar to central gaze cues, attention shifts in response to arrow cues may not be purely endogenous (Hommel et al., 2001; Pratt & Hommel, 2003). To provide more compelling support that IOR can occur under endogenous cueing conditions, Experiment 2 used symbolic (word) cues to direct attention.

EXPERIMENT 2

To provide converging evidence that IOR can be found with endogenous cues, we used a paradigm whereby endogenous cues (word labels such as “left”, “right”, “green”, “blue”) directed attention to dynamic objects or static locations. The experiment employed a variant of a paradigm used by Weaver, Lupianez, and Watson (1998), who studied the effect of peripheral cues in dynamic displays.

In the attend-object condition of the current study, participants were instructed to endogenously attend to an object that initially occurred at a particular location. The object then started moving and participants were instructed to continue attending the object until it came to a standstill. In the attend-location condition, participants were instructed to endogenously attend to the location of an object, and continue attending to that location even when the object moved away and subsequently stopped at a new location. To assure that participants complied with these instructions, targets appeared in the instructed object/location in approximately 80% of the trials. For both conditions, target detection was expected to be faster at whatever was attended—the dynamic object or the static location (when compared to a neutral baseline object/location). Of critical interest was whether or not it would be possible to observe "unmasked" IOR in these conditions. Assuming that endogenously attending to an object also involves attending to the location of that object, we expected to find IOR at the inadvertently attended object or location. Thus, in the attend-object condition, once attention is disengaged from the initially attended location to follow the to-be-attended dynamic object (Danzinger & Kingstone, 1999), IOR would be expected to occur at that initial location.

The scenario in the attend-location condition is less straightforward. If attention is also directed to an object when a location is cued, then we would expect a similar inhibitory effect for objects that appear at the cued location. If space-based attention does not necessarily imply object-based attention, however (Lamy & Tsal, 2000), no object-based IOR effect is expected in this paradigm. According to such a view, location is a more primitive feature that overrides higher level features such as object identity. Jordan and Tipper (1999), for instance, have shown that objects have a very low, if any, impact on attentional processing when they are irrelevant to a current goal, as is the case in the current attend-location condition. Moreover, studies of IOR have also shown that location-based IOR is typically larger than object-based IOR. If attention to locations engages attention to objects in only a limited way, then we would expect an asymmetry in the occurrence of IOR in the two conditions.

Method

Participants. Twelve undergraduate students participated in the experiment in exchange for course credit.

Procedure and stimuli. Testing was conducted in a dimly lit room. Participants were seated in front of a computer monitor with a refresh rate of 85 Hz and their heads were stabilized in a chinrest to assure a viewing distance of 44 cm. The sequence of events during each trial is shown in Figure 3 and was as follows: Three circles in red, green, and blue colour, approximately 2.6° in diameter, appeared in a triangular pattern on the computer screen, centred around the fixation cross for 500 ms at a distance of approximately 7.1°. While the three circles remained visible in the same

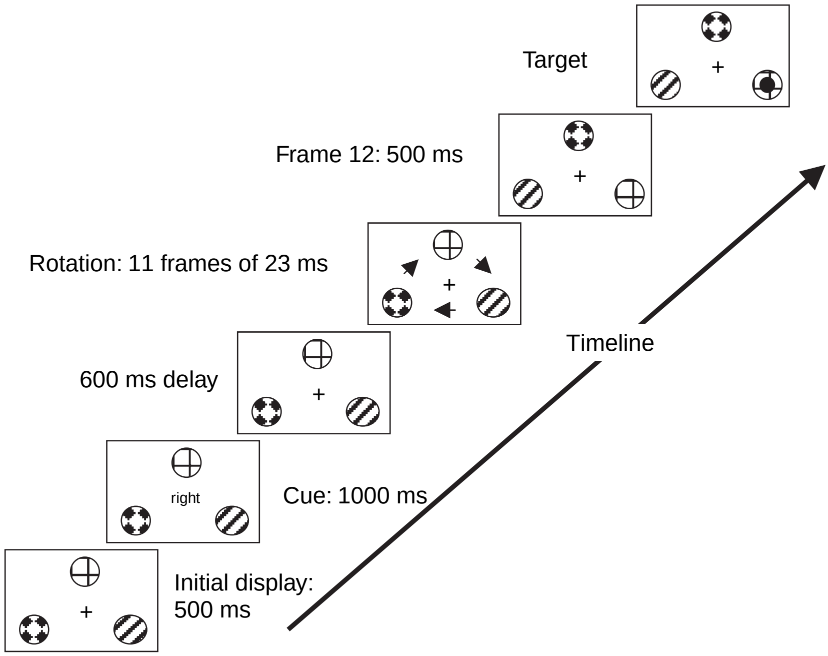

Figure 3. Sequence of events during an attend-location trial in Experiment 2.

location, the fixation cross was replaced with a word that either instructed the participant to attend to one of the locations in the attend-location condition ("TOP", "LEFT", "RIGHT") or to one of the objects in the attend-object condition ("GREEN", "RED", "BLUE") and stayed on the screen for 1000 ms. The cue was then again replaced with the fixation cross and, after another 600 ms, the three circles started rotating in 11° increments in a clockwise manner until each circle occupied the location of the subsequent circle (120° rotation). Each increment appeared for 23 ms, creating the image of a continuous, if not perfectly smooth movement. In the attend-object condition, participants were instructed to move their attention with the rotating circle while keeping their eyes fixated at the central cross. In the attend-location condition participants were instructed to keep their attention at the instructed location despite the rotating display, and to also keep their eyes fixated at the central fixation cross.[1] After the last frame had appeared for 500 ms (i.e., a total cue–target SOA of 2353 ms,

[1] Before the beginning of the task, participants received a demonstration showing how to separate covert attention from the overt attention that was established by the eyes' fixation at the central fixation cross.

which again is comparable to the SOA used by Frischen & Tipper, 2004), the target (a black dot) appeared in one of the three circles, constituting the continuously attended (CA), initially attended (IA), and never attended (NA) trials. Subjects were instructed to press the spacebar as soon as they detected a target. CA trials were those where the target appeared in the to-be-attended object/location. NA trials in both conditions were those where a target appeared in a noncued and nonattended object/location. IA trials in the attend-object condition were those where the target appeared in the location where the to-be-attended object was initially located (i.e., at the time of the cue, prior to the onset of the rotation). IA trials in the attend-location condition were those where the target appeared at the rotated object that had initially occupied the to-be-attended location but now appeared in a new location. Trials were separated by a 1500 ms intertrial interval.

Targets appeared in the CA, IA, and NA conditions with a likelihood of 79%, 5%, and 5% (on 135, 9, and 9 trials). Eighteen catch trials (11%), during which no target appeared, were added to avoid anticipatory responses, yielding a total of 171 trials in both the attend-object and attend-location condition.

Attend-object and attend-location trials were blocked, with a brief break in between both blocks. Participants were repeatedly instructed to keep their eyes at a central fixation cross. They were informed that they were being video monitored to assure that they complied with the instructions. A 3 (cue-type: CA, IA, NA) $\times$ 2 (attention-condition: Attend-object, attend-location) ANOVA was conducted to investigate overall effects. Post hoc tests were two-tailed *t*-tests.

Results

The first five trials of each block were eliminated as practice (2.9%) and so were responses with latencies below 100 and above 800 ms (1.6%).

Mean reaction times for the CA, IA, and NA conditions are shown in Figure 4. There was a main effect of cue type, $F(2, 22) = 14.2$, $p < .001$, with responses being faster in the CA than both the IA and the NA conditions. There was no main effect of attention condition, $F(1, 11) = 2.65$, $p = .13$ but a significant interaction indicated that the pattern of results differed for the attend-object and attend-location condition, $F(2, 22) = 4.21$, $p < .05$. Post hoc tests showed that while there was no difference between the two conditions for either CA trials, $t(11) = -0.83$, $p = .42$, or NA trials, $t(11) = +0.83$, $p = .42$, targets on IA trials in the attend-object condition were responded to more slowly than targets on IA trials in the attend-location condition, $t(11) = 2.56$, $p < .05$. Moreover, in the attend object-condition, targets appearing on IA trials were responded to more slowly

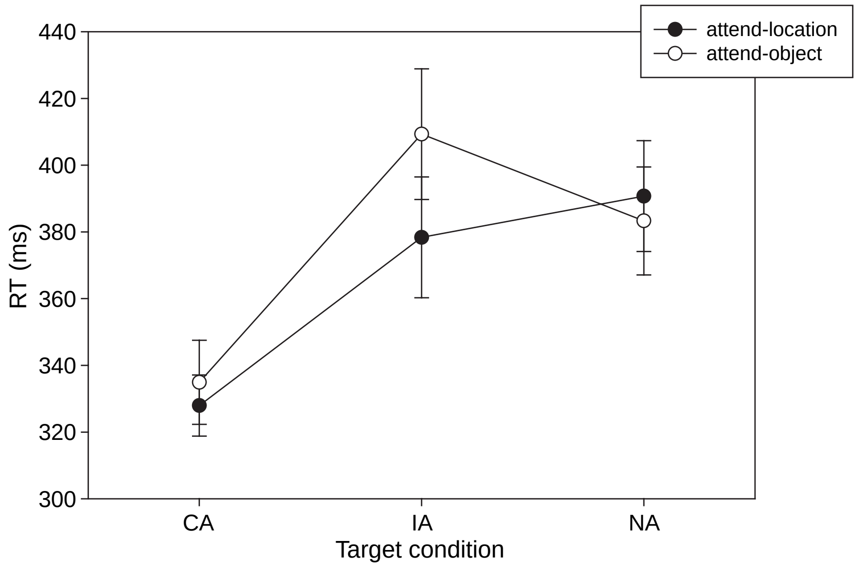

Figure 4. Mean reaction times for attend-object and attend-location trials in Experiment 2 in the continuously attended (CA), initially attended (IA), and never attended (NA) condition.

than NA-trial targets revealing the presence of IOR, $t(11) = 2.25$, $p < .05$. The difference between IA- and NA-trial targets yielded no reliable difference in the attend-location condition, $t(11) = 1.03$, $p = .32$.

Discussion

The results of the second experiment provide further evidence that IOR can occur with endogenous cues. When attention was directed to an object via an endogenous cue, and movement of the object disengaged attention from the cued location, target detection at that location was later inhibited. Thus, the object motion permitted the unmasking of IOR. Conversely, when attention was directed to a location and remained at that location instead of following the moving object, no inhibition occurred for the object. These results are in agreement with an asymmetric relationship between object- and location-based attention, the assumption being that when attention is directed to an object, its location is also encoded. Conversely, when attention is directed to a location, object-based encoding does not necessarily take place.

GENERAL DISCUSSION

Two experiments investigated IOR under conditions of volitional attentional orienting using predictive validities of endogenous cues (arrows or words). Experiment 1 used a variant of the Egly et al. (1994) paradigm to investigate the radiation of attention through an object. This radiation appears to be fairly robust, since it occurs without any explicit instructions and, given the target probabilities in the present study, would not facilitate target detection. Importantly, after a relatively long SOA, the benefit produced by the radiation of attention became a cost. As a result, at the long cue–target interval we observed IOR: Participants were slower to detect a target in the cued object than in the uncued object, despite still being fastest at the cued location itself.

Experiment 2 used dynamic objects to investigate whether IOR can occur at an object's cued location when attention subsequently moves with the object to a novel location. Once again, IOR was observed despite the fact that attention was endogenously allocated to either dynamic objects or static locations on the basis of centrally presented word cues. Taken together, the two experiments show that when attention is disengaged from a cued location via a probability manipulation, IOR can occur under conditions of endogenous attentional orienting.

Why has IOR never been observed in previous studies using classic endogenous cues (i.e., informative and centrally presented cue stimuli)? Referring to the absence of IOR at early SOAs in traditional exogenous cueing paradigms, Danzinger and Kingstone (1999) argue that attention continues to be directed to the cued location even after cue offset, thus masking IOR at that location. Once this attentional facilitation is eliminated, IOR can be observed at very short SOAs. Here we assume a similar bias to explain why IOR may have never been observed under endogenous cueing conditions.

A key assumption we have made in this study is that the engagement of attention at a location or on an object is even stronger and more long-lasting in endogenous than in exogenous cueing conditions. There is evidence to support this assumption, as endogenous attention is known to be more slow moving, compared to exogenous attention (e.g., Wolfe et al., 2000). Studies have shown, for instance that attentional dwell-time—the time to switch from one item to another, for instance in a visual search task—is much slower when search is controlled in an endogenous, top-down fashion than when it is controlled in an exogenous, bottom-up fashion (Theeuwes et al., 2004). Endogenous orienting has also been shown to modulate and reduce the effect of exogenous cues (Mueller & Rabbitt, 1989), thus making the flicker of the central fixation cross potentially less efficient in disengaging attention from the cued location. As a result, there may be a continuing bias towards the cued location that is much stronger in conditions of endogenous as opposed to exogenous attentional orienting and may never fully recede unless participants are motivated to direct attention elsewhere. Once attention is successfully disengaged from the cued location, however, as is the case when the cue predicts the target to appear at a different location, IOR may occur with endogenous cues. The comparably long time it took for IOR to build up in the current experiments is in line with earlier results that have shown a similarly slow build-up of IOR in the presence of central gaze cues (Frischen & Tipper, 2004).

Although IOR was found in both experiments, it did not occur at the initially attended object in the attend-location condition of Experiment 2. One explanation would be that it did in fact occur but was masked by residual facilitation that stemmed from attention being directed to the object while the object appeared at the to-be-attended location. While we would certainly favour such an account, it appears to be unlikely given the high predictive validity of the cue that summoned attention at the to-be-attended location. Residual attention at a highly unlikely location that is maintained for more than 2 s appears to be unlikely. Rather, we attribute this effect to an asymmetry in efficiency with which object- and location-based attention are controlled. *Location*-based attention is evolutionarily older and more salient and an object's location may thus be prominent even when attention is directed to the object itself. Conversely, when attention is directed to a location, no such carryover effect occurs, rendering the irrelevant object no different from the uncued object in the attend-location condition. This asymmetry comports with other research showing that the *location* of an object receives attention irrespective of whether it is task-relevant or not, while object-*features* (such as form or colour) receive attention only when such features are task relevant (Lamy & Tsal, 2000).

The current experiments controlled attentional orienting via probability manipulations using predictive central cues. Both experiments yielded increased reaction times at locations to which attention was first directed but later withdrawn. The effect was asymmetric in that IOR occurred for cued locations but not for cued objects. While objects can mediate location-based inhibitory cueing effects (Experiment 1) they may not become a source of endogenously controlled inhibition on their own (Experiment 2).

It is worth noting that the experiments we needed to show IOR with classic volitional cues (informative and central) are relatively complex. The complexity of the designs show that finding IOR with true endogenous cues is not easy. Yet, the results require a reassessment of previous concepts of attention that assumed strict differences between endogenous and exogenous control. Both types of attention may be more similar to each other than previously thought—a conclusion that has been reached previously (Abrams & Law, 2000). Earlier studies have also shown that the differentiation between endogenous and exogenous attention, based upon the type of cue (for instance, arrow cues) is not as strict as previously though, as arrows can also lead to exogenous shifts of attention (Hommel et al., 2001; Pratt & Hommel, 2003). The current experiments follow along these lines in that they suggest that IOR can also follow endogenous cues.

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