

Dissociating inhibition of return from endogenous orienting of spatial attention: Evidence from detection and discrimination tasks

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In the present series of experiments, peripheral informative cues were used in order to dissociate endogenous and exogenous orienting of spatial attention using the same set of stimuli. For each block of trials, the cue predicted either the same or the opposite location of target appearance. Crucially, using this manipulation, both expected and unexpected locations could be either cued or uncued. If one accepts the hypothesis that inhibition of return (IOR) is an attentional effect that inhibits the returning of attention to a previously attended location (Posner & Cohen, 1984), one would not predict an IOR effect at the expected location, since attention should not disengage from the location predicted by the cue. Detection and discrimination tasks were used to examine any potential difference in the mechanism responsible for IOR as a function of the task at hand. Two major results emerged: First, IOR was consistently observed at the expected location, where, according to the traditional “reorienting” hypothesis, IOR is not supposed to occur. Second, a different time course of cueing effects was found in detection versus discrimination tasks, even after controlling for the orienting of attention. We conclude that IOR cannot be accounted for solely by the “reorienting of attention” hypothesis. Moreover, we argue that the observed time course differences in cueing effects between detection and discrimination tasks cannot be explained by attention disengaging from cues later in discrimination than in detection tasks, as proposed by Klein (2000). The described endogenous–exogenous dissociation is consistent with models postulating that endogenous and exogenous attentional processes rely on different neural mechanisms.

Unexpected, novel, salient, and potentially dangerous events take high priority in the brain. There is now a wealth of literature showing that

these stimuli are typically processed in an automatic (or bottom-up) fashion, involving what has been labelled exogenous or involuntary attention

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(Corbetta & Shulman, 2002; Egeth & Yantis, 1997; Jonides, 1981; see Ruz & Lupiáñez, 2002, for a review about attentional capture). Spatial attention, however, can be voluntarily directed to a particular location or object depending on the goals or expectancies of the task at hand, involving more endogenous or voluntary forms of attention. According to the spotlight metaphor (Posner, Snyder, & Davidson, 1980), exogenous and endogenous attention are the behavioural expression of the same unitary mechanism. This metaphor assumes that attention is a unique spotlight that can be oriented to a location either voluntarily (endogenously) or involuntarily (exogenously), favouring the processing of objects and locations illuminated by this focus.

In a seminal study, Posner and Cohen (1984) developed the cost and benefits paradigm, in order to investigate the processes that were involved in the orienting of attention. In this paradigm, a fixation point is normally presented at the centre of the screen, and two boxes appear to the left and right of fixation. An uninformative peripheral cue (e.g., a brief flash in one of the boxes) is normally used when investigating exogenous attention, while endogenous cueing studies usually involve central informative cues (e.g., an arrow pointing left or right). Uninformative peripheral cues are supposed to capture spatial attention exogenously (or involuntarily), while central informative cues are presumed to produce a voluntary orienting of spatial attention.

The behavioural effects of both types of cue are clearly different. Central informative cues normally produce faster and/or more accurate target responses at the expected than at the unexpected location, even for long cue–target time intervals (Posner, 1980). However, the use of uninformative peripheral cues leads to two different effects in the detection of a subsequent target across time. If the target appears soon after the appearance of the cue (less than 300 ms), a facilitatory effect is observed—that is, response times (RTs) are faster at cued than at uncued locations. However, if the target appears 300 ms after cue onset or later, an inhibition of return (IOR) effect is

observed (i.e., RT is slower for cued than for uncued trials, Posner & Cohen, 1984).

IOR was proposed to be a mechanism that evolved to maximize sampling of the visual environment. The effect was observed for peripheral cues but not central cues. In addition, Posner and Cohen (1984) found IOR when attention was redirected to the central fixation, supposedly producing a disengagement of attention from the cued location. Taking into account these results, and considering attention as a single spotlight (which may be oriented in two modes, endogenously or exogenously), Posner, Rafal, Choate, and Vaughan (1985) concluded that IOR was an attentional effect, consisting of an inhibition of the return of attention to a previously attended position. According to this hypothesis, when a peripheral cue appears, attention is automatically drawn to its position, but subsequently attention is disengaged from that particular spatial position, and an inhibitory mechanism starts to operate, inhibiting the return of attention to that previously attended position. This hypothesis, which we call the *reorienting hypothesis* from now on, has been widely accepted by many researchers (see Klein, 2000, for a review).

According to the reorienting hypothesis, no inhibition should be measured until attention is disengaged from the cued location. However, Berlucchi, Tassinari, Marzi, and Di Stefano (1989) reported an experiment in which, even though participants knew in advance where the target would appear, RTs were slower when the target was presented at the same position as the peripheral exogenous cue. In this study, the target always appeared at the same spatial position within a block of trials. Thus, although these results seemed to challenge the reorienting hypothesis, a potential problem with this interpretation could be that a habituation process decreased the effect of the voluntary allocation of attention at the cued position. This concern was resolved in a more recent study, where Berlucchi, Chelazzi, and Tassinari (2000) presented targets at one of four possible locations randomly. Targets were preceded by nonpredictive exogenous cues. In each block of trials, participants were

asked to voluntarily attend to a position related to the exogenous cue (e.g., to attend to the position symmetrical to the cued location). Overall, RTs were faster at the voluntarily attended position and slower at the cued location (i.e., a main effect of IOR was observed). Importantly, these effects were completely independent from each other: IOR was observed at both the endogenously attended and the unattended position.

Recently, Berger, Henik, and Rafal (2005) presented a paradigm in which a central informative cue (an arrow with 80% validity) was followed by a peripheral uninformative cue. After a variable stimulus onset asynchrony (SOA) the target was presented, and the participants were asked to complete a detection task, a two-choice localization task, or a saccadic eye movement to the target (Experiments 1, 2, and 3, respectively). The results of the three experiments showed that the endogenous orienting of attention (elicited by the central informative cue) was independent of the exogenous orienting of attention (elicited by the peripheral uninformative cue), with IOR being observed at both endogenously attended and unattended locations. These results are opposite to those predicted by the reorienting hypothesis, according to which IOR is not supposed to occur until attention is disengaged from the cued location. At the expected location, since attention is allocated at that position, no IOR effect should be observed.

It is worth noting here that Posner, Cohen, and Rafal (1982) reported an experiment where the cue predicted either the same or the opposite position of target appearance. The authors' main conclusion was that the appearance of the cue produced an early facilitatory effect even though the cue predicted the target to appear at the opposite location. However, they did not take into account that the inhibitory effect (IOR) was also observed when the target appeared at the position to which participants were attending (as was predicted by the cue). Recently, Lupiáñez et al. (2004) employed a similar experimental setting and compared RTs to targets appearing at cued versus uncued positions at endogenously attended locations (i.e., cued location trials in a 80% valid

condition and uncued location trials in a 20% valid condition). The main result that emerged from this study was that IOR was consistently found at the endogenously attended location. Additionally, a similar IOR effect was also observed when the target appeared at an unexpected location (i.e., cued location trials in the 20% valid condition vs. uncued location trials in the 80% valid condition). Thus, IOR appeared in both endogenously expected and unexpected locations.

Similar findings emerged from the reanalysis (Lupiáñez et al., 2004) of the results of a previous study by Bartolomeo, Siéoff, Decaix, and Chokron (2001) exploring performance of normal individuals and of patients with left unilateral neglect. These patients showed a lack of IOR for right, ipsilesional targets, confirming previous findings (Bartolomeo, Chokron, & Siéoff, 1999; see also Vivas, Humphreys, & Fuentes, 2003). This result is also consistent with the idea that these patients' attention is biased towards right, ipsilesional objects (Bartolomeo & Chokron, 2002). Lupiáñez et al.'s (2004) reanalysis of Bartolomeo et al.'s results demonstrated that the lack of IOR was present for both expected and unexpected right-sided targets.

In summary, previous research has shown that it is possible to observe cueing effects (specifically IOR at long cue–target intervals) at a position where attention is being maintained voluntarily (by means of instructions to attend to a position related to a peripheral cue, Berlucchi et al., 2000; Berlucchi et al., 1989; Lupiáñez et al., 2004, or a central cue, Berger et al., 2005).

In the present study, we attempted further to dissociate endogenous and exogenous orienting of spatial attention using the same set of stimuli. As in Lupiáñez et al.'s (2004) study, an informative peripheral cue was used, which predicted, in each block of trials, either the same or the opposite position of target appearance (see Procedure section for details). Crucially, with this manipulation, expected and unexpected positions could be either cued or uncued. If IOR is observed at the position predicted by the cue (at which attention is supposed to be allocated), this effect would

be difficult to explain as the inhibition of the return of attention to the cued location (because no return of attention is supposed to take place in this condition).

A second aim of the present study was to investigate the time course of cueing effects (facilitation followed by IOR) in detection and discrimination tasks. It has been shown that IOR appears later in discrimination than in detection tasks (Lupiañez, Milán, Tornay, Madrid, & Tudela, 1997). Klein (2000) proposed that these differences might be due to a later disengagement of attention in discrimination tasks than in detection tasks. He argued that discrimination tasks are more difficult than detection tasks, and as such they demand a more effortful set for the processing of the target. Furthermore, it would be very difficult to adopt and implement a different set for the processing of the cue and target when they are presented very close in time. For that reason, in cueing discrimination tasks, the author proposed that more attentional resources would be allocated to the processing of the cue, and thus the disengagement of attention from the cued location would take longer than in detection tasks. This would delay the occurrence of IOR in discrimination tasks, as compared to detection tasks. In the paradigm used here, the allocation of endogenous attention is controlled by the predictiveness of the cue. At the expected location, no disengagement of attention is supposed to occur, whereas at the unexpected location attention should be disengaged, at least at long enough SOAs. If the time course differences in cueing effects between detection and discrimination tasks are due to differences in the disengagement of attention, no such differences should be found with our procedure.

If the results of the present series of experiments show that IOR can be observed at the attended location and/or if IOR still appears later in the discrimination than in the detection task, it could be argued that these effects cannot be solely explained by the orienting-disengagement of attention. Instead, one would have to invoke other processes, perhaps related to the presence or absence of an object (the cue) before the onset

of the target (Lupiañez et al., 2004; Milliken, Tipper, Houghton, & Lupiañez, 2000).

EXPERIMENT 1

An informative peripheral cue was presented that could predict (with 75% validity) in each block of trials, either the same or the opposite position of target appearance. With this manipulation, both expected and unexpected locations can be either cued or uncued, making it possible to dissociate endogenous and exogenous orienting of attention using the same set of stimuli. Two SOAs (100–1,000 ms) were used, in order to study both facilitation, normally observed at short SOAs, and IOR, usually observed at longer SOAs. Detection and discrimination tasks were used, in order to compare the cueing effect at expected and unexpected locations in both tasks.

Method

Participants

A total of 48 psychology students from the Faculty of Psychology of the University of Granada participated in this experiment (24 performed the detection task, and 24 the discrimination task). The average age of the participants was 20 years. All of the participants reported to have normal or corrected-to-normal vision, were naïve as to the purpose of the experiment, and participated voluntarily for course credits.

Apparatus and stimuli

The stimuli were presented on a 15-in. colour VGA monitor. An IBM-compatible PC running MEL2 software (Schneider, 1988) controlled the presentation of stimuli, timing operations, and data collection. The participants sat 57 cm from the monitor with their head resting on a chinrest. At the beginning of each trial a fixation point (a plus sign) was displayed at the centre of the screen, on a black background. Two grey boxes (17 mm in height by 14 mm in width) were displayed to the left and right of fixation. The inner edge of each box was 77 mm from fixation.

As the orientation cue, one of the boxes flickered (turned to white) for 50 ms, giving the impression of a brief flash. The target was either a red or a yellow asterisk appearing at the centre of one of the boxes. A 400-Hz sound, 100 ms in duration, was used to provide response feedback.

Procedure

A fixation point (plus sign) and two boxes (to the left and right of fixation) were displayed at the beginning of each trial. The peripheral cue appeared 1,000 ms later, for 50 ms. After a random variable SOA (100–1,000 ms) the target was presented. It could be either a red or a yellow asterisk presented at the centre of one of the boxes for 33 ms. If no response was made after 1,800 ms or the wrong response was made, auditory feedback was provided for 100 ms. The intertrial interval (on which the screen remained in black) was 1,000 ms duration.

On 20% of the trials (catch trials) no target was presented, and no response was required. On the remaining 80% of the trials a target was presented, and the participants were asked to detect the target or to discriminate its colour (depending on the experimental group). In the detection task the participants were instructed to press the “m” or “z” key on a keyboard as soon as they saw the asterisk (independently of its colour), while in the discrimination task, the participants were asked to press one of the keys when the asterisk was red and the other key when it was yellow (the response mapping was counterbalanced across participants).

The experiment consisted of two blocks of trials. In one of them, the cue predicted the likely position of target appearance on 75% of trials (i.e., in 75% of the trials the target appeared at the same position as the cue). These were expected trials (because the target appeared where the participants were expecting it to appear) and cued trials (because the cue and

target appeared at the same position). However, in the remaining 25% of the trials, the target appeared at the opposite location to that of the cue. These were unexpected trials (because the target did not appear at the position predicted by the cue) and uncued trials (because the cue and target appeared at different locations). In the other block of trials, the cue predicted the target to appear at the opposite position on 75% of the trials. Thus, when the target was presented at the position opposite to the cue, these were expected but uncued trials. However, when the cue and target were presented at the same position (25% of trials), these were unexpected and cued trials. The order of blocks was counterbalanced across participants. The participants were informed about the most likely location of target appearance at the beginning of each trial and were encouraged to take this information into account. The task lasted about 45 minutes, and the participants were allowed to take a short break after every 36 trials.

Design

The experiment had a $2(\text{task}) \times 2(\text{expectancy}) \times 2(\text{cueing}) \times 2(\text{SOA})$ design, with the first variable being manipulated between participants, and the remaining three variables being manipulated within participants. Task had two levels: detection and discrimination tasks. Expectancy had two levels: expected and unexpected location trials.¹ Cueing had two levels: cued and uncued location trials. Finally, SOA had two levels: 100 and 1,000 ms.

The experiment consisted of two series of three experimental blocks of 72 trials. Each series was preceded by a practice block of 36 trials. There were a total of 432 experimental trials. For each experimental condition of cueing and SOA, there were 81 observations for expected trials and 27 for unexpected trials.

¹ Note that expected trials refer to expected cued trials in one block (where the cue predicts that the target would appear at the same position), and expected uncued trials in the other block (where the cue predicts that the target would appear at the location opposite to the cue). Similarly, unexpected trials refer to unexpected uncued trials in one block (where the cue predicts that the target would appear at the same position), and unexpected cued trials in the other block (where the cue predicts that the target would appear at the location opposite to the cue).

Results

Responses to catch trials (false alarms) were 5.1% of the trials in the detection task and 3.1% in the discrimination task. Trials on which no response was made (misses) were 1.7% and 1.5% of trials in the detection and discrimination task, respectively. In the discrimination task, incorrect responses (7.06%) were discarded from the RT analysis. Finally, trials with responses faster than 100 ms or slower than 1,200 ms were also removed from the RT analysis, which discarded 0.44% and 1.34% of trials in the detection and discrimination task, respectively.

As opposite cueing effects (facilitation vs. IOR) were expected for the short and long SOA, two separate analyses of variance (ANOVAs) with the factors 2 (task) \times 2 (expectancy) \times 2 (cueing) were performed, one for each SOA condition, in order to explore the effect of task, expectancy, and cueing separately for the short and long SOA (see Table 1).

SOA 100 ms

The analysis of the mean RTs showed a significant main effect of task, $F(1, 46) = 98.79$, $MSE = 15,732$, $p < .0001$, with RT being faster in the detection task ($M = 436$ ms) than in the discrimination task ($M = 616$ ms). The expectancy effect was significant, $F(1, 46) = 39.88$, $MSE = 342$, $p < .0001$. The participants responded faster

when the target was presented at the expected position ($M = 518$ ms) than at the unexpected position ($M = 535$ ms), revealing that they were able to voluntarily orient their attention to the expected location with an SOA as short as 100 ms. The interaction between cueing and task was significant, $F(1, 46) = 39.88$, $MSE = 342$, $p < .0001$. In the discrimination task, a significant facilitatory effect appeared, $F(1, 46) = 13.77$, $MSE = 787$, $p < .001$, while in the detection task, a marginally significant IOR effect was shown, $F(1, 46) = 3.21$, $MSE = 787$, $p = .07$. The interaction between expectancy, cueing, and task was significant, $F(1, 46) = 6.32$, $MSE = 2,235$, $p < .01$, revealing that, at the expected location, no cueing effect appeared in either the detection or the discrimination task, $F < 1$. However, at the unexpected location, the cueing effect was different in the detection and the discrimination task, $F(1, 46) = 12.15$, $MSE = 2,140$, $p < .001$: A significant facilitatory effect was observed in the discrimination task, $F(1, 46) = 7.13$, $MSE = 2,140$, $p < .01$, while a significant IOR effect was observed in the detection task, $F(1, 46) = 5.10$, $MSE = 2,140$, $p < .05$.

SOA 1,000 ms

The analysis of the mean RTs revealed significant main effects of task, $F(1, 46) = 126.18$, $MSE = 14,834$, $p < .0001$, and expectancy, $F(1, 46) = 15.94$, $MSE = 514$, $p < .001$, with participants

Table 1. Mean reaction time^a and percentage of incorrect responses in the discrimination task in Experiment 1, as a function of cueing, stimulus onset asynchrony, task, and expectancy

		100				1,000			
		Detection task		Discrimination task		Detection task		Discrimination task	
		Expected	Unexpected	Expected	Unexpected	Expected	Unexpected	Expected	Unexpected
Cued	RT	422	462	607 (6.0)	606 (8.4)	412	439	611 (7.0)	615 (7.5)
Uncued	RT	432	432	614 (6.0)	641 (7.2)	382	384	581 (5.9)	600 (8.1)
Mean cueing effect		-10	-30	7	36	-30	-54	-30	-14

Note: Percentages of incorrect responses are in parentheses. The bottom row shows the mean cueing effect for each condition. The headings 100 and 1,000 denote stimulus onset asynchrony (SOA), in ms. RT = reaction time.

^aIn ms.

responding faster in the detection task, and at the expected location ($M = 496$ ms) versus the unexpected location ($M = 509$ ms). The cueing effect also reached significance, $F(1, 46) = 53.99$, $MSE = 926$, $p < .0001$, and interacted with task, $F(1, 46) = 5.38$, $MSE = 926$, $p < .05$, showing a significant IOR effect both in the detection task, $F(1, 46) = 46.73$, $MSE = 926$, $p < .0001$, and in the discrimination task, $F(1, 46) = 12.64$, $MSE = 926$, $p < .001$, although the effect was larger in the former. Expectancy did not interact with cueing, $F < 1$, but the interaction between task, expectancy, and cueing was marginally significant, $F(1, 46) = 3.48$, $MSE = 1,340$, $p = .06$. This interaction showed that, although the IOR effect was significant in both expected and unexpected locations, $F(1, 46) = 29.47$, $MSE = 739$, $p < .0001$, and $F(1, 46) = 18.62$, $MSE = 1,527$, $p < .0001$, respectively, at the expected location, the IOR effect was similar in magnitude in the detection and the discrimination tasks, $F < 1$. However, at the unexpected location, IOR was larger in the detection task (mean cueing effect, defined as the mean RT difference between uncued and cued trials, -54 ms) than in the discrimination task (mean cueing effect -14 ms), $F(1, 46) = 6.32$, $MSE = 1,527$, $p < .01$ (see Figure 1).

The mean error data in the discrimination task were submitted an ANOVA with the factors 2(expectancy) \times 2(cueing) \times 2(SOA). In this analysis only the main effect of expectancy

reached significance, $F(1, 23) = 5.66$, $MSE = .001$, $p < .05$, with participants' responses being more accurate for expected ($M = .06$) than for unexpected location trials ($M = .07$).

Discussion

The results of the present experiment show that participants are able to attend to the likely position predicted by the cue, since the effect of expectancy reached significance at a SOA as short as 100 ms. At this short SOA, when the target appeared at the expected location, no cueing effect was observed either in the detection task or in the discrimination task. However, when the target was presented at an unexpected position, a facilitatory effect appeared in the discrimination task, while an IOR effect was observed in the detection task. At the longer SOA, a significant IOR effect appeared at both the expected and the unexpected location. At the expected location, this IOR effect was similar in magnitude for the detection and discrimination tasks. However, at the unexpected location, the IOR effect was larger in the detection task than in the discrimination task.

These results clearly differ from those predicted by the reorienting hypothesis of IOR. If IOR is a mechanism that inhibits the returning of attention to a previously attended position, no IOR effect should be observed until attention is disengaged from the cued location. At the expected location, since attention has not been disengaged, no IOR effect is supposed to occur. However, in the present experiment, IOR was observed at the expected location in both the detection task and the discrimination task.

An important result that emerged from this experiment was that at the expected location, the detection and discrimination tasks yielded similar IOR effects, whereas, at the unexpected location, IOR was larger in the detection task than in the discrimination task. Experiment 2 was designed in order to replicate the results of Experiment 1 and to study the temporal course of cueing effects in detection and discrimination tasks while controlling the locus of endogenous orienting of attention.

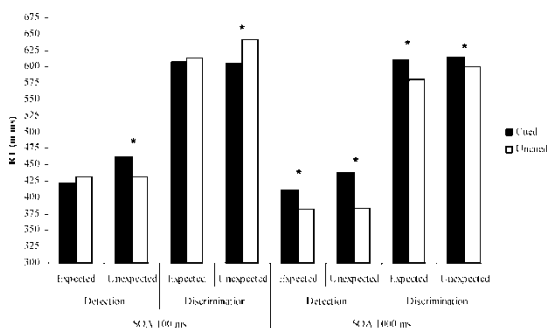


Figure 1. Mean reaction time (RT, in ms) for cued and uncued trials, in Experiment 1, as a function of expectancy, task, and stimulus onset asynchrony (SOA). Asterisks indicate significant effects.

EXPERIMENT 2

This experiment was designed to confirm the results of Experiment 1, in which we demonstrated that IOR can be observed at both expected and unexpected positions predicted by an informative peripheral cue. A further aim of Experiment 2 was to study the time course of cueing effects across SOAs in both detection and discrimination tasks. For this purpose, SOA was manipulated at four levels: 100, 300, 500, and 700 ms. Previous research has shown that the time course of cueing effects is different in detection and discrimination tasks (Lupiáñez et al., 1997). As described in the Introduction, the “later disengagement” hypothesis (Klein, 2000) proposes that, as discrimination tasks are more difficult than detection tasks, once attention is engaged at the cued location, the disengagement of attention from that position requires a longer period of time than in detection tasks. As a consequence, IOR is observed at longer SOAs. With our paradigm, the allocation of attention is controlled by the predictivity of the cue, so attention is held at the expected location (or disengaged from the unexpected location). If cueing effects between detection and discrimination tasks show the same time course differences, the explanation that attention is disengaged later from the cued location in discrimination than in detection tasks cannot hold, as the disengagement of attention is being controlled and measured by the expectancy effect.

Method

Participants

A total of 40 psychology students from the Faculty of Psychology and the Faculty of Physical Education and Sport Sciences of the University of Granada participated in this experiment (20 for the detection task and 20 for the discrimination task), 22 women and 18 men. A total of 38 of the participants were right-handed, 1 left-handed, and 1 ambidextrous by self-report. The average age of the participants was 20 years, and all reported to

have normal or corrected-to-normal vision. They were naïve as to the purpose of the experiment and participated voluntarily for course credits.

Apparatus and stimuli

Apparatus and stimuli were the same as those in Experiment 1, with the following exceptions: An IBM-compatible PC running E-prime software (Schneider, Eschman, & Zuccolotto, 2002) controlled the presentation of stimuli, timing operations, and data collection. As an orientation cue, the contour of one of the boxes briefly thickened, giving the impression of a flash. When participants made a mistake, a 1997-Hz sound occurred for 50 ms.

Procedure

The procedure was the same as that in Experiment 1, except that the SOA variable had four levels: 100, 300, 500, and 700 ms.

Design

The experiment had a $2(\text{task}) \times 2(\text{expectancy}) \times 2(\text{cueing}) \times 4(\text{SOA})$ design, with the first variable being manipulated between participants, and the remaining three variables being manipulated within participants. Task had two levels: detection and discrimination. Expectancy had two levels: expected and unexpected location trials. Cueing had two levels: cued and uncued location trials. Finally, SOA had 4 levels: 100, 300, 500, and 700 ms.

The experiment consisted of two experimental blocks of 320 trials, each being preceded by a practice block of 24 trials. For each experimental condition of cueing and SOA, there were 48 observations for expected trials and 16 for unexpected trials.

Results

False alarms accounted for 0.59% and 0.17% of trials in the detection and discrimination task, respectively. Misses were 0.88% of trials in the detection task and 0.17% in the discrimination task. In the discrimination task, trials with an incorrect response (4.20%) were excluded from

the RT analysis. Finally, RTs faster than 100 ms or slower than 1,200 ms were also removed from the RT analysis. This resulted in a further 0.66% of trials being discarded in the detection task and 0.41% of trials in the discrimination task.

The mean RT data were submitted to a repeated measures ANOVA, with the following factors: task(2), expectancy(2), cueing(2), and SOA(4). The first variable was manipulated between participants, while the remaining three variables were manipulated within participants (see Table 2). As in the previous experiment, the RT analysis revealed a significant main effect of task, $F(1, 38) = 105.54$, $MSE = 47,641$, $p < .0001$, expectancy, $F(1, 38) = 63.81$, $MSE = 763$, $p < .0001$, cueing, $F(1, 38) = 5.64$, $MSE = 1,145$, $p < .05$, and SOA, $F(3, 114) = 45.91$, $MSE = 846$, $p < .0001$. The interaction between cueing and task was also significant, $F(1, 38) = 19.35$, $MSE = 22,149$, $p < .0001$, as was the interaction between cueing and SOA, $F(3, 114) = 9.73$, $MSE = 478$, $p < .0001$. Importantly, expectancy and cueing again did not interact, $F < 1$, the cueing effect being -7 ms at the expected position and -5 ms at the unexpected position.

In order to test the later disengagement hypothesis about IOR (which postulates that IOR appears later in discrimination tasks than in detection tasks because attention is disengaged later from the cued location in the former), it is important to analyse the time course of cueing effects in both tasks at the expected location (where attention is not supposed to be disengaged in either task) and at the unexpected location (where attention is supposed to be disengaged in both tasks). To this aim, two repeated measures ANOVAs, with the factors task(2), cueing(2), and SOA(4), were performed, one for expected locations and the other for unexpected locations.

Expected location

The main effects of task and SOA were significant. The interactions between cueing and SOA and between cueing and task were also significant. The interaction between task, cueing, and SOA was not significant, $F < 1$, showing that the

cueing effect became more negative (or less positive) across SOA in both the detection task and the discrimination task. The absence of Task \times Cueing \times SOA interaction can be taken as an indication that the orienting of attention was controlled, since the same attentional orienting (Cueing \times SOA interaction) occurred in both tasks. However, in the detection task, IOR reached significance beginning at the 500-ms SOA, $F(1, 38) = 9.54$, $MSE = 497$, $p < .005$, while in the discrimination task, no cueing effect appeared at the 500-ms SOA, $F < 1$, with IOR being only observed at the 700-ms SOA, $F(1, 38) = 4.80$, $MSE = 428$, $p < .05$ (see Figure 2). Thus, at the expected location (where attention is not supposed to be disengaged), IOR still appears, and it still does so later in the discrimination task than in the detection task.

Unexpected location

Again, the main effects of task and SOA were significant. Significant interactions between cueing and SOA and between cueing and task were also observed. Once again, the cueing effect became more negative (or less positive) across SOAs in both the detection task and the discrimination task, as can be observed in the absence of Task \times Cueing \times SOA interaction, $F < 1$. However, IOR was observed beginning at the 500-ms SOA in the detection task, $F(1, 38) = 10.42$, $MSE = 1,134$, $p < .005$, while, in the discrimination task, no IOR appeared even at the 700-ms SOA, $F < 1$.

The mean error data in the discrimination task were submitted to a repeated measures ANOVA, with the following factors: expectancy(2), cueing(2), and SOA(4). In this analysis, only the cueing effect reached significance, $F(1, 38) = 7.55$, $MSE = 0.002$, $p < .05$, with responses being more accurate for cued ($M = .04$) than for uncued ($M = .06$) trials overall.

Discussion

In Experiment 2, as in the previous experiment, participants were able to attend to the likely position predicted by the cue, which can be measured by a main effect of expectancy. However, at a long

Table 2. Mean RT^a and percentage of incorrect responses in the discrimination task in Experiment 2, as a function of cueing, expectancy, task, and stimulus onset asynchrony

		Expected								Unexpected							
		Detection				Discrimination				Detection				Discrimination			
		100	300	500	700	100	300	500	700	100	300	500	700	100	300	500	700
Cued	RT	371	336	343	365	537 (5.1)	505 (5.7)	515 (3.7)	539 (4.2)	383	359	375	381	548 (4.7)	519 (5.9)	525 (3.8)	549 (4.3)
Uncued	RT	364	326	321	334	552 (4.6)	516 (5.1)	511 (6.2)	525 (4.9)	381	349	341	353	564 (5.19)	529 (8.79)	527 (8.3)	557 (6.5)
Mean cueing effect		-7	-10	-22	-31	15	11	-4	-14	-2	-10	-34	-28	16	10	2	8

Note: Percentages of incorrect responses are in parentheses. The bottom row shows the mean cueing effect for each condition. The headings 100, 300, 500, and 700 denote stimulus onset asynchrony (SOA), in ms. RT = reaction time.

^aIn ms.

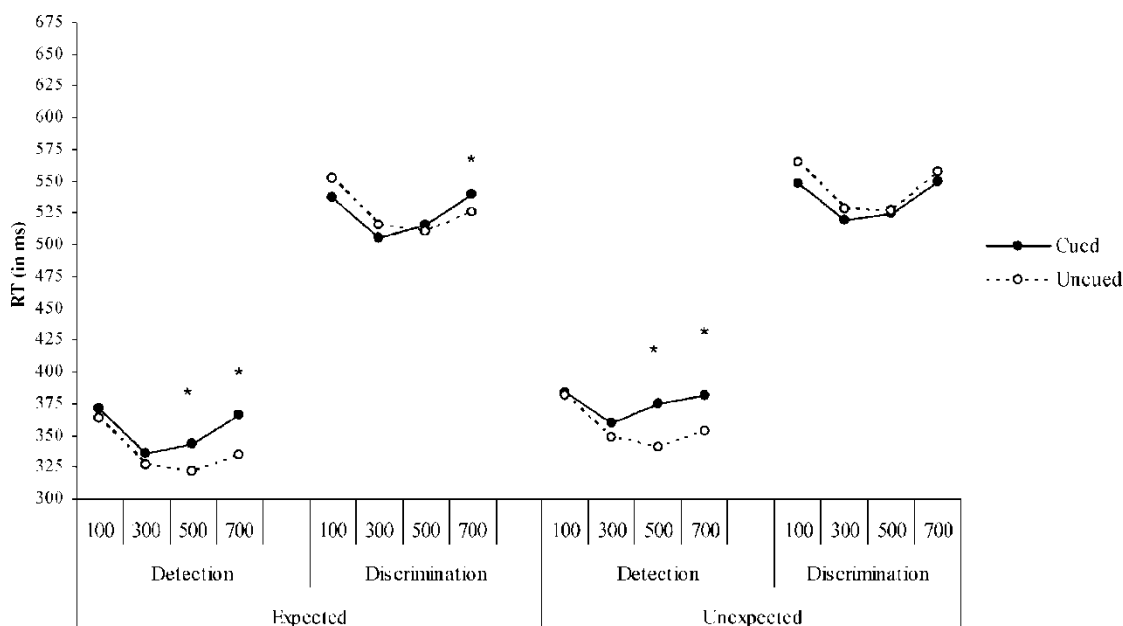


Figure 2. Mean reaction time (RT, in ms) for cued and uncued trials, in Experiment 2, as a function of stimulus onset asynchrony (SOA), task, and expectancy.

enough SOA (700 ms), IOR did occur at the expected location (where attention was being voluntarily allocated) in both detection and discrimination tasks. This IOR effect is difficult to explain by the inhibition of the return of attention to that position, as attention is supposed to be endogenously maintained there.

Concerning the differences in the time course of cueing effects in detection and discrimination tasks, the present results showed that IOR still appears later in the discrimination than in the detection task, even when the orienting of attention is controlled. This result is opposite to the prediction of the later disengagement hypothesis, which postulates that IOR is observed later in discrimination tasks because attention is disengaged later from the cued location than it is in detection tasks. With our paradigm, we controlled the allocation of attention at the position predicted by the cue, so the differences in the time course of cueing effects between the detection and discrimination tasks cannot be explained, at least in the present experiment, by factors related to

the disengagement of attention from the cued location.

As in the previous experiment, cueing effects in detection and discrimination tasks were more similar at the expected location than at the unexpected location. At long SOAs (more than 500 ms), when the target appeared at the position predicted by the cue, IOR was observed in both the detection and the discrimination task. A planned comparison revealed that, at the expected location, the IOR effect was not significantly different between tasks, $p > .05$. However, when the target was presented at an unexpected position, the cueing effect was different in both tasks, $p < .05$, with IOR being observed in the detection task but not in the discrimination task.

EXPERIMENT 3

Could IOR be further delayed when participants are asked to discriminate targets appearing at an unexpected location? To test this possibility, we

conducted a further experiment, with a larger range of SOAs: 100, 400, 700, and 1,000 ms.

Method

Participants

A total of 40 psychology students from the Faculty of Psychology and the Faculty of Physical Education and Sport Sciences of the University of Granada participated in this experiment (20 for the detection task and 20 for the discrimination task), 29 women and 11 men. A total of 36 of the participants were right-handed, 3 left-handed, and 1 ambidextrous by self-report. The average age of the participants was 20 years. All of them reported to have normal or corrected-to-normal vision, were unaware of the purpose of the experiment, and participated voluntarily for course credits.

Apparatus, stimuli, procedure, and design

The apparatus, stimuli, set-up, procedure, and design were the same as those in Experiment 2, with the exception of the SOA variable, which was manipulated at four different levels: 100, 400, 700, or 1,000 ms.

Results

False alarms accounted for 0.97% of trials in the detection task and 0.89% in the discrimination task. Responses to catch trials were 0.52% and 0.50% of trials in the detection and discrimination task, respectively. Responses faster than 100 ms and slower than 1,200 ms were also excluded from the RT analysis, which discarded a further 0.95% and 0.50% of trials in the detection and the discrimination task, respectively. Finally, trials with an incorrect response in the discrimination task (4.03%) were also removed from the RT analysis.

The mean RT data were submitted to a mixed ANOVA, with the factors of task(2), expectancy(2), cueing(2), and SOA(4). Table 3 shows the mean RT and mean error data for each experimental condition. The analysis showed a significant main effects of task, $F(1, 38) = 115.51$, $MSE = 44,349$, $p < .0001$, expectancy,

$F(1, 38) = 94.65$, $MSE = 693$, $p < .0001$, cueing, $F(1, 38) = 37.13$, $MSE = 976$, $p < .0001$, and SOA, $F(3, 114) = 38.76$, $MSE = 669$, $p < .0001$. The interactions between cueing and SOA, $F(1, 38) = 11.52$, $MSE = 336$, $p < .0001$, and cueing and task, $F(1, 38) = 21.94$, $MSE = 976$, $p < .0001$, were significant. Once again, the interaction between expectancy and cueing was not significant. However, the interaction between expectancy, cueing, and task was marginally significant, $F(1, 38) = 3.54$, $MSE = 2,470$, $p = .06$. Importantly, this interaction showed that at the expected location, the cueing effect in the detection and discrimination task did not differ, $F(1, 38) = 1.14$, $MSE = 1,213$, $p = .29$. However, at the unexpected location, the cueing effect differed between tasks, $F(1, 38) = 12.89$, $MSE = 2,231$, $p < .001$. IOR occurred in the detection task, $F(1, 38) = 23.04$, $MSE = 2,231$, $p < .0001$, but not in the discrimination task, $F < 1$ (see Figure 3).

In order to test the later disengagement hypothesis, separate ANOVAs were carried out, for the expected and unexpected location, with the following factors: Task(2) \times Cueing(2) \times SOA(4).

Expected location

The analysis revealed significant main effects of task and SOA. The interaction between cueing and SOA was also significant. Again, the interaction between task, cueing, and SOA was not significant. However, IOR was observed from the 400-ms SOA in the detection task, $F(1, 38) = 9.65$, $MSE = 652$, $p < .005$, while in the discrimination task, no cueing effect appeared at the 400-ms SOA, $F(1, 38) = 1.72$, $MSE = 652$, $p = .19$, with IOR being observed beginning at the 700-ms SOA, $F(1, 38) = 6.26$, $MSE = 494$, $p < .05$.

Unexpected location

The main effects of task and SOA were again significant, and the interaction between cueing and SOA was borderline significant, $F(3, 114) = 2.64$, $MSE = 524$, $p = .05$. Cueing also interacted with task. Once again, the interaction between task, cueing, and SOA was not significant, $F < 1$. However, in the detection task, IOR was

Table 3. Mean RT^a and percentage of incorrect responses in the discrimination task in Experiment 3, as a function of cueing, expectancy, task, and stimulus onset asynchrony

		<i>Expected</i>								<i>Unexpected</i>							
		<i>Detection</i>				<i>Discrimination</i>				<i>Detection</i>				<i>Discrimination</i>			
		<i>100</i>	<i>400</i>	<i>700</i>	<i>1,000</i>	<i>100</i>	<i>400</i>	<i>700</i>	<i>1,000</i>	<i>100</i>	<i>400</i>	<i>700</i>	<i>1,000</i>	<i>100</i>	<i>400</i>	<i>700</i>	<i>1,000</i>
Cued	RT	381	360	366	378	547 (5.2)	533 (4.6)	543 (6.2)	557 (4.7)	411	383	398	407	566 (6.5)	543 (5.9)	563 (5.5)	570 (6.3)
Uncued	RT	378	335	341	362	560 (6.6)	522 (4.7)	525 (3.7)	537 (5.3)	386	349	358	363	579 (7.8)	547 (5.3)	562 (8.6)	563 (5.6)
Mean cueing effect		-3	-25	-26	-16	13	-11	-18	-21	-26	-34	-40	-45	13	4	-1	-7

Note: Percentages of incorrect responses are in parentheses. The bottom row shows the mean cueing effect for each condition. The headings 100, 400, 700, and 1,000 denote stimulus onset asynchrony (SOA), in ms. RT = reaction time.

^aIn ms.

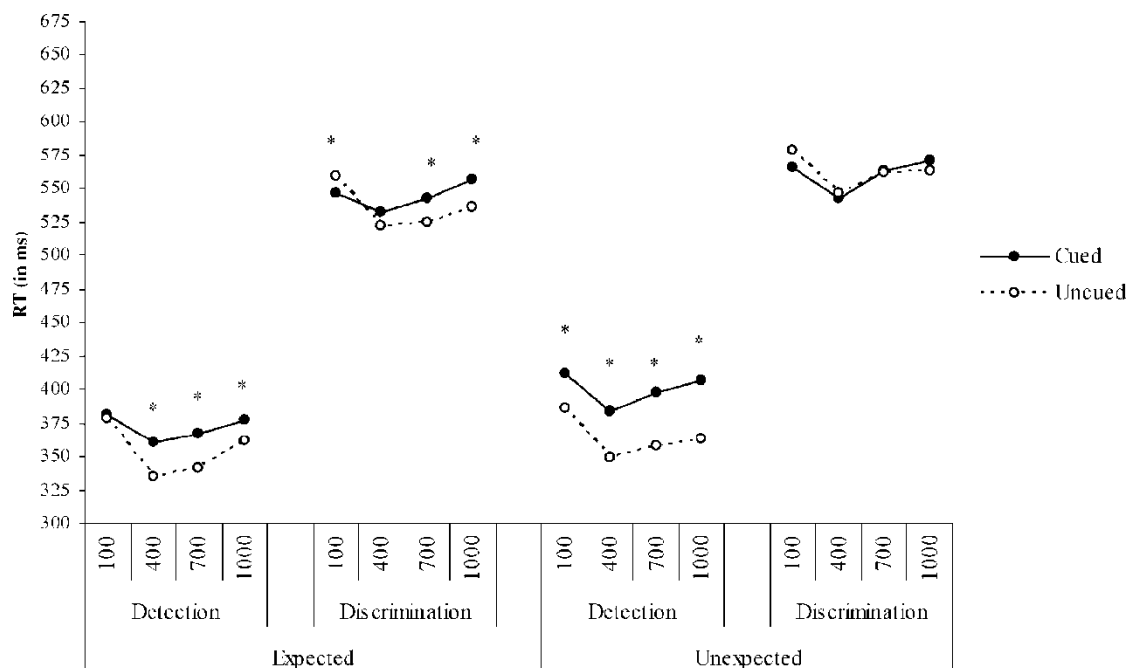


Figure 3. Mean reaction time (RT, in ms) for cued and uncued trials, in Experiment 3, as a function of stimulus onset asynchrony (SOA), task, and expectancy. Asterisks indicate significant effects.

observed beginning at the 100-ms SOA, $F(1, 38) = 6.22$, $MSE = 1,028$, $p < .05$, whereas in the discrimination task, no such cueing effect was observed even at the 1,000-ms SOA, $F < 1$.

The mean error data in the discrimination task were initially submitted to a repeated measures ANOVA, with the factors task(2), expectancy(2), cueing(2), and SOA(4). In this analysis, only the expectancy effect reached significance, $F(1, 38) = 5.00$, $MSE = 0.002$, $p < .01$, with the participants being more accurate when the target appeared at the expected position ($M = .04$) than when it appeared at the unexpected position ($M = .06$).

Discussion

Experiment 3 replicated the results from Experiments 1 and 2. IOR was again observed at the expected location in both the detection and the discrimination task. At this expected location, IOR appeared for SOAs greater than 400 ms in

the detection task, while in the discrimination task no cueing effect was observed at the 400-ms SOA, with IOR being observed for SOAs greater than 700 ms. At the unexpected location, IOR appeared from the shortest SOA in the detection task, while this effect did not reach significance in the discrimination task, even at the longest SOA. Thus, as shown by the interaction between expectancy, cueing, and task, which approached significance, at the expected location, the cueing effects were similar in the detection and the discrimination task. However, at the unexpected location, a more negative cueing effect was observed in the detection than in the discrimination task.

GENERAL DISCUSSION

In the present series of experiments endogenous and exogenous orienting have been dissociated using the same set of stimuli. An informative

peripheral cue was used, which predicted, in each block of trials, that the target would appear at either the same or the opposite position to the cue. Crucially, both expected and unexpected locations were either cued or uncued. The results revealed that the expectancy effect was significant at all the SOAs used here, showing that participants were able to attend to the position predicted by the cue. As noted above, if participants were already attending to the position predicted by the cue, no disengagement of attention from that location was supposed to occur when the target appeared at this position (expected location trials). However, in the three experiments reported here, IOR was observed at the expected location, both in the detection and the discrimination task. This result argues against the reorienting hypothesis (Posner & Cohen, 1984), which predicts no IOR effect until attention leaves the cued location (see Klein, 2000, p. 139, line 22).

It could be argued that endogenous attention was not completely engaged in the expected location as the cue was not 100% predictive of target's appearance. In support of this idea, it has been demonstrated that attentional capture (i.e., facilitatory effects) can be overridden by 100% informative cues, but not by 80% informative cues (Yantis & Jonides, 1990). However, in Berlucchi et al.'s (1989) experiment, although participants knew in advance where the target would appear (as it was presented at the same spatial position on all trials within a block), IOR was still observed at the expected location. In the experiments presented here (75% informative cue) we cannot be sure that attention was completely oriented endogenously at the expected location (as it might be using a 100% informative cue). Moreover, we reckon that attention might be always more oriented to the position predicted by the cue (expected location) than to the opposite location (unexpected location). Nevertheless, Experiments 2 and 3 showed that in the discrimination task IOR was observed at the expected location, but not at the unexpected location. Thus, it can be concluded, at least concerning the present experiments, that attentional

disengagement from the cued location is not necessary to observe IOR.

Moreover, given that the predictivity of the cue was manipulated between blocks of trials, one might wonder whether the expectancy effect observed in the three experiments actually reflects the orienting of attention. Note that, within a block of trials, one type of trial was more frequent than the others, which might have elicited other processes than the orienting of attention. For instance, in the block where the cue predicted the target to appear at the opposite location, the participants would have been habituated to a stimulation pattern consisting of the cue and target appearing at opposite locations. A target appearing at the same location as the cue would have broken this pattern, increasing RT on those trials, resulting in an "expectancy effect". However, we have shown elsewhere that the same pattern of results emerges when the expectancy is manipulated within a block of trials (Chica & Lupiáñez, 2004). In that study, the central fixation point (a "+" or "-" sign) informed the participants regarding the predictivity of the upcoming peripheral cue. When the fixation point was a "+" sign, the peripheral cue predicted the target to appear at the same location (75%). In contrast, when the fixation point was a "-" sign, the peripheral cue predicted (75%) the target to appear at the opposite location. Therefore, all kinds of cue-target combinations were equally frequent. The only way to account for the expectancy effect that was observed in our study is to assume that participants were taking into account the information provided by the fixation point and orienting attention according to it, either to the same location as the cue or to the opposite location. As in the experiments presented here, the results of Chica and Lupiáñez showed that IOR can be observed at endogenously attended locations, from where attention is not supposed to be disengaged.

The second important aim of the present study was to test the later disengagement hypothesis—that is, the later appearance of IOR in discrimination task than in detection tasks (Klein, 2000). According to this hypothesis, since discrimination

tasks are more difficult than detection tasks, more attentional resources are needed for the processing of the target. Klein proposed that it would be difficult to implement a different set for the processing of the cue and target, since they are normally presented very close in time. Thus, more attentional resources are also allocated to the processing of the cue when discrimination tasks instead of detection tasks are used. As a consequence, the disengagement of attention from the cued location occurs later, and IOR is observed later in discrimination than in detection tasks.

The results of Experiments 2 and 3, in which orienting of attention was controlled (in both tasks, attention could be allocated either to the position predicted by the cue or to the opposite location), showed that IOR still appears later in discrimination tasks than in detection tasks, especially in unexpected location trials, in which attention is already disengaged from the cued location when the target appears. It is important to note that the interaction Task \times Cueing \times SOA did not approach significance (in either experiment). This can be taken as an indication that the orienting of attention was controlled, since the same orienting of attention (Cueing \times SOA interaction) appeared in the two tasks (Lupiáñez, Milliken, Solano, Weaver, & Tipper, 2001). In expected location trials, attention was allocated to the position predicted by the cue (i.e., no disengagement of attention from that location is supposed to occur when the target appears). At the unexpected location, attention is supposed to be already disengaged from the cued location when the target appears. However, at both the expected and the unexpected location, IOR appeared later in the discrimination than in the detection task. Therefore, the time course differences between the detection and the discrimination task observed in these experiments cannot be explained solely by attention being disengaged later from the cued location in the discrimination task than in the detection task.

The present results (i.e., IOR at the expected location and IOR appearing later in the discrimination than in the detection task) are difficult to explain solely by the orienting of attention, the

disengagement from the cued location, and the subsequent inhibition of the return of attention. Alternatively, we propose that the appearance of a cue shortly before the target can capture spatial attention so that it is oriented to its position, but other perceptual processes can also affect the processing of the subsequent target (see e.g., Handy, Jha, & Mangun, 1999; Hawkins, Hillyard, Luck, & Mouloua, 1990; Li & Lin, 2002). When the cue appears, it is encoded as a new perceptual event, and this is why it captures attention. If the target is presented shortly after the cue, at the same spatial position, it is possible to encode the two objects as the same perceptual event (Kahneman, Treisman, & Gibbs, 1992; Lupiáñez et al., 2001). This would lead to a facilitatory effect at short cue–target SOAs. However, at a longer SOA, if the target appears at the same position as the cue, the perceptual analysis of the cue would have finished, and no integration within the same perceptual event will occur. Alternatively, the target could be labelled as an “old” object, since that location has been recently analysed. Moreover, if the target is presented at the opposite location to the cue, it could be labelled as a “new” object, since that position has not been recently analysed and therefore will benefit from attentional capture. This would lead to a faster processing of the target at uncued locations (i.e., IOR). Thus, IOR is not conceived as the inhibition of orienting of attention to the cued location, but as the loss of advantage for objects appearing at “old” (previously cued) locations (Milliken et al., 2000).

In addition, the analysis of the cue and its influence on target processing could be different when detection and discrimination tasks are used. Lupiáñez et al. (2004) proposed that when performing a detection task, the most important process might be to dissociate the new object (the target) from the previous one (the cue). Thus, participants would need to implement a set to dissociate events. For that reason, the presence of an object before the target usually produces a “detection cost” from very short SOAs. However, when performing a discrimination task, it is not as important to dissociate

events as it is to analyse the features of the target required to select the appropriate response. Here, the presence of the cue before the target might facilitate its discrimination, by helping to select the spatial position where the analysis of the features is going to occur. This “spatial selection benefit” finishes when the analysis of the cue is completed, giving rise to a later appearance of IOR in discrimination than in detection tasks.

In Experiments 1 and 3, IOR was observed at the unexpected location at a SOA as short as 100 ms. Although this result is not common in cueing studies (Lupiáñez et al., 1997, 2001; Posner & Cohen, 1984), Danziger and Kingstone (1999) obtained similar results using a cueing paradigm with four possible locations. In Danziger and Kingstone’s experiment, the cue was presented in one of the locations, and the participants were told to attend to the clockwise position related to its location. With this manipulation, IOR was found at a SOA as short as 50 ms. The authors proposed that, in a typical cueing paradigm (e.g., Posner & Cohen, 1984), the IOR effect at short SOAs is masked by the orienting of attention to the peripheral cued location: When the cue appears, attention is automatically summoned to its position (Posner et al., 1982). But if the cue predicts that the target would appear at another location, attention quickly moves away from that position. Thus, when the target appears at the cued location, a cost in performance (IOR) is observed. However, Danziger and Kingstone’s results can also be explained by factors related to the perceptual analysis of the cue. As the cue predicted a clockwise position, its perceptual analysis would have to be fast, in order to start the analysis of the target at the other location. This would lead to an early appearance of IOR, since the cued location becomes “old” when the analysis of the cue finishes.

It is important to note that Danziger and Kingstone (1999) proposed that it was IOR that was unmasked by their procedure. However, using detection and discrimination tasks, we have shown that it is not always IOR that is unmasked, with facilitation being unmasked under some conditions. Therefore, one may conclude that it

is the cueing effect that is unmasked by making the cue counterpredictive. At unexpected locations, IOR was observed in the detection task, while a facilitatory effect emerged in the discrimination task. Therefore, cueing effects manifest differently depending on the task that the participants are asked to complete (detection vs. discrimination). These cueing effects are usually more negative in detection than in discrimination tasks. In fact, we have constantly found that at the expected location there were no differences in cueing effects between the detection and discrimination tasks. However, at the unexpected location cueing effects were more negative in the detection than in the discrimination task.

A reanalysis of the three experiments described in this paper confirmed these results. We pooled together the data for short SOA (i.e., 100 ms) and compared them with those for long SOAs (i.e., 700 ms for Experiment 2 and 1,000 ms for Experiments 1 and 3; see Figure 4). At the expected location, the cueing effect was not significantly different between the detection and discrimination tasks, either at the short or at the long SOA, $F(1, 126) = 2.66$, $MSE = 677$, $p = .10$, and $F < 1$, respectively. However, at the unexpected location, the effect of cueing was significantly different between the tasks, both at

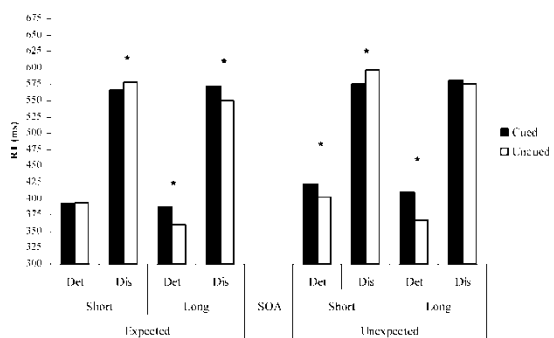


Figure 4. Mean reaction time (RT, in ms) for cued and uncued trials, in Experiments 1–3, as a function of expectancy, stimulus onset asynchrony (SOA), and task. Note that the short SOA refers to the 100-ms SOA, while the long SOA refers to the 1,000-ms SOA in Experiments 1 and 3 and the 700-ms SOA in Experiment 2. Asterisks indicate significant effects.

the short and at the long SOA, $F(1, 126) = 17.40$, $MSE = 1,656$, $p < .0001$, and $F(1, 126) = 19.06$, $MSE = 1,204$, $p < .0001$, respectively. Therefore, when attention has been already disengaged (unexpected locations), it is not IOR that is unmasked, but the cueing effect, which could be either negative (IOR) or positive (facilitation) depending on other factors such as the type of target or the task to be performed with it.

The dissociation of IOR from endogenous orienting that we show in the present study is not consistent with views of spatial attention as a single spotlight, which could be oriented either endogenously or exogenously. However, the described dissociation fits well with the mounting evidence suggesting the presence of distinct neuro-cognitive systems for endogenous and exogenous attention. There is now extensive behavioural evidence (e.g., Funes, Lupiáñez, & Milliken, 2005; see Klein & Shore, 2000, for a review) that exogenous and endogenous attention are in fact two qualitatively different processes. Consistent with behavioural results, neuroimaging studies suggest that the brain contains two partially segregated systems for visual orienting: a dorsal network (including parts of the intraparietal sulcus and frontal eye field), bilaterally represented, and concerned with endogenous orienting, and a more ventral, right-lateralized network (temporo-parietal junction and inferior frontal gyrus) subserving exogenous orienting (Corbetta & Shulman, 2002). There is also some suggestion that IOR might correlate with activity in right-hemisphere frontal regions such as the right medial frontal gyrus (SEF) and the right inferior prefrontal sulcus (FEF; Lepsien & Pollmann, 2002; see also Ro, Farné, & Chang, 2003). Compelling neuropsychological evidence also indicates dissociations between exogenous and endogenous attention. In left unilateral neglect, exogenous orienting is heavily biased rightward (Bartolomeo & Chokron, 2001, 2002). However, endogenous processes are largely spared, if slowed, in neglect patients (Bartolomeo et al., 2001). Importantly, as mentioned in the Introduction of this paper, these same patients may show a lack of IOR for right, ipsilesional stimuli (Bartolomeo et al.,

1999, 2001; Lupiáñez et al., 2004), consistent with their rightward exogenous bias.

The possible preferential implication of right-hemisphere regions in IOR suggests a relation of this phenomenon with exogenous attention. This relationship was initially suggested by Maylor and Hockey (1985) and was recently confirmed by the demonstration of the tendency of normal individuals to make microsaccades away from a task-irrelevant, peripherally presented visual stimulus (Galfano, Betta, & Turatto, 2004). Microsaccades are small, automatic eye movements occurring during fixation, and their direction may correlate with covert exogenous orienting of attention (Engbert & Kliegl, 2003; Hafed & Clark, 2002). Also the well-established importance of the activity of the superior colliculus to the expression of IOR (Dorris, Klein, Everling, & Munoz, 2002; Posner et al., 1985; Sapir, Soroker, Berger, & Henik, 1999) underlines the relationship of this phenomenon to exogenous attention.

Taken together, the evidence suggests that the brain may contain multiple attentional mechanisms that influence perception and action independently from one another, by biasing the competition among objects in the visual field (Desimone & Duncan, 1995). In this framework, IOR could be seen as one process (or perhaps several processes; see Sumner, 2006; Sumner, Nachev, Vora, Husain, & Kennard, 2004) decreasing attentional capture for "old" visual objects (Lupiáñez et al., 2004; Milliken et al., 2000), which are less likely to constitute a menace for the exploring organism. It makes ecological sense that such a basic ability for survival would be automatic and independent of more top-down influences on perception as is the case of endogenous attention.

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REFERENCES

- Bartolomeo, P., & Chokron, S. (2001). Levels of impairment in unilateral neglect. In F. Boller & J. Grafman (Eds.), *Handbook of neuropsychology*

- (2nd ed., Vol. 4, pp. 67–98). Amsterdam: Elsevier Science Publishers.
- Bartolomeo, P., & Chokron, S. (2002). Orienting of attention in left unilateral neglect. *Neuroscience and Biobehavioral Reviews*, 26, 217–234.
- Bartolomeo, P., Chokron, S., & Siéoff, E. (1999). Facilitation instead of inhibition for repeated right-sided events in left neglect. *NeuroReport*, 10, 3353–3357.
- Bartolomeo, P., Siéoff, E., Decaix, C., & Chokron, S. (2001). Modulating the attentional bias in unilateral neglect: The effects of the strategic set. *Experimental Brain Research*, 137, 432–444.
- Berger, A., Henik, A., & Rafal, R. (2005). Competition between endogenous and exogenous orienting of visual attention. *Journal of Experimental Psychology: General*, 134, 207–221.
- Berlucchi, G., Chelazzi, L., & Tassinari, G. (2000). Volitional covert orienting to a peripheral cue does not suppress cue-induced inhibition of return. *Journal of Cognitive Neuroscience*, 12, 648–663.
- Berlucchi, G., Tassinari, G., Marzi, C. A., & Di Stefano, M. (1989). Spatial distribution of the inhibitory effect of peripheral non-informative cues on simple reaction time to non-fixed visual targets. *Neuropsychologia*, 27, 201–221.
- Chica, A. B., & Lupiáñez, J. (2004). Inhibition of return without return of attention. *Psicothema*, 16, 248–254.
- Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, 3, 201–215.
- Danziger, S., & Kingstone, A. (1999). Unmasking the inhibition of return phenomenon. *Perception and Psychophysics*, 61, 1024–1037.
- Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review in Neuroscience*, 18, 193–222.
- Dorris, M. C., Klein, R. M., Everling, S., & Munoz, D. P. (2002). Contribution of the primate superior colliculus to inhibition of return. *Journal of Cognitive Neuroscience*, 14, 1256–1263.
- Egeth, H., & Yantis, S. (1997). Visual attention: Control, representation, and time course. *Annual Review in Psychology*, 48, 269–297.
- Engbert, R., & Kliegl, R. (2003). Microsaccades uncover the orientation of covert attention. *Vision Research*, 43, 1035–1045.
- Funes, M. J., Lupiáñez, J., & Milliken, B. (2005). The role of spatial attention and other processes on the magnitude and time course of cueing effects. *Cognitive Processing*, 6, 98–116.
- Galfano, G., Betta, E., & Turatto, M. (2004). Inhibition of return in microsaccades. *Experimental Brain Research*, 159, 400–404.
- Hafed, Z. M., & Clark, J. J. (2002). Microsaccades as an overt measure of covert attention shifts. *Vision Research*, 42, 2533–2545.
- Handy, T. C., Jha, A. P., & Mangun, G. R. (1999). Promoting novelty in vision: Inhibition of return modulates perceptual-level processing. *Psychological Science*, 10, 157–161.
- Hawkins, H. L., Hillyard, S. A., Luck, S. J., & Mouloua, M. (1990). Visual attention modulates signal detectability. *Journal of Experimental Psychology: Human Perception and Performance*, 16, 802–811.
- Jonides, J. (1981). Voluntary versus automatic control over the mind's eye's movement. In J. Long & A. Baddeley (Eds.), *Attention and performance XI* (pp. 187–283). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.
- Kahneman, D., Treisman, A., & Gibbs, B. J. (1992). The reviewing of object files: Object-specific integration of information. *Cognitive Psychology*, 24, 175–219.
- Klein, R. M. (2000). Inhibition of return. *Trends in Cognitive Sciences*, 4, 138–147.
- Klein, R. M., & Shore, D. I. (2000). Relations among modes of visual orienting. In S. Monsell & J. Driver (Eds.), *Attention & performance XVIII: Control of cognitive processes* (pp. 195–208). Cambridge, MA: MIT Press.
- Lepsien, J., & Pollmann, S. (2002). Covert reorienting and inhibition of return: An event-related fMRI study. *Journal of Cognitive Neuroscience*, 14, 127–144.
- Li, C. S. R., & Lin, S. C. (2002). A perceptual level mechanism of the inhibition of return in oculomotor planning. *Cognitive Brain Research*, 14, 269–276.
- Lupiáñez, J., Decaix, C., Siéoff, E., Chokron, S., Milliken, B., & Bartolomeo, P. (2004). Independent effects of endogenous and exogenous spatial cueing: Inhibition of return at endogenously attended target locations. *Experimental Brain Research*, 159, 447–457.
- Lupiáñez, J., Milán, E. G., Tornay, F. J., Madrid, E., & Tudela, P. (1997). Does IOR occur in discrimination tasks? Yes, it does, but later. *Perception and Psychophysics*, 59, 1241–1254.
- Lupiáñez, J., Milliken, B., Solano, C., Weaver, B., & Tipper, S. P. (2001). On the strategic modulation of the time course of facilitation and inhibition of

- return. *Quarterly Journal of Experimental Psychology*, 54A, 753–773.
- Maylor, E. A., & Hockey, R. (1985). Inhibitory component of externally controlled covert orienting in visual space. *Journal of Experimental Psychology: Human Perception and Performance*, 11, 777–787.
- Milliken, B., Tipper, S. P., Houghton, G., & Lupiáñez, J. (2000). Attending, ignoring, and repetition: On the relation between negative priming and inhibition of return. *Perception & Psychophysics*, 62, 1280–1296.
- Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, 32, 3–25.
- Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma & D. Bouwhuis (Eds.), *Attention and performance X* (pp. 531–556). Hove, UK: Lawrence Erlbaum Associates Ltd.
- Posner, M. I., Cohen, Y., & Rafal, R. D. (1982). Neural systems control of spatial orienting. *Philosophical Transactions of the Royal Society of London B*, 298, 187–198.
- Posner, M. I., Rafal, R. D., Choate, L. S., & Vaughan, J. (1985). Inhibition of return: Neural basis and function. *Cognitive Neuropsychology*, 2, 211–228.
- Posner, M. I., Snyder, C. R. R., & Davidson, B. J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology: General*, 109, 160–174.
- Ro, T., Farné, A., & Chang, E. (2003). Inhibition of return and the human frontal eye fields. *Experimental Brain Research*, 150, 290–296.
- Ruz, M., & Lupiáñez, J. (2002). A review of attentional capture: On its automaticity and sensitivity to endogenous control. *Psicológica*, 23, 283–309.
- Sapir, A., Soroker, N., Berger, A., & Henik, A. (1999). Inhibition of return in spatial attention: Direct evidence for collicular generation. *Nature Neuroscience*, 2, 1053–1054.
- Schneider, W. (1988). Micro Experimental Laboratory: An integrated system for IBM PC compatibles. *Behavior Research Methods, Instruments and Computers*, 20, 206–217.
- Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-prime user's guide*. Pittsburg, PA: Psychology Software Tools Inc.
- Sumner, P. (2006). Inhibition vs. attentional momentum in cortical and collicular mechanisms of IOR. *Cognitive Neuropsychology*, 23, 1035–1048.
- Sumner, P., Nachev, P., Vora, N., Husain, M., & Kennard, C. (2004). Distinct cortical and collicular mechanisms of inhibition of return revealed with S cone stimuli. *Current Biology*, 14, 2259–2263.
- Vivas, A. B., Humphreys, G. W., & Fuentes, L. J. (2003). Inhibitory processing following damage to the parietal lobe. *Neuropsychologia*, 41, 1531–1540.
- Yantis, S., & Jonides, J. (1990). Abrupt visual onsets and selective attention: Voluntary versus automatic allocation. *Journal of Experimental Psychology: Human Perception and Performance*, 16, 121–134.