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RESEARCH ARTICLES

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Independent effects of endogenous and exogenous spatial cueing: inhibition of return at endogenously attended target locations

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Abstract Inhibition of return (IOR) is thought to reflect a bias against returning attention to previously attended locations. According to this view, IOR should occur only if attention is withdrawn from the target location prior to target appearance. In the present study, endogenous attention and exogenous cueing were manipulated orthogonally. IOR was observed both when a target appeared at an unexpected location, and when a target appeared at the expected location. A similar pattern of results was obtained in a reanalysis of data from a study with Neglect patients. These results suggest that IOR is independent of endogenous orienting.

Keywords IOR · Exogenous orienting · Endogenous orienting · Neglect

Introduction

Orienting attention toward the location at which a target stimulus is about to appear facilitates both detection of its onset and discriminative decisions about its perceptual properties. Therefore, if one has information regarding the likely location of a future target stimulus, a beneficial strategy would be to orient attention toward that location in advance. This voluntary, or *endogenous*, allocation of attention to a spatial location prior to target onset has been thoroughly investigated during the last two decades. In studies of endogenous attention, a symbolic cue that predicts the future target location is often presented. Participants use the predictive value of the cue to orient attention toward the expected location, and then maintain attention at that location until the target appears. The usual result is that performance for targets at this endogenously cued location is more efficient than for targets at uncued locations (Posner et al. 1980).

Alternatively, attention can be captured automatically at the location of a salient stimulus or new object (see Ruz and Lupiáñez 2002 for a review of the attention capture literature). This involuntary, or *exogenous*, allocation of attention has also been thoroughly studied. In studies of exogenous attention, a salient cue, such as an abrupt change in luminance, is often presented at one of two or more potential target locations, and the cueing effect that occurs using this procedure is attributed to an involuntary, or automatic, shift of attention to the cued location. Evidence for the automaticity of exogenous orienting comes from studies showing that exogenous orienting develops much faster than endogenous orienting (Müller and Rabbitt 1989) and from results showing that even cues of which participants are unaware produce cueing benefits (McCormick 1997).

Furthermore, exogenous cues are typically not predictive (the target appears with the same likelihood at the

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cued location as at any other location), so there is no obvious incentive for participants to maintain attention at the location at which it was captured. Thus, if the target does not appear at the cued location shortly after cue onset, then an appropriate strategy would be to withdraw attention from the cued location and reorient attention toward a neutral central location that is equidistant from each potential target location. This strategy of disengaging and reorienting attention would appear to explain why cueing benefits in studies of exogenous orienting are typically observed only at short cue-target intervals.

However, Posner and Cohen (1984) noted that at longer cue-target intervals not only is there no cueing benefit but rather there is a cueing cost, that is, detection responses are slower for targets presented at the cued location than for targets presented at an uncued location. Posner et al. (1985) called this effect *inhibition of return* (IOR[1]), and it has since been extended to a great variety of tasks and experimental procedures: Maylor (1985) in both target detection and localization RT tasks; Lupiáñez et al. (1997) in choice discrimination RT tasks; and Abrams and Dobkin (1994) and Pratt (1995) in eye movement latency (see Klein 2000; Lupiáñez et al. 1999, for reviews).

From the time that Posner and Cohen (1984) first reported the IOR effect, it has been widely accepted that the effect reflects an inhibition to return attention to a location that has been previously attended (Posner et al. 1985). This conceptualization of the IOR effect presumes that it reflects a mechanism that has adaptive value in situations that require visual search because, by inhibiting attention from returning to previously explored locations, it would promote a more thorough exploration of the visual scene [Danziger et al. 1998; Tipper et al. 1991; Tipper et al. 1996; see "why" section of Klein's review (2000) for this issue]. In fact, with a variety of procedures, IOR has been shown to occur in the context of visual search tasks, in which participants search serially for a target among distractors (Klein 1988; Klein and MacInnes 1999; Müller and von Mühlenen 2000; Takeda and Yagi 2000).

In summary, IOR is widely attributed to a mechanism involved in the orienting of attention, and more specifically to the inhibition of reorienting attention toward a previously attended location. It is clear, then, that the name IOR is not theoretically neutral: there is a perfect correspondence between the name of the effect and the theory explaining it. In other words, IOR is both an empirical effect (slower RT and/or higher error rate to targets appearing at a previously cued location than to those appearing at an uncued location) and an attentional mechanism by which attention is inhibited to reorient to a previously attended location. In our opinion, this ambiguity can impede understanding of exogenous orienting and IOR, because not enough research has been conducted to clearly demonstrate that the IOR effect is caused by an IOR mechanism, that is, by the inhibition of the reorienting of attention. Thus, in the following we will distinguish between IOR as an empirical effect and the reorienting hypothesis as an explanation for the effect.

In fact, several findings give reason to doubt the reorienting hypothesis as an explanation for the IOR effect. If IOR is the result of the inhibition of attention to return to a previously attended location, two predictions can be forwarded: (a) it should always be possible to observe facilitation at SOAs shorter than those at which IOR is measured and (b) no IOR should be found if there is no need to return attention to a previously attended location.

Regarding the first prediction, quite a few studies have reported IOR at long SOAs, without a facilitatory effect at shorter SOAs. Perhaps the clearest example of this finding was reported by Tassinari et al. (1994). They observed IOR at an SOA between the cue and target as short as 0 ms. As noted by Lupiáñez and Weaver (1998), with a cue-target SOA of 0 ms, there can hardly be time to disengage attention from the cued location and then return attention to that location. Interestingly, the absence of a facilitatory effect preceding the IOR effect is more common than one might expect, at least in detection tasks (see Maruff et al. 1999 for a review). Such results contradict the view that IOR is caused by attention being inhibited to reorient to a *previously attended* location. Far from being a prerequisite for IOR to appear, some authors have argued that orienting of attention might mask the negative effect of cueing at short intervals when no IOR is measured (Danziger and Kingstone 1999; Tassinari et al. 1994).

Regarding the second prediction, several studies have demonstrated that IOR can occur even when there appears to be no need to reorient attention to the cued location. In one such study, Berlucchi et al. (2000) used a procedure in which a target appeared in one of four possible target locations following an unpredictive cue in one of those locations. Within a given block of trials, participants were instructed to attend to one particular location relative to the location of the cue (although cues at each of the four locations were equally likely). The results revealed faster RTs in the endogenously attended location compared to the other three locations, and slower RTs in the exogenously cued location than in the uncued locations (i.e., IOR). However, the most important result was that, at all cue-target SOAs, comparable IOR effects were obtained at endogenously attended and unattended locations. Note that this pattern of results contradicts the predictions set forth above, in that no IOR should be observed when the target appears at a location where attention is endogenously allocated because there is no need for reorienting attention in this situation.

In a separate study of this issue, Rafal and Henik (1994) obtained similar results with a rather different procedure. First, an arrow was presented, which pointed toward the most likely target location (80% predictive), thus producing valid and invalid trials. For both kinds of trials, an exogenous cue (a brightening of the box marker) was presented 500 ms after the endogenous arrow cue. The

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[1] The same effect has been called "inhibitory aftereffect" by Tassinari et al. (1987).

target appeared in the same location as the exogenous cue on half of the trials and in the location opposite the exogenous cue on the remaining half of the trials. The target was presented 750 ms after onset of the exogenous cue, and thus 1,250 ms after onset of the endogenous cue. The results revealed additive effects of endogenous and exogenous cueing, thus IOR was independent of endogenous orienting of attention. Similar results were obtained by Berger and Henik (2002), at least in the temporal hemifield. That is, once again, comparable IOR effects seem to be obtained at endogenously attended and unattended locations.

These results are very useful in evaluating the reorienting hypothesis of the IOR effect, as additivity between exogenous and endogenous orienting does not fit well with this hypothesis. As stated above, if the IOR effect is caused by an inhibition to return attention to a previously attended location (the reorienting hypothesis), then it is not at all clear how IOR could occur at an endogenously attended location. Further, even if there were some explanation for how IOR could occur at an attended location, it is hard to envision how it could be as large at endogenously attended as at endogenously unattended locations.

In the present study, we used a new approach to test the plausibility of additivity between exogenous and endogenous orienting processes, and thus to investigate the reorienting hypothesis as an explanation of the IOR effect. An important feature in our procedure is that the same cue was used to manipulate exogenous and endogenous orienting. Because the same cue triggered both types of orienting, we view this study as providing a particularly strong test of the notion that exogenous and endogenous orienting produce additive effects on performance. Furthermore, a range of cue-target SOAs were used to evaluate whether exogenous and endogenous orienting effects perhaps interact at some cue-target SOAs but not at others, depending on whether the exogenous effect is facilitation or IOR.

The procedure we used, first introduced by Posner et al. (1982), combined the general logic of predictive cues to measure endogenous orienting, and abrupt onset cues to measure exogenous cueing. We use the term *exogenous cueing* to refer to cue-target location correspondence (same or different) and the term *endogenous orienting* to refer to the location of the target relative to an expectancy derived from the cue (expected or unexpected). Importantly, we included both a condition in which the cue predicted the target to appear at the same location as the cue, and a condition in which the cue predicted the target to appear at the location opposite the cue. By testing both of these conditions, a target that appeared at the same location as the cue could be either expected or unexpected. Similarly, when a target appeared at the location opposite the cue it could be expected or unexpected. In this manner, we were able to study whether exogenous cueing effects are modulated by endogenous orienting of attention when the same cue is used for both exogenous and endogenous orienting manipulations.

The results from the long cue-to-target SOA conditions, for which IOR is often found, are of particular interest in this study. If IOR reflects a bias against returning attention to a previously cued location, then no such effect should be observed when the target appears at an expected location. Note that in this case, when a target appears at an expected location, participants ought to have their attention oriented to that location. Thus, no reorienting should be necessary, and therefore a bias against returning attention to that location should not be reflected in performance. In contrast, when a target appears at an unexpected location, participants should have to reorient their attention to the target location. In this case, if the target location was previously cued, a bias against returning attention to a previously cued location ought to be manifest in performance. In sum, the reorienting hypothesis clearly predicts that exogenous cueing should interact with endogenous orienting. If the results instead show additivity between exogenous cueing and endogenous orienting, then the IOR effect would have to be explained by a mechanism other than the inhibition of the reorienting of attention.

Materials and methods

Participants

The study was carried out by following the guidelines of the ethics committee of the Hôtel-Dieu Hospital in Paris. Thirty-two normal individuals participated in the study after giving written informed consent. They reported normal or corrected-to-normal vision and being right-handed. Their mean age was 60 years (SD=13, range 39–81).

Apparatus and stimuli

Stimulus presentation and response collection were controlled by the Psychlab software (Gum 1996). Three black empty square boxes, with sides 10 mm long and 0.34 mm thick, were displayed on a white background on the computer screen. The boxes were horizontally arranged, the central box being located at the center of the screen. The central box contained a small black rectangular fixation point (1.02×1.34 mm) and the distance between boxes was 30 mm. Cues consisted of a 300-ms thickening (from 0.34 to 0.68 mm) of the contour of one lateral box. The target was an asterisk 4.40 mm in diameter, appearing inside one of the lateral boxes, at a retinal eccentricity of about 3.83°.

Procedure

Participants sat in front of a computer monitor at a distance of approximately 50 cm. Each trial began with the appearance of the three placeholder boxes for 500 ms.

Then the cue followed for a duration of 300 ms. The target appeared 100, 500, or 1,000 ms after onset of the cue, and remained visible until a response was made. Participants were instructed to maintain fixation on the fixation point and to respond to the target as quickly and accurately as possible, by pressing the center of the space bar with their right index finger. Eye movements were observed by one of the experimenters. After an intertrial interval of 1,000 ms, a new trial began. Participants completed three conditions, in different sessions, according to cue predictiveness. In one condition the cue was unpredictive (50% cued trials; the target appeared with the same probability at the cued as at the uncued location). In the other two conditions the cue was predictive (80% cued trials, 20% uncued trials) or counterpredictive (20% cued trials, 80% uncued trials).

Before each block of trials, participants were informed of the level of predictiveness of the cue (50%, 80%, or 20% cued targets). In the conditions with informative cues (80% and 20% cued targets), it was stressed that cues would in most cases help to respond more rapidly. Before the condition with non-informative cues, it was explained that cues were useless to predict the target position, and thus should be ignored.

Design

Each condition (50%, 20%, and 80% cued trials) was administered on one of three consecutive days, following a Latin square design. A 10-min rest was allowed between blocks. Each block began with 12 practice trials, which were discarded from analyses.

The condition with *non-informative* cues (50% cued trials) consisted of three blocks of 96 trials, and had a 2 (Cueing; cued, uncued) × 3 (SOA; 100, 500, 1,000 ms) design. The conditions with *informative cues* (80% and 20% cued trials) consisted of three blocks of 102 trials each. In this case the design was 2 (Cueing; cued, uncued) × 3 (SOA; 100, 500, 1,000 ms) × 2 (Location Expectancy; expected, unexpected).

Cueing refers to whether the target appeared in the same location as the cue (a cued trial) or at the location opposite the cue (an uncued trial), and *SOA* (100, 500, 1,000 ms) refers to the temporal interval between onset of the cue and onset of the target. Finally, *Location Expectancy* (only in the conditions with informative cues) refers to whether the target appeared at the location predicted by the cue (cued trials in 80% cued blocks, and uncued trials in 20% cued blocks), or at the location opposite that predicted by the cue (uncued trials in 80% cued blocks, and cued trials in 20% cued blocks). All variables were manipulated within participants, with SOA being manipulated within blocks of trials, and Expectancy and Cueing manipulated within blocks and between sessions, as explained above.

Results

Trials with RT longer than 1,500 ms (0.92%) or shorter than 150 ms (5.19%) were eliminated from the analysis. Mean correct RT for each experimental condition and cueing effects for each SOA level and expectancy condition are presented in Table 1.

Unpredictive cues condition

First, we describe the results from the unpredictive cue condition, to show that our procedure produces the results typically observed with unpredictive exogenous cues. A Cueing (Cued and Uncued) × SOA (100, 500, 1,000 ms) repeated measures ANOVA was conducted on mean RTs from the 50% cued trials condition. As expected, this analysis showed a highly reliable Cueing × SOA interaction, $F_{(2,62)}=38.82$, $P<0.0001$, with significant facilitation at the short SOA, and IOR at the longer 1,000-ms SOA, as revealed by planned comparisons (both Ps<0.001; see top panel of Fig. 1). Thus, the usual transition from facilitation at the short SOA to IOR at the longest SOA was obtained. The main effect of SOA was also significant, showing the usual decrease in RT by increasing SOA, $F_{(2,62)}=29.36$, $P<0.0001$.

Predictive cues condition

Mean RTs were submitted to a repeated measures ANOVA, with Location Expectancy (Expected vs Unexpected), Cueing (Cued vs Uncued), and SOA (100, 500, 1,000 ms) as factors. Importantly, the main effect of Expectancy was highly significant, $F_{(1,31)}=20.33$, $P<0.0001$, showing that RT to targets appearing at the expected location was 12 ms faster than RT to targets appearing at the unexpected location. Although the Expectancy × SOA interaction did not reach significance ($P=0.055$), the expectancy effect was larger at the medium and long SOAs than at the shortest one (actually, it was not significant at the shortest SOA; $F<1$). Importantly, the expectancy effect was highly significant at the two longest SOAs (19 and 15 ms for the medium and long SOAs, respectively; $P<0.005$ in both cases). Note that it is critical to our research objective to obtain this endogenous orienting effect. Given this effect, we were able to test

Table 1 Mean RT for each experimental condition, and cueing effects

	Predictive cue conditions						Unpredictive cues		
	Expected location			Unexpected location					
SOA (ms)	100	500	1,000	100	500	1,000	100	500	1,000
Cued	467	427	427	473	443	442	463	427	429
Uncued	496	430	402	497	452	416	499	440	402
Cueing effect	29	3	−24	24	9	−25	36	12	−26

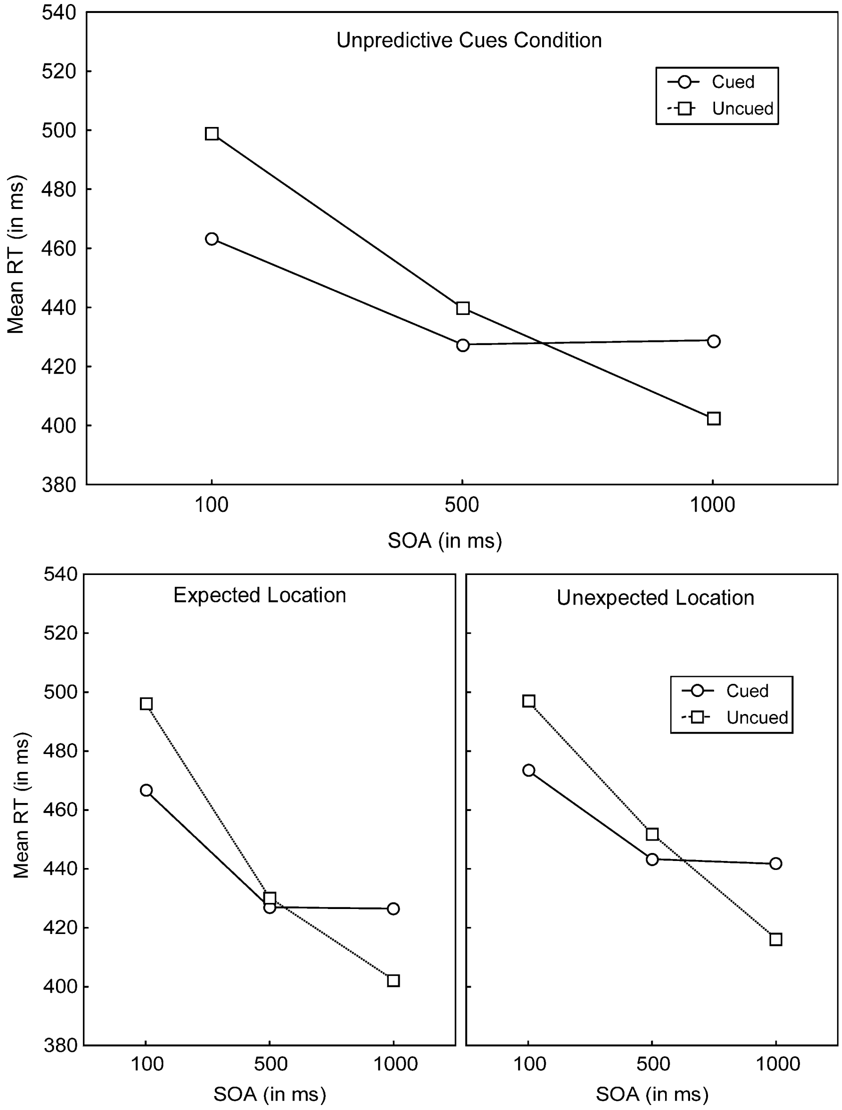

Fig. 1 Cueing effects across SOA. In the *top panel* data from the unpredictive cues condition are presented, whereas the data from the predictive cues conditions are presented in the *bottom panels* (*left* expected location; *right* unexpected location)

our hypothesis that IOR can be independent of endogenous orienting.

SOA interacted with Cueing, $F_{(2,62)}$=17.47, P<0.0001, in the predicted direction. As with unpredictive cues, the cueing effect was positive (faster responses for cued trials) at the short SOA (27 ms, P<0.0001), and negative at the long SOA (−25 ms IOR, P<0.005); the positive 6-ms effect at the intermediate 500-ms SOA was not significant (F<1). Thus, the typical pattern of exogenous cueing effects was obtained in this analysis. The critical issue, however, concerned the dependence of this interaction on endogenous expectancy. Importantly, the Expectancy × Cueing × SOA interaction was clearly non-significant, F<1. As can be seen in the bottom panel of Fig. 1, the same transition from facilitation to IOR was observed when the target appeared at the expected location as when it appeared at the unexpected location.

We had an a priori interest in establishing whether Cueing and Location Expectancy would interact at the short SOA, and whether they would interact at the long SOA. As such, two Expectancy × Cueing ANOVAs were performed, one on the data from the short SOA condition and another on the data from the long SOA condition. For the long SOA condition, the negative cueing effect (IOR) did not vary significantly as a function of Location Expectancy. Neither did the positive cueing effect observed at the short SOA condition (both Fs<1). As can be seen in the bottom panel of Fig. 1, for both SOAs, the cueing effects were virtually identical.

The only other significant effect was the main effect of SOA, $F_{(2,62)}$=30.94, P<0.0001, with RT decreasing linearly as SOA increased ($F_{(1,31)}$=36.57, P<0.0001).

Discussion

The aim of the present experiment was to investigate the interaction between endogenous orienting of attention and exogenous cueing. More specifically, we were interested in testing whether IOR, conceptualized by many researchers as the manifestation of an exogenous orienting mechanism, indeed depends on the orienting of attention.

We argued that if the IOR effect reflects a bias against returning attention to a previously cued location (the reorienting hypothesis), no such bias should be manifest if, when the target appears, attention is already oriented to the target location. In contrast, if the target appears at an unexpected location, so that participants have to reorient their attention to the target location, a bias against returning attention to a previously cued location would be expressed as an IOR effect.

The results of this experiment are clear-cut. First, the usual transition from facilitation at short SOAs to IOR at long SOAs was observed in both the unpredictive and predictive cues conditions. Second, and more important, Cueing effects did not depend on Location Expectancy, either in the overall analysis (non-significant SOA × Cueing × Expectancy interaction) or in specific analyses carried out for the short and long SOA. Thus, for the first time to our knowledge, we have observed a significant transition from exogenous cueing facilitation to IOR at the expected and the unexpected target location (the same trend was first reported by Posner et al. 1982, although not analyzed this way[2]).

In the specific analyses, significant facilitation and IOR effects were observed, but these effects did not vary as a function of Location Expectancy. It might be argued that the facilitation effect observed at the short SOA did not depend on the expectancy because the expectancy effect was not significant at this SOA. However, Chica and Lupiáñez (2004) have shown recently a lack of interaction between expectancy and short SOA facilitation in a similar procedure with a color discrimination task. They observed at the 100-ms SOA significant positive effects of both exogenous cueing and expectancy, independently of each other.

Thus, our results clearly disconfirm the reorienting hypothesis, which states that the IOR effect is a consequence of a mechanism that biases attention against returning to a previously visited location. Although inconsistent with the most widely accepted explanation for the IOR effect, the results are consistent with those reported in several other studies of exogenous cueing (see Berger and Henik 2002; Berlucchi et al. 2000; Rafal and Henik 1994, for a similar pattern of IOR effects; Riggio and Kirsner 1997, for a similar pattern of short SOA facilitation effects). Thus, there is mounting evidence that the reorienting hypothesis is incorrect, and that an alternative account of IOR is necessary. We outline one such alternative account in the General discussion.

Before doing so, however, we add to the available empirical evidence on this issue by describing the results of a study on the interaction between endogenous orienting and exogenous cueing in brain-damaged patients with left spatial neglect. Neglect patients' performance is particularly relevant to the issues discussed here because these patients suffer from a bias in exogenous orienting which penalizes events occurring on the left side of space (see Bartolomeo and Chokron 2001, 2002 for recent reviews). We reanalyzed the data from experiments 2 and 3 of Bartolomeo et al. (2001), in which a procedure similar to that in the present study was used.

Reanalysis of control versus patients data of Bartolomeo et al. (2001)

To better understand the interaction between endogenous orienting and exogenous cueing in Neglect patients we reanalyzed the data of experiments 2 and 3 of Bartolomeo et al. (2001). As in the experiment presented above, we used the term Cueing (cued vs uncued) to refer to whether the target appeared in the same location as the cue (a cued trial) or at the location opposite the cue (an uncued trial). Similarly, after recoding the data, Expectancy[3] referred to whether the target appeared at the *expected* location (cued trials of experiment 2, and uncued trials of experiment 3), or at the *unexpected* location (uncued trials of experiment 2, and cued trials of experiment 3). Two further variables were introduced in the analysis: SOA and Target Location. The cue-target SOA had three slightly different values to those in the above experiment (150, 550, 1,000 ms). Given that the focus of this study was the behavior of Neglect patients, who typically neglect information presented in the left hemifield, we analyzed the data separately for Left and Right Targets. All variables were manipulated within participants, with SOA manipulated randomly within blocks of trials, and Expectancy and Cueing manipulated within blocks and between sessions (two of the four experimental conditions in different sessions, as in the previous experiment reported here).

Six brain-damaged patients, with right hemisphere lesions and signs of left spatial neglect, and 18 age-matched participants without brain damage took part in the experiment (see Bartolomeo et al. 2001 for demographic details of both groups of participants).

Results and discussion

The data from the control participants were treated the same way as in the present study. Thus, trials with RT longer than 1,500 ms (0.49%) or shorter than 150 ms (2.05%) were eliminated from the analysis. For the patients' data, the same cut-offs as in the original Bartolomeo et al. study were used: trials with RT longer than 5,000 ms (3.94%) or shorter than 150 ms (3.86%) were eliminated from the analysis. After the elimination of the outliers, means were computed for each participant and

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[2] We thank Giovanni Berlucchi for drawing our attention to this result.

[3] Given that our main interest in this reanalysis was to compare cueing effects for endogenously expected and unexpected locations, the no expectancy data (50% cued, experiment 1 of Bartolomeo et al. 2001) were not included. Note also that in Bartolomeo et al. (2001) the order of different blocks across which cue predictiveness was varied (20% vs 80% predictiveness) were not counterbalanced across participants.

experimental condition. However, to compare the data of the Neglect patients with those of normal controls, and given that the Neglect group was much slower (as is well-known with Neglect patients, see, for example, Robertson 1993), the mean RT for each experimental condition and participant was divided by the mean overall RT for that participant. Thus, the dependent measure of interest was greater than 1.0 when a participant's RT for a particular condition was greater than his/her mean overall RT, and less than 1.0 when a participant's RT for a particular condition was smaller than his/her overall mean RT.

These transformed data, recoded according to the design we used in the previous experiment, were submitted to a 2 (Group; Neglect vs Controls) × 2 (Expectancy; Expected vs Unexpected location) × 2 (Cueing; Cued vs Uncued location) × 3 (SOA; 150, 550, 1,000 ms) mixed-factor ANOVA that treated Group as a between-participants variable. Two separate analyses were performed, one for Left Targets and another for Right Targets. Data for each experimental condition are presented in Table 2.

Left location

Apart from the main effects of Group, Expectancy, and Cueing, the most interesting results were the interactions in which Group was involved. Thus, Neglect patients showed larger than normal main effects of Expectancy and Cueing, as indicated by the Group by Expectancy and Group by Cueing interactions, $F_{(1,22)}=4.89$, $P<.05$, and $F_{(1,22)}=3.53$, $P<.073$, respectively. Interestingly, whereas the control group produced similar cueing effects for expected and unexpected locations, the large overall cueing effect produced by Neglect patients was modulated by expectancy, as indicated by the Group × Expectancy × Cueing interaction, $F_{(1,22)}=4.33$, $P<0.05$.

As shown in Fig. 2, Neglect patients showed about 50% RT increment on left uncued trials compared to left cued trials, a result that has been described elsewhere as an extinction-like pattern resulting from a deficit in disengaging attention from a right-sided event when it has to be re-engaged on a left-sided object (Posner et al. 1984; reviews in Bartolomeo and Chokron 2002; Losier and Klein 2001). However, this deficit was completely eliminated by endogenous attention, as it did not occur when Neglect patients expected the target to appear at the left location. Furthermore, the extinction-like pattern of data shown by Neglect patients at the unexpected target location was observed only at the two shortest SOAs, as can be seen in Fig. 2, and is indicated by the four-way interaction between Group, Expectancy, Cueing, and SOA, $F_{(2,44)}=7.52$, $P<0.005$. These characteristics suggest that the attentional bias shown by these patients concerns primarily exogenous orienting, consistent with abundant previous evidence (reviewed in Bartolomeo and Chokron 2002).

Right location

Again, the main effects of Group, Expectancy, and Cueing were significant in this analysis. However, the most interesting result was that Neglect patients produced a much bigger cueing effect than the Control group, $F_{(1,22)}=6.07$, $P<0.05$.

Although the Group × Cueing × SOA interaction only approached significance, $F_{(2,44)}=2.18$, $P=0.125$, as can be seen in Fig. 3, participants in the control group produced the usual transition from facilitation at the short SOA to IOR at the long SOA, $F_{(2,34)}=7.31$, $P<0.005$, independently of Expectancy ($F<1$). In contrast, Neglect patients produced a large positive cueing effect (14.12% on average) across the three SOAs, $F_{(1,5)}=7.19$, $P<0.05$, also independently of Expectancy.

This result is similar to the one observed by Bartolomeo et al. (1999) using a procedure in which cueing was manipulated by comparing target locations in the current and previous trial (target-target procedure). They reasoned that an anomalous IOR for right-sided objects could contribute to the impairment of Neglect patients, and found that Neglect patients indeed showed facilitation instead of IOR for right-repeated targets. The size of this paradoxical "facilitation of return" for right targets showed an inverse correlation with the number of *left* hits in two cancellation tasks, thus suggesting the presence of a relationship between the paradoxical "facilitation of return" for right targets and left neglect. The bigger the right facilitation of return they showed, the more pronounced was the left neglect on paper-and-pencil tasks. Apart from generalizing this finding to a cue-target

Table 2 Proportional mean RT as a function of target location, expectancy, cueing, and SOA. Data from the Neglect patients and control group of Bartolomeo et al. (2001)

	Left target location						Right target location					
	Expected			Unexpected			Expected			Unexpected		
SOA (ms)	150	550	1,000	150	550	1,000	150	550	1,000	150	550	1,000
Control group												
Cued	0.97	0.94	0.96	1.00	1.01	1.00	1.01	0.96	0.98	1.01	0.98	1.02
Uncued	1.04	0.94	0.91	1.11	1.02	1.00	1.07	0.96	0.92	1.13	1.05	1.02
Cueing effect	0.07	0.01	−0.05	0.11	0.01	0.00	0.06	0.01	−0.06	0.12	0.07	0.00
Neglect patients												
Cued	1.04	1.18	1.12	0.87	1.04	1.35	0.70	0.71	0.79	0.82	0.77	0.78
Uncued	1.11	1.12	0.98	1.46	1.48	1.25	0.87	0.89	0.93	0.90	1.00	0.84
Cueing effect	0.07	−0.06	−0.13	0.59	0.44	−0.10	0.17	0.18	0.14	0.08	0.22	0.06

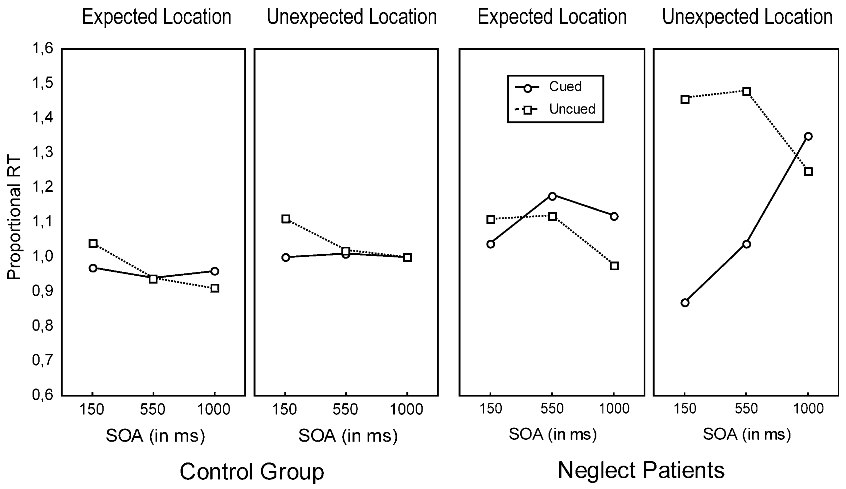

Fig. 2 Cueing effect at the expected and unexpected location for the control (*left panels*) and Neglect patients (*right panels*) groups of Bartolomeo et al. (2001). Data from left target location. Note the extinction-like pattern shown by Neglect patients, but only for targets appearing at the unexpected location

procedure, the present results are interesting in that, once again, this exogenous cueing effect (facilitatory, instead of IOR) seems not to depend on where attention is endogenously oriented (see Fig. 3).

General discussion

According to the spotlight metaphor of attention, or its neural version (Fernández-Duque and Johnson 1999), attention is conceived as a mechanism that facilitates the processing of stimuli within an attended area of space by improving functioning of the neural areas representing that part of the space. Thus, processing is enhanced at locations to which attention is allocated compared to locations to which attention is not allocated. Within this framework, it is important to know the mechanisms by which the attentional operator moves across space, the parameters of the movement, and the biases inherent to that movement. Thus, as we described in the Introduction, it is widely assumed that exogenous attention is biased against returning to previously attended locations. This bias is the basis for what we call the reorienting hypothesis, which has been used widely to explain the IOR effect.

However, the results of the present experiment, as well as the reanalysis of the results of Bartolomeo et al. (2001), confirm that IOR can be observed for locations at which a target is expected to occur. If IOR reflected a difficulty in returning attention to a previously attended location, then it ought not to occur when attention is endogenously maintained at the cued location. The present results show the opposite outcome, and thus nicely complement those reported in several prior studies in demonstrating a surprising degree of independence between endogenous orienting and exogenous cueing effects. Our methods differed from previous studies that obtained similar results (Berger and Henik 2002; Berlucchi et al. 2000; Rafal and Henik 1994) in that we used exclusively peripheral cues, and modulated participants' endogenous expectancies by systematically varying the level of cue predictiveness (50%, 80%, or 20% of cued targets). The similarity of the results in the face of this change in method suggests that the independence of IOR from endogenous expectancies is a robust phenomenon.

An important implication of this observation is that the description of spatial attention as a spotlight, and IOR as a byproduct of biases in its movement, might be inadequate. Time and accuracy of target processing seem rather to be the end product of multiple processes, independent to

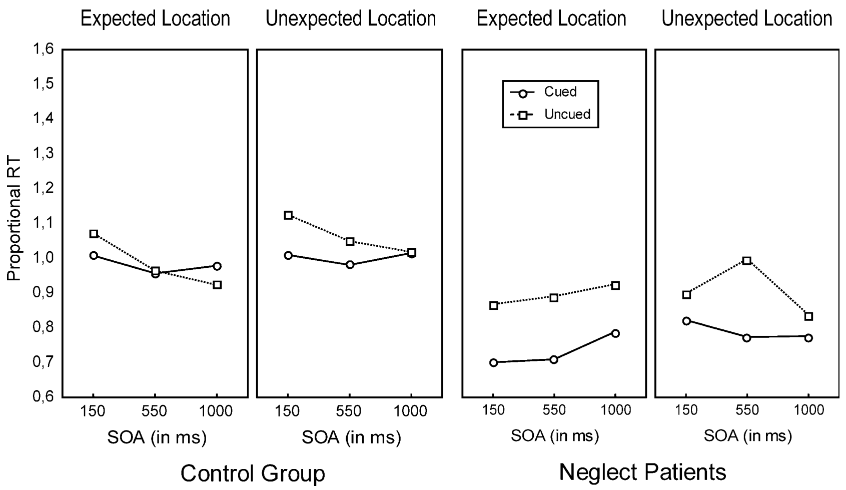

Fig. 3 Cueing effects across SOA, as a function of target location expectancy, for right target location trials in controls (*left panels*) and Neglect patients (*right panels*). Data from Bartolomeo et al. (2001)

some extent and working in parallel. Specifically, the present results suggest that exogenous processes related to bottom-up attentional capture and endogenous mechanisms related to top-down spatial expectancy contribute independently to performance. Similarly, Berlucchi et al. (2000), who observed IOR for locations where participants were told to engage their attention, proposed that their results could be accounted for by the simultaneous operation of multiple independent attentional mechanisms during covert orienting.

The dissociation between exogenous and endogenous orienting shown by the present and previous results should perhaps not come as a surprise, given that these attentional processes serve two often conflicting interests. That is, in order to maintain coherent behavior in the face of a continuously changing environment, an organism needs mechanisms that: (a) allow for the processing of novel, unexpected events, that could be either advantageous or dangerous, in order to respond appropriately with either approach or avoidance behavior, and (b) allow for the maintenance of goal-directed behavior in spite of distracting events (Allport 1989). These two ecological constraints may be satisfied by functionally independent endogenous and exogenous processes. Thus, exogenous and endogenous orienting processes seem to be in a continuous dynamical equilibrium. The salience of distracting events and the strength of the strategic set would establish the relative weight that, respectively, exogenous and endogenous orienting has on performance.

Importantly, however, rather than thinking of exogenous and endogenous attention processes as constituting two means by which a unitary spatial attention operator moves across space, it may be that exogenous and endogenous attention processes perform quite different functions, as has been put forward by Klein and colleagues to explain other dissociations between exogenous and endogenous attention (Hansen and Klein 1990; see Klein and Shore 2001, for a review). One possibility is that exogenous processes are related to perceptual processing, perhaps playing a role in perceptual integration (Kahneman et al. 1992), perceptual competition (Desimone and Duncan 1995), and novelty detection. In contrast, endogenous processes may have more to do with top-down preparation for perceptual processing rather than with perceptual processing itself.

Note that this distinction lends itself to a different explanation of exogenous cueing effects. Rather than making reference to how an abrupt onset cue affects the locus of an attention operator, the explanatory focus shifts to specific ways in which perceptual processing might be altered by an abrupt onset cue. For example, an abrupt onset cue may capture attention (Ruz and Lupiáñez 2002) in the sense that it initiates the encoding of a new perceptual event. If a target appears shortly after the cue, the temporal proximity of the two events may result in the encoding of the cue and target as part of the same perceptual event (Kahneman et al. 1992; Lupiáñez et al. 2001). As this event integration process only occurs efficiently for targets and cues that appear at the same location, and not for those appearing at different locations, it explains why there is often an exogenous cueing benefit at short cue-target SOAs. However, as the temporal interval between cue and target increases, the utility of perceptual integration processes can be expected to decrease, which explains why this facilitation effect is short-lived. Furthermore, if we assume that the perceptual system has an inherent tendency to integrate cue and target events even at longer cue-target SOAs, and even when we try to differentiate them, it follows that cued targets will be treated by the system as "old" events while uncued targets will be treated by the system as "new" events. Assuming that new perceptual events capture attention, then this attention capture could serve as the basis for explaining the IOR effect at long SOAs (cued targets are less new). Note that from this perspective, IOR does not result from inhibited processing at the cued location, but rather from the loss of the benefit that takes place at non-cued locations due to attentional capture from new onsets (Milliken et al. 2000).

In this context, we consider particularly interesting a recent finding by Dorris et al. (2002). They observed that neurons of the superficial and intermediate layers of the monkey superior colliculus (SC) show an attenuated visual response to the target if it has been preceded by a peripheral non-informative cue (i.e., they show IOR for cued targets). However, these neurons were *not inhibited* during the period of time prior to target onset (i.e., during the interval between cue and target onsets), nor were they inhibited at the time of target onset. In fact, the baseline activity in these cells was actually higher than when the cue was presented at the opposite location to the target (outside the cell's receptive field). Furthermore, when saccades were elicited artificially by electrical microstimulation of the SC rather than by actual presentation of a target, saccades were faster when the electrical microstimulation was added to the same location as the cue, than when it was added to the uncued location. That is, the presentation of a cue led to an increase in activation of the SC cells, rather than to inhibition of these cells. Interestingly, this increased activation led to a longer saccade latency to an external target (i.e., IOR), but to a shorter latency (facilitation) in artificially induced saccades.

As ironic as it might appear, rather than measuring inhibition allocated to a spatial representation, IOR may measure a negative consequence of some small activation of a spatial representation. Under some conditions (i.e., long SOAs), an activated spatial representation may fail to speed responses to targets presented at that location, but may be sufficient to impede attention from being captured by the target at that location. However, this negative effect (IOR) should only appear if participants treat the cue and target as separate events. If participants integrate cue and target into a single object representation (thus adding to its initial activation), then one might expect to observe facilitation rather than IOR, mirroring Dorris et al.'s (2002) microstimulation data.

Interestingly, this might explain the above-described "facilitation of return" pattern observed for right, non-neglected targets, in Neglect patients. The facilitatory effect might be due to the problems that these patients seem to have in creating separate representations for different objects presented at the same location, revealed in an unusually long Attentional Blink effect (Husain et al. 1997). If Neglect patients are unable to encode separate representations for consecutive stimuli appearing at the same location, then object substitution processes (see Enns and DiLollo, 1997) may lead to the integration of consecutive stimuli within the same event representation, even when they appear at relatively long asynchronies. Thus, in an Attentional Blink procedure the target would be substituted by the following distractor, leading to the Attentional Blink effect. In our cueing procedure the cue would be substituted by the target, leading to a facilitation effect, similar to the one shown by controls at shorter SOAs, and by SC microstimulated cells.

Be that as it may, the findings from Neglect patients also indicate independence between IOR and endogenous allocation of attention, consistent with the evidence suggesting a lateral bias of exogenous orienting with relatively preserved endogenous orienting in left neglect (Bartolomeo and Chokron 2002; Bartolomeo et al. 2001; Làdavas et al. 1994; Smania et al. 1998).

In support of this view, evidence suggests that the two modes of orienting might be subserved by partially distinct neural substrates. Recent neuroimaging studies (reviewed in Corbetta and Shulman 2002) have suggested that the brain contains two partially segregated systems for visual orienting: a dorsal network (intraparietal sulcus and frontal eye field), bilaterally represented and concerned with endogenous orienting, and a more ventral network (temporoparietal junction and inferior frontal gyrus) subserving exogenous orienting. Importantly, the ventral network is lateralized to the right hemisphere, and colocalizes with the brain regions most often damaged in unilateral neglect. A functional MRI study (Rosen et al. 1999), employing a cued RT paradigm to identify the brain areas involved in exogenous and endogenous orienting, demonstrated largely overlapping activations in the parietal and dorsal premotor regions for both modes of orienting, except for an activation in the right dorsolateral prefrontal cortex (BA 46) that was exclusive to the endogenous condition. On the other hand, neural activity in the superior colliculus may be important for the IOR phenomenon (Dorris et al. 2002; Sapir et al. 1999). Thus, exogenous orienting might rely on a frontal-parietal network receiving information from subcortical structures, and modulating its activity, whereas in endogenous orienting the relevant cortical network might be similar, but with a more extensive implication of prefrontal regions.

The functional specialization suggested by our present results may thus reflect a relative modularity of the neural correlates of exogenous and endogenous orienting, in agreement with neurocognitive models postulating attentional processes as resulting from competition among distinct neural networks (Desimone and Duncan 1995).

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