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The phenomenology of endogenous orienting

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Abstract

Can we build endogenous expectations about the locus of occurrence of a target without being able to describe them? Participants performed cue–target detection tasks with different proportions of valid and invalid trials, without being informed of these proportions, and demonstrated typical endogenous effects. About half were subsequently able to correctly describe the cue–target relationships ('verbalizers'). However, even non-verbalizer participants showed endogenous orienting with peripheral cues (Experiments 1 and 3), not depending solely on practice (Experiment 2). Explicit instructions did not bring about dramatic advantages in performance (Experiment 4).With central symbolic cues, only verbalizers showed reliable endogenous effects (Experiment 5). We concluded that endogenous orienting with peripheral cues can occur independently of participants developing explicit hypotheses about the cue–target relationships.

Keywords: Spatial attention; Response time; Consciousness; Implicit knowledge

1. Introduction

Attention can be directed to an object in space either in a relatively automatic way (e.g., when a honking car attracts the attention of a pedestrian), or in a more controlled mode (e.g., when the pedestrian monitors the traffic light waiting for the 'go' signal to appear). The distinction goes back at least to William James, who distinguished between "passive, reflex, non-voluntary, effortless" attention and "active and voluntary" attention (James, 1890, p. 416). More recently, this distinction has been variously referred to as reflexive/voluntary, bottom-up/top-down, stimulus-driven/goal-directed or strategy-based, or exogenous/endogenous (see Egeth & Yantis, 1997, for review). It is important to note that, logically speaking, this dichotomy must be relative rather than absolute. A strictly defined exogenous mechanism would leave no room for psychological variables such as attentional orienting (Pashler, 1998). On the other hand, it is possible that, to endogenously direct one's attention toward an object, this object must previously have been selected as such by exogenous

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processes. Endogenous orienting by itself may only facilitate location-based, and not object-based, processing (He, Fan, Zhou, & Chen, 2004; Macquistan, 1997). Thus, exogenous and endogenous mechanisms normally interact during visual exploratory behavior. Several lines of evidence indicate that, rather than being two modes of orienting of the same attentional system, they may be qualitatively different, albeit interacting, processes. This evidence includes data from normal participants, both in behavioral studies (Berger, Henik, & Rafal, 2005; Briand, 1998; Briand & Klein, 1987; Klein & Shore, 2000; Lupiáñez et al., 2004; Prinzmetal, McCool, & Park, 2005) and in neuroimaging studies (Corbetta & Shulman, 2002). The dichotomy is also supported by the patterns of performance shown by brain-damaged patients (Bartolomeo & Chokron, 2002; Bartolomeo, Siéroff, Decaix, & Chokron, 2001; Losier & Klein, 2001).

Exogenous and endogenous orienting can be studied in relative isolation from one another by using cue–target detection tasks (Posner, 1980). In a typical experiment, participants are presented with three horizontally arranged boxes. They fix their gaze on the central box and respond by pressing a key when a target (an asterisk) appears in one of two lateral boxes. Each target is preceded by a cue at various time intervals, or stimulus-onset asynchronies (SOAs). Cues can be central (an arrow presented in the central box pointing toward one lateral box) or peripheral (a brief brightening of the contour of one lateral box). Valid cues correctly predict the location of the impending target, whereas invalid cues indicate the box on the opposite side. Cues can be either informative, when targets usually appear in the cued box (e.g., 80% of the time), or non-informative, when targets can appear with equal probabilities at the cued or at the uncued location.

Peripheral non-informative cues attract attention automatically, or exogenously (Jonides, 1981; Müller & Rabbitt, 1989). This exogenous attentional shift, revealed by faster response times (RTs) for cued than for uncued trials, is typically observed only for short SOAs between cue and target. For SOAs longer than $\sim$300 ms, uncued targets evoke faster responses than cued targets (Posner & Cohen, 1984), a phenomenon known as inhibition of return (IOR; Klein, 2000; Posner, Rafal, Choate, & Vaughan, 1985) or inhibitory aftereffect (Tassinari, Aglioti, Chelazzi, Marzi, & Berlucchi, 1987).

With peripheral informative cues, the cue validity effect persists even at longer SOAs, thus suggesting that the initial exogenous shift is later replaced by a more controlled, endogenous shift toward the same location (Müller & Findlay, 1988). This endogenous shift would be motivated by strategic considerations, because subjects know that targets will appear with high probability at the cued location.

Endogenous shifts are more often studied using central, symbolic cues (arrows). However, this approach may introduce potential confounds. For example, more levels of processing, such as the interpretation of the symbol, may be involved in central cueing than in peripheral cueing. Central and peripheral cues might act on distinct stages of information processing, e.g., an early perceptual stage for peripheral cues, and a late perceptual or a decision stage for central cues (Riggio & Kirsner, 1997). Consistent with this hypothesis, facilitation induced by symbolic cues develops more slowly than with peripheral cues, requiring at least 300 ms to reach optimum (see, e.g., Müller & Findlay, 1988). Indeed, orienting in response to central and peripheral cues may implicate distinct attentional systems (Briand, 1998; Briand & Klein, 1987; Klein, 1994).

In view of these concerns, endogenous and exogenous processes can be explored and compared using exclusively peripheral cues, whose degree of informativeness about the location of the impending target is varied in different experiments (Müller & Rabbitt, 1989). Typically, one may employ cues that most frequently predict the target to occur at the cued box, or cues that are most frequently invalid, thus indicating the uncued box as the probable site of target occurrence (Posner, Cohen, & Rafal, 1982).

It is traditionally maintained that endogenous orienting is voluntary and requires conscious awareness, whereas exogenous orienting is more reflexive in nature. For example, Jonides proposed that "on the one hand, certain salient stimuli have reflexive control over attention allocation... On the other hand, subjects have internal control over the spatial allocation of attention so that, when motivated, they can voluntarily shift attention from one part of the field to another" (Jonides, 1981, p. 188). It is hard to imagine how such a voluntary shift, requiring appropriate motivation, could take place without conscious effort. Concerning the relationship between strategies and awareness, Posner and Snyder explicitly related "conscious attention" to "strategies," defined as "programs... which are under the conscious control of the subject" (Posner & Snyder, 1975, p. 73). Consistent with these views, McCormick (1997) demonstrated that exogenous cues presented below a subjective threshold of awareness can capture attention without awareness. He employed a cue–target paradigm with informative cues. Sub- and supra-threshold cues were presented near two possible target locations. Participants were informed that targets would occur at the cued location only 15% of the time, and were thus invited to shift their attention to the opposite, uncued location. Interestingly, when cues were presented above threshold, participants responded faster to uncued trials than to cued trials, as if they adopted the correct strategy of reorienting their attention from the cued to the uncued location (see Posner et al., 1982). When, however, cues were below threshold, and were thus not consciously perceived, participants showed the opposite pattern, because valid trials evoked faster responses than invalid trials. These results suggest that exogenous orienting, but not endogenous orienting, can take place without explicit awareness. In a similar vein, the study of a hemianopic patient with blindsight, G.Y. (Kentridge, Heywood, & Weiskrantz, 1999a), demonstrated that information provided by cues presented in a blind field, and thus not consciously perceived, can be used to orient attention. However, in sharp contrast with the results of normal participants in the McCormick study, G.Y. could benefit from cue-associated information even when cues and targets were spatially separated (i.e., 68.35% of the cues indicated a target appearing at the opposite location). In other words, G.Y. could engage endogenous orienting processes as a consequence of cues which he denied to have seen. Although direct comparison between the two studies is difficult, because blindsight can be qualitatively different from near-threshold normal vision (Kentridge, Heywood, & Weiskrantz, 1999b), G.Y.'s performance suggests that, at least in some cases, endogenous orienting can occur without explicit awareness.

Forms of attentional orienting different from exogenous shifts can also take place in the absence of explicit awareness, as was shown by Lambert (2003), Lambert, Naikar, McLahan, and Aitken (1999), and Lambert and Sumich (1996). They presented bilateral letter cues to participants. The relative locations of the letters predicted the side of target onset. Results showed benefits at the cued locations, independent of the participants' capacities of describing the cue–target relationships in a post-experiment questionnaire, and even of the participants' ability to acknowledge that a cue had been presented (Lambert et al., 1999). In a similar vein, Lambert and Sumich (1996) found cueing benefits for target detections preceded by words whose semantic category (living or non-living) predicted the side of occurrence of the target, again in the absence of any explicit acknowledgment of the word–target relationship. These effects cannot be attributed to purely exogenous shifts, because there was no spatial co-occurrence of valid cues and targets.

The present study originated from comments that some normal participants made after performing the experiments reported in a study devoted to orienting of attention in left spatial neglect (Bartolomeo et al., 2001), wherein we explored exogenous and endogenous orienting processes in normal participants and neglect patients using a cue–target detection paradigm with peripheral cues. In different experiments, we used different proportions of valid trials (50, 80 or 20%), and found in normal participants the typical effects of endogenous orienting. Cues gave an advantage to valid trials in the 80% valid condition, and, at long enough SOAs, a benefit for invalid trials in the 20% condition (see also Posner et al., 1982; Warner, Juola, & Koshino, 1990). Before each experiment, participants were informed of the level of cue predictiveness. Despite this, at informal debriefing some participants claimed not to have paid attention to the cues at all. Instead, they just tried to respond as fast as possible to the targets. And yet, these participants' performance showed the typical effects of cue predictiveness: Not only effects related to exogenous orienting, like IOR with non-informative cues, but also a durable advantage for cued locations with 80% valid cues and a cost for cued locations larger than IOR with 20% valid cues. Since these last effects are usually taken as resulting from endogenous orienting, we wondered whether this form of orienting is really based on volitional strategies, as is usually maintained (Jonides, 1981; Posner & Snyder, 1975), or it can rather result from more implicit processes.

To address this question, in the present study we asked normal participants to perform cue–target detection tasks with different degrees of cue predictiveness. We also varied the information about cue predictiveness given to the participants prior to the testing session, and tried to assess participants' awareness of the cue–target relationships by using a post-experiment questionnaire. In Experiments 1–3 and 5, no information was given about the relationships between cue and target positions. Participants had to figure out these relationships on their own. To obtain an internal, within-subjects control for participants' performance, in a first block of trials cues were not informative about the localization of the impending target. In a second block, which followed the first without interruption, the level of cue predictiveness varied across experiments. Any change in performance between the first and the second experimental block can only result either from practice, or from participants' reactions to changes in cue predictiveness. In addition to provide an internal control for participants' performance, this two-block structure can also be informative about the participants' capacities of developing strategies in response to unexpected changes in the cue–target relationships.

These issues are of obvious importance for theoretical accounts of attention and consciousness. In the words of Posner and Raichle, "there seems to be some general relationship between voluntary programming and awareness, since both depend on attentional systems, yet these functions may themselves be dissociated. During REM sleep we are aware of dreams but often cannot exercise voluntary control over them... The exact connection between awareness and control, and the connection of both to the attentional networks, remain for future research to resolve" (Posner & Raichle, 1994, p. 204). Moreover, because in most of our experiments participants were not informed of the cue–target relationships, but had to find out this information by themselves, our study bears implications for theories of explicit and implicit learning, and their relationship with awareness (see Jiménez, 2003). Finally, cue–target paradigms similar to the ones we employed are widely used in clinical settings, to explore performance of patients with focal brain damage (Bartolomeo & Chokron, 2001; Losier & Klein, 2001; Posner, Walker, Friedrich, & Rafal, 1984), degenerative dementia (Danckert, Maruff, Crowe, & Currie, 1998), Parkinsonian syndromes (Posner et al., 1985; Rafal, Posner, Friedman, Inhoff, & Bernstein, 1988), schizophrenia (Posner, Early, Reiman, Pardo, & Dhawan, 1988) and other pathological conditions, as well as of normal elderly participants (Castel, Chasteen, Scialfa, & Pratt, 2003). The present study intended to contribute to a better knowledge of such an elegant and widely used neuropsychological diagnostic tool as is the Posner RT paradigm.

2. General method

2.1. Participants

A total of 100 undergraduates from the Paris 5 University (27 males, median age 26 years, range 20–46) took part in a series of five experiments for course credit (20 participants for each experiment). All were right-handed and reported normal or corrected-to-normal vision. All participants were naïve to the purposes of the experiments. No participant took part in more than one experiment.

2.2. Apparatus and stimuli

Stimulus presentation and response collection were controlled by the Psychlab software (Gum, 1996). Three black empty square boxes, with a 10-mm long, 0.34-mm thick side, were displayed on a white background. 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). 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 box (Experiments 1–4), or in the presentation for 300 ms of a central horizontal arrow indicating one of the two lateral boxes (Experiment 5). The target was an asterisk 4.40-mm in diameter, appearing inside one of the lateral boxes, with its center at a retinal eccentricity of about 3.83°.

2.3. Design and 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 a cue was displayed for 300 ms. The target appeared at a variable SOA (600, 800 or 1000 ms) from cue onset, and remained visible until a response was made. These SOAs were chosen to render the target onset difficult to predict on a temporal basis, while maintaining the cue–target interval in a range apt to explore endogenous shifts of attention. 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. They were told that targets would be preceded by cues, indicating either the box in which the target was to appear, or the opposite box; however, participants were invited to concentrate exclusively on targets and to pay no attention to cues. After an inter-trial interval of 1000 ms, a new trial began.

Unknown to the participants, two blocks of trials followed one another without interruption. In the first block, consisting of 24 trials preceded by 12 practice trials, valid and invalid cues were presented in equal proportion. In the second block, made of 90 trials preceded by 18 practice trials, the level of predictability of cues varied according to the experiment. In 12 additional catch trials, interspersed within the second block, only cues were presented and participants had to refrain from responding. Trials within each block were presented in a previously randomized sequence. The same sequence of trials was used for all participants. In Experiments 1–3 and 5, participants were not informed of the cue–target relationship; they were told about the presence of the cues, but asked not to pay attention to them and invited just to respond to the targets as fast as possible.

Immediately after the experiments, participants filled out a questionnaire (inspired by Lambert et al., 1999), asking (1) whether there was any cue–target relationship, and (2) whether cues predicted most frequently the target location or the wrong location. On the basis of their responses to the questionnaire, participants were classified as 'verbalizers,' if they answered correctly either to both questions, or as 'non-verbalizers,'[1] if their answer to question 1 was incorrect. Participants who declared that there was a consistent relationship between the cues and the targets in response to question (1), but chose the wrong possibility in response to question (2), were discarded from RT analysis. Following Lambert et al. (1999), after completion of the questionnaire we asked participants to rated their confidence in their judgment on the following scale: 1 (pure guess), 2 (mainly guesswork), 3 (possibly the correct choice), 4 (probably the correct choice), 5 (very likely the correct choice), 6 (certainly the correct choice).

2.4. Analysis of results

The first 12 trials of block 1 and the first 18 trials of block 2 were discarded as practice. Response times exceeding the 100–1000 ms range were discarded from analysis. After this first trimming, the mean RT and SD were calculated for each participant. RTs exceeding the range of 2.5 SDs around the participant's mean were considered as outliers and discarded from further analysis. Overall, the trimming procedures resulted in the exclusion of 2% of responses. For each experiment, mean RTs were entered in a repeated-measures analysis of variance (ANOVA), with Group (verbalizers, non-verbalizers) as between-participants factor and Block (1, 2), Cue (valid, invalid) and SOA (600, 800, 1000 ms) as within-participants factors. The α level was set to 0.05. The critical comparisons to evaluate the hypothesis that endogenous orienting is possible independent of explicit awareness concerned the Cue Validity effect in the two experimental blocks for each group of participants. Thus, two comparisons (one per participant group) were planned in advance, with the α level set to 0.05 according to the modified Bonferroni procedure proposed by Keppel (1991).

3. Experiment 1: 50% → 80% valid trials

The first experiment addressed the following questions: Can people use a probabilistic cue–target relationship, such as the fact that most of the cues are valid, despite the absence of explicit information about this relationship? And, if yes, does this knowledge always have an explicit, declarative correlate? To explore these issues, we presented participants with a Posner-type RT paradigm with 80% valid peripheral cues, without giving any explicit instruction as to the informative value of the cue. Moreover, unknown to participants the 80% valid block started after a first block of trials with non-informative cues. Immediately before the experimental session, participants were orally given the following instructions: "You are going to see three boxes on the screen. Keep your gaze fixed on the central box and press this key as soon as you see an asterisk appearing in one lateral box. Try to be as fast as possible. Before the asterisk appears, the contour of one lateral box will briefly become thicker. Do not pay attention to this occurrence and be sure to respond only to the asterisk." Participants were asked to fill a post-experiment questionnaire (inspired by Lambert et al., 1999) soon after the RT session was completed.

[1] We preferred these more theoretically neutral terms to 'aware' and 'unaware.' Although in the following sections we occasionally used 'awareness' as a shorthand for 'ability to produce an accurate verbal report,' we would like to postpone to the Section 7 any considerations about the implications of our results for phenomenal awareness.

In this experiment, we expected to observe a cost for valid trials with respect to invalid trials (i.e., IOR) in the first block. In the second block, this cost should persist if RTs are not influenced by the change in informative value of the cues. If, on the other hand, this change modifies participants' expectations, in the sense that they now look forward to detecting the target at the cued location, this endogenous orienting should offset the cost for valid trials (IOR). Thus, IOR should be masked by this concomitant, strategy-based endogenous orienting (see Berlucchi, Chelazzi, & Tassinari, 2000; Danziger & Kingstone, 1999; Lupiáñez et al., 2004).

3.1. Methods

The task consisted of a first block with uninformative cues; a second block with 80% valid cues followed without interruption and unknown to the participants. The post-experiment questionnaire was given soon after completion of the RT session.

3.2. Results and discussion

One participant was excluded from analysis because he responded to all the catch trials. Three further participants were discarded because they gave inconsistent responses to questions (1) and (2) of the post-experiment questionnaire. They stated that there was a consistent relationship between cues and target, but chose the wrong one, i.e., that targets most often appeared at the uncued location, when answering question (2). The remaining participants were divided into verbalizers ($N = 7$) and non-verbalizers ($N = 9$) as described under Section 2. Table 1 reports the results for the two groups. The main effect of Group did not approach significance, $F < 1$, nor did this factor interact with other factors. In particular, the Group × Block × Validity interaction was not significant, $F < 1$. Overall, valid trials evoked responses slower by 18 ms than invalid trials, $F(1, 14) = 4.65$, $p = .049$. There was an effect of SOA, $F(2, 28) = 7.89$, $p = .002$, because RTs tended to speed up with increasing SOA. Importantly, an interaction between Block and Cue Validity emerged, $F(1, 14) = 30.54$, $p < .0001$ (Fig. 1A).

In the block with non-informative cues, RTs were faster for invalid trials (372 ms) than for valid trials (409 ms), consistent with the phenomenon of IOR. In the 80% validity block, instead, valid trials evoked similar RTs (380 ms) to invalid trials (388 ms), as if an endogenous facilitation for validly cued targets masked IOR. If this interpretation is correct, it would imply that people can use endogenous, strategy-based processes even in the absence of explicit instructions to do so. No other effect or interaction reached significance.

The planned comparisons showed that the Block × Validity interaction was statistically reliable both for verbalizers, $F(1, 14) = 17.61$, $p < .0001$, and for non-verbalizers, $F(1, 14) = 12.94$, $p = .0029$. All verbalizers gave a confidence rating of 3 ("possibly the correct choice") or more to their answers to the questionnaire (mean, 4.14; *SD*, 1.21). The mean confidence rating for non-verbalizers was 2.22 (*SD*, 0.83), with a single

Table 1
Mean response times (in ms) for verbalizer and non-verbalizer participants to Experiment 1 (block 1: 50% valid trials; block 2: 80% valid trials) and Experiment 2 (block 1: 50% valid trials; block 2: 50% valid trials)

	SOA (ms)	Experiment 1				Experiment 2			
		Verb		Non-verb		Verb		Non-verb	
		Valid	Invalid	Valid	Invalid	Valid	Invalid	Valid	Invalid
Block 1	600	438	370	435	382	383	330	387	339
	800	409	369	396	368	366	349	331	375
	1000	404	363	377	387	369	327	366	324
Block 2	600	394	385	399	403	384	344	394	349
	800	385	376	379	383	361	339	370	341
	1000	385	377	381	389	369	334	368	348

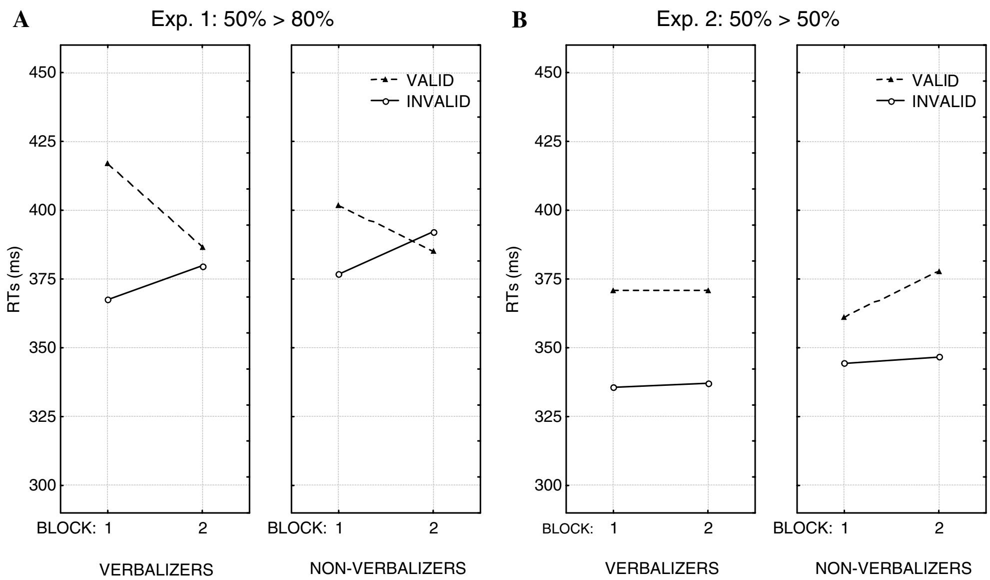

Fig. 1. Response times (in ms) for verbalizer and non-verbalizer participants as a function of the percentage of valid trials in the two consecutive blocks of Exp. 1 (block 1: 50% valid cues; block 2: 80% valid cues) (A), and for the two blocks of Exp. 2 (both with 50% valid cues) (B).

participant giving a score of 1 (“pure guess”) to his response. Excluding this participant from analysis did not change the significance of the Block × Validity interaction for non-verbalizers, $F(1,13) = 9.76$, $p = .008$. Thus, even participants unable to verbally report about the correct relationships between cues and targets were able to employ these relationships to speed up their responses to validly cued targets in block 2. This result suggests that endogenous processes may be unavailable to verbal report.

However, before concluding that the results of Experiment 1 show endogenous masking of IOR in block 2, we had to consider a possible alternative account. IOR has been shown to decrease with practice (Weaver, Lupiáñez, & Watson, 1998; but see Pratt & McAuliffe, 1999). Thus, it might be that participants continued to employ exclusively exogenous processes in the second block of Experiment 1, but the RT cost for valid trials gradually decreased as a result of practice. This seems unlikely, because we did not simply observe a decrease of IOR in the second block, but its complete disappearance. Nevertheless, to address more directly this concern, we performed an additional experiment, with an identical number of trials, but in which the percentage of valid trials remained 50% throughout the whole task.

4. Experiment 2: 50% → 50% valid trials

In this experiment, we asked a new group of participants to perform a task identical to Experiment 1, with the only exception that now the cues of the second block continued to be nonpredictive as in the first block. In other words, the proportions of valid and invalid cues remained 50% throughout the experiment. If the lack of IOR in the second block of Experiment 1 were due to practice, we expected a similar outcome in Experiment 2. If, on the other hand, IOR persisted even in the second block of Experiment 2, then practice cannot account for the difference between blocks observed in Experiment 1.

4.1. Methods

The task and the instructions were identical to Experiment 1, with the exception that now the proportion of valid and invalid trials in the second block was equal. Both in the first and in the second block of trials cues were non-informative of the location of the impending target.

4.2. Results and discussion

Table 1 shows the results of Experiment 2. One participant was excluded because he responded to most catch trials. On the post-experiment questionnaire, 13 participants correctly responded that there was no special relationship between cue and target location, and were thus considered as verbalizers; six mistakenly concluded that there was one, and were included in the non-verbalizer group. The mean confidence ratings for the two groups were, respectively, 2.50 (*SD*, 1.38) and 2.31 (*SD*, 1.25). One non-verbalizer and two verbalizers stated that their response was a pure guess. The two groups of participants did not perform differently on the RT task, $F < 1$, nor the Group factor interacted with any other factor. In particular, the Group × Block × Validity interaction did not reach significance, $F(1, 17) = 1.60$, $p = 0.22$. Valid trials evoked slower responses (370 ms) than invalid trials (341 ms), $F(1, 17) = 23.88$, $p = .0001$, thus showing a typical IOR of around 30 ms. In particular, both groups of participants showed IOR in both blocks of the experiment (Fig. 1B). No other effect or interaction reached significance. Planned comparisons confirmed a significant IOR for both groups of participants in block 2 (35-ms IOR for verbalizers, $F(1, 17) = 46.72$, $p < .0001$; 31-ms IOR for non-verbalizers, $F(1, 17) = 18.22$, $p = .0005$).

The results of Experiment 2 strongly suggest that the Block × Validity interaction observed in Experiment 1 was not an effect of practice, but was the consequence of an advantage for valid trials (or of a cost for invalid trials) that masked IOR in block 2.

The discrepancy between our results (unchanging IOR over two consecutive experimental blocks) and Weaver et al.'s (1998) results (decreasing IOR with practice) may easily be explained if one consider that in the Weaver et al.'s setting the overall number of trials per participant ($N = 2040$) was much larger than in our procedure ($N = 156$). Thus, in the Weaver et al.'s experiments, the duration of practice was much more extended than in ours, allowing for a detrimental effect on IOR to occur. Indeed, in detection tasks practice-related reductions of IOR typically occur after 200 or more trials (Lupiáñez, Weaver, Tipper, & Madrid, 2001).

4.3. Experiment 3: 50% → 20% valid trials

Thus far, our results suggest that one can show facilitation for validly cued targets in a RT task with peripheral informative cues by employing processes that (1) can be learned without explicit instructions and (2) may not be available for subsequent verbal report. This outcome is surprising in view of the traditional account of the effect of informative cues as being propositional and strategy-based; it might, instead, reflect implicit processing of the cue–target relationships. As already mentioned, McCormick (1997) showed that cues presented below a subjective threshold for awareness can capture attention without awareness, but cannot endogenously redirect attention to the uncued location. Awareness of cues seemed necessary to inhibit the cued location to reorient attention elsewhere. In other words, people might be able to "inhibit their reflexive orienting only when they can predict its location and develop a strategic set to inhibit signals there" (Rafal & Henik, 1994, p. 18). More generally, strategies of attentional orienting might primarily consist of inhibition of irrelevant objects (see Johnston & Hawley, 1994; McCormick, 1997). In light of these considerations, we wondered whether the active, strategy-based inhibition implicated in reorienting attention from a cued to an uncued location might involve a more explicit processing of cue–target relationship, which would allow participants to correctly recount it in the post-experiment questionnaire. Experiment 3 aimed at answering this question, by employing an experimental design similar to Experiment 1, but with a majority of invalid trials in the second block. Thus, the optimal strategy to produce fast responses to targets in the second block would be to inhibit the attentional capture exerted by the peripheral cue and to reorient attention toward the uncued box. This should result in an advantage of invalid over valid trials for long enough SOAs (Bartolomeo et al., 2001; Posner et al., 1982), in the range of those employed in the present study.

4.4. Methods

The task and instructions were identical to the preceding experiments, with the exception that now the second block consisted of 20% valid and 80% invalid trials.

4.5. Results and discussion

Results are presented in Table 2 and Fig. 2A.

Two participants responded to more than half of the catch trials, two other participants gave inconsistent responses to the post-experiment questionnaire. These four participants were therefore excluded from analysis. Six of the remaining participants gave correct responses to the questionnaire and were classified as verbalizers; 10 responded incorrectly and were labeled as non-verbalizers. As in Experiment 1, no effect of Group emerged, $F < 1$, nor this factor interacted with other factors. In particular, the Group × Block × Validity interaction did not reach significance, $F < 1$. The Block factor was significant, $F(1,14) = 17.57$, $p < .001$, because responses were 45-ms faster in block 1 than in block 2, perhaps as a consequence of an increased cost for valid trials in block 2 (see the Block × Validity interaction below). Invalid trials evoked faster responses than valid trials, $F(1,14) = 35.83$, $p < .0001$. RTs decreased with increasing SOAs, $F(2,28) = 7.81$, $p = .002$. A 21-ms IOR was present in the first block. In the second block, this inverse validity effect increased to 54 ms, as if an endogenous process, driven by the fact that most trials were invalid,

Table 2
Mean response times (in ms) for verbalizer and non-verbalizer participants to Experiment 3 (block 1: 50% valid trials; block 2: 20% valid trials) and Experiment 4 (same design with explicit instructions)

	SOA (ms)	Experiment 3				Experiment 4			
		Verb		Non-verb		Verb		Non-verb	
		Valid	Invalid	Valid	Invalid	Valid	Invalid	Valid	Invalid
Block 1	600	391	362	374	345	377	322	373	358
	800	384	360	370	344	340	268	379	302
	1000	356	349	340	326	314	295	357	336
Block 2	600	449	376	423	385	413	336	428	366
	800	437	370	407	364	377	312	407	343
	1000	442	380	402	371	384	305	389	344

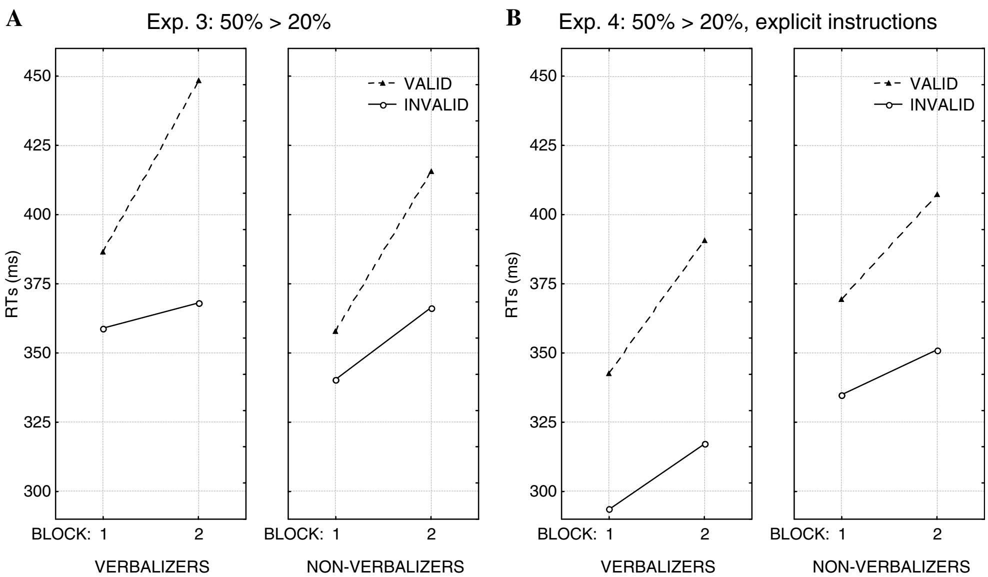

Fig. 2. Response times (in ms) for verbalizer and non-verbalizer participants as a function of the percentage of valid trials in the two consecutive blocks of Exp. 3 (block 1: 50% valid cues; block 2: 20% valid cues) (A), and for the two blocks of Exp. 4 (B) (same cue–target relationships, but with explicit instructions).

added to IOR in determining an extra cost for valid trials. This resulted in an interaction between Block and Cue Validity, $F(1,14) = 10.97$, $p = .005$. No other effect or interaction reached significance. Planned comparisons showed that the Block by Validity interaction was reliable in verbalizers, $F(1,14) = 7.58$, $p = .02$, and approached significance in non-verbalizers, $F(1,14) = 3.43$, $p = .085$ (see Fig. 2A). After excluding a single non-verbalizer participant, the interaction became reliable, $F(1,13) = 5.18$, $p = .040$. This participant showed IOR in the first block, and no valid/invalid difference in the second block, as if she had adopted the strategy of orienting her attention towards the cued box in the second block. Thus, except for this single non-verbalizer participant, the results of Experiment 3 suggest that explicit awareness of the cue/target contingencies may not be necessary to inhibit cued locations. The mean confidence ratings for verbalizers and non-verbalizers were, respectively, 2.83 (*SD*, 0.75) and 2.70 (*SD*, 0.82). No participant rated his or her response as resulting from pure guess.

5. Experiment 4: 50% → 20% valid trials with explicit instructions

Results of Experiments 1–3 suggested that phenomena related to endogenous orienting of attention following peripheral cues may result from processes that (1) can be learned without explicit instructions and (2) may not be accessible to subsequent verbal report.

We decided to pursue the issue of possible differences in performance related to the awareness of the cue–target relationships in a more direct way, i.e., by giving participants explicit information about these relationships and by comparing their performance with that of participants who had not received explicit instructions.

5.1. Methods

The procedure was identical to Experiment 3, with the only exception that participants were given explicit instructions about the information conveyed by the cue in block 2. Specifically, participants were told that the experiment would consist of two parts. In the first part, cues would not be informative about the localization of the target; targets would appear in the cued or in the uncued box with equal probability. In the second part, most targets would appear in the uncued box, so the best strategy when a cue occurs would be to expect the target appear in the other box. However, as in the previous experiments, there was nothing to alert participants that they were passing from block 1 to block 2.

5.2. Results and discussion

Three participants were excluded from analysis; two because they responded to most of the catch trials, one because he gave inconsistent responses to the post-experiment questionnaire. Of the remaining participants, 12 gave correct responses to the questionnaire, and were thus classified as verbalizers; five responded incorrectly, despite the fact that before performing the experiment they had received an accurate description of the cue–target relationships. These five participants were classified as non-verbalizers. The mean confidence ratings for verbalizers and non-verbalizers were, respectively, 4.17 (*SD*, 1.85) and 3.40 (*SD*, 1.52). No participant rated his or her response as resulting from pure guess. Results are reported in Table 2 and Fig 2B.

There was no effect of Group on performance, $F(1,16) = 1.64$, $p = .22$, nor did this factor interact with other factors. In particular, the Group × Block × Validity interaction did not reach significance, $F < 1$. RTs were faster in the first (335 ms) than in the second block of trials (367 ms), $F(1,16) = 15.23$, $p = .001$. Valid trials evoked slower responses (378 ms) than invalid trials (324 ms), $F(1,16) = 25.49$, $p = .0001$. RTs decreased with increasing SOA, $F(2,32) = 21.27$, $p < .0001$. As in Experiment 3, there was a Block × Validity interaction, $F(1,16) = 5.10$, $p = .038$, because the 43-ms inverse validity effect (IOR) in the first block increased to 65 ms in the second block. There was also a Block × Validity × SOA interaction, $F(2,32) = 4.84$, $p = .014$, probably a spurious finding resulting from unusually fast RTs (284 ms) in the invalid condition of the fist block at 800-ms SOA. No other effect or interaction reached significance.

5.3. Comparison between implicit and explicit instructions

The principal aim of this study was to better understand the relationships between conscious/declarative processes and orienting of attention. A critical comparison to address this issue is that between the results of the present experiment and those of Experiment 3, in which the same stimulus and procedure was used, but with the notable exception that participants were not informed in advance of the cue/target relationship. As we have seen, some of the participants in Experiment 3 (those labeled as 'verbalizers') were able to guess the correct cue/target relationship by themselves. However, this knowledge yielded no substantial advantage to their performance. It might be that this occurred because verbalizers understood the cue/target relationships relatively late in the course of the experiment. As a result, their knowledge had perhaps no measurable influence on their overall performance. If so, then providing participants with the appropriate knowledge before the experiment starts should yield an observable increase in the inverse validity effect, as suggested by comparing the two panels of Fig. 2. To test this prediction, we analyzed the combined results of Experiments 3 and 4 using a repeated-measures ANOVA with the additional between-participants factor of Instructions (implicit, Experiment 3; explicit, present experiment). The Block × Cue interaction was present both for verbalizers, $F(1,28) = 11.47$, $p = .002$, and for non-verbalizers, $F(1,28) = 5.12$, $p = .032$. The Instructions factor only tended to significance, $F(1,28) = 3.46$, $p = .073$. The overall RTs were 348 ms with explicit instructions and 380 ms with implicit instructions. The only significant effect involving the Instructions factor was an interaction with SOA, $F(2,56) = 3.46$, $p = .007$. RTs decreased linearly with increasing SOA for participants having received implicit instructions (respectively 389, 380, and 370 ms at the 3 SOAs). With explicit instructions, on the other hand, the already tendentially faster RTs decreased more abruptly with longer SOA, especially between the two shorter SOAs (370, 338, and 334 ms at the 3 SOAs). This effect may reflect an increased readiness to respond after 600-ms SOA for participants knowing from the beginning of the task the actual cue–target relationships. However, the three-way interaction with Instructions, SOA and Cue Validity did not approach significance, $F < 1$, suggesting that the effect was unspecific, because it occurred both for valid and for invalid trials. No other effect or interaction reached significance. Thus, comparing explicit and implicit instructions did not bring about robust evidence that knowing in advance the cue–target relationships lead to a substantial advantage in performance. To explore more directly the effect of explicit awareness, as resulting from verbal instructions, on endogenous processes, we subtracted the validity effects for the two blocks to obtain an index of endogenous orienting, and compared the index of verbalizers in Experiment 4 with that of non-verbalizers in Experiment 3 (i.e., compared the performance of those whom we can be confident were aware, with the performance of those whom we can be confident were not).[2] The endogenous index was 26 ms for verbalizers in Experiment 4 and 23 ms for non-verbalizers in Experiment 3. The 3-ms difference was far from statistical significance, $F < 1$. If one makes the arbitrary but conservative assumption that the magnitude of the advantage conferred by explicit awareness should amount at least to 30 ms, then the likelihood ratio (Glover & Dixon, 2004) in favour of a null effect is 9.2. This result indicates a lack of substantial effects of explicit instructions on participants' endogenous processes.

6. Experiment 5: 50% → 80% valid trials with central cues

We have thus far found evidence suggesting the presence of components of endogenous orienting to peripheral cues in the absence of a verbal-declarative correlate. Perhaps the importance of such a correlate would emerge if participants saw not a mere luminance change in their visual periphery, but an arrow, with its associated symbolic value, in central vision. Experiment 4 aimed at testing this possibility.

6.1. Methods

The task was identical to Experiment 1, with 50% valid cues in block 1 and 80% valid cues in block 2, except that the cue was not peripheral, but consisted of a horizontal arrow presented inside the central box, and

[2] We thank a reviewer of the present article for suggesting this comparison.

Table 3
Mean response times (in ms) for verbalizer and non-verbalizer participants to Experiment 5 (central arrow cues; block 1: 50% valid trials; block 2: 80% valid trials)

	SOA (ms)	Experiment 5			
		Verb		Non-verb	
		Valid	Invalid	Valid	Invalid
Block 1	600	377	322	373	358
	800	340	268	379	302
	1000	314	295	357	336
Block 2	600	413	336	428	366
	800	377	312	407	343
	1000	384	305	389	344

pointing to one of the lateral boxes. Prior to the task, participants were informed that an arrow would appear in the central box prior to the targets, and were invited not to pay attention to this occurrence, but to concentrate upon responding to targets.

6.2. Results and discussion

Seven participants correctly responded to the questionnaire, 11 gave incorrect responses. The two remaining participants gave inconsistent responses and were excluded from analysis. Table 3 and Fig. 3 report the results.

The Group factor did not reach significance, $F(1,16) = 1.12$, $p = 0.31$. Responses were faster in block 1 (321 ms) than in block 2 (370 ms), $F(1,16) = 47.67$, $p < .0001$, perhaps as a consequence of the introduction of catch trials in the second block.[3] Validly cued trials evoked faster responses than invalid trials, $F(1,16) = 5.36$, $p = .034$. There was an interaction between Block and Cue Validity, $F(1,16) = 6.11$, $p = .025$, because the validity effect was 19 ms in the 80% valid cue block, but only 5 ms in the first block with uninformative cues. We recall that a similar interaction had occurred in Experiment 1, which employed identical cue–target relationships but used peripheral cues. Increasing SOA led to faster RTs, $F(2,32) = 6.69$, $p = .004$.

The Group × Block × Validity interaction did not reach significance, $F(1,16) = 2.58$, $p = 0.13$, although inspection of Fig. 3B does suggest that awareness of the cue/target relationships increased validity effects. No other effect or interaction reached significance. The planned comparisons showed that the Block × Validity interaction resulted significant for verbalizers, $F(1,16) = 6.81$, $p = .02$, but not for non-verbalizers, $F < 1$. The mean confidence ratings for the two groups were, respectively, 3.43 (*SD*, 1.51) and 1.73 (*SD*, 0.65). One verbalizer and three non-verbalizers stated that their response was a pure guess. Excluding these participants from analysis did not change the overall pattern of results, and in particular the Block × Validity interactions (verbalizers, $F(1,12) = 7.06$, $p = .02$; non-verbalizers, $F(1,12) = 2.64$, $p = 0.13$). Thus, at variance with the results of Experiment 1, results of Experiment 4 do not unambiguously show that participants incapable of giving an appropriate verbal description of the cue–target relationships can make use of the informative value of a central, symbolic cue.

Hommel, Pratt, Colzato, and Godijn (2001) gave participants arrows or words (the German words for LEFT, RIGHT, UP, and DOWN) indicating a possible target location without any informative value (e.g., the target location was equiprobable and independent of the indications given by the cue), with explicit instructions stressing the non-informativeness of the cues (see also Ristic, Friesen, & Kingstone, 2002; Tipples, 1997). Despite participants' knowledge of the uselessness of the cues, their RTs to cued locations resulted faster than those to uncued locations, thus showing an automatic orienting in reaction to a symbolic cue. Perhaps

[3] Except for Experiment 3, this effect was not significant in the preceding experiments, which seems to argue against our conjecture. A tendency in the same sense was, however, always present, with the exception of Experiment 1, in which it occurred only for invalid trials. The endogenous advantage for valid trials in the second block of Experiment 1 may have offset the cost resulting from the introduction of catch trials.

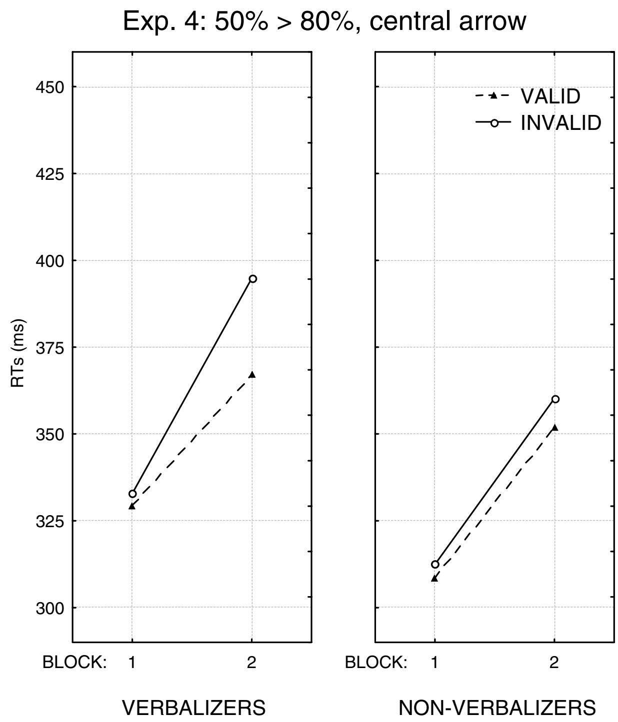

Fig. 3. Response Times (in ms) for verbalizer and non-verbalizer participants as a function of the percentage of valid trials in the two consecutive blocks of Exp. 4 (block 1: 50% valid arrow cues; block 2: 80% valid arrow cues).

the larger number of trials used in the Hommel et al.'s study encouraged their participants to develop the (erroneous) hypothesis that cues could help target detection, and their attention was consequently oriented toward the cued location. Alternatively or in addition, our task instructions, which explicitly asked participants not to pay attention to the arrows, might have been literally followed by some of our participants. Thus, our results partially support Hommel et al.'s (2001) conclusions in showing that orienting effects in response to symbolic cues can occur in the absence of explicit instructions. Nevertheless, our finding of a reliable validity effect only for the group of participants capable of giving an appropriate verbal description of the relationships between cue and target further qualifies this hypothesis by suggesting that, with symbolic cues, validity effects might depend on participants developing explicit hypotheses about these relationships. We note, however, that the lack of a significant interaction between Group, Block and Validity in the present experiment calls for further experimental evidence to settle this issue.

7. General discussion

In cue–target detection tasks, cues can influence response times to subsequent targets as a function of the proportion of valid and invalid trials. This influence is not a direct consequence of the sensory properties of the cue, but results from higher-order knowledge about the probability that the target will appear in the cued or in the uncued box. Thus, these effects are often characterized as being "endogenous" in nature, as opposed to being "exogenous" cueing effects. Exogenous effects, on the other hand, would occur on a trial-by-trial basis. Examples are the transient facilitation in responding to validly cued targets (Carrasco, Ling, & Read, 2004; Jonides, 1981; Nakayama & Mackeben, 1989), or the cost for these same targets observed with longer SOAs (IOR; Klein, 2000; Posner & Cohen, 1984; Tassinari et al., 1987). In the present experiments, most participants were able to build endogenous expectations about the side of occurrence of a target preceded by informative cues, despite the absence of previous knowledge about cue–target relationships in Experiments 1–3 and the presence of a first block of trials with non-informative cues. Thus, participants could adapt their response strategies to an unexpected change in the cue–target relationships. Additionally, the block with non-informative cues provided an important internal control for performance in the block with informative cues.[4] Any differences in cue validity effect between the two blocks would indicate that the informative value of cues in the second block influenced performance. With peripheral cues, around half of these participants were unable to describe the strategy they used, even when prompted by a two-answer, forced-choice question. Despite this, participants demonstrated an offset of IOR with 80% valid cues in Experiment 1 (which did not simply depend on a practice effect, as shown by Experiment 2), and an increase of the cost for valid trials in Experiment 3. The results of Experiment 4 showed that the fact of providing participants with advance knowledge of the cue–target relationships did not dramatically change their target detection times with peripheral cues. In Experiment 5, we observed a similar pattern of results for central symbolic cues, with the important exception that only participants capable of giving a verbal description of the cue–target relationship demonstrated a reliable RT advantage for targets occurring at the cued position.

As mentioned in Section 1, Lambert et al. (1999) showed that people can implicitly learn contingencies relating the position of the upcoming target with the identity of bilateral letter cues presented near the position expectancy boxes (e.g., W and S predicted a right-sided target). Although most participants did not answer appropriately to a post-experiment questionnaire, they showed an early facilitation for cued locations, followed by a cost for these same locations reminiscent of IOR (Lambert et al., 1999, Experiment 1). The characteristics of these attentional effects differed both from exogenous orienting, because Lambert et al.'s results implied a learned association between cue identity and target location, and from endogenous orienting, because when participants were made aware of the cue–target relationships, the late cost for cued targets reversed to a facilitation (Lambert et al., 1999, Experiment 4). Our present findings differ by those of Lambert et al., because here we show that even processes usually labeled as endogenous (late facilitation for cued targets with 80% valid cues in Experiment 1, or increased inhibition for cued targets with 20% valid cues in Experiment 3) can be learned without explicit instructions and be nevertheless impervious to subsequent verbal description. As already mentioned, McCormick (1997) ingeniously employed an orienting analogue of the process-dissociation procedure (Jacoby, Toth, & Yonelinas, 1993), and showed that below-threshold cues can capture attention, but one needs supra-threshold cues to direct attention to an uncued spatial position. An obvious difference between the present study and McCormick's is that in our study *all* cues were clearly perceptible; what some of our participants were not able to realize was the relationship between the cued side and the target side.

One might surmise that non-verbalizer participants elaborated an 'unconscious' strategy. According to this view, our participants might have used a form of implicit learning independent of hypothesis-testing strategies, and which yielded a form of knowledge that was inaccessible to consciousness (see Jiménez, 2003). It has indeed been proposed that even metacognitive processes labeled as "monitoring," and therefore implying awareness, may in fact operate without much awareness (Reder & Schunn, 1996). For example, the blindsight patient G.Y. learned to change his strategy of response during the course of an experiment with a majority of invalid cues, shifting from an advantage to validly cued targets to an advantage for invalid trials, without being able to describe this change (Kentridge & Heywood, 2000). However, although an appropriate verbalization can be considered as a reliable indicator of conscious processing (Merikle, Smilek, & Eastwood, 2001), the converse is not necessarily true. Lack of verbalization cannot be conclusively considered to indicate lack of awareness (Perruchet & Vinter, 2002; Shanks, 2003). For example, it might simply indicate lack of memory (Allport, 1988) (although in the present study this would seem unlikely, given that the post-experiment questionnaire was administered soon after the completion of each experiment; it is also hard to imagine that G.Y.'s lack of commentary about the use he made of anti-cues can be the result of a memory problem).

The phenomenological tradition has often distinguished between direct forms and more reflexive forms of consciousness, a distinction endorsed, among others, by Husserl, Sartre and Ricoeur (reviewed by Vermersch, 2000) (see Dalla Barba, 2002; Dulany, 1997; Edelman & Tononi, 2000; Marcel, 1988, for more recent proposals of similar dichotomies). In particular, the distinction between "experiential" sensitivity, which is related to phenomenal consciousness, and "informational" sensitivity, which may guide one's actions without the

[4] To avoid perturbing the participants' inferences about the cue–target relationships in the second block, the number of trials of the first block was kept to a minimum. This renders all the more impressive the significance of the Block × Validity interaction in all experiments apart from number two, which was a control for practice effects.

existence of conscious sensations (Flanagan, 1992), seems consistent with the present findings. Also relevant to our results, Merleau-Ponty (1942) distinguished between 'spoken' and 'acted' forms of perception (*perception parlée* and *perception vécue*). For example, as we enter a room we may feel an impression of disorder, only to later discover that it comes from a crooked picture on the wall. Before realizing this, our consciousness was experiencing things impervious to verbal report. This would by no means imply that the first impression on entering the room was *unconscious*. Rather, it was a form of consciousness not immediately amenable to verbal description. In Merleau-Ponty's words, "consciousness is a network of significant intentions, sometimes clear by themselves, sometimes experienced rather than spoken out" (Merleau-Ponty, 1942, p. 187). Our present results extend to endogenous orienting of attention the general notion that "doing" often precedes "understanding."

Neuropsychological evidence from brain-damaged patients offers instances of dissociations between direct consciousness and reflexive consciousness (Bartolomeo & Dalla Barba, 2002). An amnesic patient with anosognosia was able to intellectually acknowledge the presence of his deficits, as well as his incapacity to directly appreciate them (Dalla Barba, Bartolomeo, Ergis, Boissé, & Bachoud-Lévi, 1999). Patients with left unilateral neglect typically lack explicit awareness for events occurring in the neglected part of space, perhaps because these events fail to capture their attention (see Bartolomeo & Chokron, 2002, for review). However, some patients may show signs of more implicit knowledge of neglected items (D'Erme, Robertson, Bartolomeo, & Daniele, 1993). When shown two drawings of a house, identical with the exception that red flames emerged from the left side of one of the houses, a patient with neglect failed to note any difference between the drawings, but consistently chose the non-burning house when asked which one she would have preferred to live in (Marshall & Halligan, 1988). It would seem that this patient had some access to the semantics of the drawings, but could not develop the reflexive consciousness necessary to explicitly acknowledge it in verbal report. When another neglect patient showing a similar pattern of performance was asked to explain *why* he should prefer the non-burning house, he produced confabulatory responses, such as that the non-burning house had an extra fireplace (Manning & Kartsounis, 1993). This example further underlines the inaccessibility of these processes to reflexive consciousness. On the other hand, the celebrated film director Federico Fellini was perfectly conscious of suffering from neglect at an intellectual level, to the point of jokingly asking to include his new condition in his calling card; nevertheless, he persisted in producing funny drawings of women lacking their left half (Cantagallo & Della Sala, 1998). These dissociations between immediate and reflexive forms of consciousness in brain-damaged patients, together with the present results showing the possibility of endogenous orienting without verbal reports in normal participants, call into question the nature of the relatively preserved endogenous processes in left neglect patients.

As mentioned in Section 1, we showed that neglect patients are able to endogenously direct their attention to left targets preceded by right cues, if they have sufficient time to do it and if they know that most cues are invalid (Bartolomeo et al., 2001). Patients' RTs to left invalidly cued targets were in the range of their responses to right-sided targets at 1000-ms SOA, thus reversing in this particular condition the typical disengage deficit of neglect patients (see Losier & Klein, 2001, for review). This result suggested the relative preservation of endogenous processes in left neglect and therefore stressed the importance of an exogenous attentional bias in this condition (Bartolomeo & Chokron, 2002; Losier & Klein, 2001). In the light of the present results, one may wonder whether the patients' ability to endogenously direct their attention towards the neglected side resulted from explicit strategies, or from more implicit processes, similar to those demonstrated in the present study by non-verbalizer participants (patients in the Bartolomeo et al.'s study received the usual instructions before performing the RT tasks, and were thus informed about the predictive value of the cues).

The study of the relationships between immediate and high-order forms of consciousness in normal participants and brain-damaged patients is likely to put constraints on cognitive models of consciousness, to promote specific attempts to search for their neural correlates, and to suggest theoretically motivated techniques of rehabilitation for neuropsychological deficits.

Acknowledgments

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