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Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 31(31)

ISSN
1069-7977

Authors
Casagrande, Maria
Mereu, Stefania

Publication Date
2009

Peer reviewed

Unconsciously perceived arrows yield an endogenous, automatic orienting of attention

Stefania Mereu (smereu@uiuc.edu)
Department of Psychology, 603 East Daniel St,
Champaign, IL 61820 USA

Maria Casagrande (maria.casagrande@uniroma1.it)
Dipartimento di Psicologia, via dei Marsi 78
Roma, 00185 Italy

Abstract

Symbolic cues have always been thought to elicit voluntary orienting of attention. Arrows, as well as other centrally presented cues, could lead to reflexive shifts of attention, without showing, however, the biphasic pattern (initial facilitation / later inhibition) typical of peripheral automatic orienting. This study evaluated the role of awareness in endogenous orienting of attention, in order to understand whether it is necessary for either automatic or voluntary orienting, or both. Results showed a facilitation at brief cue-target intervals in both the aware and unaware conditions; a tendency to inhibition at longer intervals for non-predictive arrows, but only in the aware condition; a facilitation with no inhibition for predictive arrows, in both the aware and unaware conditions. Our results suggest that arrows can cause automatic shifts of endogenous attention, which can be triggered by unconsciously perceived cues, implying that awareness is not necessary for automatic attention to occur.

Keywords: spatial orienting; attention; arrows; symbolic cues; automatic; unconscious perception.

Introduction

Since Posner (1980) suggested the dissociation between endogenous and exogenous orienting of attention, it has been assumed that symbolic, centrally presented cues, yield to voluntary shifts of attention, while peripheral abrupt onset cues elicit automatic shifts of attention.

It is possible to observe the automatic orienting in a peripheral cueing task, even though cues are not consciously perceived (McCormick, 1997; Ivanoff & Klein, 2003; Lambert et al., 1999). McCormick (1997) instructed participants to reorient their attention toward the opposite location of a non-perceived peripheral cue. Results showed faster RT (facilitation) for target appearing at the cued location with brief stimulus onset asynchronies (SOA) and slower RT (inhibition of return, IOR) with longer SOA. Neither reorientation following predictive cues McCormick (1997), nor IOR in a non-predictive paradigm (Ivanoff & Klein, 2003; Lambert et al., 1999) has been found, with not-consciously perceived cues.

However, Casagrande, Mereu, Martella and Marotta (2006), showed facilitation at the location indicated by a centrally presented and predictive arrow, which was invisible due to visual masking suggesting that even voluntary orienting could be elicited unconsciously. However, it has been suggested that arrows (Tipples, 2002), as well as other types of central cues like eye gaze (Friesen and Kingstone, 1998), may trigger a reflexive orienting of attention because they can elicit shifts of attention even though they are not predictive of the target onset location. So, the shifting of attention found in Casagrande et al., (2006) studies can be ascribed to automatic instead of voluntary orienting.

The aim of this study is to evaluate the role of awareness in endogenous orienting of attention, in order to understand whether it is necessary for either automatic or voluntary orienting, or both.

Experiment 1

The results found in Casagrande et al., (2006) seem to suggest what was proposed earlier (e.g. Warner et al., 1990), that both a voluntary and an automatic component coexist in the endogenous orienting of attention. Otherwise, one should accept the idea that either voluntary orienting could be elicited by not consciously perceived cues or that the endogenous orienting of attention is not voluntary at all. This last case would bring into question almost 30 years of modeling of attention, which claims that endogenous is voluntary.

It is possible that if the orienting of attention found in Casagrande et al. (2006) study using a centrally presented cue is the product of an automatic orienting mechanism, the same results could be observed in a non informative paradigm where the cue is not a reliable predictor of the target onset location.

In order to verify this hypothesis, we conducted an experiment in which the cues (arrows) were non-predictive of the target location and we gave no instruction about the cue to naïve observers who never participated in a cueing task before. Showing an effect on non predictive, central, masked cues would confirm that the endogenous orienting has an automatic component, which could occur in the absence of awareness, in line with studies that showed a reflexive orienting after non-consciously perceived peripheral cues (McCormick, 1997; Ivanoff and Klein, 2003; Lambert et al., 1999).

Method

Participants Sixteen right handed students with normal or corrected-to-normal vision (age 25.7; ± DS: 2.56) participated in the experiment after signing a consent form.

Stimuli and procedure The spatial cue was a dark grey arrow or a circle (1°). The cue appeared in one of 5 possible locations, each one delimited by a squared box (3°). One was located in the center of the display and the others, on the left, on the right, above or below the center, at 5° eccentricity. The mask, similar to the one introduced by Enns and Di Lollo (1997), consisted of 4 small dots (0,2°) arranged in an imaginary square (2.8°) centered in each box. The target was a black circle, the same size of the cue, which could appear in only 2 of the 5 boxes, on the left or on the right of the display. All the stimuli were presented on a light grey background. The sequence (Figure 1) started with the fixation box. After 500 ms the 5 boxes appeared and stayed for the entire experiment. The cue was then presented, which consisted either of a circle (neutral) or of an arrow pointing to the left or to the right and indicating the target onset location in 50% of the trials. After 500 ms since the appearing of the boxes the cue was presented, together with the 4-dots masks. Two conditions were equally likely: high visibility when the cue duration was 100 ms; low visibility when the cue duration was only 10 ms. Successively the cue disappeared and only the 4-dots remained on the screen for 50 ms in the high visibility condition or 140 ms in the low visibility condition. In sequence, the 4-dots disappeared and reappeared dislocated by 0,2° externally, on the diagonals of the square where they were place. After another 150 ms they disappeared and reappeared dislocated again by 0,2°. The aim of this sequence, 450 ms long, was to give the illusion of apparent motion for reducing the cue visibility. Two SOA (Stimulus Onset Asynchrony) were used: 150 ms and 850 ms, after which the target appeared for 150 ms. Of course, the target appeared during the mask sequence in the 150 ms SOA condition but 400 ms after the end of the mask sequence in the 850 ms SOA condition; 1500 ms after the target disappeared, if no response was collected, then the next trial began.

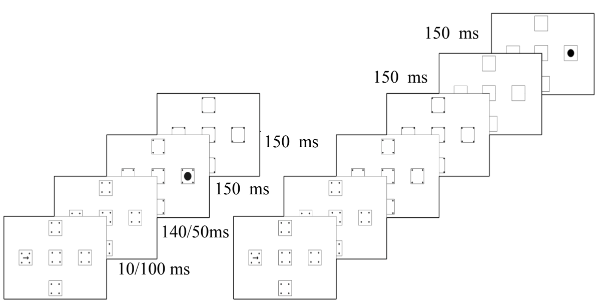

Figure 1: Sequence of the events in the procedure.

Participants did not receive any instruction regarding the cue. At the end of each trial the participant was required to answer the question “Hai visto lo stimolo grigio?” (“did you see the grey stimulus?”), by pressing one of two buttons, “SI” (“YES”) or “NO”, located on the keyboard in front of him. Trials in which the subject reported consciously perceiving the cue when the duration was 10 ms were excluded from the analysis. Participants completed 80 practice trials, 4 minutes duration, and 2 experimental blocks, 400 trials (around 15 minutes) each. There were 112 valid, 112 invalid, 112 and neutral trials; there were also 10 trials without the cue and 30 trials in which the target was not presented (catch trials).The interval between block depended on subjects' needs.

Results

Central cues. The t-test on accuracy showed an effect of *Visibility* ($t_{1,15}$=8,8; p<.0001) with a higher percentage of “yes” answers in the high visibility (mean= 98.2%; DS= ±2.8) than the low visibility (mean= 28.3%; DS=±32.1) condition. The t-test also showed that the number of “yes” answers in the low visibility condition was significantly different from zero ($t_{1,15}$=3.5; p<.002).

The ANOVA on reaction times (RT; Table 1) showed an effect of *Visibility* ($F_{1,14}$=22.2; p<.004), with faster RT in high visible trials (mean= 399 ms) than in the low visible trials (mean= 483 ms). The interaction *Visibility* by *SOA* ($F_{1,14}$=5.56; p<.003) and the interaction *Visibility* by *Cue* by *SOA* ($F_{1,14}$=15.44; p<.001) were also significant; the post hoc analysis of the means showed differences between valid and invalid trials at brief SOA, with both low (p<.03) and high (p<.001) visibility; a significant difference at longer SOA with low visibility (p<.001) and a tendency with high visibility (p=.06). The *Visibility* by *Cue* interaction was not significant (F=$_{2,34}$; p=.15).

Table 1. Mean (±DS) RT in every condition.

SOA	150		850	
Cue	Valid	Invalid	Valid	Invalid
Visibility				
Low	499 ms	523 ms	447 ms	478 ms
	±142	±135	±132	±141
High	428 ms	482 ms	346 ms	326 ms
	±144	±133	±126	±95

Peripheral cues. The t-test on accuracy showed a difference for *Visibility* ($t_{1,15}$=23.8; p<.0001), with a higher percentage of answers “yes” in the high visibility (mean= 98.4%; DS= ±1.2) than the low visibility (mean= 11.9%; DS=±15.1) condition. The t-test also showed that the number of “yes” answers in the low visibility condition was significantly different from zero ($t_{1,15}$=3.1; p<.005). The ANOVA *Visibility* by *Cue* by *Target Location* showed a significant effect of *Visibility* ($F_{1,15}$=24.9; p<0001) with faster RT in the high visibility condition (mean= 393 ms) and slower in the low visibility condition (mean= 471 ms). The effect of *Target Location* was also significant ($F_{1,15}$=32.2; p<00001), with slower RT for cue and target presented in the same location (mean= 443 ms) than when they were presented in two different locations (mean= 422 ms). The interaction *Visibility* by *Target Location* ($F_{1,15}$=43.35; p<00001) was also significant. The *post hoc* analysis of the means revealed slower RT for targets presented in the same location as the cue (mean= 417 ms) than in a different location (mean= 370 ms), but only when the cue was highly visible (p<.0002).

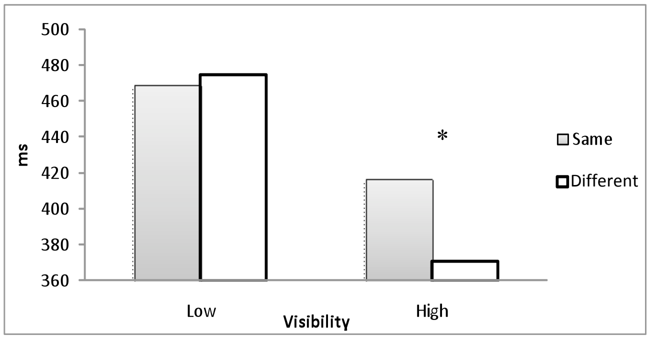

Figure 2: Mean RT for both high and low visibility conditions when the target was presented at the same location as the cue or at a different location.

Discussion

The masking procedure used in the experiment was effective in decreasing the cue visibility. When the cue was presented for very short time (10 ms), participants reported its presence in 30% of the trials when it appeared in the central location, and in only 12% of the trials when it appeared in the peripheral locations, similar to previous results (e.g. Enns and Di Lollo, 1997) showing an increase of the masking effect at bigger eccentricities. At 100 ms durations, however, participants reported its presence on 98% of the trials.

When the cues appeared in the central location, although they were not informative of the target onset location and no instruction was given on the cue, participants showed a facilitation effect for the cued location, suggesting that they were following the information driven by the cue even though the cue was not consciously perceived. Indeed, faster RTs for the cued location were observed in both the high and the low visibility conditions. This result seems to confirm the hypothesis that the arrows cause an automatic shift of attention; in fact, the observers did not have any reason for trusting the cue's indication because it was not informative. On one hand, this result seems to replicate the Tipples (2002) study, in which a centrally presented arrow was able to induce an automatic shift of attention; on the other hand it also confirms the results of studies showing that not consciously perceived cues are able to induce an automatic shift of attention (McCormick, 1997; Ivanoff and Klein, 2003). Also, the typical biphasic pattern of reflexive orienting (obtained usually with non informative peripheral cues) was observed, with a facilitation at the 150 ms SOA and a tendency toward inhibition (p<.06 but 30 ms magnitude) at the 850 ms SOA, which seems to indicate the presence of inhibition of return (IOR), but only after consciously perceived cues. With non-consciously perceived cues, facilitation was observed at both 150 ms and 850 ms SOAs. This result is relevant considering that, although centrally presented symbolic cues – like eyegaze for example – seem to elicit an automatic orienting of attention (Friesen and Kingston, 1998), IOR is not typically observed using either eye gaze (e.g. McKee, Christie and Klein, 2007), or using arrows (Hommel, Pratt, Colzato and Godijn, 2001).

On the other hand, Frischen and Tipper (2004) in a series of experiments show that it is possible to observe IOR with centrally presented non informative cues, at 2880 ms SOA but not at 1200 ms. These results seem to show that IOR in endogenous cueing could have a delayed onset; though it is possible that differences in observing the IOR effect could be due to methodological differences, because it is well known that IOR strictly depends on both the task and the attentional setting (Gibson and Amelio, 2000).

When cues appeared in peripheral locations the abrupt onset effect seems to prevail on the symbolic meaning of the cue. The IOR was observed only in the high visibility condition and never in the low visibility, consistent with the study by Ivanoff and Klein (2003), which showed IOR only when observers were not required to report the cue. The authors suggested that the IOR was observed because of this methodological difference, suggesting that asking participants to report the presence of the cue would encourage the engaging of attention (Posner and Cohen, 1984) in the cued location, impeding the disengagement and re-engagement to the new location (the mechanism that is supposed to be involved in IOR), because observers were not aware of the engagement itself.

However, it is possible the Ivanoff and Klein's (2003) results were due to a partial visibility of the cue, since not asking any report could potentially have caused the experimenters to include in the analysis the trials in which the cues were seen. According to McCormick (1997), our results suggest that IOR is not observed without awareness.

Experiment 2

The results of Experiment 1 showed that when observers subjectively reported not to see the cue it is still possible to observe that cue effect. However, some authors (e.g. Eriksen, 1960; Kunimoto, Miller and Pashler, 2001) express concern with subjective report measures.

The subjective report was used often in the first study of unconscious perception. Sidis (1898), for example, asked participants to identify alphanumeric characters. Observers were able to identify a symbol despite the fact that it was presented from such a great distance, that they only reported to see a meaningless stain at the stimulus location.

This response bias could lead observers to make a systematic mistake, denying the visibility of a stimulus that could have been partially seen (Eriksen, 1960). Accordingly, our result in the Experiment 1 could be due to a partial visibility of the cue. Participants were asked, in fact, to report the stimulus visibility as they subjectively perceived it. In other words, the observer could have adopted a conservative strategy, denying the visibility in case of uncertainty, allowing the residual perception to affect the results.

Cheesman and Merikle (1984), in the attempt to avoid response bias, used the subjects' ability to discriminate the presence / absence of the stimulus to determine the threshold of awareness. Based on this technique, they concluded that unconscious perception does not exist. Nonetheless, that definition of awareness is totally insensitive to the phenomenal aspect of consciousness (e.g. Cheesman and Merikle, 1986). Thus, it is not surprisingly that many failed show the effect of unconsciously perceived stimuli (Kunimoto, Miller and Pashler, 2001). Cheesman and Merikle (1986) argued that the definitions of awareness based on the objective report are not sensitive to phenomenal experience, which is measurable only subjectively, and suggested to distinguish between conscious and unconscious perception by qualitative differences, which would show different processing modalities. The authors (Cheesman and Merikle, 1986) showed that the *Stroop* effect increased as a function of the number of congruent trials, consistent with the results of studies on this effect in conscious conditions (e.g. Glaser and Glaser, 1982), but only with above threshold stimuli. This result seems to suggest that observers, not conscious of the contingency relation between stimuli, could not voluntarily adopt a strategy for predicting the prime information. Accordingly, Lambert et al. (1999) showed that observers did not show any cueing effect with peripheral cueing task, when the performance on the presence of the cue was at chance. Contrarily, observers showing a performance a little better than chance showed a typical automatic effect, while only subjects showing high visibility showed an additional effect due to the contingency relationship between cue and target.

In order to better understand the previous experiment's results, it seems relevant to evaluate how they were influenced by the residual visibility. Using an objective report (2-alternatives forced choice) could resolve that ambiguity and evaluate better how awareness affects the orienting of attention.

The aim of the study is to replicate and extend the results of the previous experiment and to evaluate the effective residual perception on the cue visibility with an objective report. In order to evaluate the effect of endogenous cues as a function of visibility we ran an informative cueing task, in both high and low visibility conditions asking subjects to report the direction of the arrow. We expect to replicate Casagrande et al. (2006) study, except for the IOR, which should not arise using predictive cues.

Method

Participants Eighteen right handed students with normal or corrected-to-normal vision (age= 23.7; DS ±2.24) participated in the experiment after signing a consent form.

Stimuli and procedure. The stimuli were the same as the previous experiment. The procedure was the same except for two differences. The cues were predictive (p=.80) of the target onset location and the observers were required, after each trial, to indicate whether the grey stimulus was a circle or an arrow pointing to the left or to the right, by pressing the respective button on the keyboard in front of them.

Results

Central cues. The ANOVA showed an effect of *Visibility* ($F_{1,13}$=186.8; p<.0001) with a higher percentage of correct answers in the high visibility (97%) than in the low visibility condition (56.3%). The t-test indicates also that the accuracy in the low visibility condition was significantly better than chance (t=6.34; p<.0001).

The ANOVA on RT (Table 2) showed an effect of *Cue* ($F_{1,15}$=11,6; p<.003) with faster RT in the valid (mean= 391 ms) with respect to the invalid (mean= 408 ms) condition. The ANOVA showed also the effect of *Visibility* ($F_{1,15}$=9.84; p<.01), with faster RT in the high visibility condition (mean= 386 ms) and slower RT in the low visibility condition (mean= 413 ms), as well as the effect of SOA ($F_{1,15}$=48,5; p<.0001), with slower RT at the shorter SOA (mean= 468 ms) with respect to the longer SOA (mean= 328 ms).

Table 2. Mean (±DS) RT in every condition

	150		850	
Visibility	Valid	Invalid	Valid	Invalid
Low	451	461	308	328
	±124	±145	±73	±87
High	432	467	277	306
	±115	±119	±57	±87

Peripheral cues. The ANOVA *Target Location* by *Visibility* by *Block* by *SOA* showed an effect of *Target Location* ($F_{1,15}$=13,7; p<.002); RT were slower when target appeared in the same position as the cue (mean= 423 ms) and faster when it appeared in the opposite location (mean= 382 ms). Were also significant the effect of *Visibility* ($F_{1,15}$=14,46; p<.0002), of *Block* ($F_{1,15}$=7,92; p<.01) and of *SOA* ($F_{1,15}$=52,9; p<.000003). The *Target Location* by *Visibility* by *Block* by *SOA* was also significant ($F_{1,15}$=9.19; p<.01; Figure 3).

Discussion

The masking procedure used in the experiment turned out to be effective in decreasing the cue visibility, even evaluated with an objective report. When the cue was presented for very short time (10 ms), participants correctly identified the cue in the 53% of the trials while at 100 ms duration participants correctly identified the cue in the 98% of the trials. When cues were presented in the central location, the results on RT confirm the ones obtained in previous experiments (Casagrande et al., 2006) using a subjective report for evaluating the cue visibility. We observed a facilitation effect for targets presented at the cued location in both the high and the low visibility conditions. Contrary to the experiment 1, the IOR was not observed with centrally presented cues. This result seems to confirm that the predictability of the cue could encourage the engagement of the attention and impede the disengagement and the following engagement to another location (Müller and Findlay, 1988; see Berlucchi, Chelazzi & Tassinari, 2000 for a different result). The same effect has been found in both the high and the low visibility conditions.

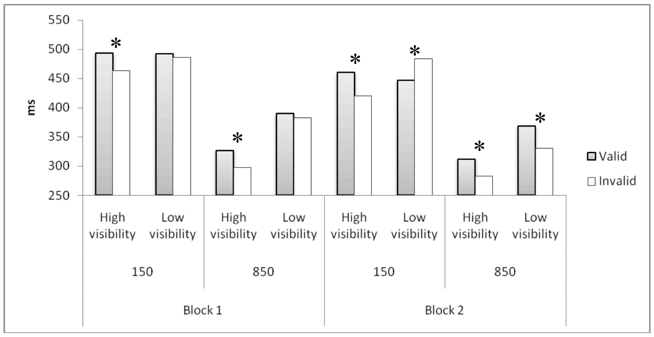

Figure 3: Mean RT for both high and low visibility conditions when the target was presented at the same location as the cue or at a different location, in both blocks at each SOA.

When cues were presented in the peripheral locations a difference arose between the first and second part of the experiment (block 1 and 2). Results showed an IOR effect when the cue was highly visible, in both the first and the second block; when the cues were less visible there was no effect on the first block, but there was in the second block. The typical biphasic pattern of peripheral orienting (Posner & Cohen, 1984) was observed, with facilitation at short SOA and inhibition at long SOA.

This result has two implications: the first concerns the automaticity of unconscious processes; the high training received on the second part of the experiment seems to have allowed the partial automation of the orienting effect (Warner, Juola & Koshino, 1990), allowing it to arise in the unconscious condition too. The second concerns the possibility to observe the IOR effect in the unconscious condition. The results in this experiment contrast with the ones obtained by McCormick (1997) and Ivanoff and Klein (2003). The differences between this experiment and the ones reported by McCormick (1997) and Ivanoff and Klein (2003) could depend on different procedures used in order to reduce the visibility of the cue. In fact, either reducing the contrast between stimulus and background (McCormick, 1997) or masking by metacontrast (Ivanoff & Klein, 2003) might not have allowed the expression of the voluntary component involved in the IOR, because of an earlier interruption of the stimulus processing with respect to the 4-dots masking (Enns and Di Lollo, 1997).

General Discussion

Taken together, these results seem to confirm that it is possible to orient attention without consciously perceiving the cue. Visual awareness, though, does not seem necessary for spatial orienting to occur. Tipples (2002) suggested that the arrow, as well as other symbolic spatial cues with high social salience (e.g. Friesen & Kingstone, 1998), could trigger an automatic, instead of voluntary, orienting of attention as suggested by many (e.g., Posner, 1980).

It is relevant that the IOR was observed with centrally resented cues. The biphasic pattern (early facilitation and later inhibition), usually observed in peripheral uninformative cueing tasks and not easily found in endogenous cueing tasks (e.g. McKee, Christie & Klein, 2007), was observed, but only in the aware condition.

There are two possible explanations for the absence of the IOR in the unconscious condition. First, it could be impossible to observe IOR with not consciously perceived cues. According to the original hypothesis on IOR (Posner and Cohen, 1984) the disengagement (and following re-engagement) of attention might be impossible without being aware of the first engaging location.

Contrarily to the Experiment 1, in Experiment 2 no IOR was observed for centrally presented cues. In this case, however, the cue was predictive of the target onset location. On one hand this result seems to confirm the automatic component of the endogenous orienting. On the other hand it could be important in the understanding of the IOR. It is possible that the lack of awareness of the cue would delay or impede the motor preparation, and the following inhibition, as well as discrimination, related to detection tasks (e.g. Klein & Taylor, 1994).

An apparently contradictory result is that IOR has been found for cues presented in peripheral locations even with not consciously perceived cues. However, a partial visibility of the cue, not sufficient for correctly identifying it but sufficient for the motor activation to occur, could be responsible for IOR in that condition. Contrarily, for centrally presented cues a correct identification would be needed for the activation to occur according to Treisman and Gelade (1980), who suggested that localization occurs before identification of complex features. Brignani et al., (in press), on the other hand, show convincingly that the neural mechanism involved in the spatial orienting of attention elicited by arrows and purely endogenous stimuli are identical, denying that those stimuli are "special". The authors suggested that the effects attributed to the automatic orienting, observed with central cues, could be due to the overlearned associations.

None of these claims is nonetheless surprising; in fact, it seems clear that both a) the information driven by a symbol has to be endogenously processed in order to be interpreted and yield a spatial orienting, and b) that a strong association between arrows and spatial region exists. Why, then, does an endogenous cue yield an orienting effect even though not consciously perceived? An alternate explanation, which does not contrast with models of visual attention (e.g. Posner, 1980) is that the endogenous orienting could have an automatic component. If this was the case, it would not be surprising that not consciously perceived arrows could elicit an endogenous orienting of attention. On the other hand, many studies showed endogenous effects driven by not consciously perceived cues (e.g. Marcel, 1983). This hypothesis would be in line with Posner and Snyder (1975), who said that a necessary characteristic of an automatic process is that it should be able to occur without awareness.

Conclusions

Awareness does not seem necessary for driving the automatic component of visual endogenous attention, as is the case for exogenous orienting (McCormick, 1997; Ivanoff & Klein, 2003). This result is highly relevant because it shows for the first time that unconsciously perceived cues lead to an en endogenous orienting of attention. It does not contrast, however, with the hypothesis of the dissociation between endogenous and exogenous orienting. It contrasts, however, with the conceptual overlapping of automatic and voluntary control respectively. We did not find a definitive answer to any of the explicative hypotheses in this study, but we did provide a good working hypothesis for future studies on the relationship between attention and consciousness.

Acknowledgments

The authors wish to thank Eric Taylor for helpful comments.

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