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Exogenous spatial cueing modulates subliminal masked priming

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Abstract

An experiment combined exogenous spatial cueing with masked repetition priming. The task consisted of an alphabetic decision task (letter/pseudo-letter classification) with central targets and peripheral primes that were preceded by a valid or invalid spatial cue in the form of an exogenous abrupt onset. In an analysis including only participants who were not aware of prime stimuli, exogenous location cueing was found to reliably modulate the size of unconscious priming effects. These findings suggest that in early vision the exogenous cue boosts the signal at the location of the cue resulting in a higher gain for the subliminal prime. Our findings therefore suggest that exogenous cueing can affect the first feedforward sweep of information through the brain, a processing stream which is considered to be automatic and unconscious.

PsycINFO classification: 2346; 2323; 2340; 2380

Keywords: Exogenous cueing; Masked repetition priming; Letter identification; Subliminal priming

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1. Introduction

In the late 1970s and early 1980s, Posner and colleagues (Posner, 1980; Posner & Cohen, 1984; Posner, Snyder, & Davidson, 1980) developed the now classic cueing technique for manipulating spatial attention independently of eye movements. Typically, participants have to detect or discriminate a target and respond manually by pressing the appropriate response keys. The target stimulus is preceded by a cue which provides information about the location of the upcoming target. In a cueing version typically referred to as "endogenous", a centrally displayed arrow points to the likely target location. Participants are instructed to use the arrow to focus their attention on the cued location before the appearance of the target. In the so-called "exogenous" version of the cueing paradigm, before the appearance of the target, the participant's attention is pulled to one of the locations by an uninformative peripheral cue (usually an abrupt increase in luminance). The target then appears either at the location of the cue or at the uncued location. The typical finding is that response times are fast and accuracy is high when the cue is valid (i.e., the target appears in the cued location) relative to the condition in which the cue is invalid (the target appears in the uncued location). It is important to note that in exogenous cueing the cue has no predictive value. If, under these circumstances the cue is effective, then the cueing effects are considered the result of a bottom-up and automatic capture of attention (Jonides, 1981; LaBerge, 1981; Theeuwes, 1991; Yantis & Jonides, 1990).

If exogenous cues automatically capture attention, one may ask whether such capture of attention can affect subliminal perceptual processes. In other words, can the allocation of attention affect those perceptual processes that people are not aware of? There is some evidence from neurophysiological investigations that responses to neurons in macaque V4 are enhanced by attracting attention to the location of the stimulus inside the neuron's receptive field. Appropriate allocation of spatial attention affected neural responses in a manner analogous to increases in contrast luminance (Reynolds, Pasternak, & Desimone, 2000). Similarly, a behavioral study of Carrasco, Ling, and Read (2004) recently showed that location cueing alters apparent stimulus contrast. These findings imply that directing spatial attention results in a greater neuronal sensitivity (i.e., a decreased threshold), changing the strength of the stimulus by increasing its salience. Increased sensitivity following an exogenous spatial cue could also be attributed to a sensory process of focused arousal arising from non-specific sub-cortical (cortico-thalamic) activation (Singer, 1977; Sheer, 1984).

The masked priming paradigm (Forster & Davis, 1984) has proven to be an important tool for investigating subliminal perceptual processes involved in the recognition of complex stimuli such as letters and words. In this paradigm, the prime stimulus is preceded by a pattern mask and followed by a target stimulus that requires a response. Because the prime is presented for a very short duration, participants are typically not aware of the stimulus. Thus, combining masked priming with an attentional cueing procedure allows one to examine whether spatial cueing can influence the processing of subliminally presented stimuli. Several studies using the masked priming paradigm have found evidence that this is indeed the case. Naccache, Blandin, and Dehaene (2002) have shown that a temporal cueing procedure modulates prime processing in a categorical priming experiment with a parity judgment task (odd–even classification of digits). Prime stimuli were either the same (e.g., 3) or different parity (e.g., 4) as target digits (e.g., 7). Significant priming (i.e., same parity advantage) was only obtained when the target appeared at a predictable moment in time (with the prime in close temporal proximity). This influence of temporal cueing on masked categorical priming has also been found in an event-related potential (ERP) study as a modulation of the size of priming effects on N400 amplitudes (Kiefer & Brendel, 2006). Another behavioral study by Lachter, Forster, and Ruthruff (2004) suggests that the same story holds for spatial cueing. Using standard masked priming and the lexical decision task with word stimuli, they found evidence for repetition priming effects (facilitation when prime and target are the same word compared to when they are different words) only when the prime location was validly cued. Most important for the present study is that in their final experiment Lachter et al. found that a valid exogenous cue was sufficient to generate significant priming when primes and targets occupied distinct spatial locations. There was no difference between the repeated and unrelated primes in the invalid cue condition (see also Besner, Risko, & Sklair, 2005). The results of these studies therefore suggest that in the absence of appropriate cueing (temporal or spatial), masked subliminal prime stimuli do not receive enough processing to subsequently affect target recognition. The spatial cue provides the extra activation input (when the stimulus appears at the cued location) that will allow prime stimuli to be processed to a level that allows appropriate integration with processing of the following target stimulus.

The present study combines a standard exogenous spatial cueing paradigm (Posner & Cohen, 1984) with the fast masked priming paradigm of Forster and Davis (1984) to investigate the modulation of early perceptual processes in the recognition of isolated letters. Following Lachter et al. (2004) Experiment 5 and Besner et al. (2005) Experiment 1, the present experiment aims to provide further support for the modulation of subliminal processing by spatial cues using the masked priming paradigm. Unlike these studies, the present study uses a horizontal rather than vertical displacement relative to fixation. This will allow us to examine the possible interactions of visual hemi-field with attention and priming. Furthermore, in order to increase the likelihood of observing a rapid and accurate shift of spatial attention in such conditions, we chose to use isolated letters rather than word stimuli, since they are more spatially compact.[1] We also opted for a more standard exogenous cueing procedure (compared with the procedure used by Lachter et al., and Besner et al.), using an abrupt onset stimulus manipulation prior to prime presentation. Finally, participants were selected on the basis of their performance in a prime visibility test in order to ensure that none of our participants could process prime stimuli to a level of conscious awareness. We opted for a more conservative measure of prime visibility (i.e., forced-choice performance on prime stimuli) than typically used in masked priming research.

2. Method

2.1. Participants

Twenty-seven individuals (17 females, 10 males, mean age = 23 years), students in psychology, volunteered to participate in the experiment. All participants were right-handed and reported having normal or corrected-to-normal vision. The results of 17 partici-

[1] Recent research in our laboratory has shown that spatial cueing effects are greater with 3-letter compared to 5-letter words.

pants were retained for analysis on the basis of their performance on a visibility test (see below).

2.2. Design and stimuli

Sixteen letters (all consonants) of the Roman alphabet served as targets along with 16 pseudo-letters designed using Font Creator 4.0 software (see Fig. 1 for an example). Each target letter was primed either by the same letter (repetition prime) or a different letter (unrelated prime), defining the two levels of the factor prime relatedness. Target stimuli were always centrally located, and prime stimuli could appear in the right or the left visual field, defining the two levels of the factor prime position. Prior to prime presentation, a cue stimulus appeared either at the same location as the prime (valid cue, 50% of trials) or the opposite location (invalid cue, 50% of trials), defining the two levels of the factor cue validity. It is important to note that since targets appeared centrally, they never appeared at the cued location. Prime relatedness (on 50% of the trials the prime was related to the target) was crossed with prime position and cue validity in a $2 \times 2 \times 2$ factorial design. Sixteen pseudo-letter targets were created for the purposes of the alphabetic decision task. It should be noted that these pseudo-letter targets were distortions of the corresponding letters used as primes (example of related condition with pseudo-letter target: prime: letter b → target: corresponding pseudo-letter b). Each participant was tested in each of the

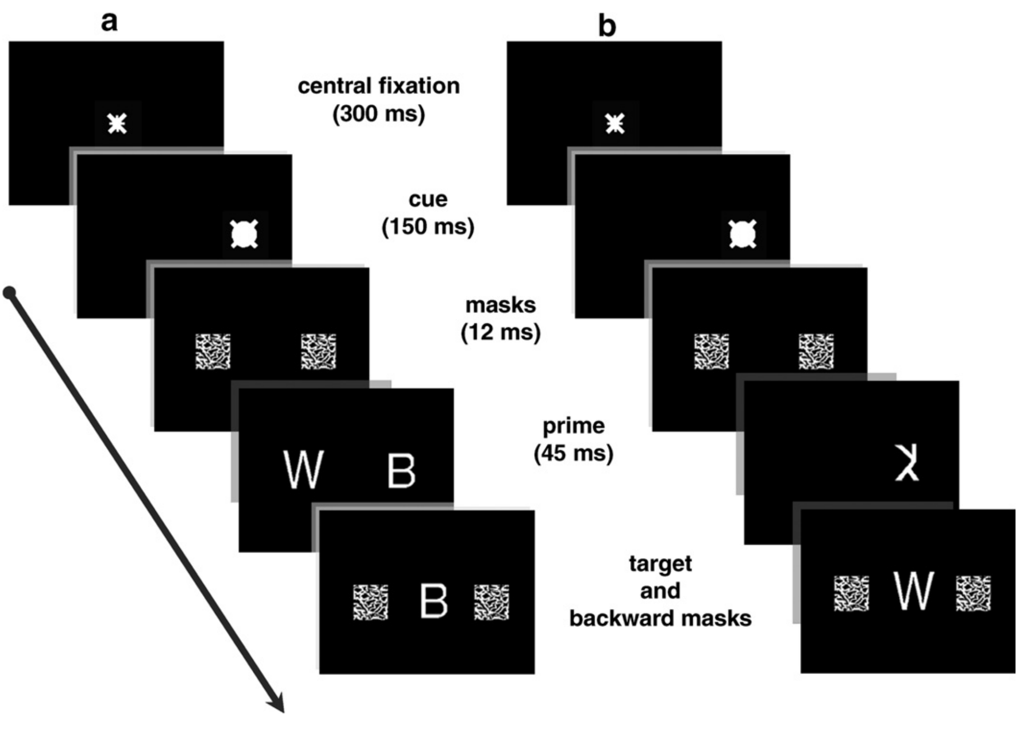

Fig. 1. Structure of a typical trial for the main experiment (a) and the visibility task (b).

eight experimental conditions with the 16 letters and 16 pseudo-letters being repeated eight times during the experiment.

2.3. Procedure

Stimuli were displayed on a computer screen in white on a black background in VGA mode (75 Hz refresh) with constant brightness and contrast of the display. The background luminance of the screen was approximately 1 cd/m^2 and the luminance of all stimuli was approximately 92 cd/m^2. The procedure is described in Fig. 1a. Each trial began with a central fixation point (an asterisk) for 300 ms. The fixation point was then replaced by a complex geometric form (a cross superimposed upon a filled circle) that constitutes the cue stimulus for 150 ms located at a distance of 3.21° of visual angle at a viewing distance of 80 cm either left or right of fixation. The cue stimulus was replaced by a forward mask consisting of a white square with black crossed stripes which appeared both left and right of fixation at the same eccentricity as the cue for 12 ms. The prime stimulus followed the forward mask and appeared either left or right of fixation accompanied by the letter W in the opposite location. The W opposite stimulus is playing the role of filler to keep similar visual complexity over both left and right visual fields. Prime and W presentation lasted 45 ms and was replaced by the centrally located target stimulus and two peripherally located backward masks that remained on the screen until participants responded.[2] The experiment was run inside a dimly lit room and was controlled using DMDX software (Forster & Forster, 2003). Participants responded by pressing one of the two joystick triggers with their index fingers: right button for letters and left button for pseudo-letters. Participants first performed a practice session with the complete set of 16 target letters and pseudo-letters, followed by the 256 trials of the main experiment in a random order. After the main experiment, each participant performed a visibility test using exactly the same stimuli and procedure as the main experiment (with manipulations of cue validity and prime position), except that the target stimulus was always the letter W and primes could be letters (on 50% of trials) or pseudo-letters appearing randomly on the right or the left of fixation and with no stimulus on the opposite side (see Fig. 1b). Participants were informed of the presence of prime stimuli appearing right or left of fixation and had to decide if the prime was a letter or a pseudo-letter on every trial (two-alternative forced-choice instructions).

3. Results

3.1. Overall analysis

Before presenting the main analysis involving participants that performed at chance levels (see *visibility test analysis*), we first report an overview of all participants' results. We conducted a repeated measures ANOVA on the RT data for target letters with prime position, cue validity and prime relatedness as factors for the whole group of participants ($N = 27$). There were no significant main effects: cue validity, $F < 1$; prime position,

[2] The total interval between cue onset and prime offset was 207 ms. This does not allow us to exclude the possible intervention of eye movements, including express saccades, in this type of paradigm (see Findlay & Walker, 1999).

$F(1,26) = 2.49$, MSE = 453.8, $p > .1$; and prime relatedness, $F < 1$. The triple interaction was also not significant, $F < 1$. There was a significant interaction between cue validity and prime relatedness, $F(1,26) = 4.49$, MSE = 568.2, $p < 0.05$ and between prime position and prime relatedness, $F(1,26) = 9.06$, MSE = 229.38, $p = .01$. No significant interaction was observed between cue validity and prime position, $F < 1$. Planned comparisons showed that the priming effect in the presence of a valid cue was not significant ($p > .05$). However, there was a priming effect ($p < 0.05$) for primes presented to the right. The same ANOVA was performed on accuracy data for the whole group and showed no significant simple effect for cue validity, prime position and prime relatedness, $F < 1$. Only the interaction between cue validity and prime relatedness was significant, $F(1,26) = 5.95$, MSE = 0.57, $p < 0.05$.

In order to test for a possible influence of compatibility between cue position (right *versus* left) and response hand (right for letter targets *versus* left for pseudo-letters: i.e., a Simon effect – Simon, 1969) we compared compatible with incompatible conditions. This analysis showed that after averaging across all appropriate conditions with letter and pseudo-letter targets, RTs did not differ significantly when cue position corresponded to the response-hand (RT = 484 ms) compared to when cue position was different from response-hand (RT = 486 ms, $t_{(108)} = -0.86$, $p > 0.1$). We also tested for a possible influence of the compatibility of prime location (right *versus* left) and response hand (right for letters, left for pseudo-letters).[3] In a new ANOVA combining the data for letter and pseudo-letter targets, we redefined the factor prime position in terms of whether or not prime position was compatible with response hand. Although RTs were shorter following compatible primes, this main effect was not significant ($F < 1$). Prime position (compatible or incompatible with response hand) interacted with relatedness, $F(1,26) = 8.56$, MSE = 402.89, $p < 0.05$, with greater priming effects in the compatible condition. However, this interaction was only evident with letter targets, $F(1,26) = 9.06$, MSE = 229.38, $p < 0.01$, and was not significant with pseudo-letter targets, $F(1,26) = 1.99$, MSE = 705.85, $p > .1$. Nevertheless, it is possible that part of the right visual field advantage for priming effects with letter targets is due to prime position–response compatibility influencing performance (e.g., Eimer & Schlaghecken, 1998).

3.2. Visibility test

Each participant's response was analyzed using standard signal-detection ROC (receiver operating characteristic) procedure (e.g., Swets, 1996). For each participant we calculated a confidence interval of the area under curve (AUC).[4] Only 17 participants at chance

[3] We thank F. Schlaghecken for pointing this out. We performed the same analysis on the data of the group of participants retained after the visibility analysis, and this produced the same pattern. Furthermore, an analysis of the priming effect sizes obtained with these participants showed that there was no main effect of prime position (compatible or incompatible with response) for pseudo-letters ($F < 1$), and the apparent inhibitory priming effect with invalid cues and incompatible prime position was not robust, neither for letters ($p > .1$) nor for pseudo-letters ($p > .1$).

[4] Area under the ROC curve, with standard error (Zhou, Obuchowski, & McClish, 2002). When the variable under study cannot distinguish between the two groups, i.e. where there is no difference between the two distributions, the area will be equal to 0.5 (the ROC curve will coincide with the diagonal). When there is a perfect separation of the values of the two groups, i.e. the distributions do not overlap, the area under the ROC curve equals 1 (the ROC curve will reach the upper left corner of the plot).

Table 1
ROC curve parameters

Participants	Sensitivity	Specificity	Criterion	AUC	95% CI[a]
S1	22.2	96.4	⩽682	0.553	[0.424; 0.678][b]
S2	34.8	94.4	⩽683	0.622	[0.492; 0.740][b]
S3	38.2	100	⩽1130	0.672	[0.543; 0.784]
S4	43.2	75	⩽768	0.522	[0.394; 0.649][b]
S5	45.8	81.2	⩽724	0.557	[0.428; 0.681][b]
S6	47.9	68.7	>699	0.511	[0.383; 0.638][b]
S7	49	80	⩽824	0.604	[0.474; 0.724][b]
S8	56.4	72	⩽1017	0.653	[0.523; 0.767]
S9	58.8	84.6	⩽877	0.693	[0.565; 0.802]
S10	60	70.6	⩽1477	0.662	[0.533; 0.775]
S11	60.9	55.6	⩽647	0.562	[0.432; 0.685][b]
S12	61.8	77.8	⩽863	0.743	[0.619; 0.844]
S13	61.9	77.3	⩽1236	0.704	[0.577; 0.812]
S14	64.9	63	⩽745	0.558	[0.428; 0.682][b]
S15	65.5	100	⩽1105	0.780	[0.659; 0.874]
S16	67.3	73.3	⩽783	0.690	[0.563; 0.800]
S17	67.6	48.1	⩽659	0.505	[0.377; 0.632][b]
S18	73.9	55.6	>566	0.611	[0.481; 0.730][b]
S19	75	83.3	⩽837	0.769	[0.647; 0.865]
S20	77.5	42.9	>358	0.595	[0.469; 0.712][b]
S21	78.4	46.2	⩽868	0.587	[0.457; 0.708][b]
S22	80	41	>529	0.563	[0.433; 0.687][b]
S23	80.6	48.5	>1289	0.537	[0.408; 0.662][b]
S24	82.8	40	<1010	0.582	[0.452; 0.704][b]
S25	83.8	40.7	⩽1343	0.580	[0.450; 0.702][b]
S26	87.5	43.7	⩽1380	0.611	[0.481; 0.730][b]
S27	93	42.9	>556	0.640	[0.510; 0.756]

[a] The 95% Confidence Interval for the area can be used to test the hypothesis that the theoretical area is 0.5. If the confidence interval does not include the 0.5 value, then this is evidence that discrimination performance is significantly greater than chance.
[b] Selected participants at chance level performance.

level performance in the visibility test were retained for the main analysis presented below (see Table 1). We also performed a *t*-test on the accuracy data in order to compare performance on valid (67.4%) versus invalid (68.8%) trials in the visibility test. There was no reliable difference across these conditions, $t_{(53)} = -0.56$, $p > .1$.

3.3. Main analysis

Table 2 provides the mean correct RTs and percent correct responses to letters and pseudo-letters for each condition in the experiment. Letter targets were responded to more rapidly [($F(1,32) = 6.2$, MSE = 13616.74; $p < 0.05$)] and not significantly more accurately ($F < 1$) than pseudo-letter targets. The percentage of errors in the task followed the same general trend as the RT data, indicating the speed was not traded for accuracy. We also analyzed separately the RT data for the sub-group of participants ($N = 10$) who were "aware" of prime stimuli. For these participants, there were no significant interactions between: cue validity and prime position, $F < 1$; cue validity and prime relatedness,

Table 2
Mean reaction times (RT in milliseconds) and accuracy (% error) plus or minus standard errors of the mean for letters and pseudo-letters with participants at chance level performance

	Left prime				Right prime			
Cue	Valid		Invalid		Valid		Invalid	
Prime	Related	Unrelated	Related	Unrelated	Related	Unrelated	Related	Unrelated
Letters								
Mean RT	446.1 ± 9.7	464.9 ± 11.9	456.3 ± 9.38	457.2 ± 10.3	453.2 ± 10.7	461.7 ± 12.5	469.2 ± 13.2	458.4 ± 12.0
% Error	3.2% ± 0.8	6.2% ± 1.5	3.2% ± 0.8	3.9% ± 0.9	3.7% ± 0.9	6.7% ± 1.2	5.5% ± 1.3	3.3% ± 0.8
Pseudo-letters								
Mean RT	494.1 ± 9.5	494.1 ± 11.9	500.7 ± 10.3	492.5 ± 11.1	488.9 ± 13.0	496.1 ± 11.4	491.7 ± 11.7	490.1 ± 8.5
% Error	4.5% ± 1.1	4.5% ± 1.1	3.9% ± 0.9	3.2% ± 0.8	4.5% ± 1.1	5.6% ± 1.4	3.9% ± 0.9	3.8% ± 0.9

$F < 1$ and between prime position and prime relatedness, $F(1,9) = 3.19$, MSE = 343.59, $p > .1$. In addition, no significant triple interaction was found, $F < 1$.

3.3.1. Letter targets

A repeated measures ANOVA was performed on the RT data for target letters with prime position, cue validity and prime relatedness as factors. There were no significant main effects: cue validity, $F(1,16) = 1.75$, MSE = 276.32, $p > .1$; prime position, $F(1,16) = 1.37$, MSE = 498.32, $p > .1$; and prime relatedness, $F < 1$. The triple interaction was also not significant, $F < 1$. There was a significant interaction between cue validity and prime relatedness, $F(1,16) = 5.80$, MSE = 507.81, $p < 0.05$. Planned comparisons revealed a significant priming effect in the presence of a valid cue ($p < 0.05$), but not when the cue was invalid ($p > .1$). There was also a significant interaction between prime position and prime relatedness, $F(1,16) = 5.82$, MSE = 176.63, $p < 0.05$. Planned comparisons further revealed a significant priming effect when primes were presented on the right ($p < 0.05$), but not when they appeared on the left ($p > .1$). The accuracy data showed no main effects: cue validity, $F < 1$; prime position, $F(1,16) = 1.07$, MSE = 0.47, $p > .1$; and prime relatedness, $F < 1$. Also, no second order interaction was significant: cue validity × prime

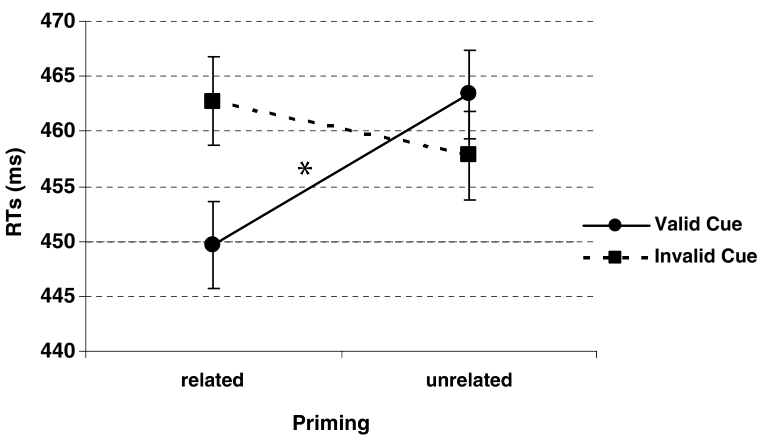

Fig. 2. Interaction between priming and cue validity. Significant priming effect is indicated by asterisk (*$p < 0.05$).

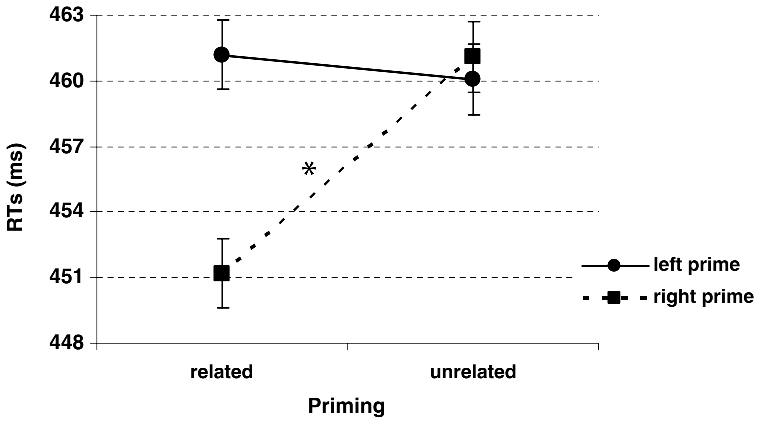

Fig. 3. Interaction between prime position and priming. Significant priming effect is indicated by asterisk ($^{*}p < 0.05$).

position, $F < 1$; and prime position × prime relatedness, $F(1,16) = 1.2$, $MSE = 0.73$, $p > .1$; except for the marginally significant interaction between cue validity and prime relatedness, $F(1,16) = 4.46$, $MSE = 2.94$, $p > .05$. Finally, there was no reliable third order interaction between the three experimental factors, $F(1,16) = 2.3$, $MSE = 1.06$, $p > .1$ (see Figs. 2 and 3).

3.3.2. *Pseudo-letter targets*

Analyses on RTs and accuracy data showed no main effects (all $Fs < 1$), and no significant second order or triple interaction.

4. Discussion

It is well known that a visual stimulus that suddenly appears (i.e., an abrupt onset) can capture our attention (Theeuwes, 1991) or even our eyes (Theeuwes, Kramer, Hahn, & Irwin, 1998). The present study demonstrates the effectiveness of exogenous cueing showing a classic exogenous cueing benefit. However, the most important finding of the present study is the demonstration that a location cueing benefit also occurs for stimuli that we are not aware of. In our study, the cueing benefit arose during the processing of subliminally presented prime stimuli. Processing of these unconscious stimuli was improved in the presence of a valid spatial cue, leading to a stronger priming effect in this condition. The fact that exogenous spatial cueing can influence the processing of stimuli that we are not aware of, strongly suggests that this exogenous cueing effect occurs early in processing. Therefore, these results are consistent with previous findings showing that an abrupt onset cue can boost the signal by increasing the effective stimulus contrast (Martinez-Trujillo & Treue, 2002; Reynolds et al., 2000), increase its sensory gain (Hillyard, Vogel, & Luck, 1998) or contrast sensitivity (Carrasco et al., 2004), and hence increase the interfering capacity of a stimulus (Mounts & Tomaselli, 2005). Our results are also in line with a recent event-related fMRI study by (Liu, Pestilli, & Carrasco, 2005) who showed that exogenous cueing (unpredictable abrupt onset cue) produced a large fMRI response in early visual areas. This enhancement in neural activity progressively increased from striate to extrastriate cortex.

The current findings suggest that in early vision the exogenous cue boosts the signal at the location of the cue resulting in a higher gain for the subliminal prime. This higher gain in prime processing results in a greater priming effect (difference between repeated and unrepeated primes) on the processing of upcoming targets. However, because the prime is immediately masked, the prime remains unconscious. In terms of models that assume that recurrent processing is necessary for awareness (e.g., Lamme, 2001; Lamme & Roelfsema, 2000), the mask disrupts recurrent interaction between higher and lower visual areas (e.g., Enns & Di Lollo, 2000). Because recurrent processing is blocked, the prime cannot enter consciousness. In line with the distinction between feedforward and recurrent processing to explain conscious and unconscious vision (e.g., Lamme, 2003; Lamme & Roelfsema, 2000), our findings suggest that unconscious vision can be affected by exogenous cueing. In other words, exogenous cueing can affect the first feedforward sweep of information through the brain, a processing stream which is considered to be automatic and unconscious. The present findings are therefore consistent with the recent studies of Koivisto and colleagues (Koivisto, Revonsuo, & Lehtonen, 2005; Koivisto, Revonsuo, & Salminen, 2005) showing that early effects of attention are elicited regardless of the presence or absence of awareness.

With respect to research on letter and word perception, the present experiment replicates and extends (to the case of isolated letter stimuli, and horizontal rather than vertical displacement) the findings of Lachter et al. (2004) and Besner et al. (2005) showing a significant modulation of masked repetition priming by an exogenous spatial cue. The present study provides a further confirmation of such spatial cueing effects observed under more tightly controlled experimental conditions, particularly with respect to the evaluation of prime visibility. Note that we only analyzed the data of participants that were at chance level on the prime visibility test, in an attempt to ensure that the primes were indeed processed subliminally.

A further contribution of the present study is that since all targets were centrally located, our results show that peripheral exogenous cueing can override the endogenous cueing effects generated by the target stimuli themselves. Targets were the only relevant stimuli in the experiment; therefore, participants could have successfully performed the experiment with attention focused at the target location. Given our attempt to ensure that primes were not consciously perceived by our participants, it is very unlikely that any of the participants retained for analysis were ever aware that primes were sometimes the same letter as targets.

Finally, the present experiment employed a horizontal manipulation of prime location relative to centrally located targets, and found a significant influence of visual hemi-field. Repetition priming effects were only robust when primes appeared in the right visual field (RVF). Indeed, although the triple interaction was not significant, an inspection of the simple effects shows that the strongest priming arises with a combination of both a valid cue and right visual field presentation. When primes appear on the right but with an invalid cue, then there is no hint of a priming effect. The effects of prime position found with letter targets could be due to the fact that RVF primes were compatible with response hand (right hand for letter targets). However, the effects of compatibility across prime position and response hand were not significant for pseudo-letter targets. Therefore, although perception–action compatibility effects could be partly responsible for the

RVF advantage found in priming with letter targets, it is likely that at least part of the effect is due to an attentional bias in favor of RVF (Ducrot & Grainger, in press; Kinsbourne, 1970; McCann, Folk, & Johnston, 1992; Mondor & Bryden, 1992; Nicholls & Wood, 1998; Ortells, Tudela, Noguera, & Abad, 1998). The attentional bias to the right could be the result of the reading habits of our participants who were all native speakers of French, a language that is read from left-to-right. Thus, a parsimonious explanation for the present pattern of results is that attentional mechanisms underlie both the effects of cueing and the effects of visual field. Spatial attention would be more rapidly and accurately allocated to a location right of fixation than to a location left of fixation.

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