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ORIGINAL ARTICLE

Endogenous cueing attenuates object substitution masking

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Abstract Object substitution masking (OSM) is a form of visual masking in which a briefly presented target surrounded by four small dots is masked by the continuing presence of the four dots after target offset. A major parameter in the prediction of OSM is the time required for attention to be directed to the target following its onset. Object substitution theory (Di Lollo et al. in J Exp Psychol Gen 129:481–507, 2000) predicts that the sooner attention can be focused at the target's location, the less masking will ensue. However, recently Luiga and Bachmann (Psychol Res 71:634–640, 2007) presented evidence that precueing of attention to the target location prior to target-plus-mask onset by means of a central (endogenous) arrow cue does not reduce OSM. When attention was cued exogenously, OSM was attenuated. Based on these results, Luiga and Bachmann argued that object substitution theory should be adapted by differentiating the ways of directing attention to the target location. The goal of the present study was to further examine the dissociation between the effects of endogenous and exogenous precueing on OSM. Contrary to Luiga and Bachmann, our results show that prior shifts of attention to the target location initiated by both exogenous and endogenous cues reduce OSM as predicted by object substitution theory and its computational model CMOS.

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Introduction

Visual perception not only proceeds through feedforward or bottom-up processes, but top-down processes also play a critical role. Over the past 20 years, both neurophysiological and psychophysical research has widened our understanding of how these top-down influences could be conceptualized and implemented within the mammalian brain (e.g., Bar, 2003; Bullier, 2001; Di Lollo, Enns, and Rensink, 2000; Grossberg and Versace, 2008; Hochstein and Ahissar, 2002; Lamme and Roelfsema, 2000). Psychophysical research on object substitution masking (OSM) has contributed considerably to this development.

Research on OSM has typically been carried out using what Di Lollo et al. (2000) refer to as the common-onset masking paradigm. In a typical experiment (e.g., Di Lollo et al., 2000, Experiment 3), an initial pattern containing 1–16 Landholt Cs with gaps in different orientations is shown briefly (i.e., 10 ms), with one of the Cs (the target) being surrounded by four small dots (i.e., the mask, which has a common onset with the target). Following the offset of this display, only the four dots which serve both as a cue and a mask remain present for durations of zero up to several hundred milliseconds (referred to as the trailing mask duration, TMD). Identification of the orientation of the target's gap reveals little or no masking when the display contains only one potential target or when the mask terminates together with the target display (i.e., TMD 0 ms). In contrast, when both multiple potential targets are present and the mask remains in view following offset of the initial display, performance drops to an asymptotic value with trailing mask durations around 160 ms. Furthermore, under these conditions more pronounced masking is observed with increasing set size. Both the set-size effect and other findings such as reduced masking for pop-out targets (e.g., Di Lollo et al., 2000, Experiments 4 and 5) have pointed towards the critical role of attention in masking by object substitution.

Di Lollo et al. (2000) proposed that masking by object substitution is caused by re-entrant processes, from higher to lower levels in the visual system. The initial onset of target and mask information initiates a feedforward sweep of activation to higher levels of the visual system responsible for object perception, resulting in a preliminary perceptual hypothesis regarding the identity of the target. This hypothesis, based on incomplete information, requires confirmation through additional input from the lower levels. If the display remains unchanged, durable representations of the target and the mask are established after several iterations. If the target and the mask are both removed before these durable representations are established, then the visual system must rely on rapidly fading trace representations (e.g., iconic memories) for confirmation. In both the cases, the initial perceptual hypothesis will be strengthened by continued activation in lower level regions because it is consistent with the hypothesis. However, if lower level activation is altered before completion of a durable representation, as is the case when the briefly presented target is removed and only the mask remains visible (trailing mask), a mismatch develops. Information continues to be sampled from the display itself, which now contains only the mask. As such, the visual system abandons the initial higher level representation and establishes a new representation based solely on the mask. The result of this new iterative confirmation process leaves no room for a representation of the target; instead it is "substituted" by the mask. In summary, OSM occurs when the target offsets before a durable representation of it has been established, and some visual information, such as the mask alone, remains in the display after target offset to support continued sampling from the display.

The process of OSM is presumed to occur prior to the arrival of focal attention to the target (Woodman and Luck, 2003). Object substitution theory and its computational model CMOS (Di Lollo et al.. 2000) predict that sooner the attention can be focused at the target's location the less masking will ensue, a prediction which is supported by several studies using a variety of manipulations known to affect speed of attentional orienting (e.g., Di Lollo et al., 2000; Enns, 2004; Enns and Di Lollo, 1997; Jiang and Chun, 2001; Kahan and Mathis, 2002; Tata, 2002). These consistent effects of attention on OSM were inferred from either manipulations of set size (increments in set size prolong the time to focus attention; Duncan and Humphreys, 1989; Treisman and Gelade, 1980), target pop-out (a target standing out from a field of distractors attracts attention faster; Duncan and Humphreys, 1989; Treisman and Gormican, 1988), or peripheral (exogenous) spatial precueing of the future target location (spatial precues produce an advanced shift of attention facilitating subsequent target identification; Corbetta et al., 2005; Deubel, 2008; Eriksen and Hoffman, 1973; LaBerge, Brown, Carter, Bash, & Hartley, 1991; Van der Heijden and Eerland, 1973).

However, in contrast to these studies, the results of a recent study by Luiga and Bachmann (2007) seem to question the general nature of the effect of attention on OSM. Specifically, their study was aimed at investigating whether endogenous and exogenous precueing of attention to the target location prior to target-plus-mask onset has a different influence on OSM. While, consistent with object substitution theory, an exogenous precue [with a cue-target stimulus onset asynchrony (SOA) of 150 and 250 ms] attenuated OSM, a central (endogenous) arrow cue (SOAs ranging from 150 to 450 ms) did not. The latter effect is at odds with object substitution theory which claims that any manipulation controlling visuospatial attention allocation to the future target location (whether stimulus-driven or symbolic top-down controlled) should affect OSM. Accordingly, Luiga and Bachmann concluded that object substitution theory should be adapted by elaborating how different ways of directing attention (i.e., exogenously versus endogenously) to the target location differentially affect OSM. Furthermore, given that both types of precues shorten the attentional time of contact but differ in terms of sensory increases at the target location, Luiga and Bachmann suggested that the localized stimulation (e.g., the local exogenous precue), regardless of its attentional effects, may facilitate sensory processing of successive stimuli (e.g., the target) thus attenuating OSM with localized exogenous but not central endogenous precues. As suggested by Luiga and Bachmann, this account of the effect of different types of precues on OSM tends to be more closely related to a feed-forward model of substitution masking, thus questioning the re-entrant model proposed by Enns and Di Lollo.

Given the importance of the theoretical implications of the results reported by Luiga and Bachmann (2007), the aim of the present study was to further examine the dissociation between the effects of exogenous (Experiment 1) and endogenous precueing (Experiment 2) on OSM. Two experiments are reported, both examining the time course of possible attenuating effects on OSM by precueing attention to the upcoming target location, using a wide range of cue-target SOAs and a trailing mask duration of 0 and 160 ms. To preview the outcome of the two experiments, significant attenuation of OSM with both exogenous and endogenous precueing was found, albeit at different SOAs as could be expected based on the characteristic time courses of attentional effects produced by the two types of precues (i.e., faster attentional orienting with exogenous precues; Cheal and Lyon, 1991; Müller and Rabbitt, 1989). In "General discussion", we offer possible explanations for why Luiga and Bachmann, (2007) did not observe attenuation of OSM with endogenous cues.

Experiment 1: Exogenous precueing

The first experiment was designed to replicate Luiga and Bachmann's finding that exogenous precueing of the future target location reduces OSM. To this end, a brief local peripheral precue was flashed at different moments prior to target-plus-mask onset. SOAs between cue onset and target + distractors onset ranged from 0 to 160 ms. The target+distractors display was shown for 13.3 ms. Note that, in the condition with a 0-ms SOA, the cue was presented at the same time (onset as well as offset) as the target+distractors display. In the condition with a 13-ms SOA, the offset of the precue coincided with the onset of the target+distractors display. In the other SOA conditions, there was a blank between cue offset and target+distractors onset. Following the target-plus-mask display, the mask either remained present for 160 ms or disappeared simultaneously with it (no-masking baseline condition). Following Luiga and Bachmann (2007) and the predictions based on substitution theory (Di Lollo et al., 2000), we expected attenuation of OSM already to be present at short SOAs given the fast attentional shifts produced by exogenous precues.

The present experiment differed in several ways from that of Luiga and Bachmann. A first major difference is the type of precue. While Luiga and Bachmann presented a localized four-dot precue, identical to the four-dot mask, prior to target-plus-mask onset, a briefly flashed outline square was used in the present study. The reason for not using a four-dot cue has to do with the finding that a preview of a four-dot mask prior to target-plus-mask onset, even when it is uninformative regarding the future target location, eliminates OSM (Neill, Hutchison, & Graves, 2002; Tata and Giaschi, 2004). This implies that the mere presence of the local four-dot precue, regardless of its attentional cueing function, may already have eliminated OSM in the exogeneous precueing condition of Luiga and Bachmann's Experiment 1. Luiga and Bachmann addressed this potential confound in their Experiment 2. Instead of presenting the local precue continuously during the entire SOA, the four-dot precue was flashed briefly at the start of the SOA (e.g., with an SOA of 150 ms, the cue was flashed for 33 ms followed by a 117-ms interstimulus interval and then the target-plus-mask display). However, recently Lim and Chua (2008) showed that a brief preview of the mask followed by both short and longer interstimulus intervals attenuates OSM. Given these considerations, we opted for a briefly flashed outline square instead of a four-dot precue. Three other differences between the present study and that of Luiga and Bachmann are worth mentioning. First, unlike Luiga and Bachmann's study, trials in the no-precueing (i.e., SOA = 0 ms either with or without a trailing mask) and precueing conditions (SOA > 0 ms) were randomly presented, instead of blocked. Furthermore, the present experiment only contained no-precueing and exogenous precueing trials while Luiga and Bachmann's study also contained endogenous precueing trials within the same experiment (endogenous precueing will be assessed in Experiment 2 of the present study). Second, a broad range of SOAs (0–160 ms) was tested to examine the time course of potential precueing effects. Finally, for reasons of comparison with Experiment 2, both target and non-target stimuli were surrounded by a four-dot mask in the target-plus-mask display.

Methods

Observers

Six participants, including the first and second author participated in the experiment. All reported normal or corrected-to-normal vision. Each subject was tested individually in a darkened cubicle. A single session lasted approximately 70 min.

Apparatus and stimuli

Participants were seated at a distance of 80 cm, set by a headrest. Stimuli were displayed black on white on a Dell P1130 21-in. monitor operating at 75 Hz.

The stimuli were Landholt Cs with a diameter subtending a visual angle of 0.95° and a gap of 0.27° oriented either left-, right-, up-, or downwards. The mask consisted of four dots (diameter 0.27°) corresponding to the corners of an imaginary square of 1.09° centered around the Landholt C. On each trial, four Landholt Cs were presented centered on the corners of an imaginary square subtending a visual angle of 6.80°. This implies stimuli being presented at a visual angle of 4.81° from the center of the screen. The centrally presented fixation point measured 0.27° in diameter. The exogenous precue was an outline square of 2.72° wide with a line width measuring approximately 0.10°. The precue was presented centered around one of the four possible target locations.

Procedure

Each trial began with the fixation point presented for 720 ms (see Fig. 1). Forty milliseconds following offset of

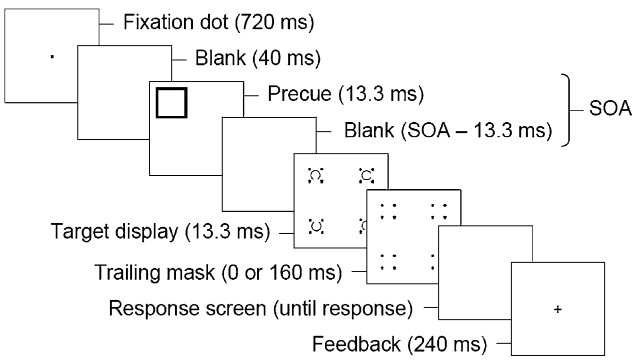

Fig. 1 Schematic representation of the stimulus sequence in Experiment 1

the fixation point, the peripheral precue was presented for a duration of 13.3 ms. Depending on the SOA, the target and three distractor stimuli appeared after a variable period of time after cue onset. There were nine SOAs (0, 13, 27, 40, 53, 67, 80, 120, 160 ms) between cue onset and target+distractors onset. At the 0 ms SOA, cue and target+distractors were presented at the same time. Target and distractor stimuli were Landholt Cs each surrounded by four dots and were shown for a duration of 13.3 ms. The four dots surrounding target and distractor stimuli either disappeared together with the offset of the Landholt Cs (TMD, equals 0 ms) or remained present for an additional 160 ms (TMD = 160 ms). The participants' task was to indicate the direction of the gap in the cued Landholt C (i.e., the one where the precue had previously flashed) with one of the four arrow keys (left, right, up, down). Accuracy feedback was provided immediately following a response by presenting either a green "+" (correct) or a red "–" (incorrect) in the centre of the screen for 240 ms. Following offset of the feedback message, the central fixation dot appeared signaling the start of a new trial.

Participants were instructed to fixate the central dot and shift their attention as fast as possible to the location where the precue had appeared. They were asked to try to keep their eyes fixated on the centre of the screen during the entire trial sequence. Accuracy was stressed over response speed.

Each participant completed one practice block of 72 trials followed by six experimental blocks of 288 trials. Participants were encouraged to take short breaks of 1–2 min between blocks of trials. Within each experimental block the 288 trials were a factorial combination of nine SOAs (0, 13, 27, 40, 53, 67, 80, 120, 160 ms) × two TMDs (0 and 160 ms) × four target positions × four gap orientations. In total, each participant completed 1,728 experimental trials, allowing for 96 observations in the smallest cell of analysis (i.e., SOA × TMD). Practice trials were a factorial combination of nine SOAs × two TMDs × four target positions, with random gap orientations.

Results and discussion

Proportion of correct responses in each of the conditions were calculated for each participant and analyzed in a nine (SOA) × two (TMD) within-subject analysis of variance (ANOVA). All main and interaction effects were significant: SOA, $F(8,40) = 34.16$, $p < 0.001$, MSE = 0.002; TMD, $F(1,5) = 238.01$, $p < 0.001$, MSE = 0.007; SOA × TMD, $F(8,40) = 20.44$, $p < 0.001$, MSE = 0.002.

With the exception of the shortest SOAs, performance in the conditions without a trailing mask was near ceiling (see Fig. 2, left panel), $F(8,40) = 3.16$, $p < 0.01$, MSE = 0.001. Comparison of the conditions in which the precue was presented at the same time as the target-plus-mask display (SOA = 0 ms) reveals a 48% OSM effect (i.e., 94% without trailing mask minus 46% with trailing mask). With increasing SOAs, the masking effect is severely reduced as evidenced by the sharp rise in performance already present as SOAs less than 80 ms in the trailing mask conditions, $F(8,40) = 30.94$, $p < 0.001$, MSE = 0.003. With an SOA of 160 ms the masking effect was reduced to 13% (i.e., 99% minus 86%)

In summary, the present results show that exogenous precueing of attention to the future target location attenuates OSM. Furthermore, the sharp and early effect of the precue (i.e., at SOAs < 100 ms) is consistent with the fast attentional shifts observed with exogenous cues.

Experiment 2: Endogenous precueing

Experiment 1 demonstrated that exogenous precueing attenuates OSM which is consistent with the findings of Luiga and Bachmann (2007) and in general, the effects of attentional modulations as proposed by object substitution theory. Experiment 2 addressed the question whether an analogous attenuation effect can be observed with a central endogenous arrow precue. Similar to Experiment 1, we examined this issue by manipulating the timing of the presentation of the central cue relative to the onset of the target-plus-mask display (SOA). If endogenous attentional shifts to the future target location prior to target-plus-mask onset do not attenuate OSM, as argued by Luiga and Bachmann (2007) performance in conditions with a trailing mask should not be affected by SOA. However, if prior endogenous attentional shifts do attenuate OSM, as can be derived from substitution theory, performance in conditions with a trailing mask should improve with increasing SOAs, albeit somewhat later compared to the exogenous precueing effect observed in Experiment 1.

Again, the present experiment differed in a number of ways from Luiga and Bachmann's study. First, unlike their study, both target and non-target stimuli in the target-plus-mask

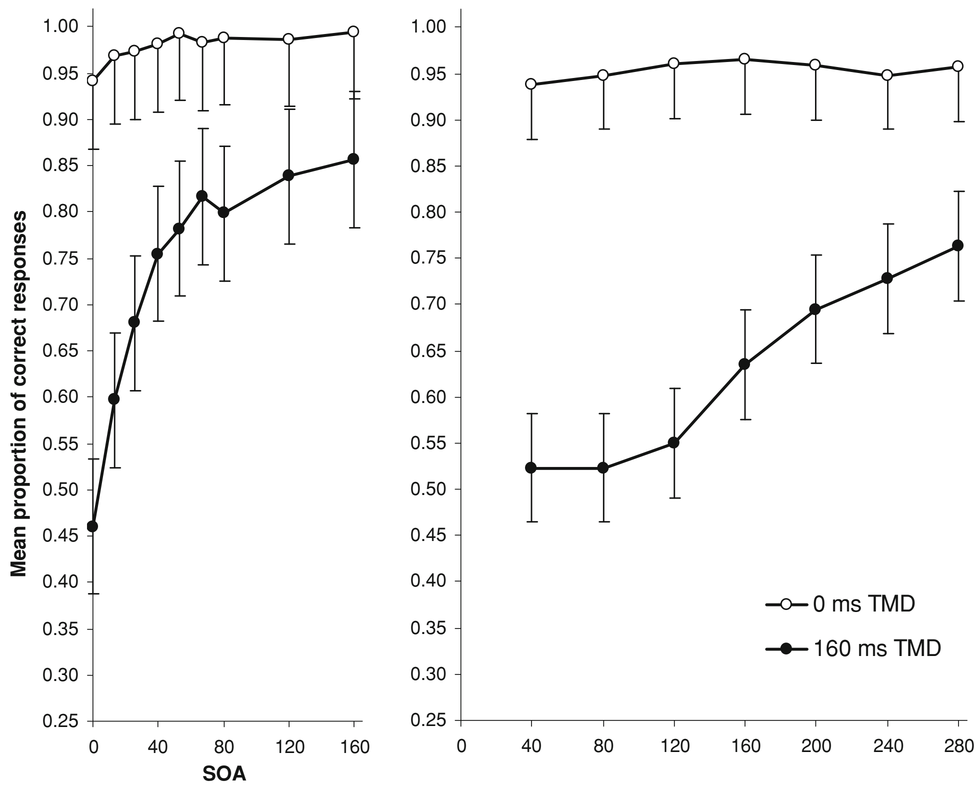

Fig. 2 Mean proportion correct responses as a function of stimulus onset asynchrony (*SOA*, ms) and trailing mask duration (*TMD*) in Experiment 1 (*left*) and 2 (*right*). Plotted 95% confidence intervals are based on the SOA × TMD error term

display were surrounded by four-dot masks instead of only the target. The motivation for this is that we wanted to prevent that a four-dot mask surrounding the target only would be used by observers as an additional and 100% reliable, but in this case peripheral, cue. Use of this peripheral cue to shift attention to the target location at the expense of processing and using the central endogenous cue would disrupt the main manipulation of the present experiment, namely the SOA between the arrow cue onset and the target-plus-mask onset. Second, unlike in the Luiga and Bachmann's study, the central cue was flashed briefly and held constant across different SOAs in order to control for any differences in the timing of attentional shifts. Third, during the entire experiment four outline squares were present indicating the possible locations at which the target and non-target stimuli could occur. The presence of these location markers combined with the central cue allows for a better comparison of the results with those of Experiment 1, in which the outline square precue provided precise location info. Finally, similar to Experiment 1, a broad range of SOAs (40–280 ms) were tested to examine the time course of potential precueing effects.

Methods

Observers

Six participants, including the first author participated in the experiment. With the exception of the first author, none of the participants had participated in Experiment 1. All reported normal or corrected-to-normal vision. Each subject was tested individually in a darkened cubicle. A single session lasted approximately 55 min.

Apparatus and stimuli

Apparatus and stimuli were identical to Experiment 1 with the following exceptions (see Fig. 3). During the entire experiment, four outline squares (2.72° wide, approximately 0.03° line width) were present, indicating the locations at which the Landholt Cs would appear. Instead of the peripheral exogenous cue in Experiment 1, an arrow cue measuring 0.77° in length presented at the center of the

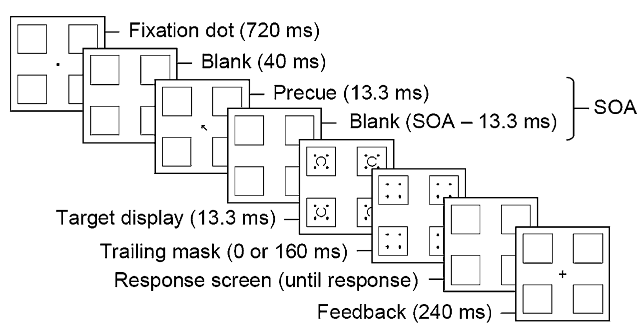

Fig. 3 Schematic representation of the stimulus sequence in Experiment 2

screen pointing in the direction of one of the four outline squares was used.

Procedure

The procedure was identical to Experiment 1 with the following exceptions. First, four outline squares indicating the locations at which the stimuli would appear were continuously present throughout the entire experiment (see Fig. 1). Second, a central arrow cue was presented for 13.3 ms instead of a peripherally flashed square. Third, participants were instructed to fixate the central dot and shift their attention as fast as possible to the location towards which the arrow was pointing once it appeared. Finally, each participant completed one practice block of 56 trials followed by six experimental blocks of 224 trials. Within each experimental block the 224 trials were a factorial combination of seven SOAs (40, 80, 120, 160, 200, 240, 280 ms) × two TMDs (0 and 160 ms) × four target positions × four gap orientations. In total, each participant completed 1,344 experimental trials, allowing for 96 observations in the smallest cell of analysis (i.e., SOA × TMD). Practice trials were a factorial combination of seven SOAs × two TMDs × four target positions, with random gap orientations.

Results and discussion

Similar to Experiment 1, proportion of correct responses in each of the conditions were calculated for each participant and analyzed in a seven (SOA) × two (TMD) within-subject ANOVA. All main and interaction effects were significant: SOA, $F(6,30) = 24.15$, $p < 0.001$, MSE = 0.001; TMD, $F(1,5) = 201.46$, $p < 0.001$, MSE = 0.011; SOA × TMD, $F(6,30) = 22.79$, $p < 0.001$, MSE = 0.001.

As shown in Fig. 2, performance in the 0-ms TMD conditions was near perfect and unaffected by SOA ($M = 0.95$; $F < 1$). In contrast, performance in conditions with a TMD of 160 ms improved steadily with longer SOAs, $F(6,30) = 31.00$, $p < 0.001$, MSE = 0.002. This enhancement started at SOAs of approximately 120–160 ms. Comparison of the masking effect shows a reduction from approximately 42% (i.e., 94% without trailing mask minus 52% with a trailing mask) at 0-ms SOA to 20% (i.e., 96% minus 76%) at 280 ms SOA. The present results show that endogenous precueing of attention to the future target location attenuates OSM much in the same way as exogenous precues do (Experiment 1). Although the precise time course of attenuation differs between endogenous and exogenous precues, their respective effects are in accordance with what could be expected based on the characteristic time courses of attentional effects produced by the two types of precues (Cheal and Lyon, 1991; Müller and Rabbitt, 1989).

General discussion

The goal of the present study was to further examine the dissociation between the effects of endogenous and exogenous precueing on OSM as observed by Luiga and Bachmann (2007). They provided evidence that precueing the target location prior to target-plus-mask onset by means of an exogenous peripheral precue attenuated OSM, while precueing with a central endogenous arrow cue did not. Contrary to Luiga and Bachmann (2007), the two experiments reported here show that prior shifts of attention to the target initiated by both exogenous and endogenous cues reduce OSM as predicted by object substitution theory and its computational model CMOS (Di Lollo et al. 2000). A briefly flashed peripheral precue reduced OSM already with SOAs below 80 ms, while precueing with a central arrow started to attenuate OSM at SOAs of approximately 160 ms.

Why did Luiga and Bachmann (2007) fail to observe attenuation of OSM with endogenous precues? We offer a possible explanation that is based on two major differences between the present endogenous precueing experiment (Experiment 2) and the experiments reported by Luiga and Bachmann. First, the endogenous precueing trials in Luiga and Bachmann's experiments contained two cues signaling the location of the target: (1) the central arrow cue presented 150–450 ms prior to target-plus-mask onset, and (2) the four-dot mask surrounding the target in the target-plus-mask display (note that the latter cue was not present in our Experiment 2, because both target and non-target stimuli were flanked by four-dot masks). Although the first cue (i.e., the central arrow) is available before the second by a duration equal to the SOA (i.e., 150–450 ms), observers may have ignored the central cue, instead actively searching for the peripheral cue (i.e., searching for a target flanked by four dots). Obviously, such a strategy would eliminate attentional precueing effects and by extension no attenuation of OSM in endogenous precueing trials would be observed. Given the possibility of such a non-optimal strategy, the question becomes why it would have been used by observers. We believe that a second major difference between our Experiment 2 and Luiga and Bachmann's experiments may have pushed observers into adopting such a strategy. In their experiments, participants completed no-precue, exogenous, and endogenous precue trials. Given that the best strategy to perform accurately in both exogenous and no-precue trials (which together constitute 66.7% of the trials) is to shift attention to the peripheral four-dot mask as quickly as possible, observers may very well have used the same strategy in the endogenous trials. Furthermore, the advantage of processing the central precue in endogenous precue trials without trailing mask may actually be minimal, given that the time-window for attention to arrive at the target location and identify the target is less stringent in this case (our results show ceiling performance even with 40 ms SOAs). Similarly, in their endogenous precue trials with the shortest SOA (150 ms), processing of the central cue for shifting attention may have been too slow to benefit from it (as evidenced by the present data). Together, this would mean that processing of the central cue would be advantageous only in approximately 22% of the trials of Luiga and Bachmann's Experiment 1. Under these circumstances, it seems quite plausible that observers ignored the central precue altogether during the experiment. Clearly, such a strategy would not result in any attentional effects of the central precue, which would explain the discrepancy between the endogenous precueing results obtained in the present experiment and those obtained by Luiga and Bachmann.

Irrespective of whether our explanation for the discrepancy holds, the present study demonstrates that endogenous precueing of attention to the future target location attenuates OSM much in the same way as an exogenous precue. This implies that, on the basis of the current results, there are no grounds for arguing that the attentional modulation of OSM in substitution theory (Di Lollo et al., 2000) and its computational instantiation CMOS should be altered in any way (i.e., that the way in which attention is directed to the target, either exogenously or endogenously, should be taken into account as suggested by Luiga and Bachmann, 2007).

Furthermore, the suggestion offered by Luiga and Bachmann (2007) that localized sensory stimulation at the target location prior to the onset of the target-plus-mask display (as with a local exogenous precue) is essential for the attenuation of OSM (a prediction based on perceptual retouch theory; see Bachmann, 2007) is clearly not supported by the present results, as attenuation of OSM was observed without any localized sensory increments in the endogenous precue trials.

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References

Bachmann, T. (2007). Binding binding: Departure points for a different version of the perceptual retouch theory. *Advances in Cognitive Psychology, 3*, 41–55.

Bar, M. (2003). A cortical mechanism for triggering top–down facilitation in visual object recognition. *Journal of Cognitive Neuroscience, 15*, 600–609.

Bullier, J. (2001). Integrated model of visual processing. *Brain Research Reviews, 36*, 96–107.

Corbetta, M., Tansy, A. P., Stanley, C. M., Astafiev, S. V., Snyder, A. Z., & Shulman, G. L. (2005). A functional MRI study of preparatory signals for spatial location and objects. *Neuropsychologia, 43*, 2041–2056.

Cheal, M., & Lyon, D. R. (1991). Central and peripheral precueing of forced-choice discrimination. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 43A*, 859–880.

Deubel, H. (2008). The time course of presaccadic attention shifts. *Psychological Research, 72*, 630–640.

Di Lollo, V., Enns, J. T., & Rensink, R. A. (2000). Competition for consciousness among visual events: The psychophysics of re-entrant visual processes. *Journal of Experimental Psychology: General, 129*, 481–507.

Duncan, J., & Humphreys, G. (1989). Visual search and stimulus similarity. *Psychological Review, 96*, 433–458.

Enns, J. T. (2004). Object substitution and its relation to other forms of visual masking. *Vision Research, 44*, 1321–1331.

Enns, J. T., & Di Lollo, V. (1997). Object-substitution: A new form of masking in unattended visual locations. *Psychological Science, 8*, 135–139.

Eriksen, C. W., & Hoffman, J. E. (1973). The extent of processing of noise elements during selective encoding from visual displays. *Perception & Psychophysics, 14*, 155–160.

Grossberg, S., & Versace, M. (2008). Spikes, synchrony, and attentive learning by laminar thalamo-cortical circuits. *Brain Research, 1218*, 278–312.

Hochstein, S., & Ahissar, M. (2002). View from the top: Hierarchies and reverse hierarchies in the visual system. *Neuron, 36*, 791–803.

Jiang, Y. H., & Chun, M. M. (2001). The spatial gradient of visual masking by object substitution. *Vision Research, 41*, 3121–3131.

Kahan, T. A., & Mathis, K. M. (2002). Gestalt grouping and common onset masking. *Perception & Psychophysics, 64*, 1248–1259.

LaBerge, D. L., Brown, V., Carter, M., Bash, D., & Hartley, A. (1991). Reducing the effects of adjacent distractors by narrowing attention. *Journal of Experimental Psychology: Human Perception and Performance, 17*, 65–76.

Lamme, V. A. F., & Roelfsema, P. R. (2000). The distinct modes of vision offered by feedforward and recurrent processing. *Trends in Neurosciences, 23*, 571–579.

Lim, S. W. H., & Chua, F. K. (2008). Object substitution masking: When does mask preview work? *Journal of Experimental Psychology: Human Perception and Performance, 34*, 1108–1115.

Luiga, I., & Bachmann, T. (2007). Different effects of the two types of spatial pre-cueing: What precisely is "attention" in Di Lollo's and Enns' substitution masking theory? *Psychological Research, 71*, 634–640.

Müller, H. J., & Rabbitt, P. M. (1989). Reflexive and voluntary orienting of visual attention: Time course of activation and resistance to interruption. *Journal of Experimental Psychology: Human Perception and Performance, 15*, 315–330.

Neill, W. T., Hutchison, K. A., & Graves, D. F. (2002). Masking by object substitution: Dissociation of masking and cuing effects. *Journal of Experimental Psychology: Human Perception and Performance, 28*, 682–694.

Tata, M. S. (2002). Attend to it now or lose it forever: Selective attention, metacontrast masking, and object substitution. *Perception & Psychophysics, 64*, 1028–1038.

Tata, M. S., & Giaschi, D. E. (2004). Warning: Attending to a mask may be hazardous to your perception. *Psychonomic Bulletin & Review, 11*, 262–268.

Treisman, A., & Gelade, G. (1980). A feature integration theory of attention. *Cognitive Psychology, 12*, 97–136.

Treisman, A., & Gormican, S. (1988). Feature analysis in early vision: Evidence from search asymmetries. *Psychological Review, 95*, 15–48.

Van der Heijden, A. H. C., & Eerland, E. (1973). The effects of cueing in a visual signal detection task. *Quarterly Journal of Experimental Psychology, 25*, 496–503.

Woodman, G. F., & Luck, S. J. (2003). Dissociations among attention, perception, and awareness during object-substitution masking. *Psychological Science, 14*, 605–611.