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Attention attenuates metacontrast masking ☆

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Abstract

The influence of attention on perceptual awareness was examined using metacontrast masking. Attention was manipulated with endogenous cues to assess the effects on the temporal and spatial parameters of target visibility. Experiment 1 examined the time course of effective masking when the target and mask set were presented at an attended vs. an unattended location. The valid allocation of attention decreased the magnitude of the masking effect (i.e. increased visibility) for approximately 80 ms. Furthermore, even with spatial displacements of the target and mask and center-to-center separations of 1.5° or 2.7° of visual angle (Experiment 2), target visibility was increased when attention was validly allocated. These results indicate that attention influences low-level visual processes to enhance visual awareness.

Keywords: Vision; Awareness; Human

1. Introduction

The ability of humans to process a visual scene is a seemingly effortless task, however, it requires numerous cognitive resources. The allocation of attention is a vital component in enabling an individual to selectively process components of a visual

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field while ignoring others. How attention influences the processing of stimuli has been thoroughly investigated, but questions still remain as to the influence it has on temporal and spatial representations of the world around us. The temporal and spatial influences of attention on visual awareness were examined here in the context of a metacontrast masking paradigm.

Metacontrast masking occurs when a temporally proximal but spatially non-overlapping stimulus (mask) impairs detection of a preceding target stimulus (Breitmeyer, 1984). The stimulus onset asynchrony (SOA) between the target and the mask is varied, with detection of the target showing a U-shaped function. Target detection is high at very short target-to-mask SOAs but drops dramatically during the optimal masking SOAs, typically between 40 and 60 ms, and then gradually recovers to very high levels. Low-level visual processing theories have proposed that during the optimal masking time window, the trailing mask interferes with the ongoing early visual processing of the preceding target and can thus inhibit the target from entering conscious awareness (Breitmeyer, 1984; Breitmeyer & Ganz, 1976; Breitmeyer & Ogmen, 2000). However, recent evidence suggests that theories of low-level visual processing may not provide a complete picture of the mechanisms operating to produce metacontrast masking. Rather, there seems to be a complex interaction between high-level visual processes, such as visual selective attention, and masking.

Attention may play a role in the effectiveness of metacontrast masking and may serve to bring a target stimulus into awareness. For example, Tata (2002) examined the allocation of attention across a circular visual array containing either 1, 2, 4, or 8 distractors in a metacontrast masking paradigm. The typical U-shaped function with set sizes of 4 and 8 was found, with a steep decrease in performance with set size 8 that was larger and longer lasting than set size 4. However, there was no masking present at a set size of 1 or 2. This is consistent with earlier reports by Spencer and Shuntich (1970) who found that the masking function was extended under conditions of high attentional load (12 stimuli) compared to that of low load (one stimulus), suggesting that attentional load may interact with masking effects in such a way that high load produces more stimulus masking (cf. Lavie, 1995; Lavie & Cox, 1997).

Tata (2002) found in one of his experiments that exogenously orienting attention also modulates the masking function. Exogenous orienting was induced with a peripheral cue (a brief flash), with no predictive value, that reflexively oriented the subject's attention to one position in space (Posner & Cohen, 1984). When a cue was presented at the target location (valid cue) at least 50 ms prior to the array, Tata found that masking was reduced relative to when the cue was presented in the location of a distractor (invalid cue). These results indicate that an exogenous valid cue can aid in target detection (reduce masking) by orienting reflexive attention to the proper location. However, no difference was found between invalid trials and trials in which no cue was present, suggesting only a benefit without any costs of exogenous attention on metacontrast masking.

In another study, Shelley-Tremblay and Mack (1999) used stimuli that have been shown to be detected without attention to test the influence of salient, attention capturing stimuli on metacontrast masking. Studies of inattentional blindness, which occurs when one fails to detect a new or salient visual stimulus when attention is focused on another visual stimulus, have demonstrated that a happy face or a person's own name can avoid inattentional blindness and capture attention (Mack & Rock, 1998). Shelley-Tremblay and Mack found that detection of a happy face target followed by a metacontrast mask was greater (more resistant to masking) across all SOAs compared to inverted or scrambled faces. Also, detection of the person's own name was greater than the scrambled variant of their name or the word "TIME". They also examined the effectiveness of salient stimuli as masks, and found that target detection was worse when the target had been masked by the person's name than its scramble. Taken together it can be concluded that attention interacts with the mechanisms of metacontrast masking, and can facilitate performance (also see Ramachandran & Cobb, 1995).

The allocation of attention over spatial distances and across spatial resolutions has also been examined with respect to metacontrast masking. Such experiments explored the consequences of a spatial variance between a target and mask set. In a study by Enns and DiLollo (1997), for example, the location of the target/mask set was varied and positioned at fixation (foveally) or 3° to the left or right of fixation (peripherally). The masking effect produced by a metacontrast mask was optimal at an SOA of 45 ms, but increased substantially when the stimulus set appeared in a peripheral location as compared to when it was presented foveally. More interestingly, a mask consisting of just four dots presented around the target failed to produce any masking at the foveal location, but produced large masking effects when presented peripherally, with the optimal masking SOA of 45 ms mimicking that of the metacontrast mask at the foveal location. Their results suggest that a spatial separation of target and mask (four dot mask) can decrease the masking effect when presented foveally (increase conscious awareness of it), but fails to do so when presented peripherally. Furthermore, when stimuli appeared outside the focus of attention, masking was more effective at preventing stimulus entry into conscious awareness.

The current study varied the temporal and spatial properties between a circular target and an annulus mask and employed valid and invalid endogenous cues to assess the influence of spatial voluntary attention on target visibility using a metacontrast masking paradigm. If the allocation of endogenous attention can increase target detection, then the cueing of spatial attention to the proper location of a target/mask set should act in reducing the masking effect across time (Experiment 1). Furthermore, attention acts differentially on items outside its focus, then by varying the spatial distance between the target and mask peripherally, we can assess the greatest spatial separation sufficient to produce a masking effect and can determine how that distance changes with the allocation of attention (Experiment 2). Due to the heightened effectiveness of masking outside the focus of attention, it is predicted that more masking will occur between spatially distant items predominantly in the invalidly as compared to the validly cued condition.

2. Experiment 1

2.1. Method

2.1.1. Participants

Eighteen undergraduate students from Rice University participated in this experiment for partial fulfillment of a course requirement. There were two left handed participants; all other subjects were right handed. Five males and 13 females, ranging in age from 18 to 21 (mean = 19) participated after informed consent, which along with this study was approved by the Institutional Review Board at Rice University. All subjects had normal or corrected to normal vision.

2.1.2. Stimuli, apparatus, and procedure

The stimuli were presented on a 17-inch Sony monitor set at 70 Hz and were viewed from a distance of 57 cm. The fixation dot, which remained present throughout the entire experiment, was displayed at the center of the screen and was 0.3° of visual angle in diameter. Eye movements were not monitored, but participants were repeatedly instructed to keep their eyes on the fixation point at all times. At the beginning of a trial, an arrowhead (a less than or greater than symbol) that served as the cue pointed to the left or the right visual field and was presented at fixation for 214 ms. The cue measured 1° in height, 0.5° in width and the end of each segment of the cue was 0.5° directly above or below the center of fixation. The tip/point of the cue was 0.5° to the right or left of the center of fixation. After a 429 ms ISI the target/mask set was presented either in the left or right visual field. The target/mask set consisted of a small solid circle (a disk) measuring 1° in diameter followed by a surrounding, but non-overlapping annulus measuring 2° in diameter. The center of the target/mask set (i.e. the center of both circles) was presented 5° of visual angle to the left or right of fixation. The target and mask were presented for 14.3 ms each and were light gray on a black background (see Fig. 1). The subject responded on a two-button box whether both the target and the mask were detected or just the mask was detected. Given that a target and mask stimulus was presented on every trial, the subject's response was based on a subjective criterion and reflected the subject's percept on any given trial. Subjects were told to respond as quickly and accurately as possible. A new trial was then presented after a 1286 ms intertrial interval.

The cue validly indicated the location of the following target/mask set on 70% of trials. There were eight different SOAs between the target and mask (0, 28, 57, 86, 114, 143, 171, and 200 ms), with 100 trials (70 validly cued and 30 invalidly cued) of each SOA randomly distributed over the course of the experiment. Each session began with approximately 20 practice trials in order to familiarize the participant with the task and to answer any questions. The practice trials were identical in format to the experimental trials. There was a total of 800 experimental trials resulting in a total session time of approximately 1 h. Subjects were given a break every 160 trials, with a duration of their choosing. Response button assignment was counterbalanced across subjects.

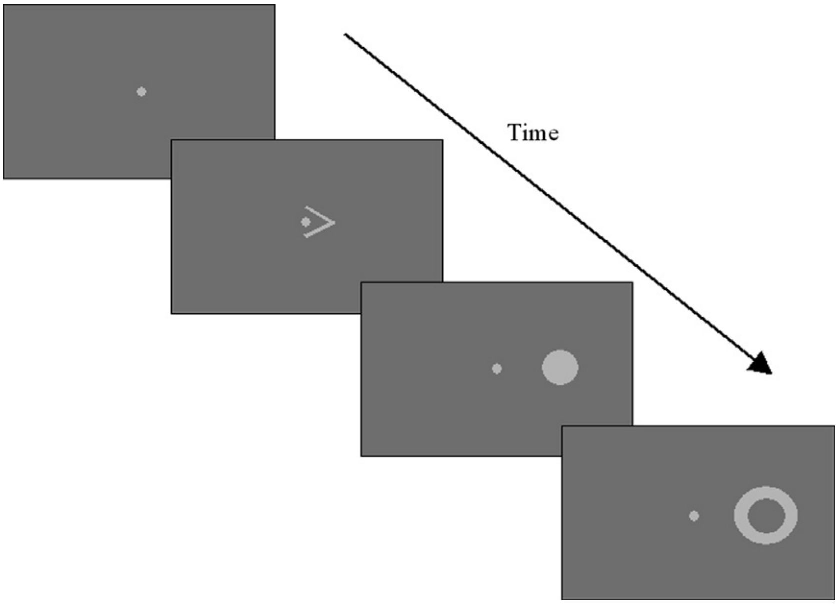

Fig. 1. Schematic showing the sequence of events on a typical trial in Experiment 1 (a valid trial is shown).

2.1.3. Design and analyses

The data were analyzed with a 2 cue validity (valid, invalid) × 8 SOA (0, 28, 57, 86, 114, 143, 171, and 200 ms) repeated measures ANOVA. The dependent measures were response time and percent of target detection. Separate analyses were conducted for each dependent variable.

2.2. Results and discussion

All reaction times greater than or less than two standard deviations from the conditional means and all trials in which the subject failed to respond within 1500 ms were excluded from the main analyses. This led to the exclusion of 7.95% of trials. Target detection rates were calculated for each condition and are presented in Fig. 2a. Results of the ANOVA revealed a significant main effect of cue validity, $F(1,17) = 13.93$, $p = .002$, with detection rates of the target disk greater when the cue was valid vs. when it was invalid. There was also a significant main effect of SOA, $F(7,119) = 98.43$, $p < .001$, reflecting optimal masking at an SOA of 28 ms, followed by a gradual recovery over time. The interaction between cue validity and SOA was also significant, $F(7,119) = 2.51$, $p = .019$. Pairwise comparisons revealed reliably greater detection rates in the validly cued condition than in the invalidly cued condition at the 84, 112, and 140 ms SOAs (all *p*s < .05).

Mean response times were also calculated for each condition and are presented in Fig. 2b. Results of the ANOVA on RTs revealed a significant main effect of cue valid-

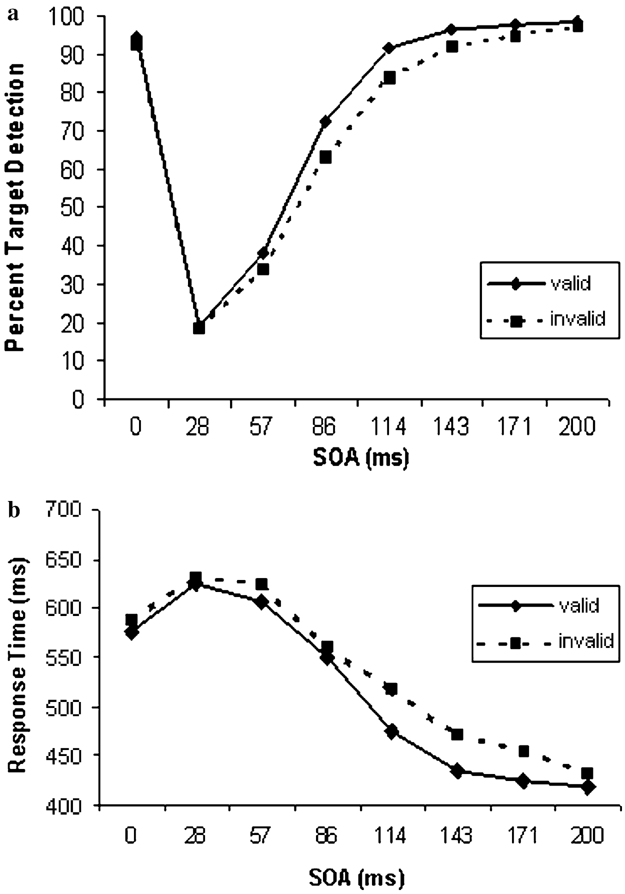

Fig. 2. (a) The percent of target detection for the validly and invalidly cued conditions at each SOA. (b) The mean response times for the validly and invalidly cued conditions at each SOA (Experiment 1).

ity, $F(1,11) = 21.18$, $p < .001$, with faster reaction times when the cue was valid than when it was invalid. There was also a significant main effect of SOA, $F(7,119) = 53.53$, $p < .001$, due to slower responses at the 28 ms SOA that then gradually got faster with longer SOAs. There was also an interaction between cue validity and SOA, $F(7,119) = 2.36$, $p = .03$, reflecting faster responses when the cue was valid than when it was invalid predominately at longer SOAs. Pairwise comparisons revealed reliably faster responses in the validly cued condition than in the invalidly cued condition at the 0, 114, 143, 171, and 200 ms SOAs (all ps < .05).

Experiment 1 demonstrated that the valid allocation of endogenous attention reduces the magnitude of the masking effect relative to the invalidly cued condition. The effect of attention was seen during the recovery period following maximal masking at the 28 ms SOA (i.e. on the positive slope of the U-shaped function), with higher target detection rates and faster recovery from masking in the validly cued condition relative to the invalidly cued condition. This difference dissipated by the 200 ms SOA at which target detection rates in both conditions returned to near ceiling levels. These findings indicate that attention modulates the temporal parameters of metacontrast masking.

The next experiment examined the influence of attention on the spatial parameters of masking. Experiment 2 was designed to test the degree of spatial separation between the target and mask that would still produce masking effects when the stimuli were presented in the periphery. The distance between the target and mask were varied along the vertical axis. It should be noted that the presentation of a mask in a spatially distinct location violates the "spatially overlapping" parameter inherent in the definition of metacontrast masking. Therefore, it may be more correct to say that we used metacontrast masking stimuli (i.e. target disk and mask annulus) to examine attentional effects on visual backward masking, of which metacontrast is a form. Also, metacontrast stimuli were chosen to compare any masking effects seen in this second experiment with that from the first. The SOA between the target and mask was kept constant at 57 ms because this was an intermediate SOA at which optimal masking was measured.

3. Experiment 2

3.1. Methods

3.1.1. Participants

Twenty-four undergraduate students from Rice University participated in this experiment as partial fulfillment of a course requirement. All participants were right handed with normal or corrected to normal vision. There were 14 males and 10 females, ranging in age from 17 to 22, with a mean age of 20. All participated after informed consent.

3.1.2. Stimuli, apparatus, and procedure

The stimuli were the same size and shape as those used in Experiment 1, and were presented using the same computer. The target/mask set presented in the left or right visual field (as in Experiment 1) were presented as overlapping, near, or far from each other, along the vertical axis (see Fig. 3). The stimulus parameters in the overlapping condition (the same spatial location) were the same as those at the 57 ms SOA of the previous experiment. In the near condition, the outer diameter of the target was aligned with the outer diameter of the annulus, and the point at which they were aligned was on the horizontal axis. The distance from the center of the target to the center of the mask was 1.5° of visual angle. In the far condition, there were 1.2° of visual angle between the edges of the target and the mask, for a total of 2.7° from the center of the target to the center of the mask. The target and the mask were equidistant from the horizontal axis. The sequence of events on any given trial was the same as in the prior experiments except that the SOA between the target and mask was held constant at 57 ms and the target/mask

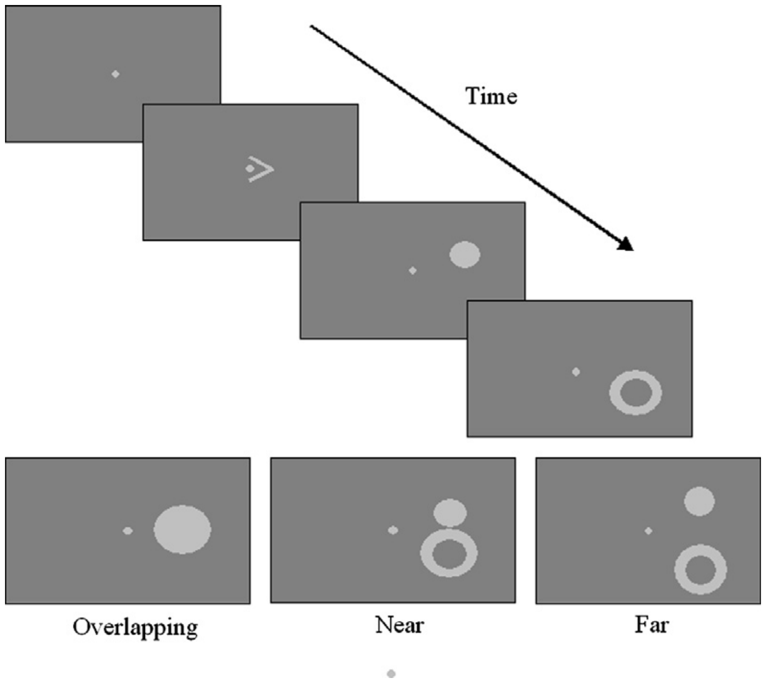

Fig. 3. The top portion is a schematic showing the sequence of events on a typical trial in Experiment 2. The bottom portion shows the spatial separation between the target/mask set if their corresponding frames were hypothetically superimposed.

set could be either overlapping (as in the previous experiments), near, or far from each other.

As in Experiment 1, the cue validly indicated the location of the following target/mask set on 70% of trials. There were three different locations of the target and mask; overlapping, near, and far, with 100 trials (70 validly cued and 30 invalidly cued) of the overlapping condition and 200 trials (140 validly cued and 60 invalidly cued) for each of the near and far conditions. All trial types were randomly intermixed within each block of 100 trials, with the constraint that any given condition could not be repeated on three sequential trials. On half of the trials in the near and far conditions (or 100 trials each; 70 validly cued and 30 invalidly cued) the target appeared above the horizontal axis and the mask appeared below it, whereas in the other half of the trials, the target appeared below the horizontal axis and the mask appeared above. Each session began with approximately 20 practice trials in order to familiarize the subject with the task and to answer any questions. The practice trials were identical in format to the experimental trials. There was a total of 500 experimental trials per session, resulting in a total session time of approximately 45 min. Subjects were given a break every 100 trials, with a duration of their choosing. Response button assignment was counterbalanced across subjects.

3.1.3. Design and analyses

The data were subjected to a 2 cue validity (valid, invalid) × 3 location (overlapping, near, far) repeated measures ANOVA. The location variable was collapsed across target above/below for the near and far conditions as preliminary analyses showed no differences for these conditions. The dependent measures were response time and percent of target detection. Separate analyses were conducted for each dependent variable.

3.2. Results

As in Experiment 1, reaction times greater than or less than two standard deviations from the conditional means were excluded. This led to the exclusion of 6.7% of trials. Target detection rates were calculated for each condition and are presented in Fig. 4a. Results of the ANOVA revealed a significant main effect of location, $F(2,46) = 276.67$, $p < .001$, such that target detection rates were highest in the far condition, followed by the near condition, and were lowest in the overlapping condition. The main effect of cue validity approached significance, $F(1,23) = 3.41$, $p = .08$. There was a significant interaction between cue validity and location, $F(2,46) = 3.30$, $p < .05$. Importantly, planned pairwise comparisons revealed reliably greater target detection rates in the validly cued condition than in the invalidly cued condition at the far location ($p < .05$), and at the near location ($p < .05$) (see Fig. 4a). Due to the lack of a significant validity effect in the overlapping condition, we conducted an additional analysis to test for any attentional differences between experiments. The experiment by validity interaction was not significant ($F(1,40) = 3.195$, $p > .05$), indicating that the attentional effect at the 57 ms SOA did not differ between the two experiments. The lack of a significant attentional effect in the overlap condition of this experiment may be due to the presentation of this condition in the context of the more visible targets in the displacement conditions.

Mean response times were calculated for each condition and are presented in Fig. 4b. Results of the ANOVA revealed a significant main effect of cue validity, $F(1,23) = 22.18$, $p < .001$, due to faster reaction times when the cue was valid vs. when it was invalid. There was also a significant main effect of location, $F(2,46) = 10.47$, $p < .001$; reaction times were fastest in the far condition, followed by the near and the overlapping conditions, respectively. The cue validity by location interaction was not significant ($p > .05$). Pairwise comparisons revealed reliably faster responses in the validly cued condition than in the invalidly cued condition for all locations (all ps $< .02$).

4. General discussion

This study sought to determine the influence of attentional allocation on target visibility using a metacontrast masking paradigm. It was hypothesized that allocating attention through the use of an endogenous cue would modulate the masking effect. The overall effectiveness of the cues in allocating attention was demonstrated via

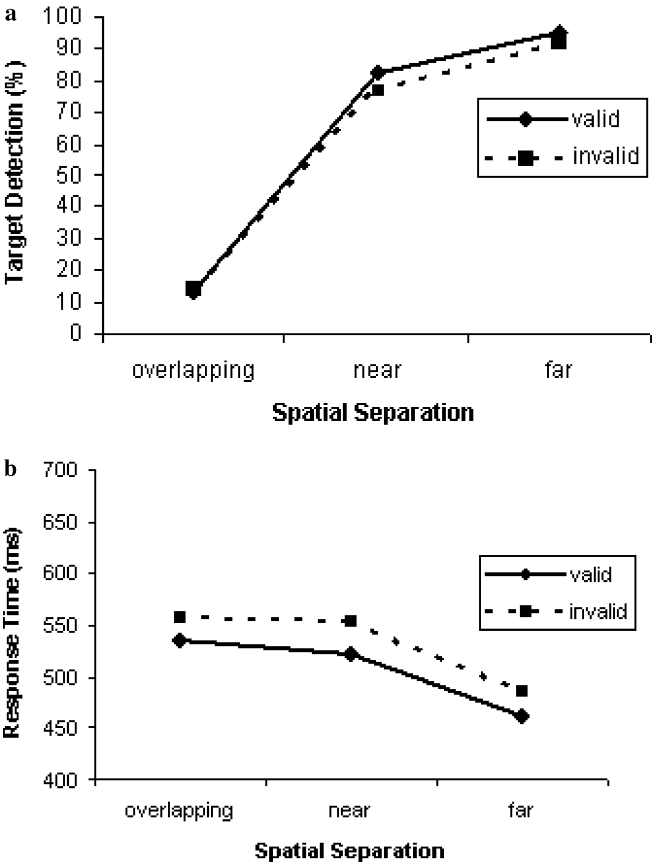

Fig. 4. (a) The percent of target detection for the validly and invalidly cued conditions at varying target/mask spatial separations. (b) The mean response times for the validly and invalidly cued conditions at varying target/mask spatial separations (Experiment 2).

faster response times and higher target detection rates when the cue was valid than when it was invalid. Furthermore, when attention was allocated to the target, visibility of that target was increased and the effectiveness of the trailing mask was reduced, thus producing an attenuated masking function. Conversely, when attention was invalidly allocated, visibility of the target was reduced producing lower detection rates and in turn a larger masking function with a slower recovery time, compared to when attention was validly allocated. The effect of attention was greatest when responses were not at floor or ceiling, but in the intermediate ranges. More specifically, this difference between the target detection rates within (valid) and outside (invalid) the focus of attention began at an SOA of approximately 86 ms and lasted until the 171 ms SOA, resulting in an attentional effect of over 80 ms. The effects of attention influenced both detection rates and reaction times in a similar manner, thus ruling out any effects due to a speed accuracy trade-off.

These results are consistent with a growing body of evidence demonstrating the effects of attention on masking, including a recent study involving the voluntary direction of attention, in which target visibility ratings were increased with the valid allocation of attention (Havig, Breitmeyer, & Brown, 1998) and with studies showing a modulatory effect of salient stimuli (Shelley-Tremblay & Mack, 1999), attentional load and exogenous cueing (Spencer & Shuntich, 1970; Tata, 2002), and disperse attentional focus (Enns & DiLollo, 1997) on the metacontrast masking function. Importantly, our results extend these previous findings by demonstrating the time course of the modulatory effects of attention on masking and show that the allocation of attention also modulated the masking effect even when the target and mask were in spatially distinct locations as in Experiment 2. Specifically, when the external borders of the target and mask were aligned, target detection rates were 6% higher when attention was validly allocated than when it was not, and when the target and mask were separated by 1° of visual angle, target detection rates were 3% higher when the target was within the focus of attention. In other words, when the target/mask set were spatially separated by 1°, overall detection rates increased, but the absence of focused attention produced more masking (lower detection rates) than when attention was properly allocated. These data support the hypothesis that differential processing occurs on items within and outside the focus of attention and that under conditions of inattention a spatially separate target and mask set may be mislocalized to produce a masking effect.

The idea that differential processing occurs within and outside the focus of attention has been noted by Treisman and others. Treisman has proposed that stimuli outside the focus of attention are left susceptible to haphazard binding (e.g. illusory conjunctions), and thus errors in perception (Treisman & Gelade, 1980; Treisman, 1988). In the case of the spatially separate target/mask set, attention may be needed to anchor these stimuli to their respective spatial locations. In the absence of focused attention such stimuli may lack the correct spatial "tags" resulting in a masking effect through their mislocalization. Conversely, when attention is directed to the target/mask set, the proper spatial "tags" are given to the stimuli and the target is perceived as a distinct object in a distinct location, resulting in an attenuated masking effect.

The effects of attention on metacontrast masking might be a consequence of two very different influences of attention on target detection. It may be the case that attention is acting to facilitate target visibility and reduce the magnitude of masking, or it may be that without the valid allocation of attention the target is never perceived (i.e. there is inattentional blindness). While this question cannot be answered definitively based on the current data, a previous study by Tata (2002, Experiment 2) measured the effects of exogenous attention on object substitution masking using valid, invalid, and no cue (neutral) conditions. In that study, he found that there was no difference between the invalid and no cue conditions, but that the valid allocation of attention produced a detection facilitation in comparison to the other two conditions. Thus, a benefit in attended target detection rather than a cost for unattended target detection was measured. Based on this evidence, it is likely that the current results also reflect an attentional enhancement of the target with the valid allocation of attention rather than an impairment or inattentional blindness of the target in the unattended conditions. However, further research is necessary to validate this assumption for voluntary orienting.

An alternative interpretation of the results from Experiment 2 is that the spatial displacement of the mask from the target resulted in a strong perception of apparent motion, and that this perception of apparent motion is what was affected and produced the modulations of masking with attention. Perception of apparent motion between a target and a mask, despite large differences in their physical shapes (cf. Kolers & Pomerantz, 1971), has previously been shown to be related to the mechanisms producing object substitution and metacontrast masking (DiLollo, Bischof, & Dixon, 1993; Kahneman, 1967; Lleras & Moore, 2003; Stoper & Baniffy, 1977). Although apparent motion is optimally perceived at longer interstimulus intervals than the 43 ms ISI used in Experiment 2 (Kolers, 1972; Petersik, 1989; see also Grossberg & Rudd, 1992), Lleras and Moore have suggested that apparent motion can also be perceived with object substitution masking stimuli at very short ISIs (<35 ms). To assess whether apparent motion may have been perceived and potentially influenced the magnitude of masking measured in Experiment 2, we conducted a follow-up experiment that was similar to Experiment 2, but with slight changes in the methods[1]. Most notably, rather than having participants detect whether one or two items/objects were presented on each trial, the task was instead to report whether apparent motion between the elements in the display was perceived or not. There was indeed a high percentage of apparent motion reports at the critical 57 ms SOA (i.e. 43 ms ISI) conditions, which in fact was marginally ($p = .08$) greater than the percentage of apparent motion reports at the typically more optimal 100 ms SOA (i.e. 86 ms ISI). These results suggest that attention may have been influencing the magnitude of masking by apparent motion in Experiment 2, rather than the magnitude of metacontrast masking per se. Although this interpretation should not be ruled out, previous studies have demonstrated that the perception of apparent motion is not necessary for producing metacontrast masking (Breitmeyer & Horman, 1981; Stoper & Baniffy, 1977). This suggests that there may have been attentional modulations on masking that were independent from those due to masking by apparent motion in our experiments. Regardless of the exact nature of how attention influences the magnitude of metacontrast masking, our main results demonstrate that the valid allocation of attention acts to increase the visibility and probability of target detection.

The findings that the valid allocation of attention reduces the masking function and that a spatially separate target/mask set may still produce masking in the absence of focused attention argues against a purely low-level visual theory of masking. Based on the evidence presented here and that of prior studies (Havig et al., 1998; Shelley-Tremblay & Mack, 1999; Tata, 2002; Enns & DiLollo, 1997), a theory postulating an interaction between visual and attentional mechanisms seems more

[1] The stimuli, apparatus, and procedures for this experiment were identical to Experiment 2 except for the following two changes. First, no arrow cue was presented at the center of the screen prior to each trial. Second, two target-to-mask SOAs were used: 57 and 100 ms. A total of 13 participants completed this study, with the data from two participants having to be discarded because the wrong response buttons were used.

appropriate (Breitmeyer & Ogmen, 2000). Attention has demonstrated the ability to strengthen or weaken the masking effect, while preserving the typical metacontrast U-shaped function, suggesting that there is a complex interplay between visual processing and attention.

Interestingly, the effects of attention primarily occur within a window of the non-optimal masking conditions: after the period of optimal masking (the 28 ms SOA) and before the end of masking function in Experiment 1, and in the spatially non-overlapping conditions of Experiment 2, when performance is not at floor (overlapping condition) or at ceiling. This suggests that at very short temporal intervals or under conditions of highly effective masking, suppression of target visibility from a mask can occur before attention has a chance to enhance target visibility. At longer SOAs or with greater spatial separations, however, attention may enhance token individuation of the target, thus making it more resilient to the presentation of the trailing mask. Other studies have also shown that different attentional manipulations can produce differential effects on the masking function. For example, Michaels and Turvey (1979) reported that masking of a target word was reduced compared to masking of a non-word, due to the automaticity of word reading. However, as in the case of the present study, they found the attentional differences only after the period of optimal masking (40 ms) on the positive slope of the masking function. More recently, Tata (2002) showed that larger attentional loads produced a deeper and longer-lasting masking function, with optimal masking occurring at 80 ms. In another study, under conditions of dispersed attention, optimal masking was shown to occur at a 45 ms SOA for a single item display, but at a 90 ms SOA for a triple item display (Enns & DiLollo, 1997). Taken together, these studies implicate a role of attention at very select and specific stages of visual information processing, subsequent to the initial entry of information into the visual system and prior to full and complete processing of it.

One minor discrepancy in the data that deserves some discussion is the finding that attention did not influence performance in the overlapping condition of Experiment 2, but did have a small, but not significant numerical trend in affecting performance in the same condition of Experiment 1. This difference, which was not significant in the between-experiments analysis, is likely the result of methodological and contextual differences between the two experiments. In Experiment 2 only one-fifth of the trials contained stimuli in the same spatial location (the standard metacontrast masking condition), and based on the findings from Experiment 1 and previous work (see Breitmeyer, 1984), the proportion of times that subjects would be able to perceive two items under these conditions was small (approximately 35% in the current study; see Fig. 2). Therefore, subjects may have been expecting to detect two items in spatially separate locations on each trial of Experiment 2 (due to the higher probability of occurrence for this percept). This context expectancy effect in Experiment 2 may have made target disk detection even more difficult when the target and mask were presented in the same location. In fact, the overall target detection rate in the overlapping condition decreased by more than 50% in Experiment 2 as compared to the analogous condition of Experiment 1. This change in detection performance was associated with a decrease in the influence of attention in the 57 ms

SOA overlapping condition of Experiment 2, providing more evidence that attention primarily exerts its influence when detection performance is not near floor or ceiling levels (cf. Experiment 1). Also, previous unpublished work from our laboratory suggests that context is an important factor in influencing the magnitude of metacontrast masking in that when SOAs of 0, 14, 29, 43, 57, 72, 86, and 100 ms were used in an otherwise identical experiment to Experiment 1, performance at the 57 ms SOA was again different from the current experiments. The target detection rates at the 57 ms SOA in this other experiment were 53% in the valid condition and 43% in the invalid condition; they were 39% in the valid condition and 33% in the invalid condition at the 56 ms SOA in Experiment 1, and were 13% and 14%, respectively, in Experiment 2. The difference in target detection rates in the three experiments for the very same condition indeed suggests that context plays a large role in these masking effects.

Persistent neural activity in early visual areas has been shown or has been suggested to occur well after the presentation of a visual stimulus (Lamme & Roelfsema, 2000; Ro, Breitmeyer, Burton, Singhal, & Lane, 2003; Vidyasagar, 1998). This recurrent activity has been proposed to produce top-down modulatory effects on visual awareness and subsequent performance via feedback projections from higher-order processing regions, such as those in the parietal lobe involved in attention. Therefore, during the range of SOAs from approximately 84 to 168 ms, when attention produced modulations of the metacontrast masking function, it may be that attention was acting to facilitate processing of the target in early visual cortex, and that this attentional modulation was sufficient for inducing token individuation of the target through feedback projections, preventing interference from the trailing mask. Although this interpretation makes predictions about neural processes not directly tested here, the localization of such attentional effects on early visual processes warrants further investigation and may shed insight into the influences of attention on visual awareness.

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