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New object onsets reduce conscious access to unattended targets

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Abstract

Attention to a visual target can affect perception of a subsequent target for half a second, increasing its sensitivity to backward masking (the attentional blink, AB). In 6 studies, we compared the AB when the second target and its mask had a common onset and when the mask appeared after the target. The results indicate that common-onset masks do not produce large ABs even when there is a feature change or an interruption of the mask after the target but do produce a large AB if the location of the mask is changed. The data suggest that new object onsets reduce conscious access to unattended targets.

Keywords: Visual perception; Target identification; Attention; Common-onset masking; Metacontrast masking

1. Introduction

Visual perception has fundamental temporal limitations. For example, when a brief image (a target) is closely followed by a second image (a mask), the perception of the target image can be impaired (Breitmeyer, Battaglia, & Weber, 1976; Enns & Di Lollo, 2000; Rogowitz, 1983). Backward masks have an even larger interference effect when targets are unattended. When attention has been engaged on a previous task in the last half-second, a backward mask can interfere with target identification even if it was insufficiently strong to mask an attended target. This effect has often been observed when two successive targets are embedded in a rapid stream of visual stimuli; attention to the first target producing a significant interference on the second target when it is followed by a backward mask, the attentional blink (AB) (Raymond, Shapiro, & Arnell, 1992; Seiffert & Di Lollo, 1997).

The exact role of masks in the AB effect is still unclear. The amplitude of the AB can be influenced by masking properties such as target–mask discriminability and proximity (Chun & Potter, 1995; Grandison, Ghirardelli, & Egeth, 1997; Maki, Bussard, Lopez, & Digby, 2003; Raymond, Shapiro, & Arnell, 1995; Seiffert & Di Lollo, 1997). However, increasing the amount of masking at the first (T1) or second target (T2) does not necessarily enhance the AB (McLaughlin, Shore, & Klein, 2001). The type of mask accompanying the second target appears to play a critical role in the AB. When T2 is masked by a simultaneous and spatially overlapping stimulus (integration masking) no AB is observed, while an AB is present when the mask follows the offset of the second target (interruption masking) (Brehaut, Enns, & Di Lollo, 1999; Giesbrecht & Di Lollo, 1998). Giesbrecht and Di Lollo (1998) hypothesized that a critical masking effect underlying the AB is the substitution of the second target in the visual system by a new pattern while the target is unattended.

The object substitution hypothesis has been explored with common-onset masks which overlap temporally but not spatially with the target and last longer than the target (Giesbrecht & Di Lollo, 1998). Common-onset masks can produce a strong interference on identification of the associated target. However, there is evidence that common-onset masking of the second target does not produce a strong attentional blink. Giesbrecht, Bischof, and Kingstone (2003) did not find any AB when the second target was accompanied by a four-dot common-onset mask and

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they did not find any interaction between the AB and masking strength. This suggests that specific processes, crucial for the AB, are absent in common-onset masking. These data also shed doubt on the notion that the role of interruption masks in the AB is linked to object substitution. The AB observed using interruption masks may thus depend on some other property of post-target stimuli.

Giesbrecht et al. (2003) proposed that early visual processing of the unattended target is disrupted by a trailing mask in the AB. This hypothesis is supported by data showing that the AB can disappear in scotopic vision (Giesbrecht, Bischof, & Kingstone, 2004). However, the difficulty of integration masking, which should increase early masking, does not appear to affect the AB (Brehaut et al., 1999). Also, there is evidence that four-dot masking, thought to involve late visual processing, can produce an AB when mask onset occurs after target offset (Dell'Acqua, Pascali, Jolicoeur, & Sessa, 2003; but see Giesbrecht et al., 2003). It thus appears that both distant and overlapping mask shapes can produce an AB when presented after target offset, but not if the target and the mask have a common onset.

Previous work suggests that when masks follow the target, the AB is not strongly affected by the target–mask delay within a certain range (Giesbrecht & Di Lollo, 1998; McLaughlin et al., 2001). However, the effect of the temporal overlap between target and mask has not been examined parametrically in the same task. The present studies addressed this question by examining the effect on the AB of the temporal overlap between target and mask using metacontrast figures. Metacontrast figures have close contours which create interference between the target and the mask. Masking can be obtained with metacontrast figures, even when the target and the mask have a common onset, if the mask lasts longer than the target (Di Lollo, Bischof, & Dixon, 1993). In the following studies, we used metacontrast figures to directly test the effect of target–mask asynchrony on the AB.

2. Experiment 1

Common-onset masking is often examined in tasks in which attention is spatially distributed (Di Lollo, Enns, & Rensink, 2000; Enns & Di Lollo, 1997). The first experiment was aimed at verifying that common-onset masking could be obtained using centrally presented metacontrast figures that can also be used for delayed-onset masking. There is evidence that metacontrast figures consisting of dotted squares can produce strong common-onset masking (Di Lollo et al., 1993). These stimuli were adapted for use as both delayed-onset masks and common-onset masks and the first experiment examined the effect of mask duration on target identification.

2.1. Method

2.1.1. Subjects

Thirteen normal adults (6 women) aged between 21 and 30 years old (mean age: 25 years) participated in the study. Informed consent was obtained before testing and subjects received a compensation of $10 for their participation. All subjects were naïve with respect to masking tasks and all had normal or corrected to normal vision.

2.1.2. Stimuli and procedure

Targets consisted of a white square presented centrally on a black background and containing one or two gaps (side: 2.3 cm; thickness: 1 mm; see Fig. 1A). Each target was accompanied by a mask consisting of a dotted square containing eight gaps (side: 1.9 cm; thickness: 2 mm) placed inside and in close proximity to the target square. In each trial, the subject had to detect whether the target square contained one or two gaps by pressing one of two keys on a keyboard. The gaps in the targets were located in pseudo-random locations, the gaps in the target matching one of the gaps in the mask. To reduce detection difficulty, the combinations in which two gaps were on opposite sides of the square were not used.

Trials began with the word "GO" presented centrally, indicating that the subjects could press a key to start the trial. At the keypress, a fixation cross appeared during 800–1200 ms followed by the target and its mask. Targets and masks had a simultaneous onset. Targets were presented for 94 ms and masks for one of four durations after target offset (T + 0, +59, +94 or +294 ms) randomly distributed across trials. Three blocks of 80 trials were presented for a total of 60 trials per conditions.

Stimuli were presented on a CRT screen (refresh rate: 85 Hz) at a viewing distance of 50 cm under standard overhead fluorescent lighting. The sequence was controlled by a Pentium IV PC running E-prime 1.0 software (PST).

2.2. Results and discussion

Target identification performance is summarized in Fig. 1B. Target identification accuracy decreased with longer mask duration. Analyses of variance (ANOVAs) on the proportion of correct target identifications confirmed a significant effect of mask duration, $F(3,36) = 29.87$, $p < 0.001$ and contrasts showed a significant decrease between T + 0 and T + 59, $F(1,12) = 34.80$. $p < 0.001$, and between T + 94 and T + 294, $F(1,12) = 5.87$, $p < 0.05$, but not between T + 59 and T + 94, $F(1,12) = 0.26$, $p = 0.62$.

These results confirm that common-onset masking can be obtained at central fixation with metacontrast figures and that it is sensitive to the duration of the mask after the offset of the target. Previous work has shown mask duration effects using short target duration (10–50 ms) (Di Lollo, & Bischof, et al., 1993; Di Lollo, & Enns, 2000). In our paradigm, masking was obtained despite relatively long target presentation times. This could be linked to the complexity of the stimuli used in our study, (e.g. the number of potential gap locations). When the mask and the target had the same duration, the performance was not at 100% accuracy, $t(12) = 41.27$, $p < 0.001$. This confirms the presence of some degree of contour interactions between the target and the mask when they overlap temporally.

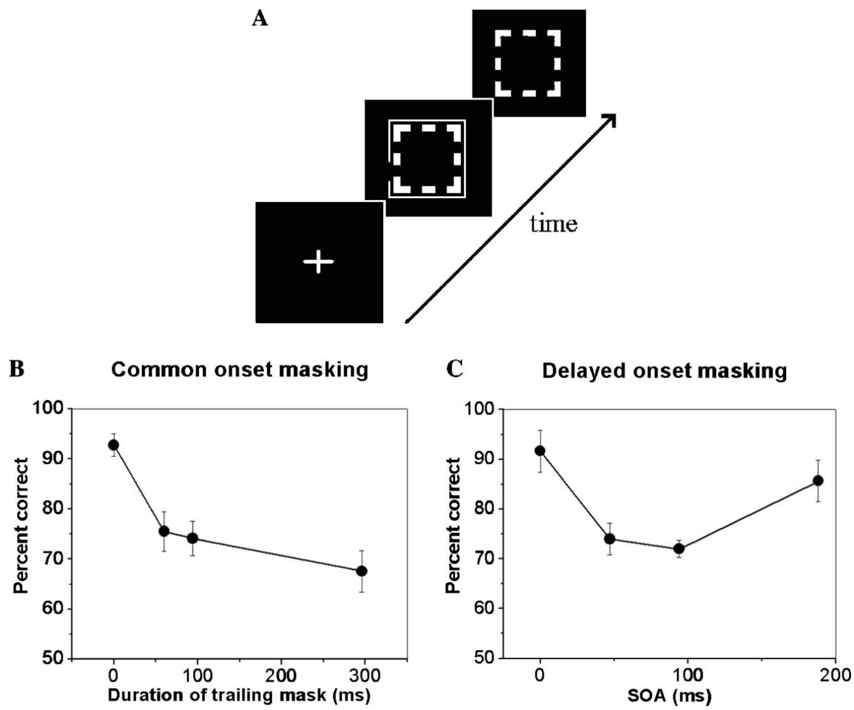

Fig. 1. (A) Schematic representation of stimuli. (B) Single target detection performance (mean ± SEM) as a function of the duration of the common-onset mask. (C) Single target detection performance as a function of the SOA of a delayed-onset mask.

To verify if our delayed-onset condition produced a masking effect, we performed a control study on 5 different adults. The stimuli and parameters were identical to the common-onset masking experiment except that the mask duration was 94 ms and the independent variable was the stimulus onset asynchrony (SOA) (0, 50, 94 or 188 ms). We found a significant effect of SOA, $F(3,12) = 37.33$, $p < 0.001$. Contrasts analyses showed a reduction in performance between 0 and 50 ms, $F(1,5) = 130.65$, $p < 0.001$, no significant difference between 50 and 94 ms, $F(1,5) = 1.0$, $p = 0.37$, and a higher performance at an SOA of 188 ms compared to 94 ms, $F(1,5) = 26.47$, $p = 0.007$ (see Fig. 1C). These results confirm that both our common-onset and delayed-onset condition produced a significant masking effect.

3. Experiment 2

Experiment 1 indicated that common-onset masking and delayed-onset masking could be obtained with the same centrally presented metacontrast figures. This enables us to compare common-onset masking and delayed-onset masking in the same task. We examined the sensitivity of the attentional blink to the timing of mask onset at T2. We predicted that no AB should be observed if T2 was accompanied by a common-onset mask, while a delayed-onset mask should produce an AB.

3.1. Method

3.1.1. Subjects

Thirteen normal adults (5 women) aged between 21 and 31 years old (mean: 25 years) participated in this study. Informed consent was obtained before testing and subjects received a compensation of 10$ for their participation. All subjects were naïve with respect to masking tasks and had normal or corrected to normal vision. Three subjects that showed a T1 performance below 65% were excluded.

3.1.2. Stimuli and procedure

In this experiment, stimuli were identical to those used in the first experiment but participants performed a dual detection task. Trials consisted of four successive white squares presented centrally on a black background. The first and the third squares were targets (T1 and T2) and the second and fourth were masks (M1 and M2). In the common-onset condition, T2 (duration: 94 ms) and M2 (duration: 224 ms) appeared simultaneously, whereas in the delayed-onset condition, M2 (duration: 94 ms) was presented 35 ms after the offset of T2. T1 was always masked by a delayed-onset mask. Instructions and stimuli were the same as in the first experiment, with the exception that in each trial the subject had to detect two target squares presented in a sequence and produce one response (one or two gaps) per target. Targets were separated by an SOA of either 757 or 309 ms. Each subject was first trained in a session of 20 masking trials (i.e. only one target) with two possible conditions (common-onset or delayed-onset masking) randomly distributed across trials. After training, subjects performed 3 blocks of 80 trials of the dual task.

3.1.3. Data analysis

Analyses were performed on the proportion of trials on which T2 was correctly reported, conditional on correct report of T1 (T2|T1).

3.2. Results and discussion

In Experiment 2, the independent variables were the inter-target lag (309 or 757 ms) and the T2 masking condition (common-onset or delayed-onset masking). T1 performance averaged 83% correct across conditions and lags with no significant effects of lag or masking condition. Analyses of T2|T1 performance showed a significant effect of lag, $F(1,9) = 30.89$, $p < 0.001$, and a significant interaction of Lag by Masking condition, $F(1,9) = 17.94$, $p = 0.002$ (Fig. 2). The amplitude of the AB, as indicated by the lag effect, was significant both in delayed-onset (AB amplitude = 22.59%; $F(1,9) = 30.27$, $p < 0.001$) and common-onset masking conditions (AB amplitude = 6.72%; $F(1,9) = 11.10$, $p = 0.009$). However, the amplitude of the AB was larger with delayed-onset masking than with common-onset masking, $F(1,9) = 17.94$, $p = 0.002$, despite a weaker masking effect, as indicated by T2 performance at long inter-target lag, $F(1,9) = 30.27$, $p < 0.001$.

There was a large difference in T2 accuracy between the delayed- and common-onset conditions at the long inter-target lag, and this could have produced a floor effect in the common-onset condition at the short inter-target lag. To test this possibility, we performed a control experiment on seven subjects using a shorter mask duration. Stimuli and presentation times where the same as previously described, with the exception that M2 duration was 129 ms instead of 224 ms. We again found significant Lag, $F(1,6) = 16.91$, $p = 0.006$, and Lag × Masking effects, $F(1,6) = 11.28$, $p = 0.01$ with a mean T2 performance in the common-onset condition of 77.88% correct responses ±6.19 at the short inter-target lag and 86.70% correct ±4.19 at the long inter-target lag.

The present results suggest that processes recruited by delayed-mask onsets play an important role in the AB. A common onset of target and mask have major effects on target detectability but appear to interact with the AB only to a limited extent, suggesting that the processes responsible for the production of the AB are less involved in this form of masking. This result is not predicted by the object substitution hypothesis which postulates that during the AB, T2 is replaced by trailing masks including common-onset masks (Giesbrecht & Di Lollo, 1998). The third experiment examined whether the effect of common-onset masking of T2 would be the same when the first target is presented with a common-onset mask.

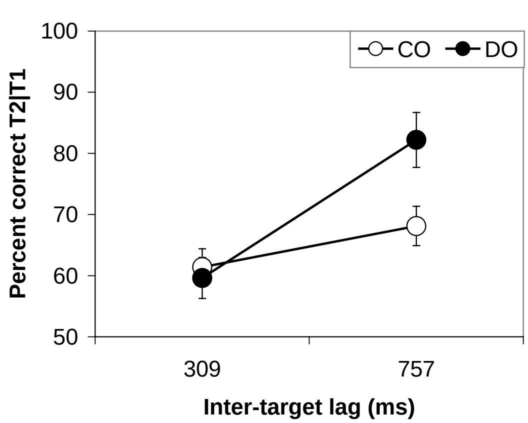

Fig. 2. Results of Experiment 2: Detection performance (mean ± SEM) on the two targets as a function of intertarget lag. T1 was masked by delayed-onset masking while T2 was masked either by common-onset or by delayed-onset masking.

4. Experiment 3

In Experiment 2, we showed that common-onset masking of T2 produced a smaller AB than delayed-onset masking in a similar task. We next asked whether this effect is specific to the context of a delayed-onset mask at T1. The type of mask used at T1 has been shown to have little effect on the AB, but few studies have examined common-onset masks at T1. Thus, we replicated Experiment 2 with the exception that a common-onset mask was used at T1.

4.1. Method

4.1.1. Subjects

Fourteen normal adults (7 women) aged between 22 and 30 years old (mean: 25 years) participated in this study. Informed consent was obtained before testing and subjects received a compensation of 10$ for their participation. All subjects were naïve with respect to masking tasks and had normal or corrected to normal vision. Four subjects that showed a T1 performance below 65% were excluded.

4.1.2. Stimuli and procedure

The timing of the stimuli, the procedure and instructions were exactly the same as in Experiment 2, with the exception that the first target was masked by a common-onset mask.

4.2. Results and discussion

T1 performance averaged 72.6% across conditions and lags with a significantly better performance at long lags, $F(1,9) = 22.44$, $p = 0.001$. Analyses of T2|T1 performance showed a significant effect of inter-target lag, $F(1,9) = 18.34$, $p = 0.002$, and a significant interaction of Lag by Masking condition, $F(1,9) = 7.25$, $p = 0.02$ (Fig. 3). The amplitude of the AB (lag effect), was significant in the delayed-onset condition (AB amplitude = 19.35%; $F(1,9) = 42.48$, $p < 0.001$) but not in the common-onset condition (AB amplitude = 8.49%; $F(1,9) = 3.52$, $p = 0.09$). Thus, when T1 and M1 had a common onset, AB amplitude was affected by the delay between T2 and M2. One possibility is that T2/M2 could have a masking effect on T1 detection. However, this should not be the case since M1 and T2 were separated by an SOA of 181 ms (Francis, 1997). Another possibility would be that performing the task at the short lag could be more difficult than at the long lag and this effect may be responsible for the slight decrease in T1 performance at the short lag.

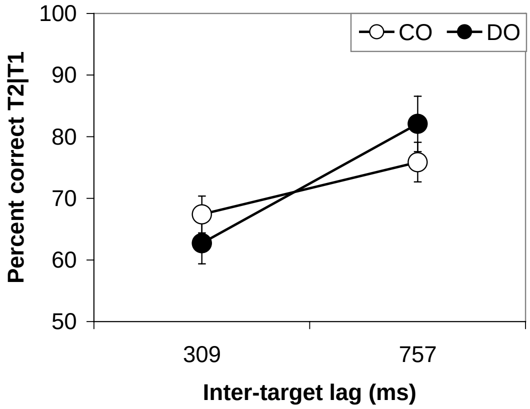

Fig. 3. Results of Experiment 3: Detection performance (mean ± SEM) on the two targets as a function of intertarget lag. T1 was masked by common-onset masking while T2 was masked either by common-onset or by delayed-onset masking.

5. Experiment 4

The results of Experiments 2 and 3, suggest that processes associated with a delayed onset of the T2 mask contribute to the AB. One possibility is that the effect of delayed-onset masks on the AB are linked to the abrupt onset of the mask. Some have suggested that transients evoked by mask onset can degrade the target through inhibitory interactions between mask transients and sustained activity linked to the target (Breitmeyer et al., 1976). However, these inhibitory interactions are dependent on the asynchrony between the target and its mask and are predicted to be nil for common-onset masks. Nevertheless, abrupt onsets may trigger visual processes which are absent in common-onset masking and which affect unattended targets. Also, abrupt visual onsets can capture attention (Jonides & Yantis, 1988), an effect which may disturb the consolidation of T2.

This study examined whether any stimulus onset after target offset can generate an AB. If all asynchronous mask onsets after T2 produce an AB, an abrupt onset produced by a brief interruption of the common-onset mask should produce an AB similar to a delayed-onset mask. However, if common-onset masks prevent the interfering effect of a trailing stimulus, an interrupted common-onset mask should not produce an AB similar to a delayed-onset mask despite significant masking.

5.1. Method

5.1.1. Subjects

Thirteen normal adults (5 women) aged between 20 and 36 years (mean age: 25.4 years) participated in the study. Informed consent was obtained prior to testing and subjects received a compensation of $10 for their participation. All subjects were naive with respect to masking tasks and all had normal or corrected to normal vision. Three subjects were excluded because of a T1 performance below 65%.

5.1.2. Stimuli and procedure

The timing of stimuli, the procedure and the instructions were identical to those used in Experiment 3, except for the T2 mask, which was varied in two conditions. In the delayed-onset condition the T2 mask was identical to the one described in Experiment 2 (mask onset: 35 ms post-target, target and mask durations: 94 ms). In the interrupted common-onset condition, the mask was presented twice, first with the same onset and offset as T2 and again 35 ms after target offset (both mask durations = 94 ms). To test whether the interruption in the mask was detected, we tested five subjects on 80 trials with a single target associated with a common-onset mask that was either interrupted or not in a random sequence. All subjects easily detected the presence or absence of the temporal delay in the mask (correct detection range: 89–100%).

5.2. Results and discussion

T1 performance averaged 79% across conditions and lags and showed a significantly lower accuracy at the short inter-target lag than at the long inter-target lag, $F(1,9) = 40.75$, $p < 0.001$. Analyses of mean T2|T1 performance showed a significant effect of inter-target lag, $F(1,9) = 32.72$, $p < 0.001$, and a significant interaction between lag and masking condition, $F(1,9) = 23.92$, $p = 0.001$ (Fig. 4). The amplitude of the AB was significantly larger when the second target was masked by delayed-onset masking as compared to the interrupted common-onset masking condition, $F(1,9) = 23.92$, $p = 0.001$; delayed-onset condition AB = 24.35%, $F(1,9) = 56.80$, $p < 0.001$; interrupted common-onset AB = 9.48%, $F(1,9) = 7.70$, $p = 0.02$.

In the interrupted common-onset condition, the decrease in T2 accuracy at the short inter-target lag was similar to the one observed at T1, Target × Lag interaction, $F(1,9) = 0.08$, $p < 0.70$. Thus, as in Experiment 3, the lag effect on T2 may be linked more to the overall difficulty of the task at the short lag than to the presence of an AB.

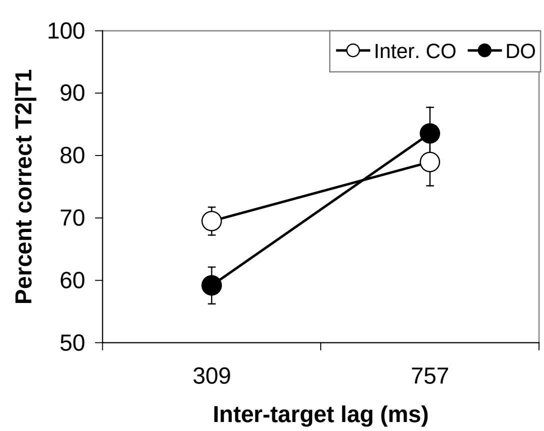

Fig. 4. Results of Experiment 4: Detection performance (mean ± SEM) for the two targets as a function of intertarget lag. T1 was masked by common-onset masking while T2 was masked either by interrupted common-onset or by delayed-onset masking.

These results show that a mask appearing after T2 induced a stronger AB than a common-onset mask which was interrupted after target offset. It is possible that the interruption was not sufficient to produce a clearly distinct onset after T2 and that the two repetitions of the mask were perceptually fused in the interrupted CO condition. Even if the interruption was clearly detectable in a single target detection situation, the detectability of an interruption is difficult to establish in the context of an AB task. We tested 8 subjects with a larger interruption (70 ms ISI instead of 35 ms) and shorter target and mask durations (70 ms) and compared this new interrupted common-onset condition to a delayed-onset condition with identical stimulus durations. Again, we found a much larger AB in the delayed-onset condition than in the interrupted CO condition, lag effect: $F(1,6) = 43.2$, $p = 0.001$; Lag × Condition interaction: $F(1,6) = 71.8$, $p < 0.001$; lag effect in interrupted CO condition: $F(1,6) = 9.6$, $p = 0.02$; lag effect in delayed-onset condition: $F(1,6) = 69.5$, $p < 0.001$; AB amplitude difference: $F(1,6) = 71.8$, $p < 0.001$. Thus, a mask onset following closely after an identical mask may not be sufficient to interrupt processing of an unattended second target. The following experiments examined the effect on the AB of two other changes in the CO mask including a change in contour features and a change in spatial location.

6. Experiment 5

The new object hypothesis predicts that significant changes in the mask after target offset would induce an AB. New objects are often defined perceptually by a configuration of features or by location, and changes in these characteristics after target offset may be sufficient for a mask to induce a significant AB. Our next experiment tested the effect of a change in the contour features of the mask while minimizing changes in location and extent. We compared the AB in two interrupted common-onset conditions: one in which the mask was repeated after target offset (as in the previous experiment), and a second in which the common-onset mask was replaced by a similar mask with a different contour after target offset.

6.1. Method

6.1.1. Subjects

Seven adults (4 women) aged between 19 and 21 years (mean age: 20.6 years) participated in the study. Informed consent was obtained prior to testing and subjects received a compensation of $10 for their participation. All subjects were naive with respect to masking tasks and all had normal or corrected to normal vision. One subject was excluded because his T1 performance was below 65%.

6.1.2. Stimuli and procedure

The timing of stimuli, the procedure and the instructions were identical to those used in Experiment 4, except for the T2 mask, which was varied in two conditions. In the interrupted common-onset condition, the T2 mask was identical to the one described in Experiment 4 (mask onset: 35 ms post-target, target and mask durations: 94 ms). In the feature change condition, the T2 mask was the same as in the first condition, except that the trailing mask was changed 35 ms after target offset; the 2 gaps on each side were replaced by a single central gap (both mask durations = 94 ms). The number of pixels in the T2 masks were identical in both conditions.

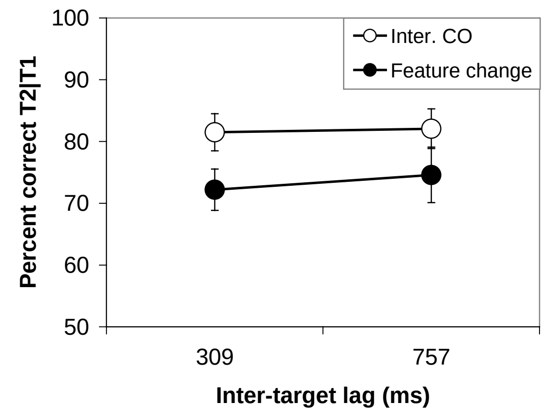

Fig. 5. Results of Experiment 5: Detection performance (mean ± SEM) for the two target as a function of intertarget lag. T1 was masked by common-onset masking while T2 was masked by a common-onset mask that was interrupted and either repeated or changed in contour features.

6.2. Results and discussion

T1 performance averaged 84% across conditions and lags and was lower at the short than at the long inter-target lag, $F(1,5) = 33.67$, $p = 0.002$. Analyses of mean T2|T1 performance did not show a significant effect of inter-target lag, $F(1,5) = 0.18$, $p = 0.68$, nor any interaction between lag and masking condition, $F(1,5) = 0.05$, $p = 0.83$. However, we found a significant effect of masking condition, $F(1,5) = 8.19$, $p = 0.03$, showing that the feature change condition induced a stronger masking effect than the interrupted common-onset condition (Fig. 5).

These results indicate that a featural change of the mask after the offset of the second target is not sufficient to produce an AB when a common-onset mask is used at T2. Although the feature change was clearly detectable, the data suggest that featural variations in a mask that do not significantly change its spatial location and extent may be insufficient to give rise to the AB. In the next experiment, we examined whether a change in the spatial location of the T2 mask after the offset of T2 could induce an AB.

7. Experiment 6

In this experiment we compared the amplitudes of the AB when T2 was masked by a common-onset mask that was repeated after target offset and when the CO mask was replaced by a similar mask at a different position.

7.1. Method

7.1.1. Subjects

Ten normal adults (4 women) aged between 20 and 36 years (mean age: 25.4 years) participated in the study. Informed consent was obtained prior to testing and subjects received a compensation of $10 for their participation. All subjects were naive with respect to masking tasks and all had normal or corrected to normal vision. Three subjects that showed a T1 performance below 65% were excluded.

7.1.2. Stimuli and procedure

The timing of stimuli, the procedure and the instructions were identical to those used in Experiment 4, except for the T2 mask, which was varied in two conditions. In the interrupted common-onset condition, the mask was presented twice, first with the same onset and offset as T2 and again 35 ms after target offset (both mask durations = 94 ms). In the position change condition, the T2 mask was changed 35 ms after target offset; the mask inside the target was replaced by a similar mask placed on the outside of the target (mask durations: 94 ms). The number of pixels was slightly smaller in the position change condition compared to the interrupted common-onset condition.

7.2. Results and discussion

T1 performance averaged 80% across conditions and lags and was lower at the short inter-target lag than at the long inter-target lag, $F(1,6) = 21.47$, $p = 0.004$. Analyses of mean T2|T1 performance showed a significant effect of inter-target lag, $F(1,6) = 15.18$, $p = 0.008$, and a significant interaction between lag and condition, $F(1,6) = 20.16$, $p = 0.004$ (Fig. 6). The amplitude of the AB was significant in the position change condition, $F(1,6) = 38.52$, $p = 0.001$, but not in the interrupted common-onset condition, $F(1,6) = 1.01$, $p = 0.35$. We also found an effect of masking condition, $F(1,6) = 27.99$, $p = 0.002$, showing that the performance in the position change condition was lower overall than in the interrupted common-onset condition.

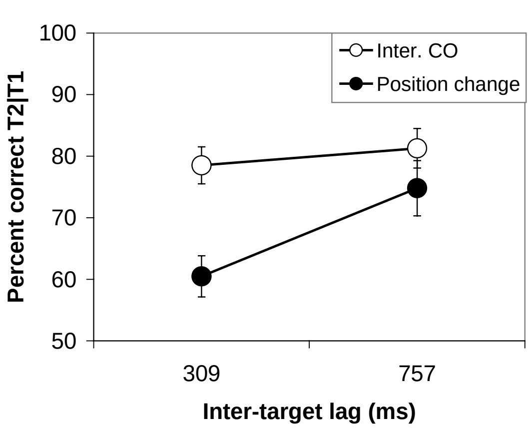

Fig. 6. Results of Experiment 6: Detection performance (mean ± SEM) for the two target as a function of intertarget lag. T1 was masked by common-onset masking while T2 was masked by a common-onset mask that was interrupted and either repeated or changed in position.

These results show that changing the position of the mask after the offset of the second target induced a stronger AB than repeating the common-onset mask. This result indicates that a change in the location of a common-onset mask after T2 is sufficient to produce an AB.

8. General discussion

The results of the present studies show that common-onset masking of the second target leads to a significant decrease in the attentional blink compared to delayed-onset masking. The AB was not reinstated when the common-onset mask at T2 was interrupted and repeated (Experiment 4) or when mask features were changed (Experiment 5), but it was reinstated when the common-onset mask was changed in location. These data suggest that processes associated with a new visual object after the second target are directly related to the production of the AB.

Traditional models of the AB involve two processing stages, the second of which is involved in target consolidation and is limited in capacity (Chun & Potter, 1995; Jolicoeur, 1998). In these models, the AB is often linked to the decay of the representation of T2 in the first stage because its consolidation in the capacity-limited second stage is delayed by T1 processing. The AB is thus viewed as a failure of late processing. The role of the T2 mask in these models is not well defined, except that it interrupts T2 processing. This role is supported by the observation that integration masking of T2 by a pattern which spatially and temporally overlaps with T2 fails to elicit an AB despite strong masking, but that interruption masking of T2 by a trailing delayed-onset mask does produce a large AB (Giesbrecht & Di Lollo, 1998). It has been suggested that trailing masks can act through object substitution, replacing the target during perceptual consolidation. Common-onset masks provide a strong perceptual alternative to the target by the fact that they were present during target presentation. Since these masks produce only small AB effects if any, it appears that substitution of the unattended target may not be a critical role of trailing T2 masks in the AB.

A previous study using targets at unattended eccentric locations did not find a reliable AB when T2 was masked by a four-dot mask whether it was presented as a common-onset mask or as a delayed-onset mask (Giesbrecht et al., 2003). These authors concluded that mask onset at T2 cannot account for the AB. In contrast, another study found a significant AB when a delayed-onset four-dot mask was used at T2 (Dell'Acqua et al., 2003). Thus, it is still unclear whether and when delayed four-dot masks produce a clear AB.

In the present studies, we directly compared common-onset and delayed-onset masks in the same task, and found a significant reduction in the AB when the onset asynchrony of T2 and its mask is reduced to zero. This result confirms those obtained by Giesbrecht et al. (2003) using four-dot common-onset masking of peripheral targets. The present data suggest that when common-onset masks and delayed-onset masks are compared in the same task, common-onset masks reduce the AB significantly. In addition, Experiments 4 through 6 suggest that a transient disappearance of the common-onset mask or a featural change in the same mask is not sufficient to reinstate the AB but that a change in the location of the mask is sufficient. Thus, to be effective on unattended targets, backward masks must involve salient changes in the objects in the visual scene after T2. There is evidence that the attentional blink can be eliminated when the first target is not a new object (Raymond, 2003), suggesting that object selection processes are important in the triggering of the AB. The present data suggest that object selection processes may also be critical in the masking of unattended targets.

One explanation for the AB reduction with common-onset masking is that early visual processes critical for the AB are recruited by delayed-onset masks but much less recruited by common-onset masks. Early visual processes have been proposed as a critical component in the role of trailing T2 masks in the AB (Giesbrecht et al., 2003). The reduction of the AB in scotopic vision is compatible with this early processing explanation (Giesbrecht et al., 2004). However, scotopic vision increases visible persistence (Di Lollo & Bischof, 1995) and may thus increase the temporal overlap between the responses to the target and the mask in the visual system. Moreover, a reduction in the AB in scotopic vision does not preclude the possibility that an interaction between attention and early processing is involved. Early visual processing is involved in detecting a transient disappearance and reappearance of the mask or a featural change in the mask but these were not sufficient to reinstate the AB. Thus, if any early visual processes are involved in the role of the T2 mask in the AB, they should be specific to salient object onsets. While it is impossible to reject the possibility of early visual processing effects in the present data, this hypothesis is not sufficiently specific to adequately account for the present data.

A second hypothesis is that the abrupt onset of a new object after T2 may pull attention away from the target significantly more than a common-onset mask. Attention and early visual processing appear to have complementary roles in delayed-onset metacontrast masking (Tata, 2002; Tata & Giaschi, 2004). Common-onset masks may be strong competitors for access to consciousness but they may not disturb the attentional engagement on T2 as much as delayed-onset masks. This explanation is compatible with the attentional capture effects of sudden onsets (Jonides & Yantis, 1988). The orienting of attention to a delayed mask could slow consolidation of T2 and thus increase its susceptibility to interference. Alternatively, orienting to a delayed-onset mask may prolong or renew the unattended status of T2. There is evidence that selective T2 precuing can reduce the AB, possibly by accelerating the initiation of the attention episode on T2 (Nieuwenstein, Chun, van der Lubbe, & Hooge, in press). Delayed mask onsets may have the opposite effect of prolonging the time that T2 consolidation is not present.

The orienting hypothesis predicts that it is the event of a new and salient M2 rather than its other masking properties that is mainly responsible for the AB. Previous work has shown that the SOA between T2 and M2 does not appear to be critical for the AB (Giesbrecht & Di Lollo, 1998; McLaughlin et al., 2001). This is compatible with a role of orienting, since orienting depends more on the event of a new mask onset before target consolidation than on its exact timing.

The attention orienting and the early processing explanations are not mutually exclusive. Automatic orienting to M2 could affect T2 processing in the early portions of the visual system or they could interact in other ways. We have recently compared delayed-onset masking with common-onset masking using functional neuroimaging (with the same metacontrast figures that were used here) and found that delayed-onset masks increase activity in visual cortex and in frontal cortex compared to similar common-onset masks (Richer & Marti, in preparation). These observations are consistent with a model in which a new object that can compete with the target recruits additional processing in primary visual cortex compared to an old object that can also compete with the target.

In summary, the present data show that processes triggered by the onset of new objects after the second target affect the size of the attentional blink. This reinforces the notion that masks can have a variety of effects on the visual system and that only some of these effects interact with the consolidation of unattended targets.

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