Research Report

The Meaning of the Mask Matters

Evidence of Conceptual Interference in the Attentional Blink

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ABSTRACT—***The*** **rapid serial visual presentation** ***(RSVP) experiment reported here investigated the role of conceptual interference in the*** **attentional blink** ***(AB). Subjects were presented with RSVP streams that contained five stimuli: Target 1, a distractor, Target 2, a second distractor, and a symbol mask. Target 1 was a green letter, Target 2 was a red letter, and the distractors were either white letters or white digits. The stimuli were presented in a font typically seen on the face of a digital watch. Thus, "S" and "O" were identical to "5" and "0," respectively. This allowed us to present streams that were conceptually different even though featurally identical: The two letter targets were followed by distractors that were recognized either as "5" and "0" or as "S" and "O." The AB was substantially attenuated when subjects were told the distractors were digits rather than letters. This result indicates that conceptual interference plays a role in the AB.***

In *rapid serial visual presentation* (RSVP; Potter & Levy, 1969), stimuli appear one after the other in the same spatial location for a fraction of a second each (e.g., 100 ms). This technique has revealed an important limitation in temporal attention, the *attentional blink* (AB), which refers to human observers' reduced ability to identify or detect the second of two targets in an RSVP stream if it appears within 200 to 500 ms of the first target (Raymond, Shapiro, & Arnell, 1992).

There are several published accounts of the AB (see Shapiro, Arnell, & Raymond, 1997, for a review). Despite some differences, these theories generally assume that most RSVP stimuli undergo conceptual processing. However, these initial representations are insufficient to support overt report, and further processing is required for item recall or recognition. This extended processing is capacity limited and requires attention. Thus, the AB occurs when the second target is presented in close temporal proximity to the first, because Target 2 must wait to be processed and, as a result, becomes more susceptible to decay and interference from other stimuli in the stream (Kawahara, Di Lollo, & Enns, 2001).

Typically, the AB has been studied using dual-target RSVP methods that involve the presentation of at least 10 stimuli. However, Ward, Duncan, and Shapiro (1997) have demonstrated that four stimuli suffice to elicit an AB: Target 1, a distractor (T1 + 1), Target 2, and a second distractor (T2 + 1). In this procedure, each target is followed immediately by a distractor, and the stimulus onset asynchrony (SOA) between the targets is systematically varied.

In the task of Ward et al. (1997), the distractors play a crucial role in eliciting the AB. Indeed, all AB theories suggest that interference between the targets and the items that directly succeed them is instrumental in causing the effect. It has been argued that T1 + 1 and T2 + 1 mask the targets. Research demonstrating that the blink is severely attenuated if either target is followed by a blank gap supports this claim (Giesbrecht & Di Lollo, 1998; Raymond et al., 1992).

Although it is clear that distractors in dual-target RSVP streams make it difficult to select and encode relevant target stimuli, there has been considerable debate regarding the type of interference between targets and distractors that is responsible for causing the AB. It has been hypothesized that conceptual interference plays an important role in eliciting the deficit. Chun and Potter (1995) provided evidence supporting this idea by demonstrating that the AB was attenuated when a letter target was directly succeeded by a symbol (low conceptual similarity) rather than a digit (high conceptual similarity). Similarly, Isaak, Shapiro, and Martin (1999) found that the AB was reduced when letter targets were followed by false-font rather than letter distractors. Further evidence suggesting that the AB has a high-level locus comes from studies showing that missed targets (Shapiro, Driver, Ward, & Sorensen, 1997) and distractors (Maki, Frigen, & Paulson, 1997) in RSVP can facilitate report of later semantically related targets. These results have been taken as evidence that unreported items in RSVP activate conceptual representations.

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Recently, the role of high-level interference in the AB has been questioned, as several researchers have claimed that although unreported stimuli in RSVP undergo considerable processing, it is low-level interference that is the key determinant of the AB. For example, Grandison, Ghirardelli, and Egeth (1997; see also Seiffert & Di Lollo, 1997) demonstrated that low-level masking of Target 1 by T1 + 1 was sufficient to cause the effect. Similarly, McAuliffe and Knowlton (2000) found that manipulations of the featural rather than conceptual complexity of T1 + 1 affected AB magnitude. In addition, Giesbrecht, Bischof, and Kingstone (2003, 2004) have shown that, although high-level masking of Target 2 by object substitution is insufficient to cause the blink (but see Dell'Acqua, Pascali, Jolicoeur, & Sessa, 2003), the deficit is influenced by adapting luminance, which has its effect at early stages of visual processing. Furthermore, Maki, Bussard, Lopez, and Digby (2003) have shown that featural rather than conceptual differences among the letter, digit, and symbol stimuli caused the blink reduction found by Chun and Potter (1995). Although Maki et al. found the blink to be attenuated when the targets were letters and the distractors were symbols, a strong AB was still present for the opposite condition. They identified increased pixel density of the letters as the source of this asymmetry.

In the present study, we investigated whether or not conceptual interference contributes to the magnitude of the AB. A problem with previous studies investigating this question is that in none of them was conceptual similarity between targets and distractors manipulated while featural similarity was held constant. As noted by Chun and Potter (1995), digits (e.g., "7") and symbols (e.g., "=") differ featurally as well as conceptually. To overcome this problem, we presented subjects with streams that were identical and used task instructions (and the nature of other items in the trial block) to manipulate whether or not the distractors were perceived as belonging to the same category as the targets (for a similar manipulation in a spatial visual search paradigm, see Jonides & Gleitman, 1972). If task instructions did not influence the magnitude of the AB (i.e., if deficits of equal size were obtained for identical trials, regardless of the instructions), then we could conclude that conceptual interference does not contribute to the AB. If, however, blink magnitude was affected by task instruction (i.e., if the AB was attenuated when identical distractors were perceived as members of a different alphanumeric category than the targets, rather than the same alphanumeric category), then this would be evidence that conceptual interference between targets and distractors does play a role in eliciting the AB.

METHOD

Subjects

Twelve undergraduate students at Macquarie University, Australia, took part in the study (8 females; mean age = 20 years). All subjects reported normal or corrected-to-normal visual acuity and normal color vision.

Stimuli and Apparatus

Figure 1 shows the stimuli used in the experiment. These were presented in Digiface font and, at a viewing distance of approximately 40 cm, subtended 1.5° of visual angle. A green Target 1 letter, a red Target 2 letter, and two white distractors that were either letters or digits appeared on a black background. Stimuli were presented centrally in the same spatial location for 100 ms each, and no stimulus appeared more than once in each trial. The experiment was programmed using DMDX software (Forster & Forster, 2003) and was conducted using a Dell PC computer that controlled a Dell Flat Trinitron monitor with a 120-Hz vertical refresh rate.

Design

Figure 2 depicts the 2 × 2 × 4 repeated measures design of the experiment. The first independent variable was distractor category, which was manipulated across blocks and had two levels: digits and letters. The second independent variable, distractor ambiguity, was manipulated within each block and also had two levels: ambiguous (identical distractor pairs in the letter- and digit-distractor blocks) and unambiguous (different distractor

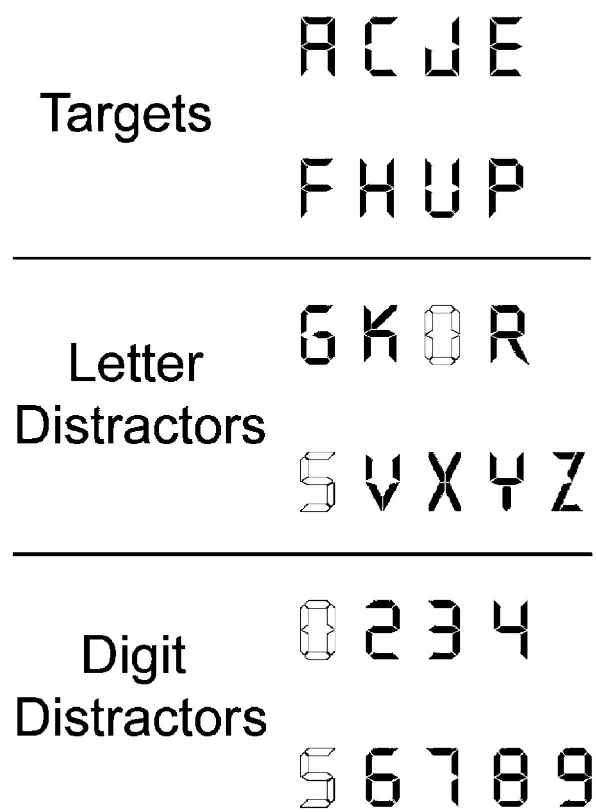

Fig. 1. Target and distractor stimuli used in the experiment. The ambiguous distractors are shown outlined, and the unambiguous distractors are shown in black.

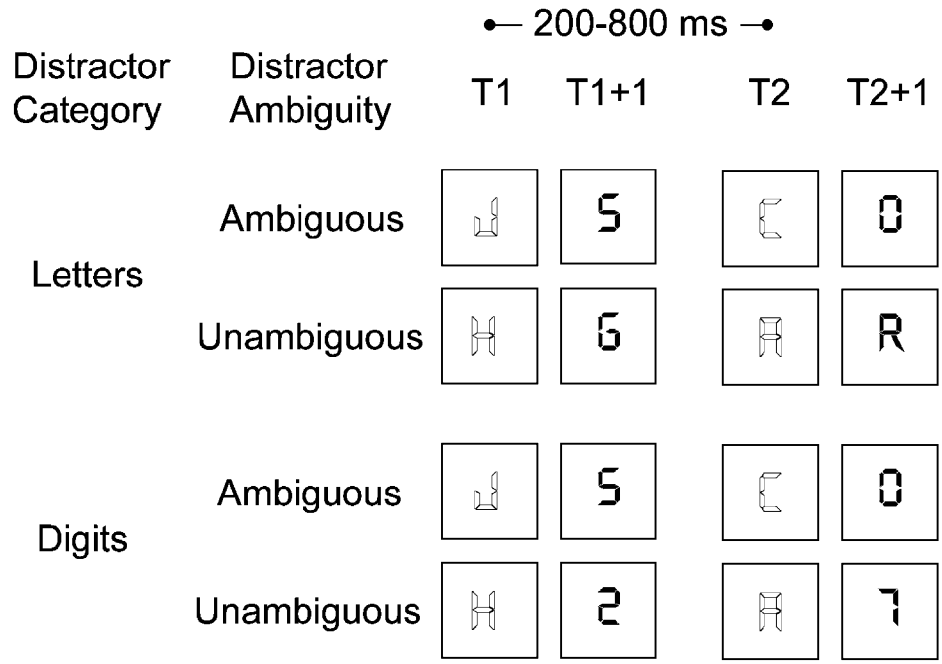

Fig. 2. Design of the experiment. The independent variables were distractor category (two levels: letters and digits), distractor ambiguity (two levels: ambiguous and unambiguous), and stimulus onset asynchrony (four values: 200, 400, 600, and 800 ms). The letters shown are example trial sequences depicting the two targets (T1 and T2) and the two distractors (T1 + 1 and T2 + 1).

pairs in the letter- and digit-distractor blocks). The third independent variable, SOA, was also manipulated within each block and had four levels: 200, 400, 600, and 800 ms. The dependent variable was accuracy in reporting the targets.

Procedure

Subjects initiated each trial by pressing the space bar. Each trial contained a green Target 1, a red Target 2, and white T1 + 1 and T2 + 1 distractors. In addition, each trial began with a white fixation cross for 500 ms and concluded with a white "&" mask that appeared directly after T2 + 1. Target 1 was presented 200, 300, 400, or 500 ms after offset of the fixation cross, and the two targets had an SOA of 200, 400, 600, or 800 ms. Subjects were required to report the "green and red letter" at the end of each trial.

Sixteen practice trials, 4 unambiguous trials at each SOA, were presented before each experimental block. Experimental blocks were made up of 10 ambiguous and 10 unambiguous trials at each SOA (80 trials).

The different targets appeared an equal number of times, and the target pairs were identical in the letter and digit blocks. Distractors were randomly selected from the unambiguous distractor set for the unambiguous trials and were the letters "S" and "O" on ambiguous letter trials and the digits "5" and "0" on ambiguous digit trials (each ambiguous distractor appeared an equal number of times as T1 + 1 and T2 + 1). Thus, the targets and distractors were identical in the ambiguous letter and ambiguous digit trials; only the instructions to subjects differed. Subjects were told that the distractors were letters in one block and digits in the other block. Block order was counterbalanced.

RESULTS

We analyzed Target 1 accuracy and Target 2 accuracy on trials on which Target 1 was reported correctly (T2|T1). Block order did not influence performance, so the data were collapsed across this variable.

T2|T1 Accuracy

Figure 3 shows the mean percentage T2|T1 accuracy as a function of distractor category and SOA, plotted separately for ambiguous and unambiguous trials. As shown in the figure, each combination of distractor category and distractor ambiguity yielded a significant AB. There were two additional important findings. First, AB magnitude was larger in both ambiguous and unambiguous trials when the distractors were letters rather than digits. Second, the AB was attenuated in digit trials when the distractors were unambiguous rather than ambiguous.

A 2 × 2 × 4 repeated measures analysis of variance confirmed these results. The main effects of distractor category, $F(1, 11) = 23.51$, $\eta_p^2 = .68$, $p < .0006$, and SOA, $F(3, 33) = 84.3$, $\eta_p^2 = .89$, $p < .0002$, were significant. There were also three significant two-way interactions—between distractor category and distractor ambiguity, $F(1, 11) = 14.43$, $\eta_p^2 = .57$, $p < .0004$; between distractor category and SOA, $F(3, 33) = 16.94$, $\eta_p^2 = .61$, $p < .0002$; and between distractor ambiguity and SOA, $F(3,$

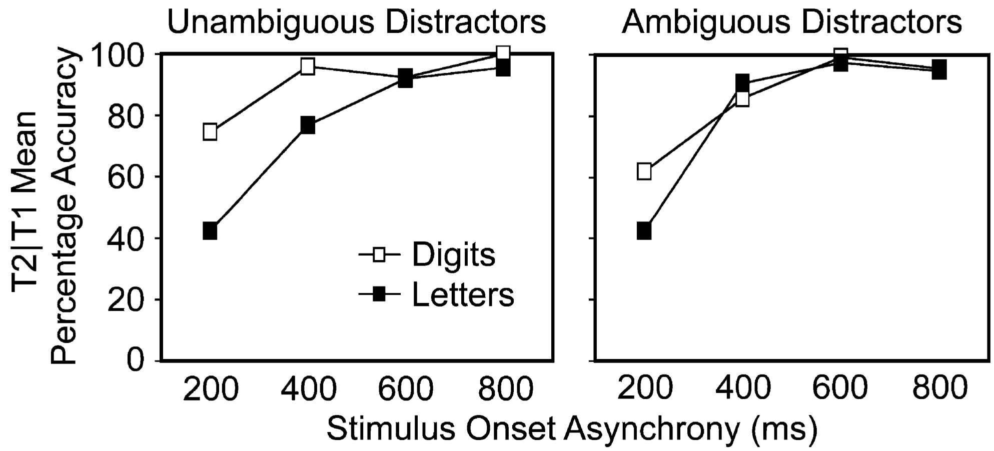

Fig. 3. Mean Target 2 accuracy on trials on which Target 1 was reported correctly (T2|T1 accuracy), as a function of distractor category and stimulus onset asynchrony. Results for unambiguous and ambiguous distractors are plotted in separate graphs.

33) = 7.54, $\eta_p^2 = .41$, $p < .0007$. Finally, the three-way interaction of distractor category, distractor ambiguity, and SOA was also significant, $F(3, 33) = 6.5$, $\eta_p^2 = .37$, $p < .002$. A planned contrast demonstrated that at the 200-ms SOA, accuracy was higher for ambiguous digit than for ambiguous letter trials, $F(1, 33) = 39.9$, $p < .0002$. In addition, performance was lower on digit trials when the distractors were ambiguous than when they were unambiguous; this was the case at SOAs of 200 ms, $F(1, 33) = 17.23$, $p < .0003$, and 400 ms, $F(1, 33) = 10.55$, $p < .003$.

Target 1 Accuracy

Overall accuracy in reporting Target 1 was 98.1%. There were no significant effects of distractor category, distractor ambiguity, or SOA, nor did these variables interact significantly.

DISCUSSION

Our study investigated whether or not conceptual interference plays a role in eliciting the AB. We presented subjects with RSVP streams that were identical and manipulated, by task instruction (and the nature of other items in the trial block), whether the distractors were regarded as conceptually similar to or conceptually different from the targets. The AB was attenuated when subjects perceived the targets and distractors as being members of different alphanumeric categories rather than as members of the same category. As the stimuli were identical in the ambiguous digit and letter trials, we conclude that the reduction in blink magnitude occurred because of the category difference between targets and distractors. We propose that when targets and distractors belonged to the same category, there was increased competition for processing resources between the preliminary conceptual representations of the stimuli. This increased competition impeded target selection, target consolidation, and distractor suppression, and, thus, AB magnitude was larger for ambiguous letter trials than for ambiguous digit trials.

These results demonstrate that conceptual interference plays a significant role in causing the AB. Recently, it has been suggested that although most stimuli in an RSVP stream are processed conceptually, it is low-level interference that is predominantly responsible for eliciting the deficit (Giesbrecht et al., 2003, 2004; Maki et al., 2003). We do not dispute that masking effects mediated by early visual mechanisms play a significant role in the AB, but rather suggest that an interaction between both low-level and high-level interference mechanisms gives rise to the effect. This suggestion fits well with recent theories (e.g., Di Lollo, Enns, & Rensink, 2000) suggesting that masking involves both bottom-up and top-down visual mechanisms that interact via reentrant processing pathways.

It should be noted that the conceptual interference effect we observed was substantial compared with the effect of featural similarity between targets and distractors. At an SOA of 200 ms, the Target 2 position where AB magnitude is typically maximal, performance was almost identical on ambiguous (42.5%) and unambiguous (42.3%) letter trials. Thus, one could assume that the level of interference in these two conditions was comparable. At the 200-ms SOA, performance on both ambiguous and unambiguous digit trials was superior to performance on letter trials. However, performance was lower for ambiguous digit trials than unambiguous digit trials, perhaps because the unambiguous digit distractors differed both featurally and conceptually from the unambiguous letter distractors, whereas the ambiguous digit and letter distractors differed only in category. Therefore, the contribution of the conceptual interference in this task is indicated by the 19.4% difference in performance between ambiguous letter and digit trials at an SOA of 200 ms. The performance difference of 32.4% between unambiguous digit and letter trials indicates the joint contributions of both featural and conceptual interference. These results suggest that although both conceptual and featural interference contributed to the AB, the greater contribution was made by the categorical differences between targets and distractors.

A final result that warrants discussion is that on digit trials, the AB was larger when the distractors were ambiguous rather than unambiguous. There are three possible explanations for this result. The first is that the ambiguous digits were more featurally similar to the letter targets than were the unambiguous digits, and thus may have interfered more at the featural level. A second possible explanation is that there may have been some activation of the letter representations "O" and "S" in the ambiguous digit trials. Such activation may have increased conceptual interference and magnified the AB. Finally, it is conceivable that both featural interference and activation of letter representations led to this result, a plausible possibility given the evidence that both low-level and high-level interference contribute to the blink.

We have shown that when alphanumeric stimuli are presented in dual-target RSVP tasks, it is not just featural interference between the targets and distractors that causes the AB; rather, conceptual interference also plays a significant role in eliciting the effect. Future research should examine further the manner in which low-level and high-level visuo-cognitive processes interact when attention is distributed temporally.

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