PRIMING FROM THE ATTENTIONAL BLINK: A Failure to Extract Visual Tokens but Not Visual Types

Kimron Shapiro,¹ Jon Driver,² Robert Ward,¹ and Robyn E. Sorensen³
¹University of Wales, Bangor; ²Birkbeck College, University of London; and ³University of Cambridge, England

Abstract—When people must detect several targets in a very rapid stream of successive visual events at the same location, detection of an initial target induces misses for subsequent targets within a brief period. This attentional blink may serve to prevent interruption of ongoing target processing by temporarily suppressing vision for subsequent stimuli. We examined the level at which the internal blink operates, specifically, whether it prevents early visual processing or prevents quite substantial processing from reaching awareness. Our data support the latter view. We observed priming from missed letter targets, benefiting detection of a subsequent target with the same identity but a different case. In a second study, we observed semantic priming from word targets that were missed during the blink. These results demonstrate that attentional gating within the blink operates only after substantial stimulus processing has already taken place. The results are discussed in terms of two forms of visual representation, namely, types and tokens.

Several studies (e.g., Broadbent & Broadbent, 1987: Chun & Potter, 1995; Maki & Padmanabhan, 1994; Raymond, Shapiro, & Arnell, 1992, 1995; Shapiro, Raymond, & Arnell, 1994; Weichselgartner & Sperling, 1987) have recently reported a robust phenomenon that has become known as the attentional blink (AB). The AB is typically observed when subjects must detect multiple targets among non-targets under conditions of rapid serial visual presentation (RSVP). In RSVP tasks, participants view a rapidly changing series of stimuli (e.g., alphanumeric characters) that usually appear at a fixed location in visual space. When subjects are asked to make judgments about two prespecified targets within the series, they are unable to report the second target accurately if it appears less than 500 ms after the first target (see Shapiro & Raymond, 1994, for review). This deficit in performance is the AB.

Recent findings reveal that this transient drop in performance for the second target is produced by attention to the first target, rather than by sensory factors such as forward masking, or by short-term memory failures (Raymond et al., 1992). Further studies have illustrated the generality of the AB phenomenon, and have identified some of its boundary conditions (e.g., Chun & Potter, 1995: Duncan, Ward, & Shapiro, 1994; Raymond et al., 1995: Shapiro et al., 1994). Thus, the situations that induce the AB are now quite well known. The present study examines one such situation in order to determine the fate of target items that go unreported during the blink.

The term attentional blink itself suggests one possibility. In order to facilitate ongoing processing of the first target, sensory processing of subsequent inputs may be temporarily suppressed, much as vision is blocked during an actual blink of the eyelid. Alternatively, the AB might prevent quite fully processed stimuli from reaching awareness. We examined this issue by using a priming measure. If the AB prevents processing of further stimuli at very early levels of the visual system, then targets missed during the AB should be unable to prime subsequent targets. If priming can be observed, however, then some degree of processing must take place during the AB.

Priming between related items is usually facilitatory (Monsell, 1978). However, an important exception has been found in the particular case of the RSVP task. Detection of an initial target (e.g., A) can specifically impair rather than enhance judgments of subsequent stimuli with the same abstract identity (e.g., a). This phenomenon of repetition blindness (RB) has been taken as evidence for two distinct forms of visual representation (Kanwisher, 1987), namely, types (or abstract categories) versus tokens (specific instances of these categories). A display such as AA comprises two tokens but only one generic type, whereas AB comprises two types with one token for each. Coding the generic type of a stimulus is not sufficient for it to reach awareness. Rather, a unique token must also be formed to code the specific instance of the generic type.

Conventional facilitatory priming is attributed to type processing: A benefit accrues when the same type representation is reactivated, provided the delay between the two events is sufficiently long for them to be readily distinguished as separate tokens. By contrast, the costs of repetition (observed when RB arises for repeated types at very short lags) are attributed to token processing. Specifically, these costs reflect a difficulty in forming multiple episodic tokens for a repeated visual type in order to distinguish the repeated instances at short lags (Kanwisher & Potter, 1990). This difficulty can make the second instance of a repeated item undetectable, even though its type may still be tacitly extracted (Kanwisher & Potter, 1990).

This type-token account makes clear predictions regarding priming from target items presented during the AB. If the AB suppresses all processing, then no priming should be found from stimuli within it. If it impairs just token formation, allowing type activation to continue, then facilitatory priming from targets missed during the blink on later targets with the same abstract identity should be found. However, if both a type and a token are extracted for the target presented during the blink (i.e., the target is reported correctly), then the opposite result should be found: Succeeding targets with the same identity should suffer from RB, rather than benefiting from type facilitation, because of the difficulty in forming multiple tokens for the same type at brief intervals. We were able to test these predictions in full by combining AB and RB procedures in our first experiment.

EXPERIMENT 1

In this experiment, subjects monitored a brief RSVP stream of alphanumeric characters, and then reported on the identities of three specified targets in the stream. The first target (T1) was used to...
produce an AB for the second target (T2), which in turn was used to enable possible priming or RB for a third target (T3). The two targets were all black digits, whereas T1 was a white digit. T2, a black uppercase letter, appeared shortly afterward, at a point chosen to maximize any AB from T1. T3, another black letter, followed shortly after T2. It was either the same letter as T2 (match trials) or a different letter (mismatch trials), but was always in lowercase to distinguish it from T2.

Participants
Ten University of Calgary students (1 man and 9 women), between the ages of 18 and 24 years (M = 20.5 years), served as participants.

Apparatus and Materials
The stimuli were all generated by an Apple Macintosh II computer and displayed on an Apple 13-in. color monitor. Participants viewed the display binocularly from a distance of 35 cm. Each trial was composed of an RSVP stream of digits and letters. On each trial, successive characters in the stream were presented for 15 ms with an intersstimulus interval of 75 ms, producing a presentation rate of 1.11 characters per second. All characters were displayed singly at the center of a uniform gray field (9.1 cd/m²) that subtended 16.3° by 12.5°. The characters were 0.82° in height and width, and all appeared in black except for T1, which was a white digit (32.9 cd/m²).

The nontargets in each stream were randomly chosen black digits from 2 through 9. T1, also a digit from 2 through 9, was the only white character in the stream. The number of nontarget characters preceding T1 varied randomly between 7 and 15 so that T1 occurred at an unpredictable point after trial initiation. Eight additional characters followed T1 on each trial. T2 occurred as the third item after T1, yielding a 270-ms stimulus onset asynchrony (SOA) between T1 and T2. T3 was always the sixth item after T1, yielding a 540-ms SOA with T1 and a 270-ms SOA with T2. These values were chosen to place T2 in the depth of the AB, the temporal position at which conscious identification has been found to be least likely (Shapiro & Raymond, 1994). The interval between T1 and T3, however, placed T3 in a temporal position beyond the known influence of the AB, yet at a sufficiently short temporal separation from T2 so that any priming or RB between T2 and T3 should be observable.

T2 was one of seven uppercase black letters (A, D, E, N, R, T, Y). T3 was drawn from the same set, but in lowercase. This set was chosen so that the letters were highly distinct, and dissimilar across case, so that any priming or RB effects would have to be abstract in nature. Half the trials were match trials, on which T2 and T3 had the same abstract identity (e.g., T2 was an A, and T3 was an a). The remainder were mismatch trials, on which T2 and T3 were different in identity as well as case (e.g., a D followed by an n). Figure 1 depicts typical event sequences for match and mismatch trials. Each of the seven possible matching pairs was presented 12 times overall, yielding a total of 84 match trials. Each of the seven upper case letters was combined with each of the six possible mismatching lower case letters to create 42 combinations, which were then each presented twice to form 84 mismatch trials.

Design
There were two within-subjects factors. The first concerned the relation between T2 and T3 (match vs. mismatch). The second concerned whether subjects correctly judged T2 or misjudged it because of the AB produced by T1. The dependent measure was the accuracy of T3 report as a function of these two crossed factors.

Procedure
Participants initiated a trial by depressing the mouse button. Each trial began with a central white fixation dot for 180 ms, followed by the RSVP stream. Subjects responded verbally, giving the identity of the white number (T1) first, then the name (e.g., "big A") of the uppercase letter (T2), and then the name (e.g., "small a") of the lowercase letter (T3), in that order. Subjects knew the possible identities of the targets. Each participant completed one 45-min session, containing a practice block of 40 trials and an experimental block of 168 trials (half match trials, half mismatch trials, in random order). During the practice block, subjects reported just T1 for 10 trials, then just T2, then just T3, before performing all three tasks simultaneously for the final 10 trials.
Results and Discussion

The identity of T1 was reported correctly on 84.2% of trials overall, and trials with T1 incorrect were excluded from all further analyses. Accuracy of T3 identification is plotted in Figure 2a, separately for match and mismatch trials, and as a function of whether T2 was reported correctly (67.1% of analyzed trials) or incorrectly (32.9% of analyzed trials). These results apparently support the predictions of the type-token account. With T2 correct (two left-most bars in Fig. 2a), T3 performance was less accurate on match trials than on mismatch trials, suggesting an RB effect. In contrast, when T2 was incorrect (two right-most bars in Fig. 2a), performance for T3 was more accurate on match trials than on mismatch trials. That is, the RB apparently reversed to become a facilitatory priming effect.

A two-way within-subjects analysis of variance (ANOVA) on T3 accuracy, with factors of T2 performance (correct or incorrect) and trial type (match or mismatch), confirms this outcome. There was an interaction of T2 performance with trial type, \( F(1, 9) = 89.9, p < .01 \). Planned contrasts confirmed that when T2 was identified correctly, participants were worse at identifying T3 if the two targets matched, \( F(1, 9) = 17.9, p < .01 \). The opposite was found when T2 could not be reported because of the AB from T1, \( F(1, 9) = 84.4, p < .01 \).

The type-token account (Kanwisher & Potter, 1990) can explain these results as follows. It argues that T2 can be reported consciously only when both a type and a token are jointly formed for it. A tokenized T2 should produce difficulties in forming a separate token for a matching T3, thus impairing conscious report for the latter. Hence, RB is found for T3 on match trials when T2 is reported correctly. This aspect of our results replicates previous RB findings when characters are repeated at short lags in RSVP (e.g., Kanwisher & Potter, 1990). The more novel finding emerged on trials in which T2 could not be reported correctly because of the AB that followed T1. The data suggest that on such trials, the identity of T2 produced facilitatory priming for a matching T3. This result implies that the AB operates relatively late. It apparently does not prevent stimuli from activating their abstract types in a manner that can produce priming across letter case. Instead, the AB seems primarily to prevent formation of an appropriate token for T2. When the blink prevents tokenization in this way, T2 cannot be judged correctly in conscious report. However, it can produce facilitatory priming for T3 (based on its type activation) rather than RB for T3 (because no T2 token was formed).

Thus, our results appear to substantiate the type-token distinction as elaborated by Kanwisher and Potter (1990), while providing initial evidence that the AB operates at high levels of processing, and so does not prevent type activation. However, we must consider alternative accounts for the observed facilitatory priming with T2 incorrect. Although our instructions emphasized the importance of case for the letter targets, subjects may sometimes have confused the case of T2 and T3 letters. In such instances, the targets would have been reported in reverse order because the uppercase letter was reported first. For example, if a subject correctly identified both letters, but for some reason confused their case, then T2 and T3 responses would both be scored as incorrect on mismatch trials. By contrast, both would be scored as correct on match trials, as the exchange in case would go undetected. This might inflate our estimate of matching performance relative to mismatching performance.

The RB effect with T2 correct cannot be explained by case exchanges because they would artifactually increase any advantages, rather than disadvantages, of match trials. However, in principle, case exchanges could conceivably have produced the benefit for match trials when T2 was incorrect (i.e., the facilitatory priming effect apparent in the two bars at the right of Fig. 2a). Consider a hypothetical trial on which abstract identity is correctly extracted for T2, but not for T3. Case exchanges for such trials could in principle produce an apparent priming effect. On such a match trial, T3 would be scored as correct with T2 incorrect (thus pushing up the white bar at the right of Fig. 2a), whereas both targets would be scored as incorrect on such a mismatch trial (pushing down the shaded bar at the right of Fig. 2a).

To examine such artifactual accounts further, we needed some
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estimate for the rate of case exchanges. These cannot be measured directly when T2 and T3 match, because the same identity was presented in upper- and in lowercase. However, case exchanges can be estimated using mismatch trials by examining how often a presented letter was reported in the wrong case. For example, with A as T2 and d as T3, the response “big D, small a” contains both presented identities, each in the wrong case; “big D, small e” contains the T3 identity in the wrong case; and “big E, small a” contains the T2 identity in the wrong case. By taking each of these various error types into account, we derived an estimate of the case-exchange rate for mismatch trials, which was used to correct the data for match trials.

The case-exchange rates for the three types just described were 3.1%, 4.2%, and 4.9%, respectively. Note that this is a conservative correction because every response on mismatch trials that could potentially have resulted from a case exchange is counted as such, even though it may actually have arisen for other reasons (e.g., a random error).

The corrected results are shown in Figure 2b. In this reanalysis of the data, mismatch trials with possible case exchanges for T2 or T3 identities, or both, were still scored as incorrect, but the proportions of such mismatch trials were used to reduce the number of responses scored as correct in the match trials by a corresponding proportion. These corrected results show the same pattern as before. A two-way ANOVA on T3 accuracy again found an interaction between T2 performance and trial type (F(1, 9) = 87.3, p < .01), with planned comparisons showing RB for T3 when T2 was correctly reported (F(1, 9) = 102.4, p < .01), but facilitatory priming for T3 when T2 was incorrect (F(1, 9) = 9.6, p < .05). Thus, our findings survive a conservative correction for possible case exchanges.

Although Experiment 1 provides encouraging support for type activation during the AB, further evidence that priming can occur in this paradigm would strengthen the main claim in this article. In our next study, we sought to accomplish this goal by replicating the priming effect in a task for which case exchanges would not be an issue. The design was similar to the first, except that we presented an RSVP stream of words. This procedure allowed us to measure any semantic priming between a related T2 and T3 (e.g., doctor followed by nurse) when T2 was missed during the AB. Because T2 and T3 in Experiment 1 had different identities even when related, we no longer had to rely on case to distinguish one from the other. Hence, the issue of case exchange no longer arose.

RB was no longer expected in any condition, as T3 was never a repetition of T2. Instead, we expected to find facilitatory priming when T2 was correctly perceived and a related T3 followed. We also expected that if the AB does indeed operate at a high level, allowing type activation, a similar result would be found even when T2 was missed because of the blink.

**EXPERIMENT 2**

The method followed Experiment 1 except as indicated.

**Participants**

Ten University of Calgary students (3 men and 7 women) between the ages of 17 and 24 (M = 19.9) served as participants. They had not taken part in the previous study.

**Apparatus and Materials**

The viewing distance was 42 cm. The temporal parameters for each RSVP stream were just as before. However, the single-character stimuli were replaced with words of three to six uppercase letters each. The new task was to identify three colored words in a stream of black non-target words. T1 was a white word taken from a list of 13 common words (see Table 1, left-most column). Thirteen pairs of related words (see Table 1, middle and right columns) were used to provide T2 and T3 on related trials. These pairs had previously been demonstrated to yield facilitatory priming with unrestricted viewing (Shelton & Martin, 1992). The same words were used as T2 and T3 on unrelated trials, but in different pairings. T2 was red, and appeared as the third item after T1, where any AB triggered by T1 should be maximal (Raymond et al., 1992), T3 was yellow, and appeared as the sixth item after T1, outside the temporal region that usually suffers from the AB caused by T1. The nontargets were drawn from a set of 30 common words (see Table 2). All words subtended 0.55° in height, with three-, four-, five-, and six-letter words subtending 1.09°, 1.64°, 2.18°, and 2.73° in width, respectively.

**Procedure**

Each participant completed one 45-min session composed of a practice and an experimental block. As before, participants first reported each type of target alone for 10 trials and then reported all three targets together for an additional 10 trials. The experimental block contained 312 trials. Each of the 13 related T2 and T3 word pairs was presented 12 times to yield 156 related trials. Each T2 word was also combined with each of the 12 unrelated T3 words to produce 156 unrelated trials. The 312 trials were then presented in a random order for each subject.

A printed list of all possible T1, T2, and T3 words throughout the experiment was presented to the participant for inspection after each trial. Responses were made by selecting one word from the appropriate list for each of the three targets. The 39 different words on the response list (13 T1 words, 13 T2 words, and 13 T3 words) were selected to minimize the likelihood that partial retrieval cues (e.g., a word beginning with the letter C) were sufficient to specify the correct response.

| Table 1. Words used as T1, T2, and T3 in Experiment 2, with related T2-T3 pairs shown on a common row |
|-----------------|-----------------|-----------------|
| **T1** | **T2** | **T3** |
| RIVER | DOCTOR | NURSE |
| LETTER | GIRL | BOY |
| GRAPE | COLD | HOT |
| NOSE | DAY | NIGHT |
| BARN | QUEEN | KING |
| ROOF | SWEET | SOUR |
| PAN | MOUSE | CAT |
| TENT | TREE | LEAF |
| FLUTE | THREAD | NEEDLE |
| CAR | FROWN | SMILE |
| LOW | COFFEE | CUP |
| NAME | KEY | LOCK |
| MIRROR | SKIP | JUMP |

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They reveal a similar facilitatory semantic priming effect from word targets that are missed during the blink.

CONCLUSIONS

Our experiments investigated the fate of targets that are missed during an AB in RSVP tasks. Experiment 1 found the usual detrimental effect of RB upon the second of two repeated targets (the same letter in different cases), but only when the first letter was consciously detected. When the first letter was missed because of an AB from a preceding target, the RB effect reversed to become a facilitatory priming effect (Fig. 2a). This finding suggests that the AB may operate at relatively high levels of processing. Awareness of events during the blink can be prevented (i.e., tokenization is disrupted), but type activation can apparently continue unconsciously, at levels of representation that transfer across cases. This conclusion was upheld after a conservative correction for possible case changes (Fig. 2b) was made.

Experiment 2 used a revised procedure to strengthen the priming claim and found semantic priming from word targets missed during an AB, under conditions in which case confusions could not arise. This second experiment provides important evidence that substantial processing, up to semantic levels, can take place during an AB. Evidently, the attentional gating that produces the blink arises at much later levels of processing than any analogy with eyelid blinks would imply.

Convergent evidence for the level of processing during the AB has recently been provided in two studies (Shapiro, Caldwell, & Sorensen, in press; Maki, Frigen, & Paulson, in press). We (Shapiro et al., in press) observed that a participant’s own name tends not to suffer from

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**Table 2. Distractor words used in Experiment 2**

<table>
<thead>
<tr>
<th>BOOK</th>
<th>CLOUD</th>
<th>CORD</th>
<th>JAM</th>
<th>UNCLE</th>
<th>SING</th>
<th>CHAIR</th>
<th>FILM</th>
<th>RECORD</th>
<th>ARROW</th>
<th>WIND</th>
<th>WATCH</th>
<th>TOP</th>
<th>DIRT</th>
<th>BONE</th>
<th>RED</th>
<th>NAIL</th>
<th>LID</th>
</tr>
</thead>
</table>

**Results and Discussion**

T1 was reported correctly on 87.8% of trials, and the remaining trials were excluded from further analyses. No corrections were required in these analyses because errors due to case exchanges could no longer arise. Figure 3 shows the accuracy of T3 identification, separately for related and unrelated trials, and as a function of whether subjects reported T2 correctly (46.3% of all analyzed trials) or incorrectly (53.7% of all analyzed trials). A two-way within-subjects ANOVA on T3 accuracy had factors of T2 performance (correct or incorrect) and trial type (related or unrelated). There was a main effect of trial type, $F(1, 9) = 11.3, p < .01$, with the advantage for related trials revealing a facilitatory semantic priming effect between T2 and T3. There was no effect of T2 performance, $F(1, 9) = 1.9, n.s.$, and the interaction with trial type did not quite reach significance, $F(1, 9) = 3.8, p < .08$. Planned comparisons of related to unrelated trials for T2 correct and T2 incorrect reveal that related trials showed better performance than unrelated trials both when T2 was correct and when it was incorrect, $t(1, 9) = 7.25, p < .05$, and $t(1, 9) = 7.34, p < .05$, respectively. Thus, facilitatory semantic priming from T2 upon T3 was observed, regardless of whether T2 was reported correctly, although the trend was for a larger effect on trials when T2 did reach awareness (see the two left-most bars in Fig. 3).

The data with T2 correct replicate previous findings of facilitatory semantic priming between the present related word pairs when they reach awareness (Shelton & Martin, 1992). The data with T2 missed, because of the AB from T1, again provide the crucial novel finding.

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**Fig. 3.** Overall percentage of correct T3 responses in Experiment 3, as a function of correct versus incorrect T2 judgments (distinguished along the abscissa), on related versus unrelated trials (light vs. dark bars, respectively).
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An AB in RSVP streams of words. This phenomenon is similar to the well-known auditory cocktail party effect, whereby a participant can detect his or her own name in the nonshadowed ear under conditions of dichotic listening (Moray, 1959). These results for names imply that during an AB, sufficient processing can take place to allow conscious detection of a stimulus with special significance. In a similar vein, but using conventional (two-target) AB methodology, Maki et al. (in press) reported significant priming of T2 by a related T1 and, more relevant to our discussion here, priming (but at a reduced level) of T2 by a related distractor occurring in the AB interval between T1 and T2. Moreover, some results by Broadbent and Broadbent (1987) are consistent with the present finding of a nonreported target priming a subsequent related target, although their effect was statistically weaker than our own findings. The present results (and those of Maki et al.) demonstrate that processing during the blink is not restricted to stimuli of special significance, as in our previous experiment (Shapiro et al., in press). Furthermore, these (and other; e.g., Luck, Vogel, & Shapiro, 1996) experiments suggest that processing can proceed to semantic levels without necessarily allowing the blinked target to become consciously reportable.

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