

Delayed Attentional Engagement in the Attentional Blink

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Observers often miss the 2nd of 2 visual targets (first target [T1] and second target [T2]) when these targets are presented closely in time; the attentional blink (AB). The authors hypothesized that the AB occurs because the attentional response to T2 is delayed by T1 processing, causing T2 to lose a competition for attention to the item that follows it. The authors investigated this hypothesis by determining whether the AB is attenuated when T2 is precued. The results from 4 experiments showed that the duration and magnitude of the AB were substantially reduced when T2 was precued. The observed improvement in T2 report did not occur at the expense of T1 report, suggesting that processing of T1 was already completed or was at least protected when the cue was presented. The authors conclude that, during the AB, there is a delay between detection and the selection of target candidates for consolidation in short-term memory.

Keywords: attentional blink, cuing, temporal dynamics, selective attention

A striking outcome from studies in which the relationship between attention and visual awareness is investigated is that clearly visible visual stimuli often fail to reach awareness when they are not attended (e.g., Chun & Marois, 2002). For example, visual scenes may undergo drastic changes unbeknownst to observers (“change blindness”; Simons & Levin, 1997), and observers may completely fail to notice a salient stimulus presented unexpectedly while they are attending to other stimuli (“inattention blindness”; Mack & Rock, 1998; Most et al., 2001). These findings indicate that “functional blindness” may occur for a clearly visible stimulus that is presented while observers perform an attention-demanding task on another object or region of space.

The Attentional Blink (AB)

One of the most intensively studied instances of functional blindness is the so-called AB (Raymond, Shapiro, & Arnell, 1992). The AB emerged from a series of studies in which rapid serial visual presentation (RSVP) was used to investigate the temporal dynamics of attentional processes involved in selecting and storing visual information in short-term memory (Broadbent & Broadbent,

1987; Reeves & Sperling, 1986; Weichselgartner & Sperling, 1987). In this paradigm, stimuli, such as letters, digits, or words, are presented in rapid succession at rates of approximately 10 stimuli per second. The stream contains two targets (first target [T1] and second target [T2]) that can be defined by visual features such as color (e.g., report two white letters from an RSVP stream of black distractor letters) or category (e.g., report two digits from an RSVP stream of letters) or any other characteristic that distinguishes them from the distractors. In a study by Raymond et al. (1992), for example, observers had to report the identity of a white letter (first target; hereafter called *T1*) presented in a sequence of black letters and to determine whether a black *X* (*T2*) was presented in the remainder of the sequence. The main finding from this study was that *T2* detection was severely impaired when the *X* followed *T1* by less than 500 ms. More important, however, detection performance was not impaired when observers were instructed to ignore the white letter and to pay full attention to the second task. On the basis of this finding, Raymond et al. termed this effect the AB, thereby emphasizing that it was the requirement to attend *T1* that caused the *T2* deficit.

Several different models have been proposed to account for the AB. Indeed, although these models differ in their exact formulation of the processing limitation that underlies the AB, all of the models commonly distinguish a high-capacity early stage of processing (i.e., Stage I) and a severely limited capacity second stage of processing (i.e., Stage II; Chun & Potter, 1995; Giesbrecht & Di Lollo, 1998; Jolicoeur & Dell’Acqua, 1998; Shapiro, Arnell, & Raymond, 1997; Vogel, Luck, & Shapiro, 1998). In Stage I, representations of the RSVP items are retained briefly, but long enough for them to activate conceptual information in long-term memory (Potter, 1993). The resulting memory trace is short-lived (Chun & Potter, 1995; Maki, Frigen, & Paulson, 1997), however, and easily overwritten by items that subsequently enter Stage I.

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Therefore, the ability to report items from RSVP depends critically on whether they can be admitted to a more durable form of short-term memory (i.e., Stage II).

Attentional control settings play a prominent role in determining which items are transferred to short-term memory, such that only those items that are potentially relevant for the observer are fully identified and selected for consolidation. However, processes mediating the selection and identification of a target are heavily taxed under the high rate of presentation used in RSVP. In particular, distractors presented in direct succession to the target interfere with its identification by masking the target representation (e.g., Chun & Potter, 1995; Grandison, Ghirardelli, & Egeth, 1997; Marois, Chun, & Gore, 2000; Raymond et al., 1992; Seiffert & Di Lollo, 1997) and by competing for identification and representation in short-term memory (Shapiro, Raymond, & Arnell, 1994). As a consequence, the available processing bandwidth for subsequent targets is temporarily restricted while the identification and consolidation of T1 occurs (Chun & Potter, 1995; Jolicoeur & Dell'Acqua, 1998; Shapiro et al., 1997). During this period, the selection of a following T2 for Stage II processing is postponed until T1 has been processed through Stage II, thereby increasing the likelihood that T2's representation is lost because of passive decay and retroactive interference from following distractors before it can be selected for consolidation (Giesbrecht & Di Lollo, 1998).

The Present Study

Studies examining the types of errors people make in reporting T2 provide some evidence against the notion that these errors occur because T2 consolidation is postponed until T1 consolidation has been completed (Chun, 1997a; Isaak, Shapiro, & Martin, 1999). In these studies, the to-be-reported feature of the targets (i.e., their identity) was distinct from the target-defining feature (e.g., letters presented in a white outline frame), thereby allowing for analyses of whether errors in T2 report involve reports of other items from the RSVP sequence (see also, Botella, Barriopedro, & Suero, 2001). The results from these analyses show that errors in report of T2s presented during the typical 500-ms duration of the AB typically involve reports of the distractor directly succeeding T2. For example, Isaak et al. (1999; see Experiment 2) found that this type of posttarget intrusion error occurred on 33% of the trials in which T2 was presented at a 180-ms stimulus onset asynchrony (SOA). Thus, the distractors that were being reported in this case were those presented at an SOA of 270 ms, that is, well within the temporal extent of the AB that was observed in that experiment.

The predominance of posttarget intrusion errors can be interpreted as evidence against the view that the time course of the AB reflects the period of time during which a serial process of consolidation is tied up processing T1. In particular, this finding suggests that consolidation of new information is possible even when this information is presented well within the typical duration of the AB. A straightforward alternative to the notion of a strict consolidation bottleneck would be that there is a delay between the moment at which a potential target (e.g., T2) is detected in Stage I and the moment at which attention can be allocated to the target representation. As a consequence, the item to follow T2 may inadvertently be selected and processed instead of the target, resulting in the high incidence of posttarget intrusion errors.

Alternatively, it may be the case that these intrusions occur when consolidation of T1 has just been completed when the item succeeding T2 is presented. In this regard, it is important to note that the period of time during which T1 occupies Stage II processes may vary, depending on factors such as the confusability of T1 and its mask (e.g., Chun & Potter, 1995; Raymond, Shapiro, & Arnell, 1995), the amount of information that is to be consolidated (e.g., Jolicoeur & Dell'Acqua, 2000; Olson, Chun, & Anderson, 2001), and variations in the mental state of the observer (Olivers & Nieuwenhuis, 2005). Given that these factors may vary from trial to trial—for example, because T1 and its mask are randomly selected from a given set of stimuli on each trial—it is likely that the duration of Stage II processing of T1 will also vary from trial to trial, allowing consolidation times to range from 200 to 500 ms. Indeed, T2 performance typically follows a gradually increasing function across SOA (time between onset of T1 and T2), with T2 report improving across SOAs of 200–500 ms, after which performance reaches an asymptotic level.

In the present study, we hypothesized that posttarget intrusion errors occur because the allocation of Stage II attention to T2 is slowed down during the AB. If a distractor that shares one of the target-defining features precedes T2, then it might initiate processing involved in selecting information for consolidation, thereby allowing the following T2 to be consolidated. This precuing manipulation should attenuate the AB, allowing for better T2 report across SOAs at which T2 performance in an uncued condition is impaired. The benefit should be strongest at the shortest lags, resulting in an interaction of SOA and cuing. Note that if posttarget intrusions depend on the inherent variability of the duration of Stage II processing of T1, then one would not expect that precuing T2 would have an influence on T2 report, as this manipulation is unlikely to speed up the ongoing processing of a previously selected T1.

In order to test the delayed attentional engagement hypothesis, we devised a series of experiments in which the observers identified two masked targets presented at different SOAs, with T2 being precued on half the trials. In the first three experiments, we used an RSVP task in which targets were defined by a conjunction of features (i.e., color and category). The precuing manipulation involved the presentation of a “false target” (i.e., a distractor presented in the same color as the targets directly in advance of T2). Recent work has shown that distractors that match the attentional set of the observer will automatically capture attention when they are searching for a target in RSVP (Folk, Leber, & Egeth, 2002; Ghorashi, Zuvic, Visser, & Di Lollo, 2003). On the basis of this finding, we reasoned that a distractor matching the target template could capture attention, thereby triggering the selection of information from Stage I for consolidation. In the fourth experiment, the effect of cuing T2 was examined in the so-called dwell-time paradigm (Duncan, Ward, & Shapiro, 1994), wherein only the two targets and their masks are presented, with T2 always appearing in a different location than T1. In this experiment, T2 was preceded by a plus sign that matched the target set in that it had a sudden onset and occurred at the same location as T2.

Experiment 1

In Experiment 1, observers were to report two red digits presented in an RSVP stream of black letters. The two targets were

presented at an SOA of 333 or 833 ms (i.e., three vs. nine distractors intervened between T1 and T2 at 83 ms per item). At the 333-ms SOA, the AB was likely to be in effect, whereas T2 report was likely to have fully recovered from the AB at the long SOA. The cuing manipulation involved the presentation of one or more red letters in advance of T2. By varying the number of red letters preceding T2 from 1 to 3, hence varying the cue-target interval, we could explore the temporal characteristics of the presumed delay in allocating attention. Performance on T2 was compared between these three conditions and an uncued baseline condition, in which T2 was not preceded by red distractors.

Method

Participants. Eighteen observers participated in the experiment, consisting of undergraduate psychology students who received course credit in return for participating and graduate students and staff members from the psychology department of Yale University, who participated on a voluntary basis. On the basis of self-report, all participants had normal or corrected-to-normal visual acuity. None of the participants reported being color-blind.

Apparatus and stimuli. The experiment was conducted at the psychology department of Yale University. The experiment was run on a Pentium III laptop, with the stimuli being presented on a secondary 17-in. (43-cm) monitor that was connected to the laptop. The refresh rate of the monitor was 60 Hz. The generation of stimuli and collection of responses were controlled using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002). The appropriate tests were conducted to ensure timing accuracy. Stimuli used were the letters of the alphabet (excluding *I* and *O*) and the digits 2–9. These stimuli were presented on a gray background, in Helvetica font (14 point). The observers viewed the stimuli from a distance of approximately 50 cm. At this viewing distance, the stimuli were 0.6° high and 0.5° wide, on average.

Procedure. A trial consisted of the presentation of a fixation cross, followed by an RSVP sequence of 16 uppercase letters (i.e., distractors)

and two digits (see Figure 1). The task for the participants was to identify the two-digit targets by typing them on the keyboard. They were encouraged to guess whether they were unsure about which digits were presented. The distractors were randomly selected letters of the alphabet (excluding *I* and *O*), with the restriction that no letter was repeated within a trial. The targets were randomly selected from the digits 2–9, with the restriction that T2 had to be different than T1. We modified the standard RSVP procedure, as used in previous studies of the AB, by using a fixed pattern mask for T2 (see Figure 1). This mask had a high degree of similarity to the digits used as targets because it comprised features of the digits 4, 5, and 7. We chose to use this pattern mask to avoid ceiling effects in T2 report, which pose a significant problem for the interpretation of potential interactions. The targets were always presented in red, whereas the distractors were presented in black. T2 could be preceded by 1, 2, or 3 red letters (hereafter referred to as the T2-1, T2-2, and T2-3 cuing conditions) or by black letters (the uncued condition).

The fixation cross was presented for 500 ms. Each item in the RSVP sequences was presented for 33 ms, and followed by a 50-ms blank interval. T1 could be presented as the fourth or sixth item in the sequence. T2 followed T1 after 3 or 9 distractors. The corresponding SOAs were 333 and 833 ms, respectively. All combinations of cuing condition (uncued, T2-1, T2-2, and T2-3) and SOA were repeated 20 times, the order of the presentation of the different trial types being random. The experiment began with a set of 16 practice trials and took approximately 20 min.

Data analysis. We performed two analyses on the data of each of the experiments reported in this study. The first analysis concerned the proportion of trials on which T2 was correctly reported, conditionalized on correct report of T1 (i.e., T2|T1). Conditionalizing the data on T1 report is typically done to certify that T1 was attended and stored in memory. The second analysis concerned T1 performance across SOA and cue condition, conditionalized on T2 report (i.e., T1|T2). This analysis was done to determine whether the potential effect of precuing T2 influenced the ability to report T1. Mean proportions correct report of T1 and T2 were corrected for guessing using a procedure described by Dell’Acqua, Pascali, Jolicoeur, and Sessa (2003).

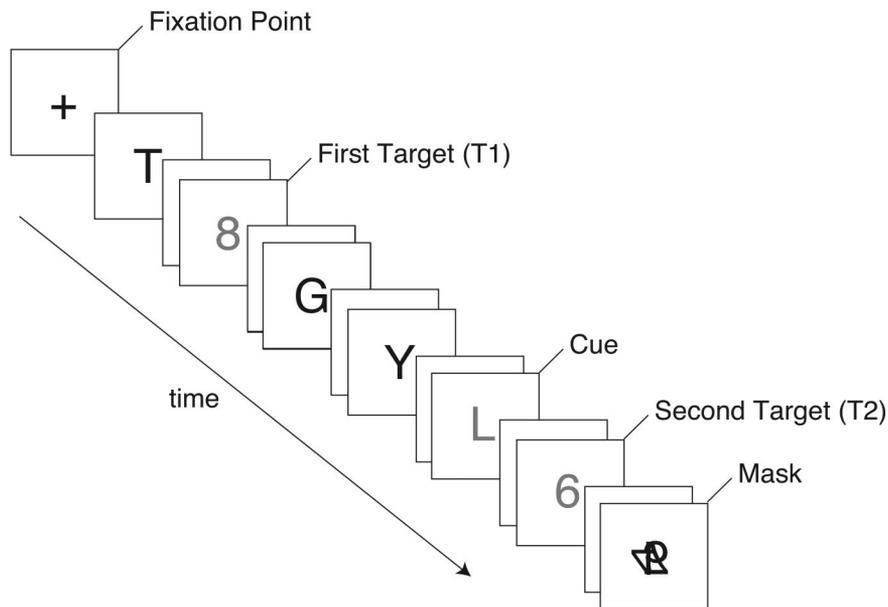


Figure 1. Example of a trial in Experiment 1. On this trial, the second target was cued by a single red distractor and presented at a stimulus onset asynchrony of 333 ms (e.g., Lag 4). Red items are depicted as gray.

Results and Discussion

The data from 1 participant were excluded because for this participant, performance was at ceiling at both SOAs in the uncued condition. For the remaining 17 observers, T1 was correctly identified on 92% of the trials. Analysis of T2/T1 was a repeated measures analysis, using cuing condition and SOA as within-subjects factors. The results from this analysis showed main effects of both SOA and cuing condition, $F(1, 16) = 24.3, p < .001$; and $F(3, 48) = 7.0, p < .05$, respectively; as well as a significant interaction of these factors, $F(3, 48) = 3.2, p < .05$. These data are plotted in Figure 2.

In order to explore the nature of the SOA \times Cuing condition interaction, we subsequently compared each of the three conditions in which T2 was preceded by red items with the uncued baseline condition. The contrast using the T2-1 and the uncued condition revealed a significant main effect of cue condition, with performance averaged across SOAs being more accurate in the T2-1 condition ($M = 82\%$) than in the uncued condition ($M = 73\%$), $F(1, 16) = 7.1, p < .05$. Contrasting the uncued and the T2-2 conditions showed that there was a significant SOA \times Cuing condition interaction, $F(1, 16) = 17.2, p < .01$. The T2-3 condition did not differ significantly from the uncued condition (all $ps > .14$). Pairwise t tests on the difference between T2 performance in the uncued condition and each of the cuing conditions for each SOA separately showed that only the difference between the uncued and T2-2 condition at the short SOA reached significance, $t(16) = 5.1, p < .001$. None of the other differences reached significance, indicating that T2 report at the short SOA was only enhanced in the T2-2 condition. Analyses of T1/T2 showed that there were no effects of SOA, cue condition, or the interaction of SOA and cue condition, indicating that T1 performance was not affected by cuing T2.

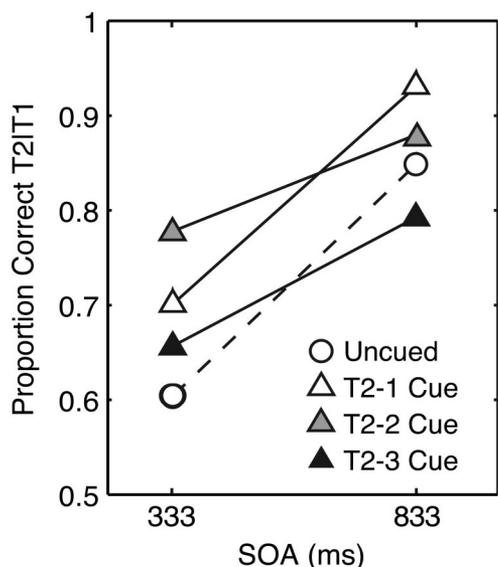


Figure 2. Results from Experiment 1. Graph shows proportion correct identification of T2 (second target) for trials on which T1 (first target) was correctly reported (T2/T1), plotted as a function of stimulus onset asynchrony (SOA) for the different cuing conditions. ms = milliseconds.

The results provide partial support for the hypothesis that pre-cuing T2 resolves a delay in attentional engagement that underlies the AB effect. On the one hand, the finding of an interaction of SOA and cuing in the T2-2 condition is consistent with this contention, as it shows that the cuing effect was strongest when the impairment in T2 report was most pronounced. In contrast, the results from the T2-1 condition showed a moderate cuing effect that was stable across SOA, suggesting that cuing enhanced T2 report independently from the locus of the AB. However, the lack of an interaction may have been driven by the absence of a strong cuing effect at the short SOA, reflecting that the cue-target interval of 83 ms was insufficient to fully counteract the delay in allocating attention to T2. On the other hand, the observed difference at the long SOA may reflect a different type of cuing effect. In particular, assuming that observers noticed the cue at the long SOA, they may have used it as a signal to prepare for the presentation of an upcoming target. More important, however, whether this resulted in better T2 performance depended on the number of cues presented such that T2 performance decreased across the T2-1, T2-2, and T2-3 cuing conditions at the long SOA ($M = 93, M = 88$, and $M = 79\%$ correct, respectively, $p < .001$ for a linear contrast). This finding is consistent with the possibility that the cue initiated a processing episode that reached full potential at approximately 100 ms after the onset of the cue and dissipated during the following 100 ms (e.g., Chun & Potter, 1995; Potter, Staub, & O'Connor, 2002; Shih, 2000; Sperling & Weichselgartner, 1995).

Experiment 2

The purpose of Experiment 2 was to distinguish between the possibility that the cue enhanced T2 report because it allowed observers to be prepared for the presentation of the target versus the possibility that cuing enhanced T2 report because it resolved a delay in attentional engagement. According to the former interpretation of the cuing effect, any perceptual event signaling the upcoming presentation of the target would result in better T2 report, thereby predicting similar cuing effects with same- and different-color cues.¹ If, on the other hand, the cuing benefit occurs because the cue elicits an attentional response because it matches the attentional set used for selection (i.e., target color), then cuing should only occur with same-color precues. These accounts of cuing were tested in Experiment 2 by comparing T2 report performance between an uncued baseline condition and two cuing conditions: one in which the cue was presented in the same color as T2, and one in which the precue was a distractor colored differently than T2. On the basis of the results from Experiment 1 that showed that two cues produce a maximal effect, we chose to use only this T2-2 condition in Experiment 2.

Method

Participants. Sixteen undergraduate students from Utrecht University, Utrecht, the Netherlands, participated in the experiment in return for monetary compensation. All had corrected-to-normal vision. On the basis of self-report, none of the observers was color-blind.

Apparatus and stimuli. The experiment was run on a Pentium III computer, with a monitor refresh rate of 85 Hz. The viewing conditions and

¹ We thank Ed Vogel and Chip Folk for raising this issue.

stimuli used were the same as those described for Experiment 1. One difference with Experiment 1 was that the targets and cues in Experiment 2 could be presented in green or red. These colors were matched for luminance for each individual observer in a flicker procedure that preceded the experiment.

Procedure. Observers first performed a flicker procedure, in which they were to adjust the luminance of either the color green or red relative to a fixed gray until they experienced minimal flicker from alternating full screens of gray and the two colors. The values for red and green were determined in two separate runs of the procedure, with each run consisting of five replications.

Each trial consisted of a stream of uppercase letters in which two digits were embedded. The color in which the targets were presented was a between-subjects factor such that the targets were red for half the observers and green for the other half. There were two cuing conditions, one in which T2 was preceded by two same-color distractors (i.e., same-color cues), and one in which T2 was preceded by two distractors presented in the other color (i.e., different-color cues). Performance in these cuing conditions was compared with performance in an uncued baseline condition, in which all distractors were presented in black. As in Experiment 1, each trial began with the presentation of a fixation cross, and T1 could be presented as the fourth or the sixth item in the RSVP stream. T2 followed T1 after 3 or 15 distractors, corresponding to SOAs of 282 and 1,129 ms at a presentation rate of approximately 14 items per second (i.e., 70.5 ms per item). We used the same pattern mask for T2 as that used in Experiment 1.

The fixation cross was presented for 494 ms. Each item of the subsequently presented RSVP stream was presented for three frames and followed by a blank interstimulus interval of three frames, yielding an SOA of 70.5 ms. All combinations of cue condition (uncued, same-color, and different-color) and SOA (282 or 1,129 ms) were repeated 12 times for each T1 position, yielding 24 trials per condition and a total of 144 trials. The experiment began with 24 practice trials and took approximately 15 min.

Results and Discussion

T1 was accurately identified on 78% of the trials. Accuracy of T1 report was not affected by SOA (282 vs. 1,129 ms) or by cuing condition (uncued, same-color cue, or different-color cue). Both factors did have significant effects on T2 report, however, $F(2, 28) = 35.0, p < .001$; and, $F(1, 14) = 47.1, p < .001$, for the effects of SOA and cuing condition, respectively. Moreover, there was a significant SOA \times Cuing interaction, $F(2, 28) = 6.4, p < .01$. T2/T1 performance is plotted in Figure 3 as a function of SOA and cuing condition, collapsed across target color.² A contrast comparing performance in the uncued condition with performance in the different-color cuing condition showed a main effect of cuing, $F(1, 14) = 16.3, p < .01$, whereas a comparison with performance in the same-color cuing condition showed that there was a significant SOA \times Cuing condition interaction for same-color cues, $F(1, 14) = 11.5, p < .01$. Pairwise t tests comparing T2 report between two cuing conditions and the uncued condition at the short SOA showed that T2 performance was significantly enhanced with same-color cues ($M = 25$ vs. $M = 59\%$ correct T2/T1), $t(15) = 8.0, p < .001$, whereas different-color cues had a small effect ($M = 25$ vs. $M = 35\%$ correct T2 report for the uncued and different-color cue conditions, respectively), $t(15) = 2.2, p = .05$. T2 report was significantly better in the same-color cuing condition than in the different-color cuing condition, $t(15) = 4.87, p < .001$. At the long SOA, both cuing conditions differed significantly from the uncued condition, $t(15) = 3.5, p < .01$; and,

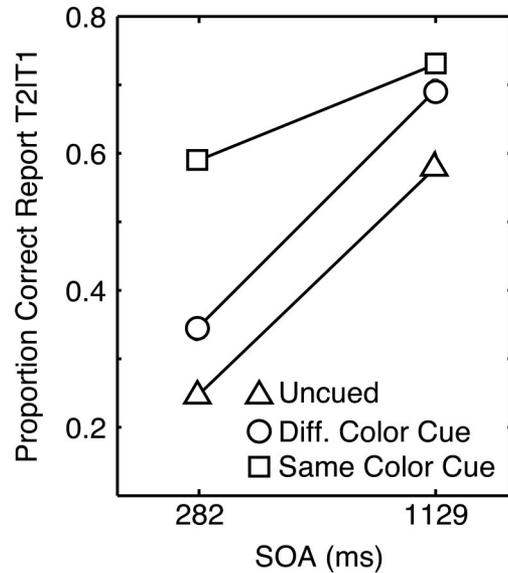


Figure 3. Results from Experiment 2. Attentional blink effects for uncued T2s (second targets) and T2s cued by distractors presented in the same or in a different (Diff.) color as T2. T1 = first target; SOA = stimulus onset asynchrony; ms = milliseconds.

$t(15) = 3.1, p < .01$, for same- and different-color cues, respectively.

Taken together, the results show that there is some enhancement in T2 report with both same and different cues at the long SOA, whereas only same-color cues produced a substantial improvement in T2 report at the short SOA. These results can be interpreted as evidence for two mechanisms of cuing. On the one hand, cues may be used as an indication of when the target will appear, thereby reducing temporal uncertainty and allowing observers to prepare for an upcoming target. This effect does not depend on a match between the physical appearance of the cue and that of the targets and is of similar magnitude across SOAs. The second type of cuing effect depends on whether the cue matches the target specification and is specific to short SOAs during the AB, in which detection of a target-defining feature triggers processes required for admitting information to short-term memory.

Experiment 3

The goal of Experiment 3 was to provide further evidence that precuing T2 attenuates the AB by initiating processes of identification and selection that are otherwise initiated too slowly to catch up with T2. An alternative account of cuing would be that precuing facilitates the low-level perceptual processing of the target through priming the color of the target. This may result in Stage I representations that are less susceptible to interference from a following mask and, therefore, more easily identified. In order to test this low-level perceptual priming account, we compared cuing effects between a single- and a dual-target condition in Experiment 3. If

² There was no significant three-way interaction of target color, SOA, and cuing condition, $F(2, 28) = 1.7, p = .21$.

cuing simply enhances perception, then similar cuing effects should be observed across the single- and dual-target conditions without any difference in cuing as a function of SOA in the latter condition. In contrast, the prediction from the present view is that cuing should produce a selective benefit for targets presented during the AB such that no benefit should be observed in the single-target condition, whereas cuing should interact with SOA in the dual-target condition.

The task in Experiment 3 concerned a “true” conjunction search in that the RSVP sequences now consisted of a mixture of letters and digits, each presented in either green, blue, or gray on a dark gray background. The targets were red digits, and all colors used were matched for luminance. In the dual-target condition, each sequence contained two red digits, whereas the single-target condition was constructed by presenting the first red digit in a color other than red. In contrast to the cuing procedure in Experiments 1 and 2, the cue now always consisted of a single red letter that directly preceded the target in the single-target condition, and T2 in the dual-target condition, on half the trials. The reason for this was that we wanted to allow for distractor digits to occur in the Lag 2 position (i.e., the second item to follow T1), that is, directly preceding the cue in trials in which T2 was presented at an SOA of 282 ms. Moreover, the results from a pilot experiment showed substantial cuing effects with only a single cue in this type of task. None of the targets was ever directly preceded or followed by a digit distractor.

Method

Participants. Fifteen undergraduate students from Utrecht University participated in the experiment. All had normal or corrected-to-normal vision, and none reported being color-blind.

Apparatus and stimuli. The experiment was conducted at Utrecht University using the same setup as that used in Experiment 2.

Procedure. The colors used for the RSVP items were matched for luminance for each individual observer using the same flicker procedure as that described in the *Method* section of Experiment 2. The presentation time of the RSVP items and the intervening blank intervals were the same as in Experiment 2. Either three or eight distractors separated the targets in the dual-target condition, yielding SOAs of 282 and 635 ms, respectively. The single-target condition consisted of nominally the same sequences, wherein T1 was presented in one of the distractor colors. In contrast to the procedures in the previous two experiments, we did not use a pattern mask for T2. Instead, T2 was masked by a randomly selected distractor. Each combination of target condition (single target vs. dual target), cuing condition (uncued vs. cued), and SOA (282 vs. 635 ms) was repeated 24 times. The single- and dual-target conditions were run in separate blocks. Observers first performed the single-target block. Both blocks were preceded by a set of 24 practice trials.

Results and Discussion

We ran two separate repeated measures analyses of variance, one for target report accuracy in the single-target condition and one for T2 report accuracy in the dual-target condition. This was done because the latter analysis was restricted to trials on which T1 was correctly identified (i.e., T2/T1), thereby creating unequal numbers of observations in the single- and dual-target conditions. In the dual-target condition, T1 was correctly reported on 78% of the trials. Performance on T1 was not affected by SOA or cuing condition. The analyses of target report in the single- and dual-

target conditions used SOA (282 vs. 635 ms) and cue condition (uncued vs. cued) as within-subjects factors. Figure 4 shows performance for the single- and dual-target conditions, plotted as a function of SOA for uncued and cued targets separately.

For the dual-target condition, there were main effects of SOA and cuing condition, $F(1, 14) = 13.1, p < .05$; and $F(1, 14) = 18.6, p < .05$, respectively. In addition, there was a significant SOA \times Cuing condition interaction, $F(1, 14) = 11.8, p < .05$. As can be seen in Figure 4, this interaction reflects the finding that cuing produced substantial improvement in T2 report at the short SOA but less improvement at the long SOA. Pairwise t tests on the differences between cued and uncued T2 performance at the short and long SOAs separately showed that cuing produced a significant effect on T2 report at both SOAs, $t(14) = 5.6, p < .001$; and, $t(14) = 4.2, p < .05$, for the short and long SOAs, respectively. Analysis of target report in the single-target condition showed that neither SOA nor cuing condition had a significant effect on target report in the single-target condition (both $ps > .20$). More important, performance in the cued condition remained below 90% correct, indicating that the absence of a cuing effect in the single-target condition was unlikely to reflect the occurrence of a ceiling effect for target report. Thus, cuing produced an enhancement in target report that was specific to the dual-target condition and that was more pronounced during than after the time course of the AB.

Experiment 4

The results from the first three experiments show that precuing T2 in RSVP improves report of the target. The effect of cuing appears specific to the AB such that cuing produced a substantial benefit for T2 report only when T2 was presented shortly after T1. In Experiment 4, we set out to generalize this cuing effect to a different paradigm that has previously been found to show similar effects as the RSVP paradigm: The dwell-time paradigm (Duncan

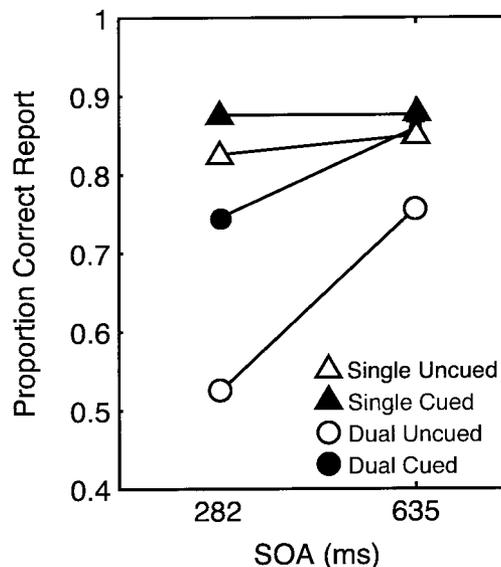


Figure 4. Results from Experiment 3. Proportion correct identification for the single- and dual-target condition, plotted as a function of stimulus onset asynchrony (SOA) and cuing condition. ms = milliseconds.

et al., 1994). In this paradigm, only the two targets and their masks are presented, with the two targets always being presented at different locations. The findings from this type of task closely resemble the findings from two-target RSVP tasks in that they show that T2 report is substantially impaired when T2 is presented within less than 500 ms from T1. Similar to the RSVP task, no impairment in T2 report occurs when T1 can be ignored. Moreover, the requirement to move the focus of attention from the location of T1 to that of T2 has been found not to contribute to the impairment in T2 report; T2 performance is similarly impaired when it is presented at the same location as T1 as when it is presented at a different location (Visser, Bischof, & Di Lollo, 1999). As such, the impairment in T2 report that is observed in this task can be considered to reflect the same postperceptual processing bottleneck as that underlying the AB in RSVP tasks (e.g., Vogel et al., 1998).

The goal of Experiment 4 was to replicate the finding that cuing T2 attenuates the AB in the dwell-time paradigm. To this end, T2 was precued in half of the trials. This involved the brief presentation of a plus sign at the location where T2 would appear (see Figure 5). The plus sign was presented for 94 ms and was directly followed by the presentation of T2. More important, the presentation duration of the targets was determined separately for each

observer so that target report accuracy remained below 75% correct. By restricting target report performance through limiting the amount of available perceptual information, we could determine whether the potential precuing benefit for T2 report occurred because precuing enhanced perceptual processing (e.g., by increasing the rate of information acquisition from the cued location; Alexander & Reinitz, 2000) or because it facilitated the selection of T2 at a postperceptual level of processing. In particular, this design entails that T2 report at the long SOA will be restricted by the short presentation time of the target. If cuing were to enhance perception of the target, then one might thus expect a cuing effect across both short and long SOAs.

Method

Participants. Fifteen colleagues from the department of psychonomics at Utrecht University, including Mark R. Nieuwenstein and Ignace T. C. Hooge, participated in the experiment on a voluntary basis. All participants had corrected or corrected-to-normal vision.

Stimuli and apparatus. The stimuli were presented on a 22-in. (56-cm) monitor. The resolution of the monitor was 640 × 480 pixels, at which the refresh rate was 85 Hz. Stimulus presentation was controlled using E-Prime software running on a Pentium IV, 2.53 GHz processor. The stimulus display consisted of a central fixation cross that was surrounded by four

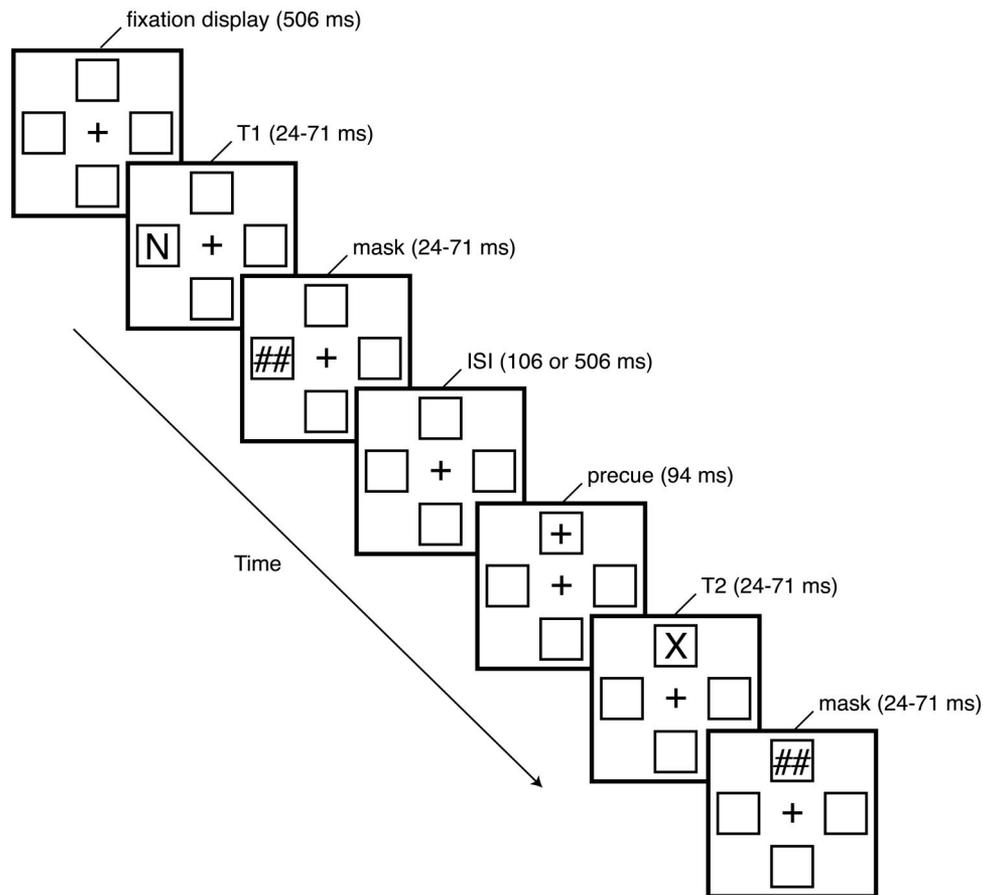


Figure 5. Sequence of events in a trial of Experiment 4. On this trial, T2 (second target) was precued. T1 = first target; ISI = interstimulus interval; ms = milliseconds.

gray outline frames that designated the potential target positions (see Figure 5). As in the experiments reported by Duncan et al. (1994), the distance between the fixation cross and the center of each of these four stimulus positions was 2.0° of visual angle. This was ensured by using a chinrest set at 64 cm from the screen. The two targets were drawn from the set {K, M, N, V, W, X, Y, Z}, and the mask consisted of two pound signs presented next to each other (i.e., “##”). Targets and masks were presented in a 12-point Helvetica font, in black. The precue was a black plus sign (i.e., “+”).

Procedure. We first determined the presentation duration at which each observer could report a single masked target in approximately 70% of the trials in order to restrict performance accuracy to levels well below ceiling for each observer. The target could be presented in any one of the possible locations. We used the method of constant stimuli for determining the presentation duration of both the targets and the masks. This procedure involved presenting targets and their masks for different durations while keeping the total duration for the target plus mask equal (e.g., McLaughlin, Shore, & Klein, 2001). The total duration of the target plus its mask was 106 ms. For example, if the target was presented for 47 ms, then the mask was presented for 59 ms, and vice versa. The target presentation duration was randomly chosen from the set {24, 35, 47, 59, and 71 ms} on each trial, with eight repetitions of each presentation duration.

After determining the presentation duration at which observers could identify a single masked target in approximately 70% of the trials, the actual experiment began. In the experiment, the two targets were presented at an SOA of 306 or 706 ms. The targets always appeared in two different locations of the display, which were selected randomly from the four possible stimulus positions. On one half of the trials, T2 was preceded by the presentation of a plus sign (see Figure 5). The SOA between the precue and T2 was fixed at 94 ms. This precue was always presented at the same location as that of T2. Thus, the design of the experiment concerned a 2×2 design, with each combination of SOA (i.e., 306 or 706 ms) and cue condition (i.e., T2 precued or not) being repeated 24 times in the experiment. The order in which the different types of trials were presented was randomized.

Results and Discussion

The average presentation duration of the targets was 49 ms (range = 24–76 ms, $SD = 14$ ms). T1 was correctly reported in 69% of the trials. There was no statistically significant correlation between presentation duration and T1 accuracy ($r = .223$, $p = .42$), indicating that different observers needed different stimulus durations to reach similar levels of target identification accuracy. The analysis of T2/T1 concerned a repeated measures analysis of variance, using SOA (306 vs. 706 ms) and cue condition (T2 precued vs. T2 uncued) as factors. These data are plotted in Figure 6.

Analyses of T2 report performance for trials on which T1 was correctly identified showed that there was a significant main effect of SOA, $F(1, 14) = 7.5$, $p < .05$, whereas there was a small effect of cue condition, $F(1, 14) = 3.5$, $p = .08$. In addition, there was an SOA \times Cue condition interaction, $F(1, 14) = 5.2$, $p < .05$. Separate analysis of the effect of SOA on T2 report in the uncued and cued conditions showed that there was a significant effect of SOA in the uncued condition ($M = .50$ vs. $M = .68$ for SOAs of 306 and 706 ms, respectively), $F(1, 14) = 9.0$, $p < .01$, but not in the cued condition ($M = .69$ vs. $M = .66$ for SOAs of 306 and 706 ms, respectively), $F(1, 14) = 0.12$, $p = .73$. As in the previous experiments, analyses of T1 performance showed no effects of SOA or cuing.

These results provide clear-cut evidence for a postperceptual locus of cuing in this task. In particular, there was no evidence for

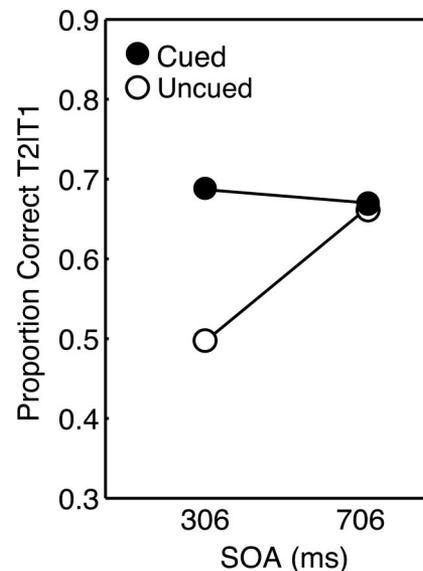


Figure 6. Results from Experiment 4. Figure plots the attentional blinks for cued and uncued targets. T2 = second target; T1 = first target; SOA = stimulus onset asynchrony; ms = milliseconds.

cuing when T2 report performance was data limited, that is, at the long SOA. In this regard, the results from this experiment differ from those obtained in the previous experiments, in which an effect of cuing was observed for T2s presented outside of the temporal extent of the AB. Of most interest, however, with the exception of Mark R. Nieuwenstein, none of the observers had noticed the cue in this experiment, suggesting that Stage II processing could be initiated without awareness of the cue.

General Discussion

In the present study, we investigated the cause of errors in report of the second of two masked visual targets presented within 500 ms, an effect known as the AB. Current models of the AB hold that these errors occur because T2 is denied access to processes involved in consolidating information in short-term memory while these processes are tied up with T1 (the bottleneck assumption; Chun & Potter, 1995; Giesbrecht & Di Lollo, 1998; Jolicoeur & Dell'Acqua, 1998; Shapiro et al., 1997; Vogel et al., 1998). As a consequence, the second target representation may be retained only briefly before it is masked, allowing implicit identification (i.e., Stage I) but no conscious memory for T2 (i.e., Stage II; Chun & Potter, 1995; Lamme, 2003; Luck, Vogel, & Shapiro, 1996; Marois, Yi, & Chun, 2004). The results from the experiments reported here consistently show that masked visual targets presented during the typical 500-ms duration of the AB effect can be reported, and therefore do gain access to short-term memory, when T2 is precued by a false target. This cuing effect was specific to the AB such that cuing had a more pronounced effect on report of targets presented during the AB than it had on targets presented outside of the typical 500-ms duration of the AB effect. Moreover, cuing did not enhance report in a single-target condition or when performance was data limited in a dual-target condition. In addition, a selective effect of cuing on the AB was observed only when

the cue matched a feature of the following target and not when the cue was a color singleton, suggesting that cuing depends critically on whether the cue is a potential target. More important, even though cuing produced large improvements in T2 report at SOAs as short as 282 ms, this did not affect T1 report.

The Case for Delayed Attentional Engagement

On the basis of the finding that presenting a false target in advance of T2 substantially reduces the AB, we propose that the AB impairment in report of masked visual targets occurs because of a delay in engaging attention on the second target representation. This may correspond to a delay in initiating consolidation (i.e., Stage II processing), which is required in order to sustain the target representation for durations long enough to allow conscious identification of the target (e.g., Chun & Potter, 1995; Lamme, 2003). Precuing T2 with a false target reduces the AB because it provides sufficient start-up time for consolidation before the onset of the actual target. As a consequence, T2 can readily be selected for Stage II when it is cued. When T2 is not cued, however, the selection of inputs to the consolidation process may begin only after the post-T2 mask has entered Stage I, thereby increasing the chance that the mask is inadvertently processed instead of T2 (i.e., object-substitution masking; Giesbrecht & Di Lollo, 1998).

Alternative accounts of cuing. The delayed engagement account of cuing can be contrasted to other possible accounts of cuing. One such account holds that cuing enhanced the low-level perceptual processing of the target, for example, by means of priming the target color. However, this interpretation is inconsistent with the finding that cuing produced a selective benefit for targets presented during the AB (e.g., see Figure 3). In addition, if cuing were to enhance the perceptual processing of the target, then cuing should have had a similar effect on target report in the single-target condition of Experiment 3, which was not the case. Furthermore, the results from Experiment 4 showed that cuing did not enhance T2 report when performance was data limited. Thus, instead of facilitating the perceptual processing of T2, cuing seems to have its effect at a postperceptual stage of processing.

A second alternative account of cuing holds that observers used the cue as a means to prepare for the presentation of T2. Similar to the delayed attentional engagement account, this preparation account predicts stronger cuing effects during the AB rather than after the AB because the predictability of T2 onset is higher at the long than at the short SOA (i.e., if T2 did not appear shortly after T1, then it was bound to appear at the long SOA). However, this temporal warning account cannot explain why a differently colored cue that had the same temporal contingency to the target as a same-color cue did not produce a substantial improvement in report of targets presented during the AB, whereas the same-color cue did.

Converging evidence for delayed consolidation. Taken together, the present findings suggest that the AB reflects a delay in selecting the target representation for consolidation. Cuing truncates this delay by initiating a new processing episode in advance of the presentation of the target. Several findings from the AB literature provide further support for this view. For example, a recent electrophysiological study of the AB shows that when T2 is not masked, the onset of the P3 component (i.e., an electrophysiological index of working memory updating) is delayed for T2s

presented during but not after the AB (Vogel & Luck, 2003). Similarly, when T2 is defined by a feature other than its to-be-reported feature (e.g., T2 is a letter appearing in a white outline frame, whereas its mask is a letter appearing in a black outline frame, with the task being to report the identity of T2), errors in report of T2s presented during the AB often involve reports of T2's mask (Chun, 1997a; Isaak et al., 1999). In addition, removing T2's mask from the RSVP stream increases the durability of T2's representation, thereby enhancing the chance that T2 is still available by the time consolidation can occur and substantially reducing the AB (Giesbrecht & Di Lollo, 1998; Jolicoeur & Dell'Acqua, 2000). Finally, a similar, slow-consolidation account has been proposed to explain the finding that when T1 and T2 are presented at SOAs of 100 ms or less, T2 is often identified more accurately than T1 (e.g., Potter et al., 2002). In this case, T2 takes control over Stage II processing initiated by T1 because it is presented before the selection of T1 can occur.

Cuing effects in related paradigms. Although the present study is the first to demonstrate that cuing substantially reduces the AB, similar effects of cuing in related inattentional blindness paradigms have been found in previous studies. For example, in the change blindness paradigm (Simons & Levin, 1997), cuing the location of one of several simultaneously presented objects allows observers to accurately detect subsequent changes to the cued object (Becker, Pashler, & Anstis, 2000; Landman, Spekreijse, & Lamme, 2003; Schmidt, Vogel, Woodman, & Luck, 2002). Similarly, when observers search for a single target that is presented in one of two concurrently presented RSVP sequences, precuing the upcoming target significantly enhances report of the target (Klein & Dick, 2002). In addition, a similar effect of cuing has been observed in studies of object-substitution masking (Di Lollo, Enns, & Rensink, 2000). This paradigm presents a visual search display of distractors that contains a target that is surrounded by a spatially nonoverlapping mask (e.g., four dots), and the task is to report on some specific feature of the target (e.g., indicate the position or orientation of a line or gap in the target stimulus). The crucial finding is that if the mask stays on after erasure of the search display, then observers fail to perceive the target and instead perceive only the mask. More important, however, when the target is precued, the object-substitution effect is substantially reduced.

Thus, as in the AB, cuing appears to save target representations from oblivion in the change blindness and object-substitution paradigms, allowing them to be reported or compared with subsequently presented stimuli. The main difference between the AB and the latter paradigms is that in the AB, attention is tied up processing a previously presented target, whereas in the other paradigms, attention may be tied to the locations of other objects presented concurrently with the target. Nevertheless, it can be argued that cuing has similar effects in these types of experiments: It helps to select the target for consolidation. This type of selection may be distinguished from spatial selective attention (i.e., location-specific enhancement of perceptual processing) in that it is relatively slow (e.g., Vogel et al., 1998). The difference in the time courses of spatial selection and selecting information for working memory is illustrated nicely by the results from a study on object-substitution masking by Woodman and Luck (2003). In this study, an electrophysiological index of the allocation of spatial attention (i.e., the N2–posterior–contralateral [N2pc] component of the evoked potential) was not influenced by object-substitution mask-

ing, indicating that spatial attention was directed to the locations of the target regardless of whether object-substitution masking hindered conscious perception of the target. Thus, although spatial attention may be rapidly deployed to the target location, the selection of information for short-term memory may occur only after the target has already been replaced by its mask. Similarly, in Experiment 4 of the present study, spatial attention may have been captured by the sudden onset of T2, but, in order to allow selection of the target for consolidation before it was masked, it had to be precued.

Why the Delay?

In addition to showing that precuing T2 substantially reduces errors in T2 report, the results also consistently showed that the increase in T2 report accuracy did not occur at the expense of T1 report. For example, even at SOAs as short as 282 ms, cuing T2 could produce a 40% increase in T2 report without affecting T1 report (see Figure 3). This finding is striking, as most models of the AB assume that the typical 500-ms duration of the AB reflects the time for which T1 occupies a serial or resource-limited process of consolidation (e.g., Chun & Potter, 1995; Jolicoeur & Dell'Acqua, 1998; Shapiro et al., 1997; Vogel et al., 1998) and would therefore predict that any enhancement in report of T2s presented during the time course of the AB should occur at the expense of T1 report. Yet, this was not the case in any of the experiments reported here.

The notion of a time-consuming process of consolidation can be salvaged, however, if it is assumed that once T1 has entered the consolidation stage, its processing can no longer be interfered with by subsequent events (e.g., Potter et al., 2002). This account is consistent with the finding that T1 report is impaired by a following target only when this second target is presented within 100–200 ms of the onset of the first (Chun & Potter, 1995; Potter et al., 2002). During this critical period, targets may compete for access to Stage II, but once one of the targets has been selected, the other can no longer interfere with its processing. Thus, in the present experiments, T1 may have already been admitted to Stage II when the cue was presented, allowing a cued T2 to enter Stage II without affecting T1. An important implication of this account is that Stage II can slowly process more than a single target at a time, an assumption that is also needed in order to account for the fact that observers can often accurately report more than one item either from a brief display of several items (e.g., Sperling, 1960) or from an RSVP stream of target items (e.g., Di Lollo, Kawahara, Ghorashi, & Enns, 2005; Kawahara, Enns, & Di Lollo, in press; Weichselgartner & Sperling, 1987). As such, Stage II can be likened to a car wash (e.g., Chun & Wolfe, 2001; Wolfe, 2003) that can process several items concurrently, whereas entry to the car wash may be restricted to a single car at a time. To be an accurate analogy, the “single car” should correspond to an attentional episode that allows entry of multiple simultaneous or temporally adjacent items into Stage II, as observed in the case of Lag 1 sparing (e.g., Chun & Potter, 1995; see also Di Lollo et al., 2005; Jolicoeur & Dell'Acqua, 1998; Kawahara et al., in press).

Alternatively, one may question whether the notion of a time-consuming stage of memory consolidation is required in order to account for the AB. Indeed, the only direct evidence for the notion of a time-consuming process of consolidation is the AB itself: The

finding that T2 often fails to be consolidated when presented within 500 ms of T1 (e.g., Vogel et al., 1998). From this perspective, the fact that the AB can be substantially reduced via a manipulation that affects T2— but not T1— suggests that the AB cannot be accounted for solely in terms of the time that is required to consolidate T1. Instead, the present results open up the possibility that the processing of T1 is completed rapidly, allowing a cued T2 to be processed without impairing T1 report. According to this account, there may be a brief period of time during which T1 processing directly blocks T2 processing, corresponding to SOAs of 100–200 ms, at which the impairment in T2 report is typically most pronounced. After this period, T1 has been consciously identified, and a subsequent cued target can therefore be processed in Stage II without impairing report of T1.

Although these accounts explain why the admission of a cued T2 to Stage II does not necessarily have to occur at the expense of T1, it leaves unresolved the question of why an uncued T2 typically fails to reach Stage II during the AB (e.g., Vogel et al., 1998). In other words, why is the selection of T2 delayed for such a long 500-ms period after T1? In addressing this question, it is important to note that under conditions of RSVP, processes involved in selecting and consolidating the targets are heavily taxed. This is indicated by the finding that intrusion rates (i.e., reports of distractors neighboring the target) may be as high as 20%–25% when the task is to report a single target in RSVP (Chun, 1997a). Thus, selecting the “right item” from Stage I is difficult even when there is no concurrent load on Stage II processing. One reason for this may be that different items represented in Stage I compete for access to Stage II, especially when they are similar to the targets (e.g., Raymond et al., 1995). This imposes a high load on processes involved in selecting and sustaining the target representation, as this initially occurs while distractors have to be filtered or inhibited (e.g., Loach & Mari-Beffa, 2003; Marois et al., 2000). It is worth noting that neural mechanisms in posterior parietal cortex are important for both selecting targets from distractors in RSVP tasks and in spatial filtering tasks, and these attentional control mechanisms are more active as distractor interference increases (Friedman-Hill, Robertson, Desimone, & Ungerleider, 2003; Marois et al., 2000).

Given such attentional demands of selecting a target from among distractors, it is plausible that target selection processes would be temporarily less responsive to new targets in the aftermath of selecting T1. As interesting support for this possibility, electrophysiological data show a reduction in the amplitude of the N2pc component in event-related potentials for second targets presented together with distractors (Jolicoeur, Sessa, Dell'Acqua, & Robitaille, in press), suggesting that selection mechanisms are indeed compromised during the AB (see also, de Fockert, Rees, Frith, & Lavie, 2001; Di Lollo et al., 2005; Jiang & Chun, 2001). The gradual improvement in T2 report observed across SOAs of 200–500 ms may therefore reflect the gradual reinstatement of a baseline level of responsiveness in these processes, with the main effect being that they are slow in responding to new targets. An alternative possibility is that the time course of the AB may reflect the period of time required to regain control over selective attention (e.g., Di Lollo et al., 2005). In this view, the demand of T1 identification may lead to a loss of endogenous control, thereby allowing the distractor following T1 to trigger the reconfiguration of filter settings so that they now match the features of this

distractor. Accordingly, the ensuing T2 will fail to be selected because it no longer matches the attentional template. In this view, selection of T2 is delayed because of the time required to reconfigure these filter settings again upon detection of T2, whereas cuing resolves this delay by triggering reconfiguration in advance of T2.

Implications for Traditional and New Models of the AB

Over the years, several different accounts have been proposed to explain the AB. As will become clear from the following discussion, each of these accounts needs to be revised in order to account for the present finding that cuing T2 reduced the AB without affecting T1 report. Traditional accounts of the AB include the suppression account, the interference model, and the bottleneck models. The suppression account holds that failures to report T2 occur because the processing of new perceptual inputs is temporarily suppressed in the advent of T1 in order to prevent interference with target identification (Raymond et al., 1992). The interference account is that T1 and distractors that are presented closely in time to T1 deplete the limited storage capacity of visual short-term memory (Raymond et al., 1995). Bottleneck models of the AB, however, account for the failure to report T2 by assuming that T2 cannot gain access to processes involved in consolidating information into short-term memory during the time course of consolidating T1 (Chun & Potter, 1995; Jolicoeur & Dell'Acqua, 1998). In addition, several hybrid models have been proposed that combine different assumptions from these models (Shapiro et al., 1997; Vogel et al., 1998). Strikingly, however, none of these traditional accounts of the AB would predict the present finding that cuing T2 substantially reduces the AB without affecting T1 report. In particular, the suppression account would predict that processing of the precue would be suppressed and, therefore, could not have an effect on T2 report. The interference model would predict that the precue competes for limited representational space in short-term memory because it is similar to the targets and would therefore not allow for a positive effect of cuing on target report. Finally, bottleneck models cannot account for the present findings because they would predict that although T2 may be processed more effectively because of the cue, it could not be stored in memory while T1 was being consolidated.

Recent work has provided some interesting alternatives to these traditional models of the AB—one that ascribes the AB to a failure to instantiate different object files for T1 and T2 (i.e., object file account; Chun, 1997b; Kellie & Shapiro, 2004; Raymond, 2003) and one that holds that the demand of T1 identification induces a loss of endogenous control over attentional selection, thereby allowing the distractor to follow T1 to exogenously reconfigure attentional control settings so that a following T2 will fail to be selected because it no longer matches the attentional template (i.e., temporary loss of control account described earlier in the *Why the Delay?* section; Di Lollo et al., 2005; Kawahara et al., in press). It is interesting to note that both of these accounts provide an explanation of the AB that would allow for cuing to occur. To start, the object file theory can accommodate the present findings if it is assumed that the role of the precue is to trigger the establishment of an object file. This object file could then be updated with T2 because it shared certain features with cue (i.e., color in Experiments 1–3 and location in Experiment 4). Similarly,

the temporary loss of control account of the AB would predict that the precue triggers the reconfiguration of the input filter so that it now matches the characteristics of the following target, thereby allowing T2 to gain access to identification processes.

To summarize, the main implications of the present findings for accounts of the AB are (a) the notion of a strict resource limitation or processing bottleneck needs to be relaxed and (b) a delay in initiating processes required for T2 report needs to be assumed. According to the different models, this delay may affect the release from suppression of posttarget stimuli (e.g., Loach & Mari-Beffa, 2003; Raymond et al., 1992), the flushing of distractor representations from visual short-term memory (e.g., Raymond et al., 1995), the reconfiguration of an input filter (e.g., Di Lollo et al., 2005), or the instantiation of a new object file (e.g., Chun, 1997b; Raymond, 2003). The present account adheres to the notion of a consolidation bottleneck in that it assumes that the delay occurs between the rapid, preconscious detection of the target and the subsequent selection of its fleeting representation for Stage II processing that is required to allow conscious identification (e.g., Chun & Potter, 1995; Jolicoeur & Dell'Acqua, 1998; Lamme, 2003; Vogel et al., 1998). However, the present account differs from traditional bottleneck models in that it does not assume that the time course of the impairment in T2 report must mirror the time course of the consolidation of T1. Rather, Stage II processing may be shorter than suggested by the AB time course, or at least it may permit entry of new target events before T1 consolidation is completed (e.g., the car wash analogy described earlier in the *Why the Delay?* section). In either case, the present results clearly demonstrate a delay in attentional engagement required to transfer information into Stage II. Full reinstatement of the baseline level of attentional responsiveness appears to occur gradually across the duration of the AB.

Conclusions

The present study shows that the AB can be markedly reduced or even fully prevented when T2 is precued. This cuing effect did not occur at the expense of T1 report, and it could not be ascribed to temporal cuing or to a facilitatory effect of cuing on the perceptual processing of T2. Instead, cuing appears to counteract a delay in the selection of potential targets for consolidation. There are several possibilities as to why selection is delayed during the AB. In particular, the cause of the delay may lie in the serial nature of selecting inputs for consolidation, the gradual recovery from a state of attentional inertia, or in the period of time required to reconfigure the input characteristics of filters mediating attentional selection. It is our hope that future experiments will determine which of these solutions provides the best account for the AB.

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