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Dissociating the effects of featural and conceptual interference on multiple target processing in rapid serial visual presentation

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Attentional blink (AB) describes the finding that, when subjects attend to a specified target in a rapidly presented visual stream, they show a decreased ability to process a subsequent probe item for up to 600 msec. In the present study, the roles of featural and conceptual interference in the processing of targets and probes in a rapid serial visual presentation stream were examined. In Experiment 1, featurally more complex T+1 items produced larger AB even when the physical energy of the stimulus (e.g., the number of pixels) was held constant. In Experiment 2, the conceptual category of the T+1 item affected target identification but not AB magnitude. These results suggest that featural interference is a major determinant of AB magnitude, whereas featural and conceptual interference both affect target identification.

The term *attentional blink* (AB; Raymond, Shapiro, & Arnell, 1992) describes the finding that, when participants identify a specified target in a visual stream of rapidly presented stimuli, they are impaired at detecting a subsequent probe presented in close temporal proximity. Fundamentally, this phenomenon arises when a target stimulus is followed by a distractor in the same spatial location (Chun & Potter, 1995; Raymond et al., 1992, 1995; Shapiro, Raymond, & Arnell, 1994). These studies suggest that some types of visual processing result in a period of decreased attentional capacity.

In one of the first demonstrations of this effect, Broadbent and Broadbent (1987) presented words in uppercase as targets and probes among lowercase distractors. They found that, for target stimulus onset asynchronies (SOAs) of less than 400 msec, participants identifying the target could only identify the probes with a probability of .1. For SOAs of more than 400 msec, participants identified the probes with a probability of .7. Weichselgartner and Sperling (1987) found that, when participants had to report a target item and three subsequent stream items, identification was impaired for SOAs of up to 400 msec after target presentation. Both of these studies suggest the existence of a process that is active for approximately 400 msec that interferes with the processing of secondary targets. In a number of recent studies, (e.g., Raymond et al., 1992), participants named a target appearing in a particular color and detected a secondary target (a probe) that was either absent or present at varied positions after the target. In Chun and Potter's (1995) study, participants detected targets and probes on the basis of category membership (i.e., letter identification among digit distractors). Processing of the visual features of the stimulus appears to be critical for AB, because simply detecting or identifying the duration of a gap in the stream does not result in AB (Shapiro et al., 1994).

A number of factors have been shown to have an influence on AB, including (1) the nature of the target task (Raymond et al., 1992), (2) the relationship between the target and the item immediately after the target (the T+1 item; Chun & Potter, 1995; Grandison, Ghirardelli, & Egeth, 1997; Raymond et al., 1992, 1995; Shapiro et al., 1994; Seiffert & Di Lollo,1997), (3) the relationship between the probe and the item immediately after the probe item (the P+1 item; Raymond et al., 1995), (4) the relationship between the T+1 item and the probe item (Shapiro et al., 1994), (5) familiarity with the probe (Maki & Padmanabhan, 1994; Shapiro, Caldwell, & Sorensen, 1997), and (6) similarity of all the items in the rapid serial visual presentation (RSVP) stream (Chun & Potter, 1995; Maki, Couture, Frigen, & Lien, 1997). Although all these factors have been shown to affect AB, the relationship between the target and the T+1 item appears to be particularly crucial; the removal of the T+1 item almost entirely eliminates AB (Chun & Potter, 1995; Raymond et al., 1992).

Although it has been clearly shown that the processing of the T+1 item appears to interfere with the processing of the target and the probe, it has not been clearly determined how the featural (e.g., the visual representation, consisting of features such as line segments and vertices) and conceptual (e.g., the phonological or the semantic) characteristics of the T+1 item interfere with RSVP processing. Raymond et al. (1992) suggested that the inter-

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ference was primarily featural, since the target and the T+1 items are processed into a unitary visual percept that have to be disambiguated. Raymond et al. (1995) suggested that both items are processed to a higher, more conceptual level and loaded into a visual short-term memory (VSTM), where they compete for retrieval with at least two other items (the probe and the P+1 item). The results of Chun and Potter (1995) suggest that both featural and conceptual interference of the T+1 item (and other items as well) play a role in producing AB.

Although conceptual interference from the T+1 item has been shown to be a factor in producing AB, (Chun & Potter, 1995; Raymond et al., 1995), conceptual manipulations can also alter the amount of featural interference present. In the Raymond et al. (1995) study, significant AB attenuation in a target-naming task was observed with a dot pattern T+1 item. The authors concluded that the T+1 item did not impair probe processing in this case because it was not similar to the target or the probe (i.e., letters) and was not loaded into VSTM. However, it is possible that the dot pattern simply did not sufficiently activate low-level visual features (such as line segments and vertices) present in letter targets to interfere at a perceptual level. Indeed, there is evidence to suggest that the visual system is preferentially tuned to detect bars (such as those making up letters; De Valois, Yund, & Hepler, 1982; Hubel & Wiesel, 1959, 1962). In another study, Chun and Potter presented target letters in a mixed stream (digits and symbols) and varied the conceptual content of the T+1 item by presenting T+1 items that were conceptually similar to the letter targets (i.e., numbers) or T+1 items that were conceptually dissimilar (i.e., symbols). They observed that conceptually similar T+1 items produced more AB than did conceptually dissimilar T+1 items and concluded that the T+1 items were interfering with target processing at a conceptual level. However, this result was not obtained consistently (see Chun & Potter, 1995, Experiment 6). More important, the visual symbols (conceptually dissimilar) and numbers (conceptually similar) may have differed in their featural characteristics. For example, with regard to spatial frequency, orientation, and bounded regions, the symbols and the numbers may have differed, and it may have been these differences in the visual (i.e., in addition to the conceptual) representations that influenced AB.

Recent studies have demonstrated that the masking properties of the T+1 item have an effect on the magnitude of AB. Grandison et al. (1997) and Seiffert and Di Lollo (1997) showed that AB can be induced by using T+1 stimuli, such as a metacontrast mask or a bright screen flash, that contain no pattern information. These results suggest that very low level interference with the perceptual processing of the target is adequate to induce AB, but these studies do not assess the relative contributions of T+1 interference from different levels of processing (i.e., perceptual vs. conceptual). McAuliffe and Knowlton (1996) demonstrated that a more featurally complex T+1 item (i.e., a W) produced more AB than a featurally simple item (i.e., an I), even though both items belonged to the same conceptual category (i.e., letters). However, this study did not control for very low level stimulus energy (i.e., the W T+1 item had many more pixels than the featurally simple I).

In the present study, we sought to determine the nature of the interference of the T+1 item on target processing. Specifically, the T+1 was precisely manipulated at either a low (i.e., featural) or a higher (i.e., conceptual) level while controlling the representations active at the other level. In each experiment, the amount of featural or conceptual interference was manipulated within subjects, allowing a direct comparison of the magnitude of the effects. In Experiment 1, we varied the features of the T+1 item while maintaining the low-level stimulus energy (i.e., the number of pixels active). Specifically, the T+1 item was a W, a thick I, or a random dot pattern covering an area as large as the W. In Experiment 2, we sought to precisely manipulate conceptual representations while maintaining the complexity of the featural representations. Specifically, the T+1 item was either a V or an inverted V. These two items were featurally equivalent but conceptually different (V is a letter, but an inverted V is not).

In the present study, we used a procedure similar to the RSVP paradigm used by Raymond et al. in their 1992 study. The participants were presented with a visual stream of letters appearing in the same location, with approximately 11 items appearing per second (i.e., 90 msec/item), and were required to (1) identify a target letter (indicated by a different color than the other items in the visual stream) and then (2) detect the presence or the absence of a previously specified probe letter. With this RSVP paradigm, successful target identification impairs subsequent probe detection for a period of up to 600 msec (Raymond et al., 1995; Shapiro et al., 1994).

EXPERIMENT 1

In Experiment 1, we manipulated the featural interference of the T+1 item, to examine how processing of the T+1 item interfered with processing of the target item and how this interference affects AB. Previous research (Chun & Potter, 1995; Raymond et al., 1995) has not directly examined the differential effects of featural versus conceptual (i.e., letter level) interference. For example, Chun and Potter showed that AB was attenuated when a letter target was identified among a stream of ASCII symbol distractors, as compared with a stream of digits. However, the ASCII symbol characters (such as > and *) may have interfered less than digits at a featural level. In Experiment 1, we manipulated featural complexity but held the number of pixels constant and also manipulated the area of the T+1 item. Specifically, the T+1 item was a W, a thick I, or a random dot pattern covering an area larger than the W. Thus, each of the T+1 items had the same number of pixels but varied in featural complexity (where featural complexity is represented here as the number of bars present in the item—i.e., W has four bars, a thick I has one bar, and a random dot pattern has no bars).

Presumably, if T+1 featural interference is a major cause of AB, the featurally complex W should produce more AB than the featurally simple I, even though they have the same physical energy (i.e., number of pixels). According to this view, we should expect that the random dot pattern would produce the least amount of AB, because it does contain features like those present in letters.

Alternatively, if the low-level stimulus energy is a major determinant of AB magnitude, the thick-I, the W, and the random dot pattern T+1 items should all produce equivalent amounts of AB, because they all contain the same number of pixels. If the overall area of the T+1 item is a major cause of AB magnitude, the random dot pattern should produce the most AB, because it covers the greatest area, the W should produce less AB, and the thick I should produce the least AB.

Method

Participants. Fifteen University of California at Los Angeles students (5 males, 10 females) participated to fulfill a course requirement. Ten participants were included in the main study, and 5 participants were tested to establish the probe detection baseline. The participants had normal or corrected-to-normal vision. The participants were given 10 practice trials.

Design. This study used a three-factor design, with condition (W T+1 item, I T+1 item, and random dot pattern T+1 item) as a within-subjects variable and relative serial probe position (positions 2–8 after the target [T+2–T+8]) as a within-subjects variable.

Apparatus. An Apple 520c Powerbook was used to execute the presentation program Macprobe (Hunt, 1993), which presented the stimuli on an Apple Multiple Scan 15 display monitor. The participants viewed the display binocularly from a distance of 60 cm. Responses were recorded with a standard Macintosh keyboard.

Stimuli. Each session consisted of 420 RSVP trials. In this and all subsequent experiments, each trial consisted of a series of consecutively presented capital letters in the helvetica font size 60, which subtended approximately 2° of visual angle (Figure 1). Each letter was presented for 30 msec, with an interstimulus interval of 60 msec. Each letter was displayed in the center of a white background and was viewed from a distance of approximately 60 cm. All the letters appeared in black, except for the target, which appeared in blue. Target letters were randomly chosen from the set of 23 letters (i.e., all letters except I, W, and Z). On one third of the trials, the T+1 item was W; on one third of the trials, the T+1 item was a thick I; and on one third of the trials, the T+1 item was a random dot pattern that covered a rectangular area that was equal to the maximum height and maximum width of the W. Each of the T+1 items had the identical number of pixels (the I had 0.3% more pixels, to make an even figure). The I and W were never presented as targets or in any other part of the stream, to avoid the possibility of double presentation (e.g., presentation of I or W as a target and a posttarget item). None of the participants incidentally detected that the T+1 item was always an I or a W. The number of pretarget letters was randomly chosen by the computer on each trial and varied between 7 and 15. Between 8 and 16 letters followed the target, depending on the position of the target item. Thus, a total of 24 letters were presented in the entire visual display. No letters were repeated during each trial.

Procedure. Each trial was preceded by a fixation oval, which was displayed for 600 msec. This was followed by a blank screen, which appeared for 300 msec. The participants' task was to name the blue target letter and then detect the presence or absence of a Z. The participant responded after the entire visual stream was presented by pressing the target letter key on the keyboard and either the key labeled "present" or the key labeled "absent." The computer randomly chose the target letter from the set of all letters except Z,

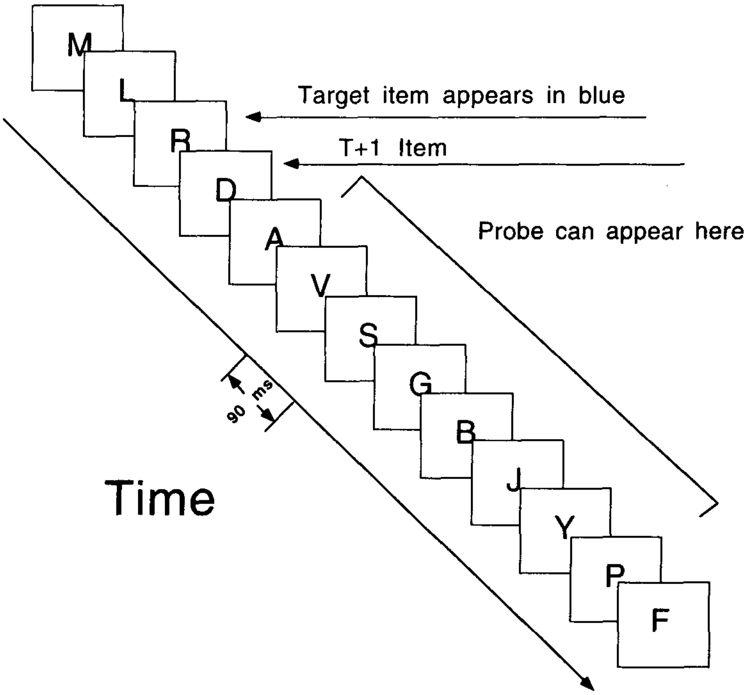

Figure 1. Presentation sequence for rapid serial visual presentation.

I, and W. For each condition, in half of the randomly presented trials, the probe was present in one of the serial positions 2–8 after the target, and in the remaining trials, the probe was not present. The probe was present 10 times in each of the 7 serial positions for each condition, resulting in 210 trials in which the probe was present and 210 trials in which the probe was absent. The participants in the baseline condition received the same stimuli but did not perform the target task: they only indicated the presence or the absence of the probe letter. After each trial, the screen displayed feedback indicating the target letter and the presence or the absence of the probe letter.

Data analysis. Previous studies of AB have relied on an analysis of probe detection hit rates. However, this measure is affected by observer bias and does not incorporate false alarm rates. Instead, we used the well-established bias-free measure of the area under the receiver-operating characteristic (ROC) curve (Green & Swets, 1966; Swets, 1996). In order to accurately compare AB magnitudes across conditions for each probe position, the area under the ROC curve was calculated for each of the three (W, thick-I, and random dot T+1) dual-task conditions (i.e., naming the target and detecting the probe) and was subtracted from the area under the ROC curve calculated from a corresponding baseline condition in which only the probe task was performed. The area under the ROC curve was calculated from the hit rate that was specific to a probe position (i.e., positions T+2 through T+8) and from the overall false alarm rate for that condition. These baseline-corrected data (i.e., areas under the ROC curve) were then subjected to a two-way (T+1 item letter × probe position) within-subjects analysis of variance (ANOVA).

Results

Probe detection. For the random dot T+1 condition, probe detection rates ranged from 64% to 88%, and the mean false alarm rate was 16%. For the thick-I T+1 condition, probe detection rates ranged from 47% to 87%, and the mean false alarm rate was 17%. For the W T+1 condition, probe detection rates ranged from 41% to 74%, and the mean false alarm rate was 15%. The mean probe detection rate in the baseline conditions (in which only the probe task was performed) was above 95%, and the mean false alarm rate was 6% or lower. Figure 2 shows the area under the ROC curve for both experimental conditions and both baseline conditions as a function of the relative serial position of the probe. Only trials on which the target was successfully identified were included in the analysis. A 3 (T+1 item I vs. T+1 item W vs. random dot pattern item) × 7 (relative serial probe position) within-subjects ANOVA performed on the baseline-corrected areas revealed a significant main effect of condition [$F(2,18) = 7.99, p < .01$]. A Scheffé post hoc test revealed significant differences between the W T+1 and the I T+1 conditions ($p < .05$), as well as between the W T+1 and the random dot-pattern T+1 ($p < .01$). The difference between the I T+1 and the random dot pattern T+1 was not significant in the post hoc test ($p = .12$), but a 2 (T+1 item I vs. random dot pattern T+1 item) × 7 (relative serial probe position) within-subjects ANOVA revealed a significant main effect of condition [$F(1,9) = 7.57, p < .01$], a significant main effect of relative serial position [$F(6,54) = 4.63, p < .01$], and a significant interaction between condition and relative serial position [$F(6,54) = 2.85, p < .05$]. Post hoc tests showed that, for

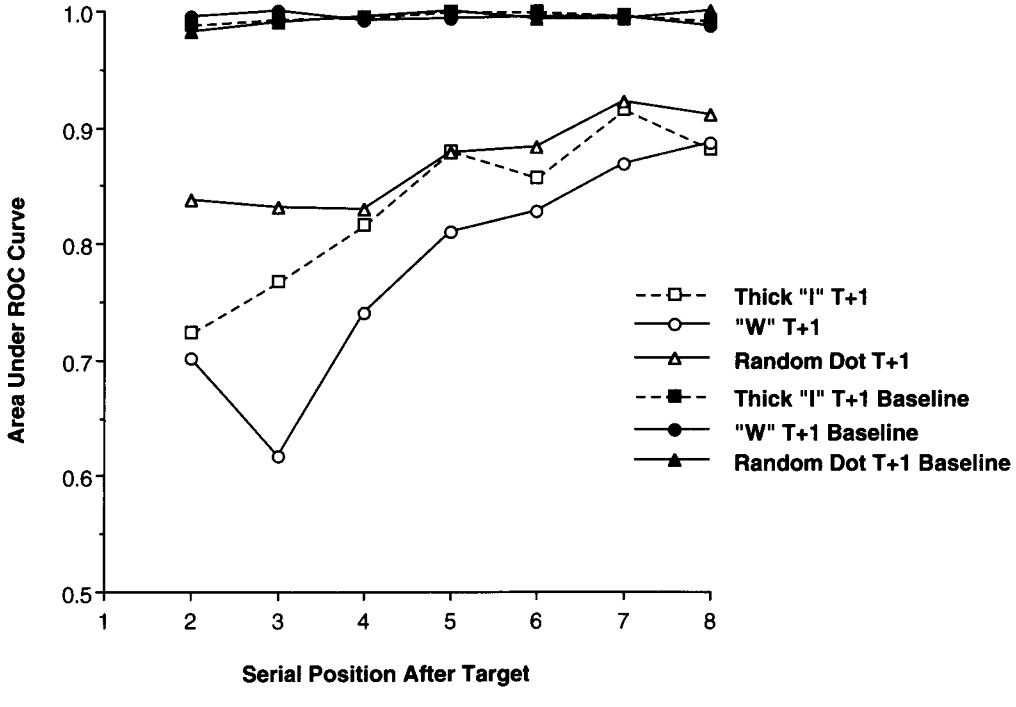

Figure 2. Experiment 1: Probe detection for serial positions 2–8 after the target as a function of T+1 item conceptual category (I vs. random dot vs. W).

probe position T+3, detection was significantly better in the T+1 random dot condition than in either of the other two conditions [$t(9) > 2.2$, $ps < .05$] and that, for probe position 2, detection was significantly better for the random dot condition than for the thick-I condition [$t(9) = 3.58$, $p < .01$]. All other *t* tests were nonsignificant [$ts(9) < 2.2$, $ps > .05$]. There was no significant difference in performance in the baseline conditions ($F < 1$), and no effect of probe position in the baseline conditions ($F < 1$).

Target identification. A *t* test revealed a significant difference in target identification between the means of the W T+1 and the I T+1 conditions (for T+1 item = I, $M = .955$, $SEM = .008$; for T+1 item = W, $M = .807$, $SEM = .029$; $t(9) = 5.95$, $p < .01$]. A *t* test revealed a significant difference in target identification between the means of the W T+1 and the random dot T+1 conditions [for T+1 item = random dot, $M = .953$, $SEM = .008$; for T+1 item = W, $M = .807$, $SEM = .029$; $t(9) = 6.54$, $p < .01$]. There was no significant difference in target identification for the I T+1 and the random dot T+1 conditions [$t(9) = 0.11$, $p > .05$].

Discussion

Experiment 1 revealed that a more featurally complex T+1 item (i.e., a W) produced more AB and poorer target identification than did the featurally simple I T+1 and the random dot T+1, even though all the T+1 items contained the same number of pixels. These results suggest that featural complexity is an important cause of AB magnitude, because the featurally more complex T+1 item (i.e., the W) produced the most AB. In addition, it appears that the area of the T+1 item is not a major determinant of AB, because the T+1 item with the greatest area (i.e., the random dot pattern) produced little AB.

The results also support the idea that features are not necessary to produce AB (Grandison et al., 1997), since the random dot pattern T+1 did produce a significant amount of AB, even though this item did not have any obvious features. However, the amount of AB produced by the random dot pattern was much less than that produced by a featurally more complex T+1 item (i.e., a W), which suggests that featural complexity has a major impact on AB magnitude.

EXPERIMENT 2

In Experiment 1, we manipulated the features of the T+1 item in an attempt to isolate the effects of featural interference on RSVP processing. In Experiment 2, the level of conceptual interference was manipulated while controlling for featural interference as much as possible. Other studies have manipulated conceptual interference in RSVP paradigms by changing the semantic category of an item (Chun & Potter, 1995) or scrambling items (Isaac & Shapiro, 1996). However, both of these manipulations are likely to alter the visual properties of stimuli, such as spatial frequency or featural complexity. Our intent was to construct T+1 items that were as similar as possible in terms of visual properties but conceptually different. V and an inverted V were chosen because they both have the same featural complexity, whereas only one of them represents the concept of a letter. If the featural activation of the T+1 item is the key determinant of AB, the V T+1 item and the inverted-V T+1 item should produce equal magnitudes of AB. On the other hand, if conceptual similarity between the target and the T+1 item has an important influence on AB, the inverted-V T+1 item should produce less AB than the upright-V T+1 item.

Method

Participants. Fifteen University of California at Los Angeles students (5 males, 10 females) participated to fulfill a course requirement. Ten participants were included in the main study, and 5 participants were tested to establish the probe detection baseline. The participants had normal or corrected-to-normal vision. The participants were given 10 practice trials.

Design. This study used a two-factor design, with condition (V T+1 item vs. inverted-V T+1 item) as a within-subjects variable and relative serial probe position (positions 2–8 after the target [T+2–T+8]) as a within-subjects variable.

Apparatus. The apparatus was identical to that used in Experiment 1.

Stimuli and Procedure. Each session consisted of 280 RSVP trials. The stimuli and temporal parameters were the same as those used in Experiment 1, except for the differences noted below. On half the trials, the posttarget item was a V, and on the remaining trials, the posttarget item was an inverted V. V was never presented as a target, to avoid the possibility of double presentation. Data analyses were similar to those performed in previous experiments.

Results

Probe detection. For the V T+1 condition, probe detection rates ranged from 54% to 89%, and the mean false alarm rate was 15%. For the inverted-V T+1 condition, probe detection rates ranged from 59% to 96%, and the mean false alarm rate was 19%. The mean probe detection rate in the baseline conditions (in which only the probe task was performed) was above 95%, and the mean false alarm rate for both conditions was 5%. Figure 3 shows the area under the ROC curve for both experimental conditions and both baseline conditions as a function of the relative serial position of the probe. Only trials on which the target was successfully identified were included in the analysis. A 2 (T+1 item V vs. T+1 item inverted V) $\times$ 7 (relative serial probe position) within-subjects ANOVA performed on the baseline-corrected data revealed no significant main effect of condition ($F < 1$) and a significant main effect for relative serial position [$F(6,54) = 7.38$, $p < .01$], demonstrating the existence of AB. The interaction between condition and relative serial position was not significant ($F < 1$). As was shown by *t* tests, there was no significant difference in AB between the two conditions at each serial position [$ts(9) <$

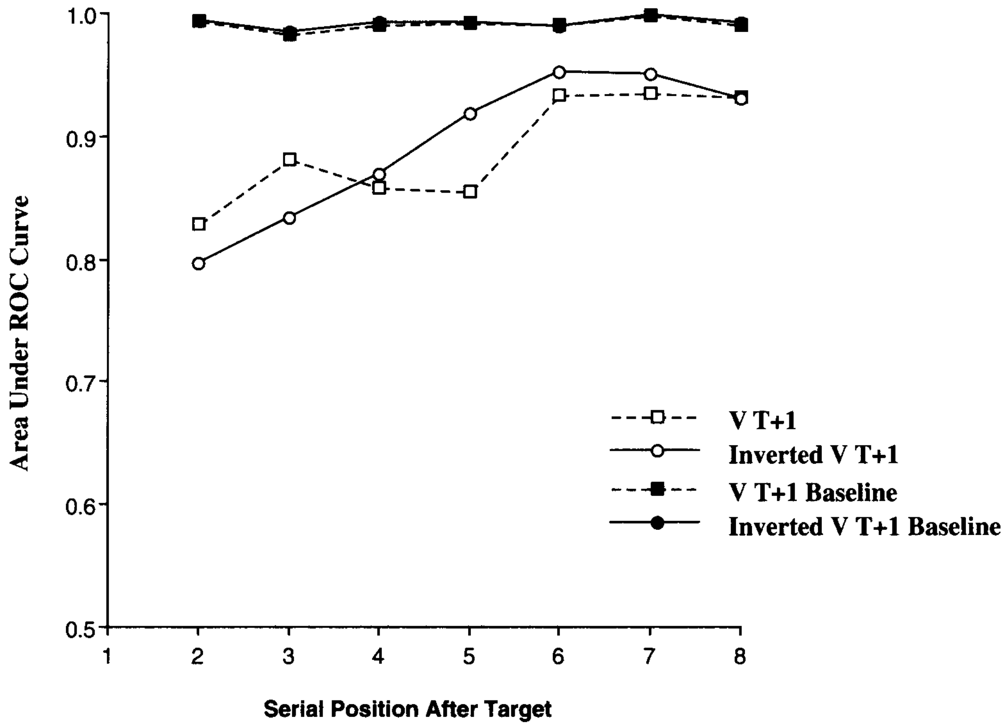

Figure 3. Experiment 2: Probe detection for serial positions 2–8 after the target as a function of T+1 item conceptual category (V vs. inverted V).

1.8, *ps* > .1]. There were no significant differences between the baseline conditions and no effect of probe position for the baseline conditions ($F < 1$).

Target identification. A *t* test revealed a significant difference between the means of the two conditions [for T+1 item = V, $M = .80$, $SEM = .03$; for T+1 item = inverted V, $M = .87$, $SEM = .03$; $t(9) = 5.26$, $p < .01$].

Discussion

Experiment 2 revealed that conceptual interference between the target and the T+1 item had an effect on target identification but not on probe detection. That is, target identification rates were higher when an inverted V was presented as the T+1 item (as compared with a V T+1 item), but the magnitude of AB observed in both conditions did not significantly differ. Thus, the conceptual difference between the V and the inverted V did affect target identification but did not affect AB significantly. Together with the results of Experiment 1, this result suggests that the AB phenomenon is influenced by featural interference, whereas target identification is affected by featural and conceptual interference. It is likely that conceptually similar T+1 items would interfere more than conceptually dissimilar items when selecting a response in an identification task.

Arguably, the amounts of featural interference of a V T+1 item and an inverted-V T+1 item are not completely identical. Indeed, because the amount of featural interference results from the overlap in features between target letters and the T+1 item, it is impossible to completely equate featural interference without knowing beforehand how the visual system processes RSVP items. Thus, a difference in featural interference may have been present and may have affected target identification rates. However, this difference in featural interference apparently was not great enough to produce significant differences in AB.

In Experiment 1, there was no difference in target identification between the dot pattern T+1 condition and the thick-I T+1 condition, although these stimuli differ conceptually in that only one is a letter. This result is not necessarily inconsistent with the target identification findings in Experiment 2, since ceiling effects were present. Target identification rates in both conditions were above 95%, presumably because featural complexity was so low for both of the T+1 stimuli.

The results of Experiment 2 suggest that T+1 item interference at the conceptual level is not a major determinant of AB magnitude and that lower level featural interference may be a more important factor in determining the magnitude of AB.

Surprisingly, when asked about letters appearing immediately after the target, the participants were largely unaware that the T+1 item was consistently a V or an inverted V. This finding demonstrates that the participants were not conscious of the incongruency of a nonletter T+1 item in an RSVP stream of letters.

GENERAL DISCUSSION

In the present study, we have sought to determine the nature of the interference of the T+1 item on target processing and AB. In Experiment 1, the featural characteristics of the T+1 item influenced AB magnitude, whereas in Experiment 2, the conceptual characteristics of the T+1 item had no influence on AB magnitude. Target identification was affected by both the featural and the conceptual characteristics of the T+1 item, suggesting a possible dissociation between target processing and AB with regard to conceptual interference of the T+1 item.

In Experiment 1, the featural characteristics of the T+1 item were manipulated while controlling for the physical stimulus energy (i.e., the number of active pixels). Consistent with the idea that featural interference is a major cause of AB, the featurally complex T+1 item (a W consisting of four bars) produced more AB and lower identification rates than did featurally simple T+1 items containing the same number of pixels (i.e., a thick I consisting of one bar and a random dot pattern consisting of no bars). In addition, it appears that the overall area of the T+1 item is not a major cause of AB, since the random dot pattern covered an area that was equal to or greater than the W but produced much less AB. These results are consistent with the view of Grandison et al. (1997) and Seiffert and Di Lollo (1997) that low-level interference between the target and the T+1 item is a primary contributor to AB.

In Experiment 2, featural interference was held constant (i.e., by presenting a V and an inverted V), and the category of the T+1 item (i.e., letter vs. nonletter) was manipulated. Consistent with the idea that featural interference is a major determinant of the magnitude of AB observed, no significant difference was found between the amounts of AB observed with conceptually different but featurally similar T+1 items. However, a difference in target identification rates was observed, suggesting that target identification is affected by the conceptual similarity between the target and the T+1 item. These results suggest that factors affecting target naming do not necessarily contribute to AB. There is previous research supporting this idea. Chun and Potter (1995, Experiment 6) manipulated the category of the T+1 item by presenting either a T+1 item conceptually different from the target (i.e., an equals sign, =) or a conceptually similar T+1 item (i.e., a number) in a task in which participants identified letters among digits. They found no difference in the AB observed, but they did find a difference in target identification rates. In another study, a difficult target discrimination task (small vs. medium targets) produced the same AB magnitude as an easy target task (small vs. large targets; Ward, Duncan, & Shapiro, 1997). These results suggest that some aspects of target processing may be independent of the processes that are tied up during AB.

The results of this study do not rule out the possibility that conceptual interference can influence AB under other circumstances. It is possible that the conceptual manipulation employed in this study (upright V vs. inverted V) was insufficiently strong to produce a difference in AB. However, the observed significant difference in target detection between the two conditions speaks against such a possibility. It may be that a stronger conceptual manipulation would produce observable differences in AB, but it may be difficult to devise a conceptual manipulation that does not produce differences in the featural properties of the stimuli. Explicitly equating conceptual and featural interference is extremely difficult, since each of these levels of processing are ill defined and usually confounded. We report here that the featural characteristics of the T+1 item had a major influence on AB, whereas the conceptual characteristics of the T+1 item did not influence AB (but did influence target detection, suggesting that the conceptual manipulation did have an effect on RSVP processing).

Whereas previous researchers (Chun & Potter, 1995; Grandison et al., 1997; Seiffert & Di Lollo, 1997) have suggested that the difficulty of the target task is the prime determinant of AB, the results of the present research suggest that target identification and probe detection can be influenced differentially by the conceptual and featural interference between the target and the T+1 item. Specifically, these results suggest that, although conceptual and featural interference can affect target identification rates, it is the featural interference of the T+1 item that is a major factor in the magnitude of AB observed.

Models of Attentional Blink

A number of models have been proposed to explain the phenomenon of AB. According to Raymond et al.'s (1992) inhibition model, AB arises from the suspended processing of items appearing after the T+1 item while the visual system attempts to separate the target item from the T+1 item on a perceptual level. In this model, the interference between the target and the T+1 item is primarily at a featural level. The results from the present study are consistent with this model, in that the featural interference of the T+1 item appears to be the prime determinant of AB.

In Shapiro et al.'s (1994) interference model, AB arises from confusion of items within VSTM. Specifically, VSTM is populated by the target, the T+1 item, the probe item, and the immediate postprobe item. According to this model, the items are conceptually identified before they enter VSTM, but competition between items in VSTM leads to impairments in probe detection. The results from the present study do not generally support the interference model, since conceptual manipulations of the T+1 item did not affect AB, whereas featural manipulations did. With regard to target identification, the results reported here partially support the interference model, in that the conceptual characteristics of the T+1 item did affect target identification.

In Chun and Potter's (1995) serial two-stage model, potential targets are processed in parallel at Stage 1 on the basis of relevant low-level visual features. As a target is fully processed in the serial capacity-limited Stage 2, AB occurs, because the probe cannot enter Stage 2 until the target has been completely identified. The results from the present study generally support the two-stage model but more precisely define the interference that produces AB as occurring at a lower level of processing. Although AB was sensitive to interference between the target and the T+1 item at a featural level, target identification was also sensitive to the conceptual category of the T+1 item. Because this conceptual interference did not significantly affect AB, it appears to occur at a stage in target processing that can proceed in parallel with probe detection. One possibility is the response selection stage.

Interference of the T+1 Item

A clearer picture of the nature of T+1 interference is starting to emerge from the results of the present and previous studies. Consistent with the findings of Grandison et al. (1997), Experiment 1 demonstrated that the T+1 item need not contain pattern information to cause AB. However, although the random dot pattern T+1 item did produce a significant amount of AB, it was much less than the AB produced by the featurally complex T+1 item. Therefore, it appears that interference can occur at multiple levels within the perceptual domain (e.g., low-level nonpattern information and patterns of features).

Although the results of the present study support the influence of T+1 featural interference on AB, the precise nature of this interference is not completely understood. The magnitude of interference may be related to the number of nonoverlapping T+1 features (i.e., those features not present in the target item), the featural complexity of the T+1 item (i.e., the total number of features), or some combination of the two. Importantly, *features* must be clearly defined at some point. In this report, we have defined features as bars, but it is possible that the orientation of these bars could impact the amount of AB observed. Because the identification of letters may involve preferential attention to bars of certain orientations and spatial frequencies (Parish & Sperling, 1991), the orientation and spatial frequency of the T+1 bars may have important effects on AB magnitude.

In the present study, T+1 conceptual interference had no significant effect on AB magnitude (Experiment 2). Although our results do not preclude the influence of conceptual interference on AB, we are forced to conclude that this effect of conceptual interference appears relatively minor, as compared with the robust effects of featural interference observed in Experiment 1. Importantly, T+1 conceptual interference was evident in target identification in the same participants. Thus, it is not the case that the manipulation (V vs. inverted V) was insufficiently strong to produce an effect.

These results do not rule out the possibility of conceptual influences on AB, but they suggest that, with regard to the T+1 item, featural interference is a major determinant of AB. Although there is evidence that conceptual representations may be activated for items in the RSVP stream (Luck, Vogel, & Shapiro, 1996; Maki, Couture, et al.,1997; Maki, Frigen, & Paulson, 1997; Shapiro, Caldwell, & Sorenson, 1997; Shapiro, Driver, & Ward, 1997), this study focused on the effects of the T+1 interference in the initiation of AB. The view that AB arises from featural interference in target processing does not preclude the idea that items in the blink period could be processed at a semantic level, especially given the extensive evidence for parallel processing in the visual system.

Paradigm differences might affect the amount of conceptual interference observed in RSVP processing. In many studies showing an effect of conceptual interference on AB, the conceptual category of all the distractors (i.e., not just the T+1 item manipulated in this study) in the RSVP stream was manipulated, so effects may have been due to conceptual differences between probes and distractors (Maki, Couture, et al., 1997; Shapiro, Caldwell, & Sorensen, 1997). Also, when targets are conceptually defined (Chun, Bromberg, & Potter, 1994), the conceptual characteristics of the RSVP items may become more salient. In this study, probes could be detected by visual features, and this may have reduced the role of conceptual interference.

Conclusion

In conclusion, the effects of featural and conceptual interference of the T+1 item on AB were examined. When featural and conceptual interference were carefully controlled, only featural interference influenced AB, whereas both featural and conceptual interference affected target identification. The increased AB resulting from T+1 featural interference was not due to stimulus energy (i.e., number of pixels) or area of the item. Although featurally simple T+1 items did produce a significant amount of AB, much more AB was produced by a featurally complex T+1 item. Although these results do not rule out the possibility of conceptual influences on AB, they suggest that, with regard to the T+1 item, lower level featural interference is a major determinant of AB.

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