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On the fate of distractor stimuli in rapid serial visual presentation

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Abstract

Observers demonstrate an impaired ability to report the second of two targets in a *rapid serial visual presentation* (RSVP) stream if it appears within 500 ms of the first target—a phenomenon known as the *attentional blink*. This study investigated the fate of stimuli in dual-target RSVP streams that do not require report—the distractors. In five experiments, observers viewed dual-target RSVP streams where the items flanking Target 1 either had the same identity (repeats) or a different identity (non-repeats). Repeated distractors reduced the attentional blink, but only if two conditions were met (1) the items flanking Target 1 were featurally identical and (2) the distractors were drawn from a different alphanumeric category to the targets (e.g. digits vs. letters). We interpret this reduced blink magnitude in the repeat trials as evidence that in RSVP streams distractor items that appear in close temporal proximity to Target 1 are inhibited and we propose that this inhibition occurs both at the level of alphanumeric features and abstract identities.

Keywords: Attentional Blink; Distractor Inhibition; Distractor Repetition Effect; Masking; Rapid Serial Visual Presentation

In the visual world stimuli constantly appear across the dimensions of both time and space. Due to a limited processing capacity, humans must sort incoming sensory information into that which is relevant and irrelevant, selecting items that are to undergo extended processing and those which are to be discarded. It has been postulated that this is

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achieved by a system that initially extracts representations for all stimuli that are encountered visually, yet only forms conscious percepts for those items that are the subject of attention (Duncan, 1984; Mack & Rock, 1998; Treisman & Gelade, 1980).

Much of what we understand about how attention is allocated across time has emerged from studies that employ *rapid serial visual presentation* (RSVP; Potter & Levy, 1969). This methodology involves the presentation of stimuli one after the other in the same spatial location for a fraction of a second each (typically for about 100 ms) and subjects are typically required to respond to one or more predefined target item(s) within the stream. An important finding yielded from this research is the *attentional blink*, as it demonstrates a limit in human attentional processing capacity (Chun & Potter, 1995; Raymond, Shapiro, & Arnell, 1992).

The attentional blink is characterised by the decreased likelihood that the second of two different targets in a RSVP stream will be reported if it appears within 500 ms of the first target (Broadbent & Broadbent, 1987; Raymond et al., 1992; Weichselgartner & Sperling, 1987). A number of different theoretical accounts have been introduced to explain the effect (e.g. Awh et al., 2004; Chun & Potter, 1995; Di Lollo, Kawahara, Ghorashi, & Enns, 2005; Duncan, Ward, & Shapiro, 1994; Giesbrecht & Di Lollo, 1998; Jolicoeur, 1998, 1999; Potter, Staub, & O'Connor, 2002; Raymond et al., 1992; Seiffert & Di Lollo, 1997; Shapiro, Arnell, & Raymond, 1997; Shapiro, Raymond, & Arnell, 1994; Vogel, Luck, & Shapiro, 1998; Ward, Duncan, & Shapiro, 1996). Each model differs with respect to the precise mechanisms and storage components that are hypothesised to be involved in eliciting the second target deficit. However, it is generally assumed that the attentional blink occurs because, when the two targets appear in close temporal proximity, the second target must wait to be the subject of limited capacity attentional resources (as these are devoted to the processing of Target 1) and as a result its representation is susceptible to passive decay and interference from distractor items (but see Di Lollo et al., 2005, for an alternative account).

While there is still debate concerning the specific nature of the mechanisms that underlie the attentional blink, a general assumption of all the models, with the exception of Raymond et al.'s (1992) gating theory, is that most stimuli presented in an RSVP stream undergo conceptual processing—target selection occurring post-perceptually. Considerable empirical support has been generated for this postulation. Maki, Frigen, and Paulson (1997) demonstrated that Target 2 report was facilitated when it was preceded by a semantically related distractor, indicating that distractor stimuli undergo semantic processing. Shapiro, Driver, Ward, and Sorensen (1997) provided further evidence that non-reported stimuli in RSVP are processed to a conceptual level. In their experiments, a missed second target primed report of the third target, suggesting that semantic information survives the attentional blink.

In addition to the behavioural research discussed above, there is also converging evidence from electrophysiology that provides support for the hypothesis that the attentional blink has a post-perceptual locus. Vogel et al. (1998; see also Luck, Vogel, & Shapiro, 1996) measured event related potentials (ERPs) during an attentional blink task and observed significant P100, N100, and N400 components when Target 2 appeared within the attentional blink temporal range. This demonstrated that the missed targets in the RSVP streams underwent perceptual and semantic analysis. Interestingly, complete suppression of the P300 component was also found, suggesting the attentional blink impairment arises at the stage of working memory.

The results from both the behavioural and electrophysiological studies discussed above provide strong support for the hypothesis that most stimuli in an RSVP stream are briefly identified, before targets are selected for extended processing. However, what is the fate of the distractor items, which appear temporally close to the targets that are not selected after preliminary analysis is complete? Do these items just simply decay and get overwritten by incoming stimuli, as predicted by current models of the attentional blink? Or do additional processes occur that inhibit these distractors in order to reduce the extent to which their representations interfere with subsequent target identification?

Previous research has demonstrated that there is considerable competition between stimuli for the capacity limited processing resources that lead to consolidation. Chun (1997a; see also Isaak, Shapiro, & Martin, 1999) and Botella (Botella, Barriopedro, & Suero, 2001; Botella & Eriksen, 1991) have shown that distractor items that appear in close temporal proximity to targets are the stimuli most likely to be reported when subjects make errors. Similarly, Visser, Bischoff, and Di Lollo (2005) have also shown that distractors briefly capture attention if they are drawn from a similar category to the targets. In addition, interference between the targets and the items that directly follow (T1 + 1 and T2 + 1) them is instrumental in causing the attentional blink. It has been shown that the crucial role played by the T1 + 1 and T2 + 1 stimuli is the masking of the targets (Giesbrecht & Di Lollo, 1998; Grandison, Ghirardelli, & Egeth, 1997; Seiffert & Di Lollo, 1997). Support for this postulation comes from research which demonstrates that if either the T1 + 1 or T2 + 1 item is replaced by a blank gap, the blink is removed or substantially attenuated (Chun & Potter, 1995; Giesbrecht & Di Lollo, 1998; Raymond et al., 1992; Seiffert & Di Lollo, 1997). The presence of a gap after Target 1 is presumed to decrease the magnitude of the blink, as it reduces the processing demands of the first target stimulus and, as a result, adequate resources are still available to encode Target 2 when it is presented. Under conditions where a blank gap follows the second target, it is assumed the blink is attenuated because there is no stimulus to overwrite the representation of Target 2 and, as a result, it can be consolidated after the first target has been encoded. Thus, it seems plausible that a mechanism may exist that inhibits distractor representations if they are activated shortly before or after the targets in RSVP. Such a process would reduce the amount of inference generated by these distractors, therefore increasing the likelihood that targets would be accurately perceived.

The idea that distractors are inhibited in some way in dual-target RSVP streams is not a new one. Raymond et al. (1992) initially proposed *gating* theory, an early selection account of the attentional blink, in which distractor inhibition played an important role. These researchers hypothesised that, when a target was selected, an "attentional gate" closed after it, thus preventing distractors from interfering with target identification processes. The gate was assumed to reopen within approximately 500 ms (the time it took to encode the target). Thus, if the second target appeared temporally close to Target 1, it would not be processed and, as a result, it would be unavailable for report. Although this model explained the observed effects, it was superseded by late selection accounts of the attentional blink. Late selection theories were able to accommodate a wider variety of findings, particularly the data discussed above which demonstrates that non-reported items in RSVP streams are processed conceptually.

Recently Loach and Marì-Beffa (2003) have provided evidence suggesting that distractors may be inhibited in RSVP streams. In their study, subjects viewed RSVP streams that contained black letter distractors and a single red letter target. The subjects made a speeded response to the identity of the last black letter in the stream and then recalled the identity of the red target. In half the trials, the last item was the same as one of the distractors that had followed the target stimulus. Subjects were slower to respond to the last item in the stream when it had the same identity as a distractor that had appeared within 270 ms of the target. This negative effect of repetition on reaction time suggests that distractors were inhibited after the presentation of the target to enhance selection of this stimulus.

Loach and Marì-Beffa's (2003) data provide some support for gating theory, however, their results are not definitive. In their experiments, subjects had to respond to only one target, whereas in attentional blink experiments responses to two targets are typically required. Thus, while these paradigms are similar, it is possible that performance on each involves different mechanisms. For example, in a single-target RSVP stream, all post-target stimuli may be inhibited, as subjects are aware that there are no additional targets to report. In dual-target tasks this may not be the case, however, as subjects continue to search for an additional stimulus (Target 2) after the presentation of the first target.

The findings of Loach and Marì-Beffa (2003) are not easily accommodated by late-selection theories of the attentional blink. However, these models still provide the best account of the phenomenon, as they assume that the identity of distractors is briefly available during processing of an RSVP stream. We know target representations are consolidated after initially having their semantic representations activated; what is less well understood, however, is what happens to distractor stimuli that appear temporally close to the targets that are not selected for further processing. It appears that the stimuli presented soon after Target 1 are *not* all inhibited based on their temporal position. However, could it be that target selection is achieved by a mechanism(s) that inhibits specific distractor representations after they are presented? And if such a mechanism(s) exists, at what level(s) does it operate?

In this study we investigate the fate of distractor stimuli in RSVP that appear in close temporal proximity to the first target. We presented a standard attentional blink task where subjects had to identify two targets at the end of each stream, and we manipulated whether the items immediately before and immediately after Target 1 ($T1-1$ and $T1+1$) were identical to each other (repeat trials) or not (non-repeat trials). As previously discussed, research has demonstrated that the $T1+1$ stimulus plays the crucial role of masking Target 1 and that, if this stimulus is replaced by a blank gap, the blink is removed or severely attenuated (Chun & Potter, 1995; Raymond et al., 1992; Seiffert & Di Lollo, 1997). If the representations of distractor stimuli that appear adjacent to Target 1 are inhibited for a short period after their presentation, a subsequent activation by a repetition of one these items should be reduced as it has previously been marked as irrelevant. A reduction in the activation of the $T1+1$ stimulus would cause this item to interfere less with Target 1 on repeat trials than on trials where the $T1-1$ and $T1+1$ stimuli are different. As reductions in Target 1 processing difficulty have previously been shown to attenuate the attentional blink (e.g. Chun & Potter, 1995; Seiffert & Di Lollo, 1997; but see McLaughlin, Shore, & Kanwisher, 1987), we predict that this reduced interference from the T1 + 1 item will lead to an increase in the availability of resources required to process Target 2, which will result in the magnitude of the blink being decreased in repeat trials (Chun & Potter, 1995; Grandison et al., 1997; Olson, Chun, & Anderson, 2001; Raymond et al., 1992; Seiffert & Di Lollo, 1997). Thus, if the repetition of the distractors attenuates the attentional blink, this would provide evidence that distractors in RSVP streams are inhibited if they appear in close temporal proximity to the targets. To investigate the second aim of this study—at what level does such inhibition occur—we also manipulated featural and categorical differences between targets and distractors, in an attempt to establish the mechanisms involved in target selection in RSVP processing.

1. Experiment 1

In Experiment 1, the subjects viewed RSVP streams that contained two black letter targets and eight black digit distractors; their task was to recall both targets at the end of each stream. In half the trials, the distractor items either side of Target 1 were identical (e.g. 2 and 2; repeat trials) and in the other half different (e.g. 7 and 4; non-repeat trials). As previously discussed, if the T1 − 1 distractor stimulus is inhibited after initial registration, then a blink of decreased magnitude is expected in the repeat condition, as the interference from the T1 + 1 item will be reduced in these trials relative to non-repeat trials. On the other hand, if interference from the T1 + 1 stimulus is unaffected by distractor repetition, then we would expect to find no difference in blink magnitude between repeat and non-repeat trials. Finally, if the repetition of the distractors increases the interference to Target 1, by enhancing the representation of the T1 + 1 stimulus, a larger Target 2 deficit should be observed in the repeat condition.

1.1. Method

1.1.1. Subjects

Nine undergraduate students at Macquarie University took part in the study. The sample consisted of three males and six females, with an average age of 21 years ranging from 18 to 33 years. All subjects reported normal or corrected-to-normal visual acuity and normal colour vision.

1.1.2. Stimuli

Stimuli were presented centrally in the same spatial location for 100 ms each, with no interstimulus interval (ISI). Black letters and digits appeared on a white background. All stimuli were presented in Courier New font (size 10) and subtended approximately 0.7° visual angle. The experiment was programmed and conducted using DMDX software (Forster & Forster, 2003) and was run on a Dell Flat Trinitron monitor with 120 Hz vertical refresh rate controlled by a Dell computer.

The targets were randomly selected from the alphabet, excluding the letters *I*, *L*, *O*, *Q*, *U* and *V*, and were presented an equal number of times with no pair of items appearing more than once. Targets were always presented in uppercase. Distractors were the digits 2–9 randomly ordered for each trial.

1.1.3. Trial structure

All trials contained two black letter targets and eight black digit distractors, with a black "&" mask appearing at the end of each stream. Target 1 was always presented in serial position 3, with Target 2 following an equal number of times at Lags 2–6. A minimum of two items followed Target 2 (a digit and the "&" mask). In half the trials, the items directly before and after Target 1 ($T1-1$ and $T1+1$) were identical (repeat trials) and in the other half different (non-repeat trials).

1.1.4. Procedure

Subjects were seated approximately 40 cm away from the computer screen. Each trial was initiated by the subject pressing the space bar. Trials began with a fixation cross for 300 ms, followed by the sequence of stimuli. Subjects were required to report the two letter targets at the end of each trial, when the prompt, "Please recall the targets", appeared in the centre of the screen.

Subjects initially completed 20 practice trials that contained two trials of each condition. Experimental trials were then commenced, with each subject completing two blocks of 50 trials. The order of the blocks was counterbalanced to control for any specific sequence effects. Five trials for each of the 10 conditions were presented in each block in a random order.

1.1.5. Design

This experiment employed a 2×5 repeated measures design. The independent variables were Trial Type (repeat vs. non-repeat) and Lag (2–6). The dependent variables were Target 1 (T1) and Target 2 given Target 1 correct (T2|T1) report accuracy.

1.2. Results

1.2.1. Conditional Target 2 report accuracy (T2|T1)

Fig. 1 shows the mean percentage T2|T1 accuracy as a function of Trial Type and Lag. T2|T1 accuracy scores were subjected to a 2×5 repeated measures ANOVA. The significant main effect of Lag revealed an attentional blink pattern, $F(4, 32)=9.55$, $P<0.0002$. This was confirmed by planned orthogonal contrast analyses which yielded significant linear, $F(1, 32)=26.81$, $P<0.0002$, and quadratic, $F(1, 32)=5.05$, $P<0.05$, trends. The main effect of Trial Type approached significance, $F(1, 8)=3.66$, $P=0.092$, with subjects reporting more targets for repeat trials (73.2%) than for non-repeat trials (67.7%).

There was also a significant interaction between Trial Type and Lag, $F(4, 32)=2.89$, $P<0.05$. A planned contrast analysis showed that this interaction occurred because the subjects' target report was superior for repeat (71%) trials rather than non-repeat (45.4%) trials at Lag 2, $F(1, 32)=14.4$, $P<0.0007$. Target report accuracy for repeat and non-repeat trials did not differ significantly at any other Lag ($F\text{s}<1$).

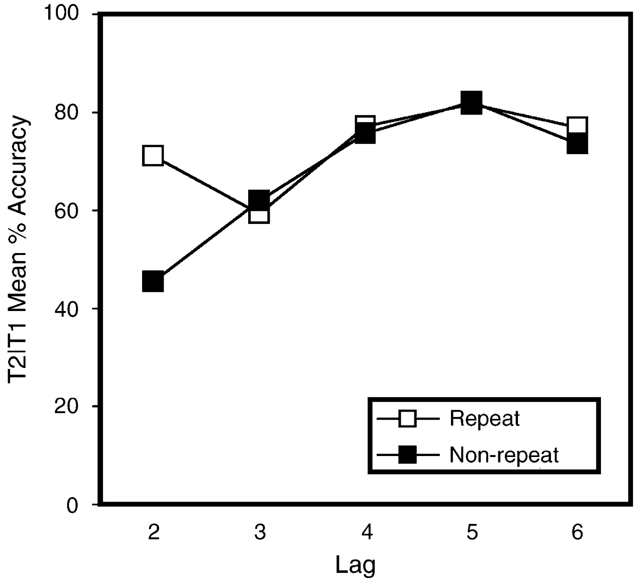

Fig. 1. Mean T2|T1 accuracy in Experiment 1 as a function of trial type and lag.

1.2.2. Target 1 report accuracy (T1)

Accuracy scores for T1 report were analysed using a 2×5 repeated measures ANOVA with Trial Type and Lag as within subject factors. The average accuracy of Target 1 report across all conditions was 90.4% and performance was not affected by Trial Type or Lag, nor did these variables interact.

1.3. Discussion

The presentation of identical distractor items either side of Target 1 significantly attenuated the attentional blink. In the non-repeat condition, the typical attentional blink pattern was observed, with performance being lowest at Lag 2 and gradually improving as Lag increased. Performance in the repeat trials did not differ significantly from that in the non-repeat trials at Lags 3–6, however, at Lag 2, where the blink is typically maximal, performance was considerably improved. This pattern of data in the repeat trials is similar to that observed when Target 1 is followed by a blank gap. Thus, the results suggest that distractors, which appear in close temporal proximity to Target 1 are briefly inhibited after they are presented in the RSVP stream. The interference caused by the $T1+1$ item appears to have been attenuated in the repeat condition, which we propose led to an increase in the resources available to process Target 1 and as a result blink magnitude was decreased.

Although this experiment provides evidence that the distractors flanking the first target are inhibited in dual-target RSVP streams, it does not indicate the level at which this *distractor repetition effect* occurs. A high-level response bias or memory explanation seems unlikely as subjects never had to respond to the repeated stimuli and no subject reported noticing a repetition when asked at the end of the experiment. However, given that the T1 − 1 and T1 + 1 stimuli were always featurally identical in repeat trials it is not possible to determine whether inhibition occurred at the featural level or at the level of abstract identities. Experiment 2 was conducted to examine this question.

2. Experiment 2

In Experiment 1, the presentation of identical distractors either side of Target 1 substantially attenuated the attentional blink. We took this finding to suggest that distractor stimuli that appear adjacent to targets in RSVP are inhibited. Experiment 2 was conducted to determine whether this inhibition of the repeated distractor (at position T1 + 1) occurred at a featural or abstract identity level.

A number of repetition deficits have been found to occur at both levels of representation. Bjork and Murray (1977) presented subjects with a 4×4 grid of hatch (#) symbols, two of which became letters for 25–50 ms before changing back, while the others changed to dollar ($) signs for the same period. Immediately after the presentation of the letters, an arrow was presented underneath one of the columns and subjects were required to make a speeded response as to the identity of the letter that had appeared in that column. The crucial manipulation was whether the two letters were identical or different. The subjects were less accurate at discriminating the target letter when the spatially adjacent distractor stimulus was identical to it compared to when it was different. These researchers took this as evidence for a model of visual processing where processing channels linked to the same feature detector inhibited one another more than channels linked to different feature detectors. Egeth and Santee (1981) found a similar but smaller effect using letters that differed in case. This result suggested, along with those of Bjork and Murray (1977), that inhibition could occur at both a featural and abstract identity level.

Another repetition effect that has been found to occur at the abstract identity level, is a phenomenon known as *repetition blindness*. Repetition blindness is similar to the attentional blink and is characterised by a reduced ability to report two nominally identical items, relative to two items with different identities, in an RSVP stream, if they are presented within 500 ms of one another. A number of models have been proposed to account for the effect, the dominant theory being the *token individuation hypothesis* (e.g. Bavelier, 1994; Chun, 1997b; Kanwisher, 1987). This account predicts that when viewing a stream of items at a rate of 1/100 ms, information regarding the identity of each stimulus (type) and its position in the stream (token) is extracted. This information must then undergo consolidation, with types and tokens being linked through a process of token individuation. This process requires attention, otherwise the activated type information will decay and be unavailable for report (Kanwisher, 1991). Repetition blindness is explained as a failure to token individuate a repeated type a second time, if it is reactivated within approximately 500 ms. This phenomenon is thought to occur at the level of abstract identities, given that the effect is also elicited by nominally identical letters that differ in case. Interestingly, repetition blindness is larger when the repeated stimuli are of the same case, suggesting that there may be an additional featural component to the effect (Bavelier, 1994; Chun, 1997b).

Experiment 2 had the same design as the previous experiment, the only difference being that digits were used as the targets and letters as the distractors. The use of letters as distractors allowed us to present items either side of Target 1 that were nominally identical but featurally different (i.e. uppercase and lowercase instances of a particular letter). Therefore, if the distractor repetition effect found in Experiment 1 was due to the T1 + 1 stimulus being inhibited at the featural level, then no reduction in the attentional blink should be found when the repeated distractors differ in case. Conversely, a finding that attentional blink magnitude is reduced in trials where the repeated items either side of Target 1 differ in case would suggest the effect occurs at the level of abstract identities.

2.1. Method

The method for Experiment 2 was identical to that of the first experiment except where specified.

2.1.1. Subjects

Ten new subjects, undergraduate students of Macquarie University, took part in the experiment. The sample consisted of two males and eight females, with an average age of 24 years, ranging from 19 to 47 years.

2.1.2. Stimuli, materials and procedure

The RSVP streams contained two black digit targets and eight black letter distractors, the letters being drawn from the set *A, B, D, E, G, H, M, N, T* and R. These letters were selected because the uppercase and lowercase versions of each were featurally different. Four uppercase and four lowercase distractor stimuli appeared in each stream in a random order, the only restriction being that T1 − 1 was always presented in lowercase and T1 + 1 and T2 + 1 in uppercase. The lowercase stimuli were presented in increased font (font size 12 as opposed to 10) so that they were approximately the same size as the uppercase distractors. Subjects were required to report the two digit targets at the end of each stream.

2.2. Results

2.2.1. Conditional Target 2 report accuracy (T2|T1)

Fig. 2 plots the mean T2|T1 accuracy as a function of Trial Type and Lag. The data were submitted to a 2×5 repeated measures ANOVA. There was a significant main effect of Lag, $F(4, 36) = 16.93$, $P < 0.0005$, revealing the presence of an attentional blink. Planned contrast analyses showed Target 2 report was lower at Lag 2 (58.3%) than at Lag 3 (69.2%), $F(1, 36) = 4.67$, $P < 0.05$, and lower at Lag 3 than at Lag 4 (82.4%), $F(1, 36) = 6.9$, $P < 0.05$. A significant linear trend, $F(1, 36) = 63.87$, $P < 0.0002$, was also present. Neither the main effect of Trial Type nor the interaction between Trial Type and Lag approached significance (Fs < 1.1).

2.2.2. Target 1 report accuracy (T1)

The data were subjected to a 2×5 repeated measures ANOVA and the overall level of Target 1 report accuracy was 93.6%. The main effects of Trial Type and Lag as well as the interaction between these two variables did not approach significance (Fs < 1.3).

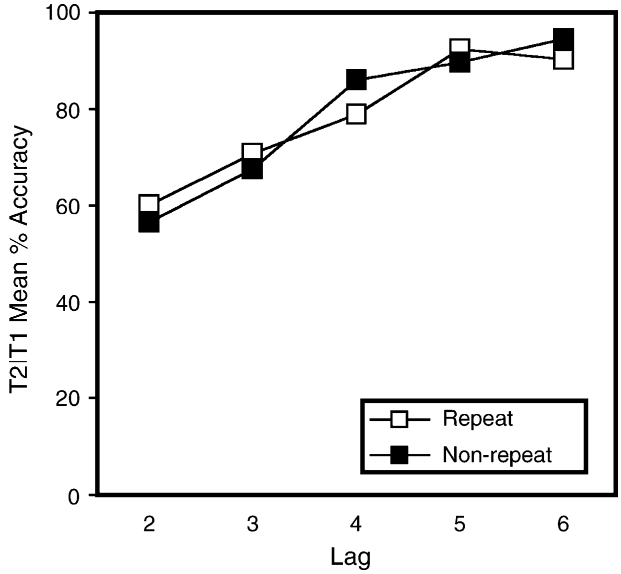

Fig. 2. Mean T2|T1 accuracy in Experiment 2 as a function of trial type and lag.

2.3. Discussion

Significant attentional blinks were observed in both the repeat and non-repeat conditions, with no effect of distractor repetition evident in either the T2|T1 or T1 accuracy data. In repeat trials in this experiment the T1 − 1 and T1 + 1 items had the same identity but were featurally different, whereas in Experiment 1 they were always featurally identical. The failure to find a reduction in blink magnitude under these conditions demonstrates that distractors must be featurally identical for distractor repetition to reduce the magnitude of the attentional blink. This suggests that distractors are inhibited at a featural level, as opposed to an abstract identity level. Thus, the mechanism that underlies the distractor repetition effect appears to differ from that responsible for repetition blindness, which has been found to occur between items that have the same identity but differ in case. We return to this point in General Discussion.

3. Experiment 3

In Experiment 3, we aimed to investigate whether or not the category difference between the targets and distractors in Experiment 1 contributed to the reduction of the attentional blink following distractor repetition. While the targets were defined by category in the previous two experiments it is also common in attentional blink studies for targets to be drawn from the same category as the distractors and to be cued by colour (e.g. "report the two red letters"). In Experiment 3, subjects viewed RSVP streams that contained red letter targets and black letter distractors all presented in uppercase, and again the items either side of Target 1 were either identical or different. If the distractor repetition effect observed in Experiment 1 specifically depends on the T1 − 1 and T1 + 1 items being featurally identical, and is not influenced by the nature of the target cue, then we should find a reduced blink in repeat trials when the targets are defined only by colour.

3.1. Method

The method for Experiment 3 was identical to that of the first experiment except where specified.

3.1.1. Subjects

Sixteen new subjects, all undergraduates of Macquarie University, took part in the experiment. The sample consisted of 3 males and 13 females, with an average age of 22 years, ranging from 18 to 30 years.

3.1.2. Stimuli, materials and procedure

All stimuli were letters randomly selected from the alphabet, excluding *I, L, O, Q, U* and *V*. Stimuli were presented in uppercase with both targets coloured red and distractors coloured black. Apart from the relevant stimuli on repeat trials, no letter appeared more than once in each stream.

3.2. Results

3.2.1. Conditional Target 2 report accuracy (T2|T1)

Fig. 3 shows the mean percentage T2|T1 accuracy as a function of Trial Type and Lag. The data were analysed using a 2×5 repeated measures ANOVA. As was the case in the

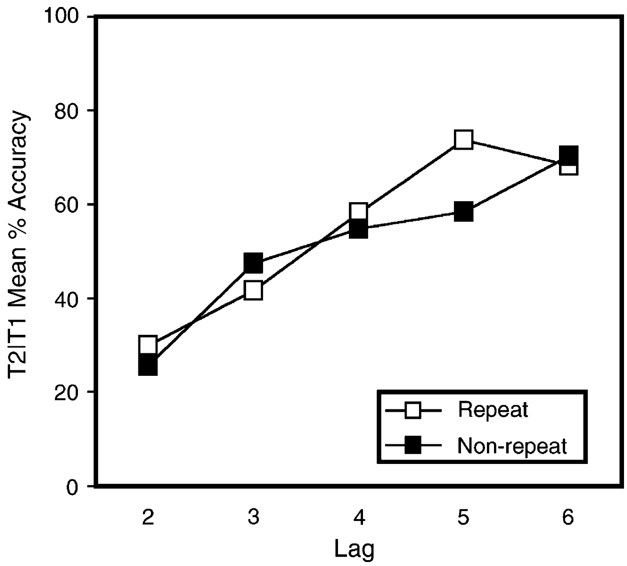

Fig. 3. Mean T2|T1 accuracy in Experiment 3 as a function of trial type and lag.

first two experiments, a significant main effect of Lag was present signalling the occurrence of an attentional blink, $F(4, 60)=26.83$, $P<0.0005$. This was confirmed by planned orthogonal contrast analyses that demonstrated significant linear, $F(1, 60)=101.45$, $P<0.0005$, and quadratic, $F(1, 60)=5.78$, $P<0.02$, trends. There was no effect of Trial Type and Trial Type and Lag did not significantly interact.

3.2.2. Target 1 report accuracy (T1)

Fig. 4 plots T1 accuracy as a function of Trial Type and Lag. Once again a 2×5 repeated measures ANOVA was used to analyse the data. A significant main effect of Trial Type was found, $F(1, 15)=19.74$, $P<0.0006$, with superior T1 report on repeat trials (89.3%) relative to non-repeat trials (81.8%). The main effect of Lag was not significant, however, this variable significantly interacted with Trial Type, $F(4, 60)=3.3$, $P<0.02$. The interaction arose because subjects only performed better on repeat trials relative to non-repeat trials at Lag 2, $F(1, 60)=4.14$, $P<0.05$, Lag 5, $F(1, 60)=13.19$, $P<0.0007$, and Lag 6, $F(1, 60)=10.2$, $P<0.003$.

3.3. Discussion

In Experiment 3, the target and distractor stimuli were drawn from the same category (letters), with the targets defined by colour. We found significant attentional blinks in both repeat and non-repeat trials, however, distractor repetition had no effect on blink magnitude. These results, therefore, are inconsistent with the idea that the distractor repetition effect is *only* dependent on inhibition occurring at a featural level.

How do we reconcile these results with those we obtained in Experiment 1? The major difference between Experiment 3 and the first experiment was that in Experiment 3 the targets and distractors were members of the same category, whereas in Experiment 1 the

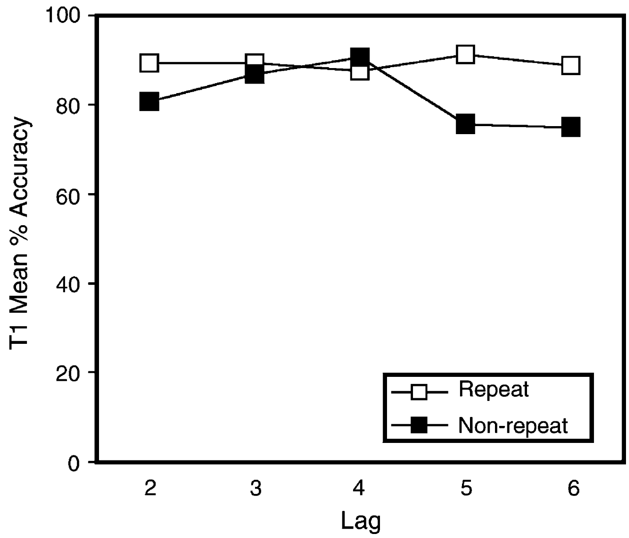

Fig. 4. Mean T1 accuracy in Experiment 3 as a function of trial type and lag.

targets and distractors were drawn from different stimulus categories. The lack of a distractor repetition effect on the attentional blink in this experiment suggests that an explanation based on inhibition at the feature level alone is insufficient to account for all the data. It appears that the way targets are defined also influences the effect of distractor repetition on dual-target report.

An interesting result from Experiment 3 was that at some lags report of Target 1 was superior on repeat trials compared to non-repeat trials. This is evidence that some inhibition of the repeated distractor did occur, however, for some reason it did not affect Target 1 processing at all Target 2 lags nor did it incur a reduction in blink magnitude. It appears that in addition to the suppression that occurs at the featural level, a mechanism that inhibits the distractor representations as a set is also involved in eliciting the distractor repetition effect. To illustrate, consider the stimulus characteristics in Experiment 1: there the repeated distractors were identical and as a result inhibition occurred at the feature level. In addition, the $T1-1$ and $T1+1$ items were drawn from a different alphanumeric category to the targets, which meant that they, as a set, could also have had their representations inhibited categorically (i.e. inhibit everything that is not a letter). We might expect this combination to lead to a large distractor repetition effect and that is indeed what we observed in the first experiment. In contrast, while in the present experiment there would be a similar amount of featural inhibition, as the repeated distractors were identical, there would now be only limited categorical inhibition of the distractor representations because subjects were continuously monitoring the streams for letter targets. As a result, the interference from the $T1+1$ item would only be moderately attenuated on repeat trials, leading to a reduced effect of distractor repetition on dual-target report. Such results were found in Experiment 3 as distractor repetition had a minimal influence on Target 1 report accuracy that was reliable only at Lags 2, 5, and 6. As this explanation is post hoc Experiments 4 and 5 were designed to test our hypothesis, which we elaborate in General Discussion.

4. Experiment 4

We have argued, based on the data from the previous three experiments, that distractor stimuli, which are presented in close temporal proximity to the first target, are inhibited in order to reduce the extent to which they interfere with target selection. The explanation we have suggested for the distractor repetition effect involves two mechanisms, one that acts at a featural level and another that operates based on stimulus category and involves attention. If a distractor is identical to one that has appeared briefly before it, this representation will be inhibited as it maps on to the same feature detectors. At the same time, distractor representations as a set are also inhibited if they are drawn from a different category to the targets. The output of these two processes interact and the effect of distractor repetition on the attentional blink is a result of this interaction.

In Experiment 3, the targets were cued by colour, but were drawn from the same category as the distractors. Under these circumstances, we found no effect of distractor repetition on the attentional blink, although there was a small effect on Target 1 accuracy at Lags 2, 5 and 6. This suggests that the colour target cue allowed the distractors to be inhibited to some extent, but that this was not sufficient to attenuate the blink or reliably affect Target 1 accuracy at all Target 2 lags. If colour information can be used to inhibit distractors, then we would predict that defining targets by both colour and category should increase the efficiency with which the distractor set is inhibited, further reducing the amount of interference from the T1+1 stimulus and, therefore, the magnitude of the attentional blink. To test this, we presented RSVP streams containing letter targets and digit distractors, identical to those used in Experiment 1, except here the targets were also red in colour, while the distractors remained black.

4.1. Method

The method for Experiment 4 was identical to that of Experiment 1 except where specified.

4.1.1. Subjects

Seven new subjects, undergraduate students of Macquarie University, took part in the experiment. The sample consisted of one male and six females, with an average age of 22 years, ranging from 19 to 36 years.

4.1.2. Stimuli, materials and procedure

The targets were red letters and were presented amongst black digit distractors. Subjects were required to report the two red letter targets at the end of each stream.

4.2. Results

4.2.1. Conditional Target 2 report accuracy (T2|T1)

Fig. 5 shows the mean T2|T1 accuracy as a function of Trial Type and Lag. The data were subjected to a 2×5 repeated measures ANOVA with Trial Type and Lag as within subject factors. There was a significant main effect of Trial Type, $F(1, 6)=6.77$, $P<0.05$, with superior performance on repeat trials (92.2%) relative to non-repeat trials (86.2%). A significant main effect of Lag, $F(4, 24)=9.87$, $P<0.0002$, was also evident. Planned orthogonal contrast analyses revealed significant linear, $F(1, 24)=33.47$, $P<0.0002$, and quadratic, $F(1, 24)=5.8$, $P<0.03$, trends.

There was also a significant interaction between Trial Type and Lag, $F(4, 24)=5.19$, $P<0.005$. As shown in Fig. 5, this interaction occurred due to differences in the length and magnitude of the attentional blink for repeat and non-repeat trials. Planned contrast analyses revealed that for non-repeat trials performance at Lag 2 (62.7%) was significantly inferior to that at Lag 3 (79.8%), $F(1, 24)=17.17$, $P<0.0005$. In addition, performance at Lag 3 was significantly worse than the average accuracy across Lags 4, 5 and 6 (96.2%), $F(1, 24)=23.42$, $P<0.0002$. For repeat trials, the only contrast that was significant was that comparing performance at Lag 2 (81.3%) and Lag 3 (91.4%), $F(1, 24)=6.03$, $P<0.03$. A comparison between repeat and non-repeat conditions showed that performance was worse in non-repeat trials at Lag 2, $F(1, 24)=20.15$, $P<0.0003$, and Lag 3, $F(1, 24)=7.84$, $P<0.01$.

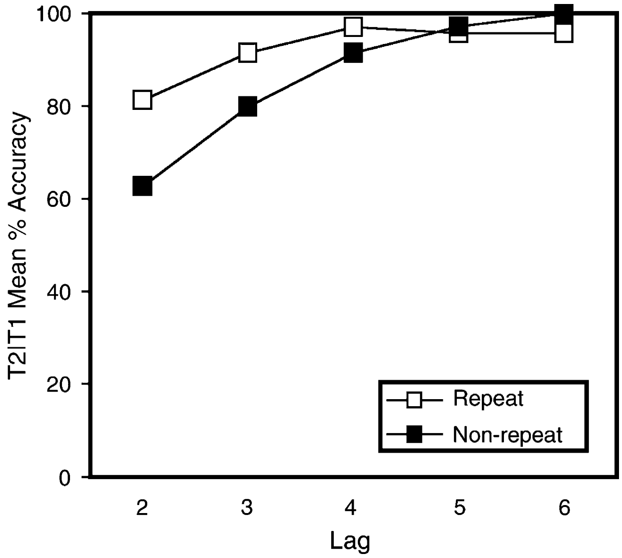

Fig. 5. Mean T2|T1 accuracy in Experiment 4 as a function of trial type and lag.

4.2.2. Target 1 report accuracy (T1)

The average T1 accuracy across all conditions was 99%. A 2×5 repeated measures ANOVA revealed no significant effect of either Trial Type or Lag and the two variables did not significantly interact.

4.3. Discussion

In Experiment 4, targets were cued both by category and colour, thereby increasing the extent to which distractors as a set could be inhibited. In addition, on repeat trials the items either side of Target 1 were identical, which should have resulted in maximal inhibition at the featural level. Under these conditions, we predicted a more pronounced effect of distractor repetition on the attentional blink than that found in Experiment 1. The results supported this prediction. In Experiment 1, repeat and non-repeat trials only differed at Lag 2, however, in the present experiment the subjects' performance was superior on repeat trials relative to non-repeat trials at both Lags 2 and 3. These data provide support for the suggestion that distractor inhibition in RSVP streams is mediated by two mechanisms, one that operates at the featural level and another that has its locus at the categorical level. We suggest that these inhibitory mechanisms act to reduce distractor interference during target selection.

The results of Experiment 4 also have two other important implications. Firstly, in Experiment 1 we found that T2|T1 performance at Lag 2 was superior on repeat trials compared to non-repeat trials. We suggested that this occurred because distractor repetition inhibited the activation of the $T1 + 1$ stimulus and, as a result, interference between the representation of this item and that of Target 1 was reduced, thus causing the blink to be attenuated. While we have hypothesised that the magnitude of the second target deficit was reduced in the repeat trials of Experiment 1 because the repetition of the distractors increased the efficiency with which Target 1 was processed, it is also possible that the blink was attenuated because this manipulation enhanced the visibility of the second target perhaps by reducing the extent to which this stimulus was forward masked by the T1 + 1 item. This alternative hypothesis that distractor repetition affected the efficiency with which Target 2, rather than Target 1, was processed can account for the results of the first experiment where T2|T1 performance was only enhanced at Lag 2. In Experiment 4, T2|T1 accuracy was superior at both Lags 2 and 3 in repeat trials compared to non-repeat trials. Therefore, while the effect of distractor repetition on the blink at Lag 2 may have been due to the increased visibility of the second target, the enhanced T2|T1 accuracy in the repeat trials at Lag 3 is more likely to have occurred because distractor repetition influenced Target 1 processing efficiency. This is the case because Target 2 was forward masked at Lag 3 to the same extent in both repeat and non-repeat trials, since in both conditions the second target was preceded by a non-repeat item. This result, therefore, favours the notion that Target 1 processing is enhanced by distractor repetition and that this facilitated selection/consolidation of the first target contributes significantly to the reduced attentional blink magnitude observed in repeat trials.

Secondly, the results of Experiment 4 also provide indirect support for our hypothesis that the distractor repetition effect is contingent on the T1 − 1 and T1 + 1 stimuli being identical. In Experiment 2 we failed to find any effect of distractor repetition on the attentional blink, which we reasoned was the result of the T1 − 1 and T1 + 1 stimuli being featurally different in the repeat trials. Given that the overall accuracy in Experiment 2 was superior to that of the first experiment, it is possible that there was no difference between repeat and non-repeat trials in the second experiment because the increased accuracy resulted in the blink being less sensitive to the manipulation of distractor repetition. In Experiment 4, not only did we replicate the results of Experiment 1, but we also found a large distractor repetition effect on the attentional blink when the difficulty of the dual-target task was comparable to that of the second experiment (as indicated by the overall increase in accuracy in Experiment 4 compared to Experiment 2). Therefore, it appears that the distractor repetition effect was removed in Experiment 2, not because overall accuracy in this experiment was greater than that observed in Experiment 1, but because the items flanking the first target in the repeat trials were visually different.

5. Experiment 5

Thus far, we have demonstrated that if the distractor items either side of Target 1 are featurally identical and drawn from a different alphanumeric category to the targets, then the attentional blink is substantially attenuated (Experiments 1 and 4). In Experiment 4, we obtained a stronger distractor repetition effect than in Experiment 1, by including an additional target cue (colour). In contrast, in Experiment 3, where the targets were only defined by colour, we failed to find an effect of distractor repetition on the attentional blink, although there was a small effect of this variable on Target 1 report that was significant at Lags 2, 5 and 6. These findings are consistent with the idea that inhibition of distractor category plays an important role in target selection. If this is the case, then we would expect no distractor repetition effect if Target 2 were drawn from the same category as the distractors. Under these conditions, we would predict that the distractors would not be inhibited based on alphanumeric category, as the system would be searching for the appearance of a second target that was a member of the distractor set. This prediction was tested in Experiment 5, by asking subjects to report a first target that was defined by both category and colour and a second target that was only cued by colour.

5.1. Method

The method for Experiment 5 was identical to that of Experiment 4 except where specified.

5.1.1. Subjects

Fourteen new subjects, undergraduate students of Macquarie University, took part in the experiment. The sample consisted of 2 males and 12 females, with an average age of 18 years, ranging from 18 to 20 years.

5.1.2. Stimuli, materials and procedure

The experiment had two blocks. In Block 1, Target 1 was a red letter, Target 2 a red digit and the distractors were black digits. In Block 2, Target 1 was a red digit, Target 2 a red letter and the distractors were black letters. Both blocks were preceded by practice trials and their order was counterbalanced. Within each stream, only seven rather than eight distractors were presented because one of the distractors was now a target. Subjects were told to report the red letter and red digit at the end of each stream in Block 1 and a red digit and red letter at the end of each stream in Block 2. In addition, subjects were also informed that the distractors were black digits in Block 1 and black letters in Block 2.

5.1.3. Design

This experiment employed a $2\times2\times2\times5$ mixed design. The within subject independent variables were Trial Type (repeat vs. non-repeat), Target 1 Type (Letter vs. Digit) and Lag (2–6), the between subject factor was Block Order (Target 1 Letter first vs. Target 1 Digit first). The dependent variables were T1 and T2|T1 accuracy.

5.2. Results

Preliminary data analysis revealed that the effect of Block Order did not approach significance nor interact with any other variables, therefore we collapsed the data across this factor.

5.2.1. Conditional Target 2 report accuracy (T2|T1)

Fig. 6 plots the mean T2|T1 accuracy as a function of Trial Type, Target 1 Type and Lag. The data were subjected to a $2\times2\times5$ repeated measures ANOVA. The only significant effect was that of Lag, $F(4, 52)=55.69$, $P<0.0002$, revealing the presence of an attentional blink. A planned contrast analysis showed there to be a significant linear trend, $F(1, 52)=216.36$, $P<0.0002$.

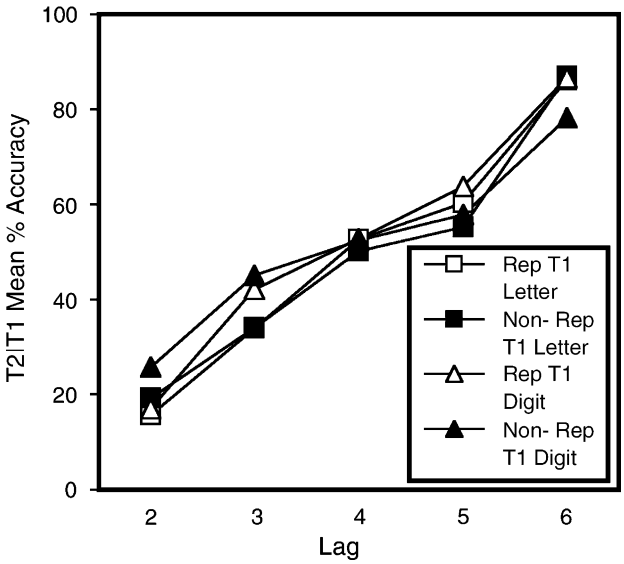

Fig. 6. Mean T2|T1 accuracy in Experiment 5 as a function of trial type, Target 1 type and lag.

5.2.2. Target 1 report accuracy (T1)

The data were analysed using a $2 \times 2 \times 5$ repeated measures ANOVA. The overall level of Target 1 accuracy was 96.5% and none of the manipulations of the variables had a significant effect on target report, nor were there any significant interactions.

5.3. Discussion

In a task where Target 1 was cued by colour and category and Target 2 was defined only by featural information (colour), we found no evidence of an effect of distractor repetition. The data provide support for our hypothesis that inhibition of the distractors as a set is crucial for distractor repetition to reduce the attentional blink. In Experiment 4, we found a pronounced effect of distractor repetition on the blink when both targets were featurally and categorically defined and we hypothesised that this occurred because the $T1+1$ item suffered not only featural inhibition, but also categorical inhibition. We suggest that this inhibition reduced interference to Target 1, which made this stimulus easier to process and as a result the attentional blink was attenuated in the repeat condition. In Experiment 5, Target 2 was drawn from the same category as the distractors. Under these conditions, we predicted that distractor representations as a set would not be inhibited as subjects still had to search for a second target stimulus from the same category. This hypothesised reduction in categorical inhibition can explain why the attentional blink did not differ now between repeat and non-repeat trials. In Experiment 5, interference from the $T1+1$ item to Target 1 would have been greater in repeat trials than in the repeat trials of Experiments 1 and 4. This increased interference would have reduced processing resources for Target 2 and, as a result, attentional blink magnitude was increased, but performance on repeat and non-repeat did not differ significantly.

Did we fail to find an effect of distractor repetition in Experiment 5 because a task switching cost, insensitive to distractor repetition, obscured a reduction in the magnitude of the attentional blink? Potter, Chun, Banks, and Muckenhoupt (1998) found a significant attentional blink when subjects searched for two black letter targets that appeared amongst a stream of black digits distractors. In addition, they demonstrated that this second target deficit was increased when subjects searched for a digit (Target 1) and then the presence/absence of an X (Target 2) within a stream of letter distractors (all the stimuli were presented in the same colour). Potter et al. (1998) suggested that the deficit observed in the latter condition was larger than that elicited in the former, because not only was second target accuracy impaired by the attentional blink but also by the switch in category between the two targets. They argued that this task switching cost was amplified under these conditions because subjects had to change from ignoring letter distractors when they searched for Target 1 (a digit), to searching for a second target that was a letter.

In our experiment subjects were required to identify two targets both of which were coloured red, nevertheless our targets were members of different alphanumeric categories and therefore it is possible that a task switching cost contributed to the magnitude of the second target deficit we observed. However, Potter et al. (1998, see also Chun & Potter, 2001) demonstrated that costs which are incurred due to the attentional blink and task switching are *additive*. Therefore, if the blink was reduced by distractor repetition in Experiment 5, an improvement in second target accuracy should have still been observed in the repeat trials, as the attentional blink component of the second target deficit would have been reduced. This postulation is supported by the fact that we found a robust attentional blink in Experiment 4 when both targets were defined by colour and category (red letters amongst black digits) and that this deficit was strongly influenced by distractor repetition.

6. General discussion

The goal of the present study was to investigate the fate of distractor stimuli in dual-target RSVP streams, that appear in close temporal proximity to Target 1. We presented dual-target RSVP streams where the $T1-1$ and $T1+1$ stimuli were either nominally identical or different. In addition, we manipulated the characteristics that defined the targets to examine the locus of the inhibition effects observed. In the following sections we summarise the results of the study and present an account of the distractor repetition effect. In addition, we discuss our results in relation to other RSVP findings, particularly those from research on the attentional blink and repetition blindness.

6.1. Summary of results

Table 1 provides a summary of the stimulus conditions and results from the five experiments. In Experiment 1 we presented RSVP streams that contained letter targets and digit distractors and found T2|T1 performance to be significantly better at Lag 2 in trials where the items either side of Target 1 were identical, as opposed to different. This effect

Table 1
Summary of the stimulus conditions and results from Experiments 1 to 5

Experiment	Stimulus conditions	Effect of distractor repetition
Exp 1	4 7 G 3 D 5 9 4 7 G 7 D 5 9	Attentional blink reduced at Lag 2 in repeat trials
Exp 2	H a 4 N 7 Y f H a 4 A 7 Y f	No effect of distractor repetition
Exp 3	H A G N D Y F H A G A D Y F	T1 accuracy superior at lags 2, 5 and 6 on repeat trials. No effect of distractor repetition on T2|T1 accuracy
Exp 4	4 7 G 3 D 5 9 4 7 G 7 D 5 9	Attentional blink reduced at lags 2 and 3 in repeat trials
Exp 5	4 7 G 3 8 5 9 4 7 G 7 8 5 9 H A 8 N G Y F H A 8 A G Y F	No effect of repetition

Note: Outlined stimuli denote red targets.

of distractor repetition was more pronounced in Experiment 4, where the two targets were defined by both colour and category, with red capital letters appearing amongst black digit distractors. These conditions led to superior T2|T1 accuracy on repeat trials at Lags 2 and 3. In Experiment 2, targets were also defined by category, however, here the targets were digits and the distractors letters. These conditions allowed the items either side of Target 1 to be presented in different case, thus on repeat trials the T1 − 1 and T1 + 1 items had the same identity but differed at the featural level. Reducing the featural overlap between the T1 − 1 and T1 + 1 stimuli on repeat trials removed the effect of distractor repetition on the attentional blink. In Experiment 3, colour cues were used to define the targets, with red capital letter targets appearing amongst black capital letter distractors. Thus, on repeat trials the T1 − 1 and T1 + 1 items were featurally identical, as in Experiment 1, but were drawn from the same alphanumeric category as the targets. As in Experiment 2, distractor repetition did not influence the magnitude of the blink, although in this experiment it did improve Target 1 report when Target 2 appeared at Lags 2, 5 and 6. Finally, in Experiment 5, Target 1 was cued by both colour and category, whereas Target 2 was drawn from the same category as the distractors and defined only by colour. Once again, distractor repetition had no effect on either T1 or T2|T1 accuracy.

6.2. An inhibitory account of distractor processing in RSVP

The results indicate that distractor repetition reduces the magnitude of the attentional blink if 1) the items either side of Target 1 (T1 − 1 and T1 + 1) are featurally identical and 2) the targets and distractors are members of different stimulus categories. As previously discussed, the Target 1 task must place sufficient processing demands on attentional resources for an attentional blink to be elicited. Evidence in support of this claim comes from the fact that the attentional blink is strongly attenuated when Target 1 is followed by a blank gap of approximately 100 ms. In addition, there is evidence that more difficult

Target 1 tasks, that place direct demands on attentional processing, lead to blinks of increased magnitude (Chun & Potter, 1995; Grandison et al., 1997; Olson et al., 2001; Raymond et al., 1992; Seiffert & Di Lollo, 1997; but see McLaughlin, Shore, & Klein, 2001). We hypothesise that in our study, when the above conditions were met, the processing resources required for Target 1 identification/encoding were less likely to be depleted by T1 + 1 interference and, as a result, the magnitude of the attentional blink was attenuated. We take this reduction in interference from the T1 + 1 item in repeat trials as evidence for the inhibition of distractor representations in RSVP streams that appear in close temporal proximity to the targets.

The fact that this inhibition of distractors was dependent both on the T1 − 1 and T1 + 1 stimuli being featurally identical and on how the targets were defined, suggests that the distractor repetition effect involves both low-level and high-level processes. We propose that the effect reflects the interaction of two mechanisms, one that operates at the level of feature detectors and another attentional process that acts to suppress likely distractor representations.

6.2.1. Inhibition of features

Borrowing from the work of both Bjork and Murray (1977) and Estes (1972), we assume that feature detectors in our visual system are hierarchically arranged based on the complexity of the information they process. We suggest that alphanumeric characters are represented by a small set of distinct simple features (e.g. vertical, horizontal and oblique lines, and concave and convex curves) that give rise to more specific representations that are made up of distinct combinations of these features (e.g. particular angles formed by line intersections). For each letter and digit, a specific representation exists, which specifies the unique featural configuration of the character. Thus, at this level there would be separate representations for the stimuli *E* and *e* (for example). At the simple feature level there will be considerable featural overlap between stimuli, as a particular feature may be present in a number of characters, however, as information ascends up the hierarchy this similarity decreases, eventually leading to the more separate specific feature representations of each letter and digit.

When first presented with a letter or digit in an RSVP stream (whether it be a target or distractor), simple features are extracted leading to the activation of a specific featural representation of that stimulus. This, in turn, then leads to the activation of the distinct abstract letter or digit detector that is invariant to case and font (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; McClelland & Rumelhart, 1981). Following activation of a letter or digit's specific combination of simple features (specific feature detector), there is a refractory period when this detector is unable to receive input. As a result, its representation could be said to be inhibited relative to specific feature representations that have not recently been activated. This refractory period may be necessary for a particular feature detector to encode all relevant information before it passes its output on to the next level of representation, which in this case is an abstract identity detector. The refractory period we discuss is similar to that proposed by Luo and Caramazza (1996) to account for repetition blindness. These researchers suggested that abstract stimulus identities were inhibited, whereas we postulate that in our experiments inhibition occurred at the featural level. The reason for this conclusion is that we failed to find any evidence of an effect of distractor repetition when Target 1 was flanked by items that had the same identity but differed featurally (Experiment 2).

6.2.2. Inhibition of category

Although inhibition at the level of specific feature detectors could explain the results obtained in Experiments 1 and 2, this explanation alone would have difficulty accounting for the results of the last 3 experiments. While repeated distractors either side of Target 1 reduced the attentional blink, the effect was strongly dependent on the nature of the cue(s) used to define the targets. Specifically, the repetition of distractors only affected blink magnitude when the targets and distractors were members of different alphanumeric categories (digits vs. letters).

To accommodate these findings, we postulate the existence of a second mechanism that inhibits likely distractor representations based on category. This mechanism is similar to one proposed by Maki and Padmanabhan (1994) who suggested, after demonstrating that practice markedly reduces the blink, that subjects became more efficient at suppressing the distractor set. We hypothesise that the system achieves this inhibition of distractors by raising the baseline activation of the abstract identity types of the target category. As a result, targets are more likely to be detected than those stimuli whose abstract identity types are not in an active state. Thus, the distractors, relatively speaking, are inhibited. We propose that this second type of distractor inhibition occurs at the abstract identity level, rather than at a featural level, because of the large body of research, already discussed, which suggests that virtually all non-reported stimuli in RSVP streams are briefly identified.

It could be argued that a mechanism which suppresses distractors based on set alone is responsible for the distractor repetition effect, with individual distractors that are members of a different stimulus category to the targets being inhibited after they are presented. Such a mechanism may be similar to that involved in the negative priming phenomenon, where subjects are slower to respond to a target if it has previously been presented as a distractor (Tipper, 1985). This account is attractive, as it can easily explain the results of Experiments 1 and 4. However, we favour the dual-process hypothesis, as we also found some evidence in Experiment 3 that distractor repetition affects Target 1 selection/consolidation when the targets and distractors are members of the same alphanumeric stimulus category. In addition it has been demonstrated that negative priming takes place at the level of abstract identities (see Tipper, 1985), whereas our distractor repetition effect is strongly dependent on the repeat stimuli being featurally identical. Thus, the two phenomena, while perhaps related, appear to have different loci.

6.3. How the distractor inhibition hypothesis explains our results

Our *distractor inhibition hypothesis* accounts for the results of the present study in the following way: In Experiments 1 and 4, the distractors differed in category from the targets and, in repeat trials, the items either side of Target 1 were featurally identical. Under these conditions, the T1 + 1 stimulus on repeat trials would have suffered both from inhibition of its specific feature detectors and suppression at the abstract identity level. As a result, the interference to Target 1 from the T1 + 1 stimulus was considerably reduced on repeat trials relative to the non-repeat trials and the blink, therefore, was attenuated. In contrast, while the T1 + 1 stimulus in Experiment 2 would have also suffered inhibition at the abstract identity level, here there would have been only limited featural inhibition, as T1 − 1 and T1 + 1 where visually different in both the repeat and non-repeat trials. Consequently, the distractor inhibition hypothesis predicts no effect of distractor repetition on the attentional blink or Target 1 accuracy, as the T1 + 1 item would have experienced similar levels of inhibition in both repeat and non-repeat trials. The results confirmed this prediction. Finally, in Experiments 3 and 5, the items either side of Target 1 were featurally identical, thus the specific feature detectors of the T1 + 1 item would have been inhibited on repeat trials relative to non-repeat trials. While our account predicts that the specific featural representation of the T1 + 1 item would have been inhibited in this case, there would have been limited attentional suppression of the distractor set as they were all members of the target category. This increased activation level of the distractor identity types would have meant that interference from the T1 + 1 stimulus was not significantly reduced on repeat trials and, as a result, Target 1 would have still required considerable processing. Thus, there was no effect of repetition on the attentional blink.

Our distractor inhibition hypothesis can also account for the fact that T2|T1 accuracy was lower in the non-repeat trials of Experiments 3 and 5 than in those of Experiments 1, 2, and 4. In Experiments 3 and 5, targets could also appear as distractors and as a result their representations could not be effectively inhibited, thus leading to considerable distractor interference and, therefore, large attentional blinks. Reduced attentional blink patterns were obtained in Experiments 1, 2 and 4, where targets and distractors were members of different categories because under these conditions distractors could be inhibited more effectively, thus reducing distractor interference. Varying levels of distractor inhibition may also contribute to effects of target-distractor discriminability on the attentional blink. Chun and Potter (1995) demonstrated that the blink was reduced when letter targets appeared amongst computer symbol rather than digit distractors. It may be the case that distractor inhibition is positively related to target-distractor discriminability and as a result the blink was attenuated when letters were presented within a stream of symbols as these distractor stimuli were more easily inhibited.

An issue that remains to be considered is the role played by the colour cue in Experiments 3 and 4, as there was some evidence that it, too, could be used to inhibit distractors. In Experiment 3, when both targets were defined only by colour, subjects were more accurate at Target 1 report for repeat trials than non-repeat trials when Target 2 appeared at Lags 2, 5, and 6. Similarly, the reduction in blink magnitude due to distractor repetition in Experiment 4, when targets were cued by both category and colour, was extended over two Lags rather than just one as observed in Experiment 1, where the targets were only defined by category. These two results suggest that the colour differences between targets and distractors allowed the T1 + 1 stimulus to be inhibited to some extent, perhaps by making the targets more distinctive. To account for these results, we propose that the extent to which stimuli can be inhibited is reduced when targets are only cued by colour. The reason that colour is not as effective as category at differentiating distractors from targets is that colour is not an intrinsic part of a stimulus's specific representation or its abstract identity. Consequently, a colour must be bound to a specific shape before an item can be reported as a target (Chun, 1997b). As a result a set of specific representations cannot be effectively inhibited based on colour, and there is still considerable interference from T1 + 1 stimulus on Target 1 processing.

6.4. Implications for theories of the attentional blink

The focus of this study has been to establish what happens to stimuli in dual-target RSVP streams that appear in close temporal proximity to the targets but are not selected for extended processing. While many studies have tried to trace the path of targets from initial perception to report, few have examined the extent to which distractors are processed and none to our knowledge has examined the fate of non-reported distractors. Our results, as previously discussed, suggest that the T1 − 1 and T1 + 1 distractors are inhibited, in order to reduce the likelihood that they will interfere with subsequent target selection. We propose that inhibition can occur both at the specific feature detector level and the abstract identity level, however, the extent of the inhibition is strongly dependent on stimulus characteristics. We believe that the suggestion that distractors are briefly inhibited after preliminary analysis has ecological validity. It seems likely that our visual system would deprioritise stimuli marked as irrelevant. In addition, the postulation that distractor inhibition occurs both at a featural and categorical level is supported by previous data which has shown that the attentional blink involves both low-level (Giesbrecht, Bischof, & Kingston, 2003; Giesbrecht, Bischof, & Kingston, 2004; Maki, Bussard, Lopez, & Digby, 2003) and high-level (Maki et al., 1997; Olson et al., 2001; Shapiro, Arnell, & Raymond, 1997; Vogel et al., 1998) mechanisms.

The priming data from both Maki et al. (1997) and Shapiro, Driver, Ward, and Sorensen (1997) may appear to pose a problem for the hypothesis that distractors are inhibited in RSVP streams if they are presented temporally adjacent to the first target. These studies have shown that non-reported items can facilitate report of later targets if the prime and target are related. These data are not inconsistent with our present conclusion, however, as in those studies the missed stimuli were drawn from the same category as the targets and there was no featural overlap between the prime and target stimuli. Under these conditions, no inhibition of the repeated stimulus would be expected and there would most likely be facilitation at the level of abstract identity representations. Recently, Dux and Harris (2004) have provided data that support this hypothesis. We presented dual-target RSVP streams of pictures of objects (taken from Snodgrass & Vanderwart, 1980) and demonstrated that a distractor that appeared in the T1 − 1 position primed Target 2 report when the two items had the same identity. Interestingly this priming effect was only present when the prime and target were in different orientations—i.e. if there was no visual overlap of features. The priming effect disappeared if the prime and target were in identical orientations (i.e. complete visual overlap of features).

A further implication for theories of RSVP search is that we found significant attentional blinks when the distractor repetition effect was both present and absent. These results suggest that distractor inhibition is not a critical mechanism for target selection in RSVP and that it is only employed under specific conditions. As previously discussed, research on the attentional blink has involved paradigms where targets have been defined by a range of characteristics (e.g. alphanumeric category, colour, font, specific identity). Therefore, while such tasks have been previously assumed to be tapping the same cognitive processes, our study suggests that target selection in RSVP may not always involve the same mechanisms.

6.5. Implications for theories of repetition blindness

The distractor repetition effect appears to be similar to another RSVP phenomenon, that of repetition blindness. However, there are some differences between the two phenomena. Firstly, in tests of repetition blindness subjects typically have to report at least one or two stimuli, whereas in our experiments subjects never had to respond to the repeated items. This difference appears to be an important one, as the dominant theoretical account of repetition blindness, the token individuation hypothesis (e.g. Bavelier, 1994; Chun, 1997b; Kanwisher, 1987), suggests that the effect represents a failure to individuate two stimuli when they have to be encoded for report. As our repeated items never had to be overtly recognised or recalled, it is unlikely that these stimuli ever underwent token individuation. Thus, inhibition rather than a failure to encode appears to provide the most parsimonious account of the data. A second difference is that, while repetition blindness has been found to occur between repeated stimuli that differ in case, the distractor repetition effect is strongly dependent on featural overlap between the repeated stimuli. Thus, it appears that repetition blindness has its locus at the level of abstract identities whereas the distractor repetition effect involves inhibition at the level of specific feature detectors.

6.6. Conclusion

We have shown that the presentation of repeated stimuli either side of Target 1 strongly attenuates the attentional blink if (1) the $T1-1$ and $T1+1$ stimuli are featurally identical and (2) the distractors are members of a different alphanumeric category to that of both the targets. These results suggest that distractors are inhibited in dual-target RSVP streams if they appear in close temporal proximity to targets. This inhibition we suggest reflects the interaction of two visual mechanisms, one operating at the specific feature detector level and another at the level of abstract stimulus identities. The distractor inhibition hypothesis provides an account of our findings and shows how this inhibition of distractors can enhance target selection/consolidation—a vital visual task.

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