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When similarity leads to sparing: probing mechanisms underlying the attentional blink

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Abstract When two targets are embedded in a temporal stream of distractors, second-target identification is initially impaired and then gradually improves as inter-target interval lengthens (attentional blink; AB). Notably, in about half of the published studies, this deficit is partially ameliorated when the targets follow one another directly, a condition known as "lag-1 sparing". Here, we probe the impact of target-distractor similarity on lag-1 sparing, with the surprising finding that while high similarity impairs second-target accuracy at all subsequent lags, it actually improves accuracy when the targets follow one another directly. We suggest that this improvement reflects the positive influence of over-committing resources to target processing in the AB.

Introduction

Laboratory research examining allocation of attention to objects over time has often employed a task analogous to visual search. In this rapid-serial-visual-search (RSVP) paradigm, a series of target and distractor items are presented to observers in rapid succession (e.g. 10 Hz) at the same spatial location. Results from these studies have shown that observers have little trouble identifying a single target from an RSVP stream (e.g. Broadbent and Broadbent 1987; Raymond et al. 1992). However, if two targets must be identified, a very different pattern emerges. While identification of the first target (T1) remains quite accurate, second-target (T2) identification varies as a function of the temporal interval (lag) between the targets. Specifically, T2 accuracy is generally poor at shorter lags and gradually increases to the level of T1 as lag increases. This pattern of improving performance across lags is known as the attentional blink (AB).

Theoretical accounts of the AB have posited two distinct stages of target processing. In the first stage, known variously as the "target template" (Raymond et al. 1992; Shapiro and Raymond 1994; Isaak et al. 1999), "precentral processing" (Jolicoeur 1998; see also Chun and Potter 1995), or the "input filter" (Visser et al. 1999, 2004), incoming stimuli are analysed in order to identify the potential targets. Although analysis at this stage is rapid and relatively complex (e.g. Shapiro et al. 1997; Luck et al. 1996), resulting representations are prone to decay or masking. Thus, potential targets must be passed onto a second capacity-limited stage of processing, known as "visual short-term memory" (Raymond et al. 1992) or "central processing" (Jolicoeur 1998), for identification, memory consolidation, and response planning to occur. On these accounts, the AB occurs at shorter lags because T2 is presented while capacity-limited resources are occupied with T1. This prevents T2 from accessing these resources and leaves it vulnerable to decay or masking (Giesbrecht and Di Lollo 1998).

While voluminous empirical evidence leaves little doubt that T1 processing is the primary cause of the AB, other factors have also been shown to impact T2 accuracy. One such factor is whether T1 and T2 follow one another directly or are separated by distractors. Extant theories of the AB imply that the deficit should be greatest when T1 and T2 follow one another directly because T2 is

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maximally likely to be presented while attention is focused on T1. However, this pattern occurs in only about one-half of the published studies (Visser et al. 1999a). In the other half, T2 accuracy is significantly better at Lag 1, when T1 and T2 are presented consecutively, than at Lags 2 and 3 when T1 and T2 are separated by one or more distractors. This relative benefit experienced by T2 has been coined as "lag-1 sparing" (Potter et al. 1998).

In their review of the lag-1 sparing phenomenon, Visser et al. 1999a suggested that T2 accuracy at Lag 1 was determined by whether observers needed to substantially alter their attentional set from the first to the second target. When two or more non-spatial switches were necessary (e.g. switches in target task, switches in target category) or when targets were presented in different spatial locations, T2 accuracy at Lag 1 was always impaired. In contrast, when these conditions did not arise, lag-1 sparing was reliably obtained. This pattern of results can be explained by assuming that the presentation of T1 initiates an attentional gate that shunts information from the first to the second processing stages. This gate opens rapidly but closes slowly, thus allowing the item directly after T1 to gain access to attentional resources (Chun and Potter 1995; Shapiro and Raymond, 1994). For this to happen, however, T2 must also be broadly similar to T1 so that it can pass through the same input filter (Visser et al. 1999a). If T2 is dissimilar to T1 (e.g. T1 is a letter; T2 is an oriented line segment), the input filter must be reconfigured to pass the new target type and T2's opportunity to enter the attentional gate generated by T1 is lost.

Another factor that substantially influences performance is target-distractor similarity (e.g., Chun and Potter 1995; Maki et al. 2003; Visser et al. 2004b). For example, Visser et al. (2004b) presented observers with two sequential masked targets displayed around a central stream of distractors. Observers were instructed to ignore the central distractor stream and identify only the peripheral targets. However, despite explicit instructions to ignore distractors, identification of both targets was more impaired when distractors were similar to targets (e.g., digit distractors, letter targets) than when they were dissimilar (e.g., random-dot patch distractors, letter targets).

While the deleterious effects of high similarity have been well documented when T1 and T2 are separated by at least one distractor (i.e. Lags 2 and beyond), it is notable that previous studies have not included a condition in which T1 and T2 follow one another directly. This omission is potentially significant because there is some reason to believe that T2 accuracy will be impacted differently by target-distractor similarity at Lag 1 than at later lags. In particular, the over-investment hypothesis of Olivers and Nieuwenhuis (2005, 2006) suggests that under conditions of high task difficulty, the AB arises because too many attentional resources are devoted to the AB task in an effort to maximise accuracy. This results in inadvertent processing of distractors that impairs target accuracy. However, while over-committal of resources to the AB task may be detrimental at later lags, it is likely to be beneficial at Lag 1. This is because both targets are processed simultaneously and thus over-committal of resources to T1 leaves extra resources available for T2 processing. In turn, this would be expected to yield improvements in T2 accuracy. On this account, increasing target-distractor similarity, and thus the difficulty of the AB task, should impair T2 accuracy at Lags 2 and beyond and improve T2 accuracy at Lag 1.

To test this possibility, in Experiment 1 we presented observers with two blocks of RSVP trials in which targets were letters, and distractors were either digits (high similarity) or random-dot patches (low similarity). Targets were either presented directly one after another (Lag 1), or separated by two (Lag 3) or six (Lag 7) distractors. This allowed us to directly compare target accuracy at Lag 1 with that at later lags.

Experiment 1

Participants

Participants were 12 (7 female) individuals who reported normal or corrected-to-normal vision and received course credit towards an Introductory Psychology course in exchange for their time. Participation was voluntary and observers were allowed to discontinue the experiment (none did so).

Apparatus and stimuli

Stimuli were presented on a 19-inch Viewsonic monitor at a refresh rate of 100 Hz, on a Pentium-4 computer running Presentation software (Version 0.81, Neurobehavioural Systems 2002). The background and surrounding visual field were dark, and the keyboard was dimly illuminated. All stimuli subtended approximately 1° of visual angle at a viewing distance of 60 cm. Targets were shown in uppercase Arial font (28 point; 46 cd/m^2; RGB: 167, 167, 167) and consisted of all letters of the English alphabet except I, O, Q and Z, which were omitted due to their structural similarity to the digits 1, 0, 2 and 7. Random-dot distractors comprised ten different patterns consisting of 400 single-pixel dots distributed randomly within an imaginary square subtending 1° of visual angle. Digit distractors were shown in Arial font (28 point) and consisted of all single digits except 1, 0, 2, and 7, which were omitted due to their similarity to the letters I, O, Q, and Z. Target masks were symbols shown in Arial font (28 point) that were chosen randomly from the set @, #, and %. Distractors and masks were displayed at a luminance of 110 cd/m^2 (RGB coordinates: 250, 250, 250). Distractor and mask luminance were increased relative to the target in order to decrease target discriminability and ensure that accuracy remained below a ceiling level of performance.

Design and procedure

The experiment comprised 450 trials in counterbalanced order (75 trials per lag). In one condition, target-distractor similarity was high (targets: letters; distractors: digits); in the other, similarity was low (targets: letters, distractors: random-dot patches). In both the conditions, targets were masked by a keyboard symbol, which avoided confounding differences in target-distractor similarity with changes in masking effectiveness.

Each trial began with a fixation-cross in the screen's centre. Participants focused their gaze at fixation and pressed the spacebar to initiate a trial. Trials began with a series of randomly-chosen distractors at the centre of the display. Each item was displayed for 10 ms, and was followed by a 70 ms blank display. Identical distractors were never presented in succession. After five to ten distractors, T1 was presented. Depending on T1–T2 lag, T1 was followed by: T2 directly (Lag 1), a symbol mask, one distractor and T2 (Lag 3), or a symbol mask, five distractors and T2 (Lag 7). The second target was always a different letter from the first and was followed by the presentation of a single symbol mask.

When the mask disappeared, the display remained blank as a signal to the participants to report the letters presented during the trial by pressing the appropriate key on the keyboard. After two responses, the fixation cross reappeared and participants began the next trial by pressing the spacebar.

Results and discussion

Responses to T1 and T2 were recorded as correct, regardless of the order of the report. Mean T1 accuracy levels were calculated as a function of lag and target-distractor similarity and are shown in Fig. 1a.

Accuracy was analysed in a 2 (target-distractor Similarity: high vs. low) × 3 (Lags: 1, 3, 7) repeated-measures analysis of variance (RM-ANOVA). There was a significant main effect of Similarity, $F(1, 11) = 11.95$, $P < 0.01$, indicating that overall T1 performance was poorer in the high similarity condition, and a significant effect of Lag, $F(2, 22) = 10.86$, $P < 0.01$, indicating that T1 performance at Lag 1 was significantly poorer than at later lags. The interaction was not significant ($P > 0.72$).

Mean T2 accuracy levels were calculated separately as a function of lag and target-distractor similarity and are shown in Fig. 1b. To ensure T1 was attended, only trials with correct T1 identification were used. Means were submitted to a 2 (target-distractor Similarity) × 3 (Lag) RM-ANOVA. There were significant main effects of Similarity, $F(1, 11) = 47.57$, $P < 0.001$, and Lag, $F(2, 22) = 36.56$, $P < 0.001$, indicating that overall T2 accuracy was lower in the high-similarity condition and accuracy increased with lag in both the conditions, consistent with the presence of an AB. Critically, the interaction between Similarity and Lag was also highly significant, $F(2, 22) = 9.33$, $P < 0.01$, indicating that the pattern of performance across lags varied with target-distractor similarity.

To examine the source of this interaction, planned paired-samples t-tests were conducted at each lag to

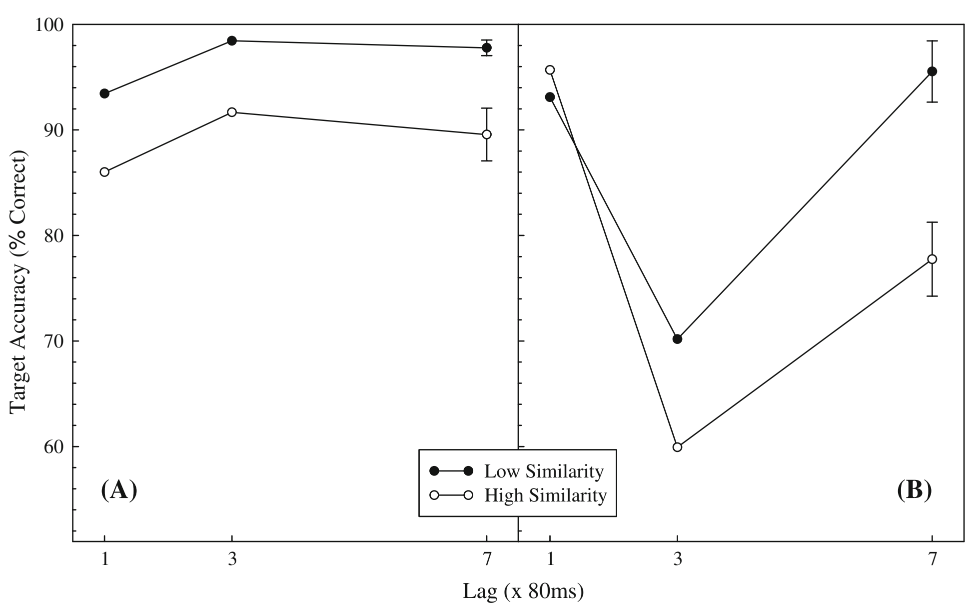

Fig. 1 **a** Mean percentage of correct identification of the first target calculated separately for the low and high target-distractor similarity trials. **b** Mean percentage of correct identification of the second target, calculated separately for the low and high target-distractor similarity conditions given that the first target had been identified correctly. *Error bars* represent one standard error of the mean averaged across each lag for a given condition

compare T2 accuracy in the high- and low-similarity conditions. As suggested in Fig. 1b, T2 accuracy was significantly poorer in the high similarity condition at Lag 3, $t(11) = 3.02$, $P < 0.02$, and Lag 7, $t(11) = 4.66$, $P < 0.01$. However, this pattern was reversed at Lag 1, where T2 accuracy was significantly *better* in the high similarity condition, $t(11) = 2.35$, $P < 0.05$. While this performance advantage was relatively small in absolute terms (about 3%), it represents a relative improvement of about 13% in comparison to Lag 3. Moreover, the size of the advantage at Lag 1 was likely underestimated because performance was close to a ceiling level of accuracy. Regardless, from a theoretical standpoint, the dissociation between performance at Lag 1 and at later lags suggests that target-distractor similarity has strikingly different effects on T2 processing across inter-target interval.

The obvious question that emerges from this experiment is the means by which increasing target-distractor similarity improves T2 accuracy at Lag 1. The present results are consistent with the notion of over-committal of attentional resources suggested by Olivers and Nieuwenhuis (2005, 2006). Specifically, additional resources allocated to the AB task under conditions of high similarity resulted in distractor processing at Lags 2 and beyond, thereby impairing T2 accuracy, but benefited T2 at Lag 1 when distractor processing was not possible because the targets directly followed one another.

On the other hand, improvements in T2 accuracy at Lag 1 might also be attributable to other factors. For example, if we assume that T1 and T2 both enter the same attentional gate at Lag 1, one possible explanation for improved T2 performance is that it is more likely to win a competition for resources with T1 (Potter et al. 2002) under conditions of high similarity. However, not only is this account somewhat ad hoc, but it would also predict that T1 accuracy would be lower at Lag 1 than at later lags as a result of the loss of resources to T2. Instead, while T1 performance was poorer overall in the high similarity condition, this deficit was not significantly greater at Lag 1 than at later lags.

A second possibility is that increasing similarity extends the time that the attentional gate remains open. This might occur because the system takes more time to process incoming stimuli in order to determine whether items should gain access to high-level processing. In turn, prolonging the time the attentional gate is open should increase the proportion of trials on which T2 was admitted, and thus benefit target accuracy at Lag 1. As well as increasing T2 accuracy at Lag 1, it seems that extending the duration of the attentional gate should also increase the chances that T2 will enter the same processing window as T1 at longer lags. While clearly this is not the case at Lag 3, where T2 performance was significantly more impaired under conditions of high similarity, it is not known whether this might occur at Lag 2 which was not included in the present experiment. To address this issue, and test whether increased lag-1 sparing arises from a prolonged attentional gate, we added this shorter lag to Experiment 2.

A third possible explanation for increased lag-1 sparing under conditions of high similarity is suggested by the work of Chun and Potter (1995) and Shih (2000) who argued that increased similarity makes it more difficult to select targets amongst distractors. On this account, rather than leading to greater resource allocation to targets, increased similarity is thought to simply delay allocation of resources to targets. In turn, to the extent that the duration of the attentional gate remains constant, a delay in the opening of that gate upon presentation of T1 should be functionally equivalent to prolonging the opening of the attentional gate. Namely, the proportion of trials in which T2 is presented prior to the closing of the attentional gate will increase, thereby increasing lag-1 sparing. To test this option, in Experiment 2, we varied target-distractor similarity, but held selection difficulty constant by presenting targets and distractors in different spatial locations.

Experiment 2

There were two conditions in Experiment 2 that differed in terms of the location of targets. One condition was identical to Experiment 1 with all items presented at fixation. In the other condition, we used an experimental paradigm similar to that of Visser et al. (1999b), in which a central RSVP stream of distractors was presented along with two targets in the same location, either above, below, left, or right of the distractors. Not only does this procedure generate robust lag-1 sparing, but it would be expected to ameliorate target selection difficulties because targets are presented in a different spatial location from that of the distractors. Thus, to the extent that increased Lag 1 sparing is due to target selection difficulties, should be reduced or eliminated with eccentric targets. Experiment 2 also incorporated two other methodological changes. First, the number of lags was increased from three to six to include Lags 2, 4, and 5. These changes allowed us to test whether the duration of the attentional gate is prolonged under conditions of high similarity and more closely examine the influence of similarity on the timecourse of the AB. Second, similarity was varied randomly from trial-to-trial rather than between blocks in order to ensure that the effects seen in Experiment 1 were not due to preparation effects (i.e. attentional set).

Participants

Twenty-two participants (19 female) reporting normal or corrected-to-normal vision from the same participant pool took part. Participation was voluntary and observers were allowed to discontinue the experiment at any time (one did so).

Apparatus and stimuli

Apparatus and stimuli were identical to Experiment 1.

Design and procedure

There were two conditions presented in counterbalanced order: central and peripheral. The central condition consisted of 240 trials, evenly divided between high (distractors: digits; targets: letters), and low (distractors: random-dot patches; targets: letters) target-distractor similarity, and six T1–T2 lags (1, 2, 3, 4, 5, 7, yielding 30 trials per similarity level and lag. Similarity level and lag varied randomly from trial to trial. All other aspects of the design and procedure were identical to Experiment 1.

The peripheral condition was identical to the central condition, except that both targets and their trailing masks were displayed in the same spatial location, either above, below, left, or right of the central stream of distractors. The centre-to-centre separation between targets and RSVP stream was approximately 1.33°.

Results and discussion

Responses to T1 and T2 were recorded as correct regardless of the order of report. Mean T1 accuracy levels were calculated as a function of lag, target-distractor similarity and Target Location and are shown in Figs. 2a (central target) and 3a (peripheral target).

Means were analysed in a 2 (Target Location: central vs. peripheral) × 2 (target-distractor Similarity: high vs. low) × 6 (Lags: 1, 2, 3, 4, 5, 7) RM-ANOVA. This yielded significant main effects of Target Location, $F(1, 20) = 10.65$, $P < 0.01$, suggesting that T1 accuracy was poorer in the peripheral condition, Similarity, $F(1, 20) = 23.93$, $P < 0.001$, suggesting that T1 accuracy was poorer when similarity was high, and Lag, $F(5, 100) = 2.95$, $P < 0.02$, suggesting that T1 accuracy was poorer at Lags 1, 3, and 4 than at Lags 2, 5, and 7. There was also an interaction between Target Location and Similarity, $F(1, 20) = 11.95$, $P < 0.01$, suggesting that high similarity led to greater impairment when T1 was located in the periphery. This likely reflects greater difficulty in shifting the attention away from similar central distractors akin to spatial capture effects shown by Folk, Leber, and Egeth (2004). No other effects were significant (all P's > 0.10).

Mean T2 accuracy levels were calculated as a function of lag, target-distractor similarity and Target Location and are shown in Figs. 2b (central target) and 3b (peripheral target). Means were analysed in a 2 (Target Location) × 2 (target-distractor Similarity) × 6 (Lag) RM-ANOVA. This yielded significant main effects of Target Location, $F(1, 20) = 19.29$, $P < 0.001$, suggesting that T2 accuracy was generally poorer in the central condition, Similarity, $F(1, 20) = 27.61$, $P < 0.001$, suggesting that T2 accuracy was generally poorer when similarity was high, and Lag, $F(5, 100) = 152.04$, $P < 0.001$, indicating a robust pattern of lag-1 sparing followed by improved accuracy as lag increased. There was also an interaction between Target Location and Lag, $F(1, 20) = 6.62$, $P < 0.001$, indicating that T2 accuracy improved more rapidly across lags in the peripheral condition than in the central condition. Most importantly, as in Experiment 1, there was a significant interaction between Similarity and Lag, $F(5, 100) = 10.50$, $P < 0.001$, indicating that the influence of similarity varied across lags. Moreover,

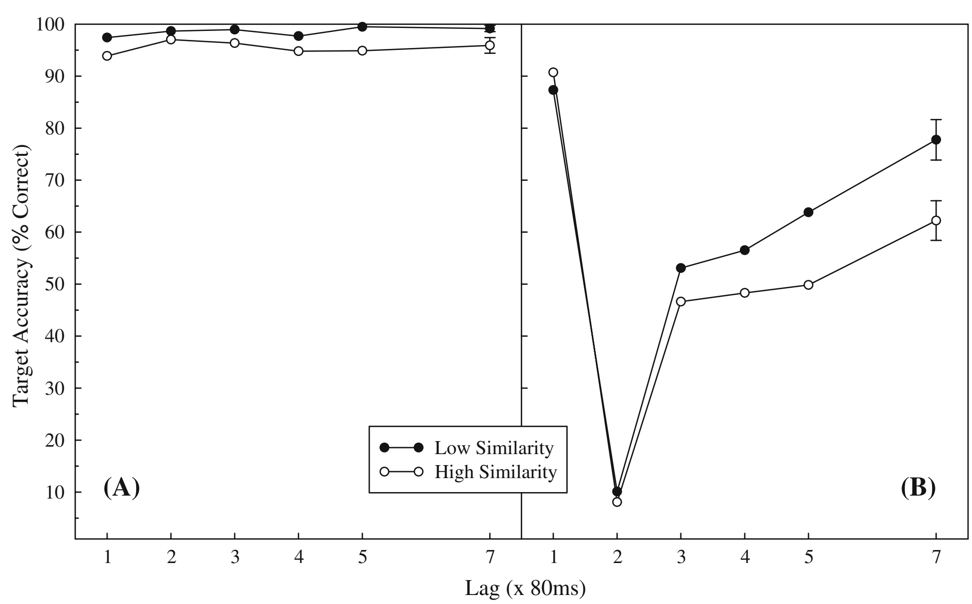

Fig. 2 Central condition. **a** Mean percentage of correct identification of the first target, calculated separately for the low and high target-distractor similarity trials. **b** Mean percentage of correct identification of the second target, calculated separately for the low and high target-distractor similarity conditions given that the first target had been identified correctly. *Error bars* represent one standard error of the mean averaged across each lag for a given condition

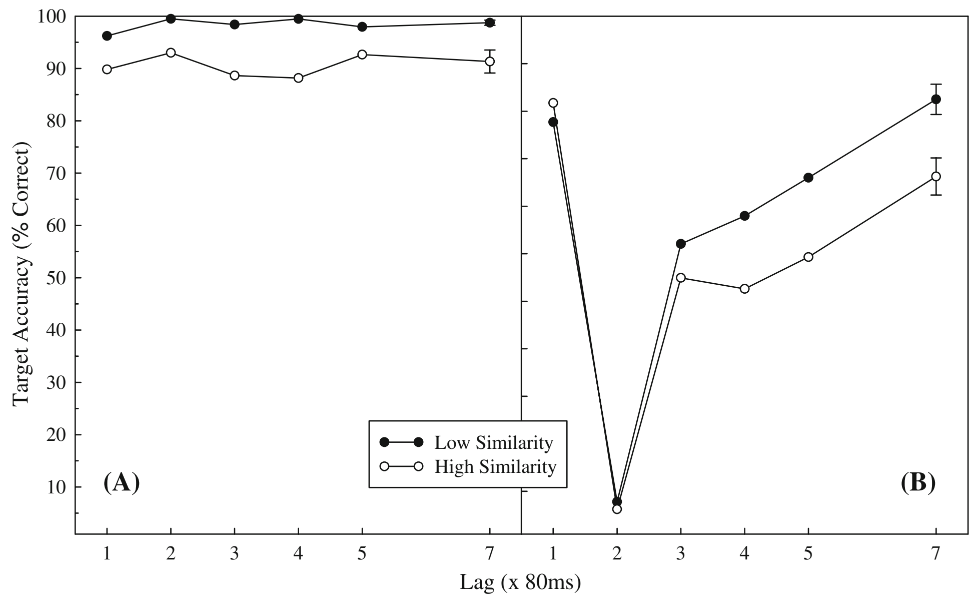

Fig. 3 Peripheral condition. **a** Mean percentage of correct identification of the first target, calculated separately for the low and high target-distractor similarity trials. **b** Mean percentage of correct identification of the second target, calculated separately for the low and high target-distractor similarity conditions given that the first target had been identified correctly. *Error bars* represent one standard error of the mean averaged across each lag for a given condition

this interaction did not vary as a function of Target Location ($P > 0.76$), indicating that the presence of increased Lag-1 sparing with high similarity was not attributable to selection difficulties arising from having all items presented at the same location. No other effects were significant (all P's > 0.37).

To confirm that T2 accuracy at Lag 1 was superior when target-distractor similarity was high, paired-samples *t*-tests comparing T2 accuracy across similarity were conducted at Lag 1 for both peripheral and central targets. These showed significantly higher T2 accuracy when distractors were similar for both central, $t(20) = 2.21$, $P < 0.04$, and peripheral, $t(20) = 2.52$, $P < 0.03$, targets.

To determine whether high similarity led to any improvement in T2 accuracy at Lag 2, we conducted identical paired-samples *t*-tests at Lag 2. In both the central and peripheral conditions, T2 accuracy was actually slightly worse when targets and distractors were highly similar, but this difference was not significant in either condition, $t(20) = 1.21$, $P > 0.23$ (Central), $t(20) = 1.15$, $P > 0.26$ (Peripheral). Clearly, the results do not suggest that T2 benefits seen at Lag 1 extend to Lag 2.

Although the fact that T2 does not significantly benefit from increased similarity at Lag 2 seems inconsistent with the notion of a prolonged attentional gate, two potential caveats should be noted. First, examination of Figs. 2 and 3 clearly shows that the difference between T2 accuracy in the high and low similarity conditions is much smaller at Lag 2 than at Lag 3. Is it possible that this reduced deficit reflects the beneficial effect of a prolonged attentional gate? While this option is possible, we suggest that the near-floor level of T2 identification at Lag 2 is a more likely explanation. That is, a much larger difference between high and low similarity conditions would have been found at Lag 2 if overall accuracy had been higher, thus allowing such a difference to emerge.

A second question concerns the relevance of the distractor interposed between T1 and T2 at Lag 2. Recently, Hommel et al. (2006) have suggested that the presentation of a distractor following T1 may close the attentional gate. If that were the case here, then the absence of a performance advantage for T2 in the high similarity condition might be due to the distractor interposed between T1 and T2 at Lag 2, and not because high similarity failed to prolong the duration of the attentional gate. Although at first glance, this interpretation seems reasonable, it is important to note that closure of the attentional gate is thought to be initiated by a mismatch between distractor and target templates or because dissimilar distractors initiate a task set that "ignores" sensory input (Hommel et al. 2006). Such a mismatch is unlikely to occur here, however, because targets and distractors are, by definition, quite similar in the high-similarity condition. Thus, it seems that our failure to find a benefit for T2 accuracy at Lag 2 in the high similarity condition cannot be attributed to the interposing distractor.

Despite significant methodological differences, the results of Experiments 1 and 2 bare striking similarities, which are apparent both upon visual inspection of the data and statistical analysis of the results. In both the experiments, high target-distractor similarity impaired T2 identification at later lags but benefited T2 accuracy at Lag 1, resulting in more lag-1 sparing. These similarities suggest that the beneficial impact of high similarity at Lag 1 is a robust and replicable phenomenon. The present experiment also provided evidence against three possible explanations for this improvement. First, the improvement does not appear to be due to selection difficulties as identical benefits to T2 accuracy were found when distractors and targets were presented at the same and different locations. Second, the improvement does not seem to be due to a prolonged attentional gate because there is no evidence that T2 accuracy improves at Lag 2 under conditions of high similarity. Third, the improvement cannot be attributed to an attentional set adopted by participants as identical results were found whether difficulty was blocked (Experiment 1) or mixed (Experiment 2).

General discussion

Our experiments demonstrated a novel empirical result: lag-1 sparing increases when target-distractor similarity is high. This benefit was obtained regardless of whether the similarity was manipulated between blocks of trials or was varied randomly on each trial. Moreover, the effect was not modulated by the ease with which targets could be selected from amongst distractors, or attentional set. Taken together, these results confirm the robustness of the phenomenon as well as offer a challenge to existing accounts of the AB phenomenon.

Past experiments examining the role of target-distractor similarity in the AB (e.g. Folk et al. 2002; Visser et al. 2004b; see also Ghorashi et al. 2003) have found profoundly detrimental effects of increasing target-distractor similarity. To explain this, Visser et al. (2004b) suggested that access to high-level processing is mediated by an input filter designed to pass items matching a target template, while denying access to items that are dissimilar from targets. While this mechanism is effective when targets and distractors are dissimilar, highly-similar distractors often pass the input filter. This, in turn, delays the access of actual targets to attentional resources, and increases the likelihood that targets will be masked or decay before they can be identified. Notably, as it stands, this framework implies that T2 identification should suffer regardless of inter-target lag because lag should not influence the likelihood that a distractor will pass through the input filter. Thus, the present finding that high similarity improves performance at Lag 1 implies that the input-filtering theory of Visser et al. (2004b) must be modified.

Conventional accounts of lag-1 sparing imply that it results from an attentional gate that opens upon presentation of T1 and closes slowly thus allowing T2 to gain access when it follows T1 closely in time. This account is consistent with the present results and numerous reports showing that improved T2 accuracy at Lag 1 is accompanied by decrements in T1 performance (e.g. Ferlazzo et al. 2007; Dell'Acqua et al. 2007, Olivers and Nieuwenhuis 2006; Akyürek and Hommel 2005; Visser et al. 2004a). Such performance tradeoffs between T1 and T2 imply that the two targets interfere with one another. The attentional gating account is also broadly consistent with the work of Potter et al. (2002) suggesting that accuracy for both T1 and T2 varies dynamically as a function of inter-target interval.

The present results imply that increasing target-distractor similarity changes the operation of this attentional gating mechanism. Earlier, we suggested that this could take four possible forms. One possibility is that increasing similarity biases the competition between T1 and T2 in favour of T2. However, this option is not supported by the data as the decrement in T1 accuracy at Lag 1 was no larger when target-distractor similarity was high as would be expected if T2 received a proportionally larger allocation of shared attentional resources. Another option is that high target-distractor similarity extends the closing time of the attentional gate opened by T1. This might be expected under conditions of high similarity because additional time is required to verify that an item is a potential target when there are many confusable distractors also present in the environment. Again, however, this option failed to be supported by the data. There was no evidence that improvements in T2 accuracy extended to Lag 2, as might be expected, if the attentional gate were open for longer. A third possibility is that high similarity increases target selection difficulties, thereby delaying the opening of the attentional gate, and effectively increasing the likelihood that T2 will arrive in time to enter the gate spawned by T1. Contrary to this option, Lag 1 sparing was not decreased when targets were made highly discriminable from distractors by presenting them at a different spatial location.

Although these three alternatives were not supported by the present experiments, our work does seem consistent with the tenets of the over-investment hypothesis advanced by Olivers and Nieuwenhuis (2005, 2006). According to this hypothesis, the attentional blink arises because too many attentional resources are devoted to the AB task in an effort to maximise accuracy. This results in inadvertent processing of distractors that impairs target accuracy. This hypothesis provides a natural explanation for the consistent detriments in T2 accuracy we obtained under conditions of high similarity beyond Lag 1. It can also explain why high similarity benefits performance at Lag 1 if we assume that because both the targets are processed simultaneously at this lag, over-committal of resources to T1 leaves extra resources available for T2 processing. In turn, this yields an improvement in T2 accuracy that does not require a concomitant decrement in T1 accuracy as would be the case if a limited pool of resources were simply allocated differentially to the two targets.

This explanation not only accounts for the present findings, but it also potentially sheds some light on a puzzling result obtained by Di Lollo et al. (2005). In their first experiment, observers were presented with letter targets embedded in a stream of confusable digit distractors. Surprisingly, when observers were required to identify three consecutive letter targets, second-letter accuracy was significantly higher than both other items, a pattern reminiscent of lag-1 sparing (for similar results see Kawahara et al. 2006a, b; Olivers et al. 2007). This significant benefit for the second letter may sensibly reflect the increased availability of resources for target processing under conditions of high target-distractor similarity. Additionally, the fact that this benefit did not extend to third target of the triplet implies that the "boost" to target processing conferred by over-commitment of resources to an initial target (i.e., T1) is limited to the immediately trailing item.

In summary, two conclusions can be drawn from the present work. First, high target-distractor similarity benefits T2 accuracy at Lag 1 leading to increased Lag-1 sparing. Second, this improvement at Lag 1 is due to the interplay of an input filtering mechanism that sometimes allows distractors access to attentional resources when they are similar to targets, attentional gating that allows sequential items simultaneous access to processing resources, and over-commitment of resources to the AB task under conditions of increased difficulty. This account suggests that the identification of sequential targets is a complex exercise involving multiple interactive mechanisms. Clearly, the nature of these interactions demand further investigation, which will no doubt yield valuable additional insights into the mechanisms underlying allocation of attention to sequential objects.

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