Investigating Two Strategies in the Attentional Blink: Target-Passing and Distractor-Rejection

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Abstract

When two targets are presented in close temporal contiguity among distractors in a *rapid serial visual presentation* (RSVP) stream, perception of the second target is impaired. This deficit is known as the *attentional blink* (AB). The major objective of the present work was to test a two-strategy hypothesis of how the target-identification task is performed: target-passing and distractor-rejection. This hypothesis was tested in Experiment 1 by comparing AB magnitude in groups that experienced the same distractors throughout, with groups that experienced a switch in distractor category halfway through the experiment. In Experiment 2, the type of instructions was manipulated in order to assess the cognitive penetrability of the processes that underlie strategy choice. It was found that choice of strategy neither affected AB magnitude nor was it cognitively penetrable. Instead, an asymmetry in switch effects on T2 performance pointed to the importance of type of distractor and direction of switch.

Keywords: Attentional Blink, strategy, cognitively penetrable, switch effects, practice effect.

Dedication

To my parents for always believing in me and never judging me.

To Hyacinth for always being happy to see me.

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I would like to thank everyone who helped get me through the last two years. For your words of encouragement and strength, I will always be grateful.

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Introduction

When two targets are presented among distractors in a *rapid serial visual presentation* (RSVP) stream, identification accuracy for the second target (T2) is impaired when it follows shortly after the first target (T1) (e.g., Chun & Potter, 1995; Raymond, Shapiro, & Arnell, 1992). This second target deficit is known as the *attentional blink* (AB) and is typically large at short lags (e.g., 100ms, 200ms, and 300ms) but becomes progressively smaller as the inter-target lag is increased.

Theories of the attentional blink include the *two-stage theory* (Chun & Potter, 1995), *resource depletion theory* (e.g., *interference theory* proposed by Raymond & Shapiro, 1994), and the *temporary loss of control* (TLC) theory (Di Lollo, Kawahara, Ghorashi, & Enns, 2005). All of these theories postulate an input mechanism, such as a filter or an endogenous template that is configured to detect stimuli with target-relevant features. Di Lollo, Smilek, Kawahara, and Ghorashi (2005) suggested that the visual system, including the input mechanism, is malleable and dynamic. In the current work, I consider whether the fluid nature of the system could allow for the input mechanism to be endogenously reconfigured over the course of blocked trials as a function of a participant's mind-set while doing the AB task.

Theories of the AB

The major theories of the AB share two common assumptions: 1) when subjects are engaged in the AB task, they search for targets; 2) there is an input mechanism that is endogenously configured to recognize target-defining features.

Chun and Potter (1995) explained the AB deficit using their two-stage theory, which is based on the idea of a bottleneck (see Jolicoeur, Dell'Acqua, & Crebolder, 2001 for a brief review of evidence for the existence of a bottleneck). Chun and Potter's model of the AB consists of two stages: Stage 1 involves rapid detection of all RSVP items and Stage 2 involves serial consolidation and processing of potential targets so that they might be consciously reported. Items entering Stage 1 form conceptual representations, which last long enough for the system to distinguish any target relevant features from distractor features. Once a probable target has been detected, Stage 1 sends the information to Stage 2. In Stage 2, a transient attentional response occurs, which is the signal for the system to begin processing the target representations for consolidation and report. The bottleneck is said to exist between Stage 1 and Stage 2. That is, as long as Stage 2 is busy with the first target, it cannot accept the second target for further processing. Any conceptual representations left to linger in Stage 1 are susceptible to being overwritten by incoming stimuli. The AB results when the second target representation is overwritten in Stage 1 while Stage 2 is still busy processing the first target.

Another theory of the AB is resource depletion, which underlies Shapiro and Raymond's (1994; see also Raymond, Shapiro, & Arnell, 1995) interference model. According to this view, the attentional blink results when T2 loses a competition with T1 for retrieval out of *visual short-term memory* (VSTM).

Items are admitted to VSTM based on their similarity to an endogenous template. When T1 arrives, it gains entry to VSTM and resources are engaged to assign it a heavy weight due to the item's match with the internal template. The item immediately following T1 also gains entry to VSTM because of its temporal proximity to T1. This +1 item slips through the sluggish attentional gate that is opened quickly once the target appears (i.e. the gate is triggered by an attentional episode), but closes slowly allowing at least one trailing item to sneak through. If the +1 trailing item is T2, then resources will also be engaged to assign it a heavy weight due to its match to the template. Since both target items have entered into VSTM and both have received heavy weights, they are likely to be retrieved from iconic memory and processed for conscious report. This phenomenon in which performance on T2 is very high as long as it follows directly after T1 is known as *lag-1 sparing* (Potter, Chun, Banks, & Muckenhoupt, 1998).

However, if the +1 trailing item that sneaks through the sluggish attentional gate is a distractor then the resources assigned to deal with it will assign it a lesser weight than T1 because it is not as good of a match to the template. When T2 finally arrives, it also gains entry into VSTM and resources are engaged to assign a weight. However, if the inter-target lag is short then there will be very few resources left in the pool to properly deal with T2. As such, T2 receives a lesser weighting value than the T1 +1 trailing item despite the target's match to the internal template. The AB results when the heavier weighted T1 and +1 items win the competition for retrieval out of VSTM, leaving the lesser weighted T2 susceptible to decay. On the other hand, if the intertarget interval is long, then it is more likely that T1 and the post-target item have been flushed out of VSTM, leaving more resources available to deal with T2 when it arrives. Thus, T2 will not be in competition with T1 and so T2 is easily retrieved for identification and report.

Finally, Di Lollo, Kawahara et al. (2005) have proposed the TLC theory to account for the attentional blink. The major component of this theory is an input filter that can be optimally configured to pass targets and exclude distractors. The filter is configured endogenously based on the observer's attentional set at the beginning of a trial. For example, if the observer is instructed to identify and report letter targets, then the filter will be tuned to allow letter-like stimuli to pass through and to disregard anything else. The input filter setting is maintained by endogenous control signals from a central processor in the brain. When T1 arrives, it will move through the filter to be processed and identified. At this point, the central processor becomes engaged with the task of processing the first target and can no longer send maintenance signals to the input filter. This state of affairs leaves the input filter susceptible to exogenous influences, namely, the stimulus following T1. If a distractor follows T1, then it will disrupt the setting of the filter so that targets no longer match the configuration. Once this disruption occurs, T2 will not pass through the filter, creating a second target performance deficit. However, if enough time passes between the arrival of T1 and the arrival of T2, then T1 can be processed and the central processor can resume sending maintenance signals to the filter. Once the maintenance signals are resumed, the filter will be reset so as to recognize target-defining features of T2 when it arrives, resulting in improved T2 performance at later lags compared to earlier lags. In addition, if the second target follows directly after the first with no intervening distractors, then the filter configuration will remain unchanged despite the lack of endogenous maintenance signals. As such, T2 passes through to be processed and identified, resulting in lag-1 sparing (Potter et al., 1998)

Two Possible Strategies for Visual Search

The three major theories mentioned above clearly focus on a mechanism that is configured to pass targets to explain the AB. However, what if the assumptions underlying these theories are incomplete? To be explicit, the input mechanism in these theories is configured by an observer's attentional set to actively recognize target-defining features and by extension, the mechanism also simultaneously and passively rejects distractors. However, target-distractor segregation could also be accomplished by a mechanism that actively rejects the distractors and instead, lets the targets passively move on to higher processing. Therefore, assuming that the visual system is dynamic and malleable, it might be possible for subjects to adopt one of two different strategies for doing the AB task: either an active *target-passing strategy* or an active *distractor-rejection strategy*.

Strategies Within Spatial Visual Search Paradigms

The hypothesis that participants have more than one strategy available to them for performing a given task has been proposed in other domains. For example, Bacon and Egeth (1994) examined this hypothesis as it pertains to spatial visual search. According to Bacon and Egeth, a participant can perform a visual search task while being in either *feature-search mode* or *singleton-detection mode*. Feature-search mode is characterized by a specific search for a relevant target feature. In other words, this strategy is based on top-down processes since the participant is engaging in a goal-directed search for the target. Alternatively, engaging in singleton-detection mode means monitoring the visual display for an item that is uniquely different from all of the other items in the display. This strategy is said to be based on bottom-up processes because the participant's attention would be automatically captured by a local mismatch that indicates the presence of a discontinuity in any given part of the display (Theeuwes, Atchley, & Kramer, 2000).

Bacon and Egeth (1994) created a method to show that subjects could be effectively 'nudged' into choosing one search mode over the other. They hypothesized that if a participant knew the identity of the relevant target feature before engaging in the task, then she could employ either feature-search mode or singleton-detection mode. However, if the visual display could be manipulated in such a way that would make using the singleton-detection mode an ineffective strategy, then a subject would be left with no option other than to adopt a feature-search mode.

To investigate their hypothesis, Bacon and Egeth (1994) created Distractor displays in which a green target circle was presented amongst green diamonds with one red diamond serving as the distracting singleton. They also created No-Distractor displays that consisted of a green target circle amongst green diamonds but no red distracting singleton. Display sizes were five, seven, or nine. Subjects were asked to determine the orientation of a line within the green target circle and reaction times were compared between the Distractor and the No-Distractor conditions. If participants were inclined to use a singleton-detection mode, then reaction times should be slower in the Distractor condition than in the No-Distractor condition on account of the interference from the salient red diamond. On the other hand, if participants were to adopt a feature-search mode, then there should be no significant difference between reaction times for the two conditions because the salient red diamond would not be relevant to a participant's goal-directed feature search (see Folk, Remington, & Johnston, 1992, for an explanation of goal-directed visual search known as the *contingent involuntary orienting hypothesis*). The results for Experiment 1 showed that an irrelevant red singleton interfered with target search resulting in slower reaction times for the Distractor condition compared with the No Distractor condition. Hence, subjects may have been in singleton-detection mode while performing the visual search even though they knew beforehand the identity of the relevant target feature (green circle).

Bacon and Egeth (1994) then reasoned that if there were indeed two modes of visual search available to the participants, then it should be possible to nudge participants into using either one method or the other. In order to be sure that participants would not use the singleton-detection mode to carry out their task, the authors introduced one, two, or three targets into the displays and randomized the trials so that subjects could not predict how many targets would be in the display on any given trial. The idea was that by introducing more than one target at a time, the target was no longer a singleton. If this was the case, then subjects would not be able to monitor for discontinuities in the display and they would have to rely on a top-down, goal-directed search for the known target feature (green circle). As such, when participants were engaged in a goal-directed search, they would not be susceptible to attentional-capture effects from the salient red singleton in the Distractor conditions (Folk et al., 1992). Indeed, the results of Experiment 2 showed no reliable differences in reaction times between the Distractor and the No-Distractor conditions regardless of whether there were 1, 2, or 3 targets in the display. It is particularly important to note that while there was a significant distraction effect found in Experiment 1 (one-target trials only), there was no such effect found in the one-target condition of Experiment 2. Thus, the authors showed that participants could be nudged into adopting one particular strategy over another based on the nature of the items in the visual display.

Visual Search Strategies Within the AB Paradigm

It is possible that just as in Bacon and Egeth's (1994) spatial search experiments, the nature of the targets and the distractors within an RSVP stream could lead subjects to change the way they approach their task during the course of an AB experiment. According to the *two-strategy hypothesis* posited above, subjects may choose to adopt one of two strategies when engaging in an AB task: a distractor-rejection strategy or a target-passing strategy. In the target-passing strategy, participants are concentrating only on looking for the two targets to be identified. In contrast, in the distractor-rejection strategy participants are concentrating on disregarding anything that is not a target. Such a change in cognitive strategy could in turn endogenously reconfigure the input mechanism to either actively pass targets or actively reject distractors, resulting in quantitatively different AB deficits.

For example, in a typical AB experiment, Falcon (2005) found that when symbols were used as distractors (letters and digits as targets), subjects showed good T2 performance at the shorter lags (80% T2 correct and above) compared to when digits were used as distractors (symbols and letters as targets; 65% T2 correct and below). It is possible that changing the nature of the stimuli affected how participants chose to go about the AB task. Perhaps subjects engaged in the target-passing strategy when faced with digit distractors but moved away from this to a distractor-rejection strategy when faced with symbol distractors.

However, while it was generally the case that a typical AB effect was present using digit distractors in Falcon's (2005) study, there was one exception. In a digit distractor condition with T1 as a letter and T2 as a symbol, an attenuated AB was apparent. Otherwise, when T1 and T2 were from the same stimulus category (two letters or two symbols) or when T1 was a symbol and T2 was a letter then a standard-sized AB effect was observed. In contrast, when symbols were used as distractors, the AB effect was attenuated regardless of target category membership.

As a possible explanation for the differences in T2 performance observed in Falcon (2005), one might consider that subjects were motivated to change the way they approached their task from one condition to the next. In the symbol distractor conditions, participants may have been more likely to engage in a distractor-rejection strategy regardless of target identity. As such, the input mechanism was configured to recognize distractor-defining features.

However, in the digit distractor conditions perhaps target identity was important for strategy choice. For example, it could be that when two targets from the same category were presented among digit distractors, participants were more likely to actively search for targets in the RSVP stream: a target-passing strategy was adopted and the input mechanism was endogenously configured to recognize target-defining features. Similarly, if T1 was a symbol and T2 a letter, perhaps it was also likely that the target-passing strategy was used. However, when T1 was a letter and T2 a symbol presented among digit distractors, subjects may have moved away from the target passing strategy and instead adopted a distractor-rejection strategy. Thus, a typical AB deficit was observed in the majority of the digit distractor conditions while an attenuated AB effect was observed in the latter condition.

But the question remains, in Falcon (2005) why would the participants have been motivated to adopt one strategy over the other because of the nature of the RSVP stream stimuli? Perhaps, when targets belonged to the same category and were presented among digit distractors, using the target-passing strategy was the easiest way to accomplish the

AB task. In a typical AB experiment and as implied by the leading AB theories, participants are usually instructed to search for the targets, which encourages a target-passing mode. If, however, there was something about the stimuli that made this strategy less effective for maximizing T2 performance, participants might change their mental-set for the task. For example, when targets were from two different categories presented among digit distractors, actively searching for two categories of targets may have been more difficult than rejecting one category of distractors. Thus, subjects may have been motivated to adopt a distractor-rejection mode for the task because this might have been the easiest and most effective way of maximizing T2 performance.

Overview of the Target-Passing and Distractor-Rejection Strategies

At this point, it is necessary to discuss the two-strategy hypothesis in more detail. As described above, perhaps there are two different strategies that can be used when participants are engaged in an AB task, with each strategy resulting in a quantitatively different AB deficit. If this is indeed the case, then an explanation is needed as to why a target-passing strategy could yield a typical AB deficit and a distractor-rejection strategy could yield an attenuated AB deficit. As such, it would be helpful to consider the factors that are implicated in the occurrence of the AB and discuss them in terms of both strategies.

It is implicitly assumed in the three major AB paradigms that, by default, participants are searching for targets when doing the AB task. When subjects are instructed to identify and report two letter targets and ignore anything else in the RSVP stream, they set themselves up to only look for letter-like stimuli. This mind-set in turn configures the input mechanism to detect stimuli with letter-defining features.

When subjects actively search for targets within the RSVP stream, in other words adopt a target-passing strategy, there is always the possibility that distractors may pass from first stage processing into second stage processing simply because they are similar to targets. As such, distractors could tie up processing mechanisms in Stage 2 preventing T2 from being processed for conscious report and leading to poor T2 performance. Visser, Bischof and Di Lollo (2004) demonstrated this effect using a spatially separated RSVP stream, which consisted of centrally presented distractors preceding and following peripherally presented T1 and T2. Their results revealed that level of performance on the AB task varied as a function of target/distractor similarity. Specifically, when target/distractor similarity was high (i.e. letter targets and pseudoletter distractors) subjects showed poor performance on both T1 and T2 compared to when target/distractor similarity was low (i.e. letter targets and random dots distractors).

Even though Visser et al. (2004) presented spatially separated targets and distractors, their results are consistent with earlier data. Nearly ten years before, Chun and Potter (1995) explored the global effects of distractor category on letter targets. Their results showed that when letter targets were presented among digit distractors (high level of target/distractor similarity), T2 performance dropped down to 40% correct at the shorter lags. Conversely, when letter targets were presented among symbol distractors (low level of target/distractor similarity), performance was only as low as 80% at the shorter lags.

These two sets of results are ambiguous in terms of theoretical interpretation. Chun and Potter (1995) explained their data using the two-stage bottleneck theory of information processing by saying that letter targets among symbol distractors were easier to process in Stage 2. What this means is that the level of discriminability between the targets and distractors was high and therefore, second stage processing of T1 would be faster due to ease of target recognition. As such, if second stage processing for T1 consumed less time overall, then the bottleneck between Stage 1 and Stage 2 would open up in plenty of time to allow T2 to pass through for further processing before it was overwritten by trailing items.

In contrast, Visser et al. (2004) explained their results in terms of *contingent capture* as an underlying mechanism of the target deficit and an input filter that is configured to recognize target-defining characteristics (much like the input filter posited in the TLC theory of the AB). Contingent capture refers to the observation that irrelevant stimuli sharing similar characteristics to a target capture attention and reduce target identification accuracy. The authors posited that an input filter for parallel Stage 1 was optimally tuned to recognize target-defining characteristics. If a possible target arrived, it would be tagged as a match to the filter setting and so receive ‘permission’ to pass through into the serial second stage for consolidation and conscious report. However, this meant that items similar to targets might also pass through the filter and be tagged as possible targets. Therefore, as the level of target/distractor similarity increased across the RSVP streams in their study, so did the chances of a distractor passing through the input filter and being processed in lieu of a target. As a result, distractor items that were erroneously passed through the input filter and tagged as a possible target could make Stage 2 unavailable for an actual target, leaving the target in Stage 1 vulnerable to being overwritten by trailing stimuli or decay over time.

However, the two-strategy hypothesis could also be applied to both Chun and Potter's (1995) and Visser et al.'s (2004) results. Perhaps instead of being caught up in a bottleneck or erroneously matched to the input filter setting, stimuli were processed using a different strategy as a function of the target/distractor relationship. One could posit that participants adopted a target-passing strategy when target/distractor similarity was high, resulting in a typical AB effect. In this case, distractors were similar enough to targets that they may have been mistaken for targets and therefore, processed and reported. But, subjects may have adopted a distractor-rejection strategy when target/distractor similarity was low, resulting in an attenuated AB deficit. The reason for this is that if a distractor is discarded as unimportant, then it probably will not be accidentally mistaken for a target.

A second contributing factor to poor performance in the AB task is backward masking (Brehaut, Enns, & Di Lollo, 1999; Chun & Potter, 1995; Giesbrecht & Di Lollo, 1998; Raymond, et al., 1992). The distractors that follow directly after T1 and T2 are thought to mask the targets. These masks overwrite the visual trace of the targets while the stimuli are still in Stage 1 processing. If the targets are overwritten in Stage 1 then they never reach Stage 2 and so are not processed for conscious report.

Research has shown that masking of both targets is a significant contributing factor in producing the AB effect. For example, Giesbrecht and Di Lollo (1998) showed that a delayed mask after T2, and not a simultaneous mask with T2, always produced an AB deficit. In a control condition in which there was no item trailing T2 there was no AB deficit. This effect of different masks on the AB was confirmed by Brehaut et al. (1999, Experiment 1). The researchers showed that regardless of whether there was an interruption mask (i.e. delayed) or an integrated mask (i.e. simultaneous) for T1, for T2 an interruption mask, not an integrated mask, was necessary to produce an AB deficit.

Evidence for the attenuation, and even elimination, of the AB effect due to T1 masking comes from at least two sources. First, Raymond et al. (1992) showed that when blank intervals of 90ms, 180ms, and 270ms were inserted immediately following T1 there was no AB. However, the AB effect was apparent when blank intervals of 90ms and 180ms were inserted after the T1 +1 distractor item. In this latter case, the blank interval had no attenuating effect on target masking because the blank was two items removed from the target. Chun and Potter (1995, Experiment 3) also found that when a 100ms blank replaced the T1+1 item, there was a reduced AB deficit compared to when the blank replaced the T1+2 item or when there was no blank at all. The fact that Raymond et al. found no AB when a blank followed immediately after T1 yet, Chun and Potter's results revealed a blink reduced in magnitude, could have been due to methodological differences between the two studies. Chun and Potter suggested that perhaps different tasks and different methods of RSVP stream presentation between the studies contributed to the incongruent results, implying that masking of T1 was not erratic in its effect on the AB. Instead, taken together the two sets of differing results suggest that masking of T1 is one of the necessary factors needed to produce a typical AB deficit.

In addition, target/distractor similarity, as previously discussed, has also been shown to affect the strength of masking. If the distracting items immediately following T1 and T2 are very similar to the targets, then one would expect these items to be more effective masks than less similar distracting items (Fehrer, 1966; Harmon & Julesz, 1973). This prediction is supported by the results of an experiment by Chun and Potter (1995, Experiment 4), where the conditions used had identical RSVP streams except for the category of items that followed the letter targets. What they found was that when the second target was followed by a symbol distractor, the AB deficit was less pronounced compared to when T2 was followed by a digit distractor.

Now, if instead of using the default target-passing strategy subjects were to adopt a distractor-rejection strategy for the AB task, target/distractor similarity and backward masking effects would be lessened and T2 performance should improve, resulting in a smaller AB deficit. This is because participants could set themselves up to reject distractors and the input mechanism would be configured to detect stimuli with distractor-defining features. Simply put, when doing the AB task using a distractor-rejection strategy, subjects are merely discarding anything that is NOT a target rather than picking out anything that IS a target.

In adopting this particular method, the strength of masking is reduced because subjects could be learning to ignore the masks (Schubo, Schlaghecken, and Meinecke, 2001). Schubo et al. showed that subjects were capable of learning to ignore the same pattern mask over the course of three separate sessions. It is possible to extrapolate and expand from Schubo et al's. results to say that to the extent that subjects are able to ignore a mask, then they could also learn to ignore an entire category of distracting items. Therefore, the items masking T1 and T2 in the RSVP stream would not have to be exactly the same, just from the same class of distractor. As such, to the extent that subjects can learn to ignore the category of the masks, the items trailing the targets can be rejected before they exert backward masking effects on the targets.

Further, by learning to actively ignore the distractors as a category, the effect of target/distractor similarity on performance is lessened in two ways. First, given that a higher level of target/distractor similarity will create a stronger backward masking effect than a lower level of target/distractor similarity, then learning to ignore the mask will improve performance to a greater degree for the latter situation than for the former situation. This is because with a higher level of similarity, the process of learning to ignore the mask would be a more difficult task and therefore, the actual ability to learn to ignore the mask would be hindered. Second, remembering that in a typical AB paradigm, target/distractor similarity contributes to poor performance because distractors can be mistaken for targets, one could say that if subjects are ignoring the distractor category and not searching for targets, then it is less likely that distractors would be processed in lieu of a target. In fact, the interfering effects of distractors preceding targets should be lessened to the same degree that backward masking effects are lessened: as a function of high or low target/distractor similarity.

In summary, if subjects were to adopt a distractor-rejection strategy, the result should be an attenuated T2 performance deficit. Since discarding items that match the input mechanism setting is the primary task, targets should not be actively rejected. Once the RSVP stream is finished, the conceptual representations of the targets can be attended to in second stage processing, making the items available for conscious report. Further, backward masking and target/distractor similarity are less likely to disrupt T2 processing and conscious report because it is possible for subjects to learn to ignore the distractors as a category. On the other hand, when participants use the default target-passing strategy, it is more likely that a larger AB deficit will occur compared to if they adopted a distractor-rejection strategy. This is because evidence has clearly shown that distractors presented either before or after the targets can affect the magnitude of the AB deficit.

In understanding the two-strategy hypothesis, the next question to ask is why would participants be motivated to adopt one strategy over the other as a function of the RSVP stream stimuli. This decision could be related to at least two factors. The first is variability within target and distractor sets (as opposed to between target and distractor sets), which can be described as *lumpability*. Lumpability can be thought of as the ease with which targets or distractors can be grouped together into one category. This will of course depend on the similarity between the items, as well as the familiarity that the individual has with those items. For example, if the items are all letters, then given how over-learned the alphabet is, it would be trivial for a participant to be able to group all of the items into a single category. However, if the items were what are referred to as pseudoletters – novel items that are made by arbitrarily combining the line and curve features found in letters and digits – then the individual does not have any pre-existing representations of those items, let alone a categorical representation that they could use to group those items together. When the targets are more lumpable than the distractors then the observer might be more likely to adopt a target-passing strategy. On the other hand, when the distractors are more lumpable than the targets then a distractor-rejection strategy might be more likely.

The second factor that may affect a participant's decision to adopt one strategy over the other is level of similarity between targets and distractors (as opposed to lumpability within target sets or within distractor sets). Research has shown that as similarity between targets and distractors increases, performance on both targets decreases (Chun & Potter, 1995; Visser et al., 2004). When similarity is high (e.g. letter targets and pseudoletter distractors), it might be easiest to search for the two targets in order to maximize T2 performance. High target/distractor similarity would make the overall AB task harder to accomplish because the targets look very similar to the distractors. In this situation, subjects might find it more efficient to search only for the two targets instead of actively trying to reject a large number of distractors because by virtue of being too similar to the distractors, targets may get rejected as well. On the other hand, when target/distractor similarity is low (e.g. letter targets and symbol distractors), then it might be easiest to reject distractors. For example, as a category, symbols may stand out more making it easier for subjects to adopt a mental set to reject symbols as a group.

Perhaps a good way to discuss why the two factors described above, lumpability and target/distractor similarity, would affect participants' choice of strategy is by using the concept of cost-benefit analysis. Depending on the nature of the RSVP stream stimuli, there would be costs and benefits associated with adopting either the default target-passing strategy or switching instead to the distractor-rejection strategy. Typically, subjects would want to maximize their performance on their assigned task. Weighing the costs against the benefits for each strategy in a given situation would be their best hope for choosing the most successful strategy given the nature of the stimuli.

So, since evidence has shown that masking and level of target/distractor similarity appear to be major factors in the occurrence of an AB effect, the cost of adopting a target-passing strategy would most likely be poor T2 performance at the shorter lags. On the other hand, the benefit is that the targets will remain available for possible processing and conscious report as opposed to using a distractor-rejection mode in which there is always the chance that targets will be rejected along with the distractors.

However, if target/distractor similarity was low and distractor lumpability was high, there could be benefits to switching to a distractor-rejection strategy; namely, much improved T2 performance. The cost of this particular action is that perhaps discarding an entire set of distractors, regardless of lumpability, is more laborious and effortful than using the default target-passing strategy. Further, as mentioned above, if rejecting RSVP stream items is the primary task, then this leaves the targets vulnerable to rejection along with the distractors. In the end, if the goal is to maximize performance and there are two choices available to subjects, then they should choose the strategy for which the benefits outweighed the costs.

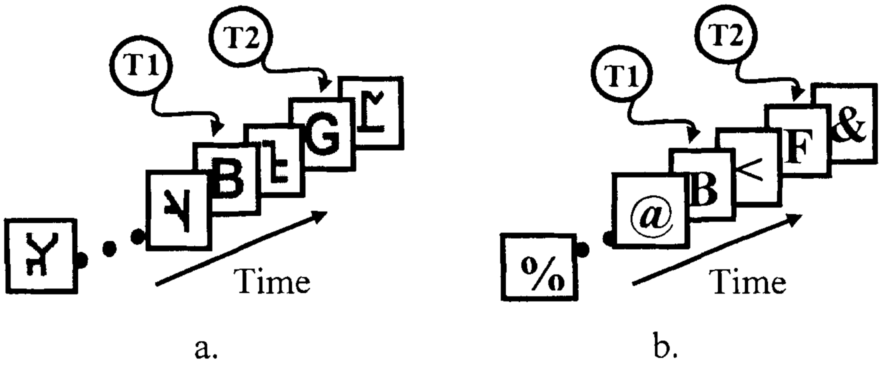
Present Study

The main objective of the present work was to explore whether or not participants may adopt one of two different strategies for doing the AB task: a target-passing strategy or a distractor-rejection strategy. In Experiment 1, this issue was investigated by pairing blocks of high and low target/distractor similarity with blocks of high and low distractor lumpability; in other words, the nature of the stimuli in the RSVP stream was manipulated. By doing this, a situation was created in which using one particular strategy for a given set of stimuli in the first block of trials may not have been optimal for the given set of stimuli in the second block of trials. As such, one could anticipate that participants would switch strategies from the first block of trials to the second block trials. In other words, the benefits of the chosen strategy outweighed the costs during the first block but this may not have been true for the second block. In Experiment 2, based on the assumption that strategy choice is *cognitively penetrable* (Whittlesea, 2002) the effect of instructions on strategy choice was examined. The term cognitively penetrable means that subjects have the ability to consciously choose how they are going to process the stimuli. Two groups of participants received the same stimuli but with instructions either emphasizing a target-passing or a distractor-rejection strategy. If participants were able to consciously adopt one strategy over the other then the results should show significant differences in magnitude of the AB deficit between the two conditions.

Experiment 1

The purpose of Experiment 1 was to provide a straightforward, although covert, test of the two-strategy hypothesis. If subjects do indeed have two possible strategies available to them for doing the AB task, then based on the principles of target/distractor similarity and target or distractor lumpability explained previously, subjects should adopt the strategy with which to maximize T2 performance.

To create conditions with varying levels of stimuli similarity and lumpability, letter targets were presented among symbol or pseudoletter distractors. Symbols are a well known category of characters, which makes them highly lumpable. In contrast, pseudoletters are novel characters that subjects most likely had not seen before and so would not have associated with any known group of items. Not only are pseudoletters strange, but they also contain the features of both letters and digits, which would make it difficult to lump them into one category. Finally, using two letter targets meant that lumpability within target sets was always the same across conditions, while the level of target/distractor similarity changed as a function of distractor type: high with pseudoletters and low with symbols.



a) letter targets and pseudoletter distractors b) letter targets and symbol distractors

Figure 1: RSVP stream stimuli used in Experiment 1

Figure 1 shows two different RSVP streams. Figure 1a represents stimuli in which two letter targets were presented among pseudoletter distractors. In this condition, there should be high target/distractor similarity, high target lumpability, and low distractor lumpability. High target/distractor similarity would be a result of letter targets sharing similar features with pseudoletters. High target lumpability would be a result of having two targets from the same category. Finally, low distractor lumpability would be a result of being unable to allocate pseudoletters to any known category due to their amalgamation of alphanumeric features and also because they are novel characters. It was expected that subjects presented with this RSVP stream would adopt the default target-passing strategy because there was no incentive for them to choose a distractor-rejection mode. The results should therefore show the typical AB curve with low T2 performance at earlier lags and recovering thereafter.

Figure 1b represents stimuli in which two letter targets were presented among symbol distractors. In this condition, there should be low target/distractor similarity, high target lumpability, and high distractor lumpability. Low target/distractor similarity would be a result of letter targets and symbol distractors belonging to distinct categories and because they look very dissimilar to each other. High target lumpability is, again, because both targets are from the same category. Finally, high distractor lumpability is a result of changing the distractor set from pseudoletters to symbols, which are known to belong to a specific semantic category of characters.

When the RSVP stream represented in Figure 1b was presented, it was expected that a distractor-rejection strategy would be adopted because there was incentive to do so. In this case, low target/distractor similarity and high distractor lumpability might be enough to motivate subjects to move away from the default, target-passing strategy. The benefits of a distractor rejection strategy would be improved T2 performance at the earlier lags compared to using a target-passing mode. If the goal of the task is to identify and report the targets, then the benefit of good performance could very well outweigh the costs of the distractor-rejection strategy; namely, rejecting targets along with the distractors. Further, the expectation that the results should show an attenuated AB curve would be consistent with Falcon (2005), in which improved T2 performance at earlier lags was observed in conditions with symbol distractors compared to conditions with digit distractors.

In order to test the idea that subjects have two strategies available to them when doing an AB task, the RSVP streams represented in Figure 1a and 1b were paired into four blocked conditions. Of particular interest was T2 performance as a function of lag across the first third (first 40 trials) and last third (last 40 trials) of Block 2. Presumably, each group of subjects would adopt the optimal strategy for maximizing T2 performance during Block 1. For those who received pseudoletter distractors, they should have adopted a target-passing strategy and for those who received symbol distractors, they should have adopted a distractor-rejection strategy. Once the Block 2 trials began, there were three possible outcomes.

First, observers could persist with their chosen optimal strategy into Block 2 but then switch strategies shortly after a change in distractor category (i.e. during first few trials). In this case, performance for the first and last third of Block 2 should be the same for all those who received pseudoletters and again for all those who received symbols. In other words, switching or not switching would not matter because subjects should always adopt the optimal strategy for a given distractor set.

Second, participants might initially persist with their chosen optimal strategy from Block 1 into Block 2. In the case of the two no-switch conditions, participants would continue with the same distractor type, and thus, the same optimal strategy. Therefore, it was expected that T2 performance would remain consistent across the first third and last third of trials in Block 2 within each no-switch condition. For the two switch conditions, subjects would initially persist with their optimal strategy and would likely find this strategy to be ineffective for the new distractor set. As such, the results should show a corresponding impairment in T2 performance during the first third of Block 2. However, if subjects were to switch to an optimal strategy for the given distractor set, then the results should show improved T2 performance during the last third of the block. Therefore, it was expected that between the switch and no-switch conditions that shared the same distractors in Block 2, there would be a difference in T2 performance for the first third of Block 2 but no difference during the last third of Block 2.

Third, participants could persist with their chosen optimal strategy from Block 1 throughout Block 2, regardless of condition. Thus, performance in the first and last third of Block 2 within each of the four conditions should be the same.

Methods

Participants. University undergraduates with normal or corrected to normal vision participated for course credit. They were naïve to the purpose of the experiment and each observer took part in one condition.

Stimuli. Using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002) the stimuli were presented in an RSVP stream at a rate of 10 items/second. The RSVP stream was between 10 and 24 characters long on any given trial with two targets and the rest of the characters as distractors. The two targets came from a set of 22 upper-case English letters (excluding I, O, Q and Z) and the distractors came from a set of 26 pseudoletters or a set of eight keyboard symbols. Pseudoletters are characters created from line and curve combinations of both letters and digits so as to resemble the physical features of letters and digits. Yet, pseudoletters are novel items with which subjects were likely to be unfamiliar. All stimuli were presented in black on a white background. The items subtended approximately 1° of visual angle

Procedure. When participants entered the lab, they read a consent form and put their signature on the sign-in sheet. Participants were then seated in front of a computer monitor at a distance of approximately 60cm in a room with very low lighting. Once seated in front of the display, participants read through instructions on the screen and then received a verbal review by the experimenter. At this point, participants were invited to ask questions if they needed any further clarification.

There were four conditions consisting of two blocks of experimental trials each (see Figure 2 below). Targets were always letters while distractors changed with condition. In the Pseudo/Pseudo condition, both blocks of trials had pseudoletter distractors while in the Symbol/Symbol condition, both blocks trials had symbol distractors. In the Pseudo/Symbol condition, the first block of trials had pseudoletter distractors and the second block of trials had symbol distractors. Finally, in the Symbol/Pseudo condition, the first block of trials had symbol distractors and the second block of trials had pseudoletter distractors.

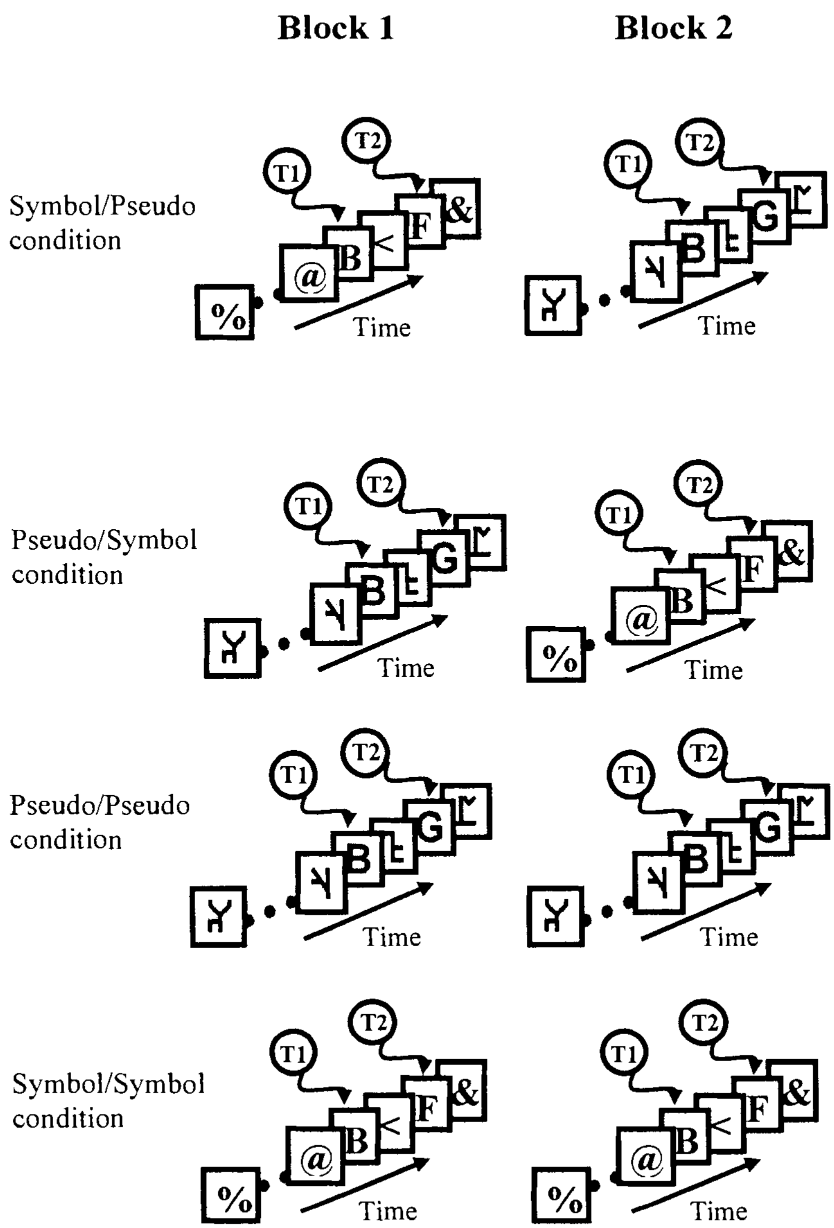


Figure 2: Four conditions for Experiment 1

The experiment began with 12 practice trials followed by 240 experimental trials; 120 trials for each block. Each trial started with a fixation cross in the centre of the screen and observers initiated a trial by pressing the spacebar. Each item in the RSVP stream was visible for 100ms, after which the next item immediately replaced it, yielding a presentation rate of 10 items per second. On any given trial, T1 was preceded by 7 to 14 distractors randomly selected with replacement from a set of pseudoletters or a set of keyboard symbols with the constraint that no single distractor was presented twice in a row. For any given trial, targets were randomly selected with replacement with the constraint that the targets were never the same character within any given trial. T2 was presented at one of four lags following T1: 100ms, 200ms, 300ms, or 800ms. Distractors filled out the inter-target interval and one distractor always ended the RSVP stream immediately after T2. Once the trial ended, participants were asked to identify and report the two letter targets. Instructions on the screen prompted participants to enter the first and second items that they saw. Order of target report was not important.

Results and Discussion

Data are presented for Block 2 T2 proportion correct given that T1 was also correctly identified (T2|T1) with an overall sample size of $N = 80$ and 20 participants in each condition. Overall mean T1 proportion correct for symbol distractors was .88 and for pseudoletter distractors, .68. A repeated measures analysis of variance (ANOVA) was performed on the proportion correct T2 scores for the first third (40 trials) and last third (40 trials) of the second block in all four conditions. Position (First 40 or Last 40) and Lag (1, 2, 3, 8) were within-subjects factors and Block 2 Distractor (symbols or pseudoletters) and Switch (yes, subjects switched distractors in second block or no, they did not switch distractors in second block) were between-subjects factors.

The ANOVA yielded a main effect of Lag, $F(3, 228) = 115.577$, $p < .001$, $MSE = 3.949$; a main effect of Position, $F(1,76) = 13.024$, $p = .001$, $MSE = .299$; and a main effect of Block 2 Distractor, $F(1,76) = 77.584$, $p < .001$, $MSE = 6.482$. The data also showed a Lag x Block 2 Distractor interaction, $F(3,228) = 6.037$, $p = .001$, $MSE = .206$; a

Position x Lag interaction, F(3,228) = 6.013, p = .001, MSE = .157; and a Block 2 Distractor x Switch interaction, F(1,76) = 3.959, p = .05, MSE = .331.

The main effects of Lag and Position should be interpreted in light of the Lag x Position interaction. Figure 3 below shows an attenuated AB deficit for the last 40 trials in comparison to the deficit for the first 40 trials at Lags 2 and 3, but not at Lags 1 and 8: Lag 2, t(158) = -2.852, p = .005, Lag 3, t(158) = -1.74, p = .08. The fact that subjects improved their T2 performance at Lags 2 and 3 over the course of Block 2 suggests a practice effect that occurred regardless of switch in distractor set or type of distractor presented. This practice effect would not necessarily extend to Lag 1 and the phenomenon of Lag 1 sparing, since the literature is not clear on the mechanisms behind this occurrence. Nor, would the practice effect extend to Lag 8, since targets presented at this particular interval are outside of the AB time window and it is expected that T2 performance would recover by the later intertarget lags.

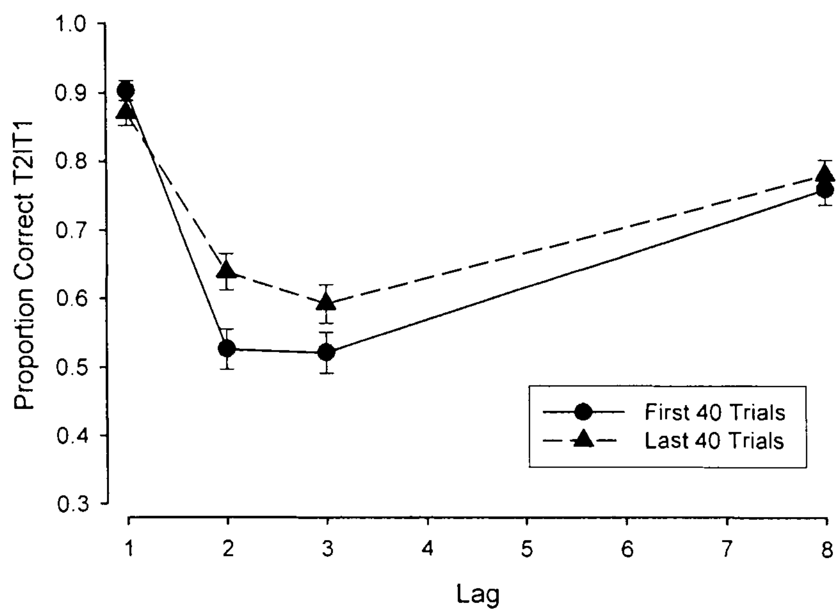


Figure 3: Lag x Position Interaction

The main effect of Block 2 Distractors should be interpreted in light of the significant Lag x Block 2 Distractor interaction, shown below in Figure 4a. The data in Figure 4a reveal that when distractors were symbols, the AB curve is shallower than when the distractors were pseudoletters. The attenuated AB effect for symbol distractors is consistent with the two-strategy hypothesis presented in the introduction. Specifically, when engaged in the distractor-rejection strategy, subjects may have learned to ignore the category of distractor items. To the extent that subjects were able to ignore the distractor category and, therefore, the T2 mask, the end result would be an attenuated AB effect for the distractor-rejection strategy in comparison to a target-passing strategy.

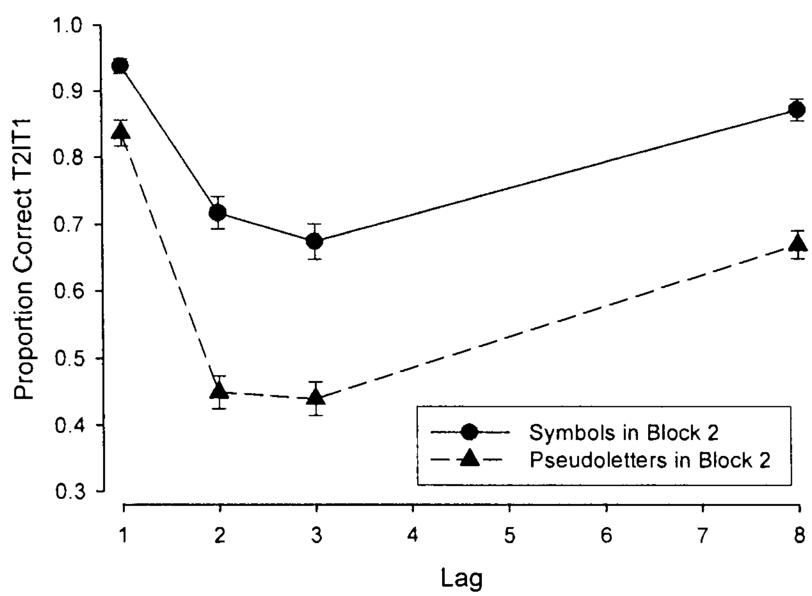


Figure 4a: Lag x Block 2 Distractor Interaction

Although this account of the Lag x Block 2 Distractor interaction effect is consistent with the theorizing and predictions set out in the introduction, there is another possible interpretation. It could be that the Lag x Block 2 Distractor interaction shown in Figure 4a is the result of a ceiling effect at Lag 1. It is possible that the Lag 1 score for the symbol condition was artificially constrained by the 1.0 limit imposed by the response scale. If the response scale could have been expanded so as to permit scores beyond 1.0, then perhaps the results might have shown higher performance at Lag 1 than is evident in Figure 4a. Specifically, performance at Lag 1 in the symbol condition might have been substantially higher, resulting in parallel curves. Thus, the interaction would be absent leaving only a main effect of Block 2 Distractor.

In order to determine whether the interaction effect is due to an artificially constrained ceiling at Lag 1, an analysis using Lags 2, 3, and 8 was conducted. If the Lag x Block 2 Distractor interaction is still evident in the new analysis, then the two-strategy hypothesis account remains plausible. This is because T2 performance across the lags was being affected by strategy choice despite the appearance of a ceiling effect at Lag 1. However, if the interaction is absent and there is only a main effect of Block 2 Distractor, then the results would no longer be consistent with the two-strategy hypothesis put forth in the introduction.

A repeated measures ANOVA was carried out with Lag (2, 3, and 8) and Position as within-subjects factors and Block 2 Distractor and Switch as between-subjects factors. The analysis revealed a main effect of Block 2 Distractor, $F(1,76) = 71.872$, $p < .001$, $MSE = .092$, but no Lag x Block 2 Distractor interaction, $F(2,152) = 1.148$, $p = .320$, $MSE = .038$.

The absence of an interaction in these new results suggests that the significant Lag x Block 2 Distractor interaction shown in Figure 4a may have been due to a ceiling effect at Lag 1. Even though T2 performance for the symbol conditions was higher at Lags 2 and 3 than T2 performance in the pseudoletter conditions, there was no difference in the magnitude of the AB deficit when Lag 1 was dropped from the analysis. This means that if the two strategies exist, then regardless of whether subjects were using a target-passing strategy or a distractor-rejection strategy, the magnitude of the AB deficit remained the same across the symbol and pseudoletter conditions.

In light of these new results, the argument for attributing the pattern of data in Figure 4a to the two-strategy hypothesis set out in introduction is weakened. The two-strategy hypothesis clearly predicts that adopting a distractor-rejection strategy with symbols over a target-passing strategy with pseudoletters will lead to an attenuated AB deficit in the symbol conditions compared with the pseudoletter conditions. Yet, the Lag x Block 2 Distractor interaction showing this reduced AB deficit was noticeably absent in the subsidiary analysis. As such, one must be open to the possibility that a ceiling effect at Lag 1 produced the interaction in the original ANOVA results and not that subjects had adopted either a distractor-rejection or a target-passing strategy.

However, while the explanation of the two-strategy hypothesis laid out in the introduction cannot account for the lack of a Lag x Block 2 Distractor interaction, perhaps a revised version of the two-strategy hypothesis can. Imagine for a moment that there are two optimal strategies for the AB task that produce a deficit equal in magnitude, but these strategies are not necessarily distractor-rejection and target-passing. The lack of an interaction in the subsidiary analysis of the data in Figure 4a suggests that subjects were doing something other than rejecting distractors when engaged in the AB task. A revised explanation of the two-strategy hypothesis could be that there is a strategy "S" used for symbols and a strategy "P" used for pseudoletters. Both strategies led to the same AB deficit shown in Figure 4a. But, due to different distractor categories, there may have been something about the relationship between targets and distractors (e.g. target/distractor similarity) that led subjects to go about the task differently.

The main effect of Block 2 Distractor revealed in the subsidiary analysis of the data shown in Figure 4a confirms a significant difference in overall performance across the two distractor types. Specifically, T2 performance in the symbol conditions was better than T2 performance in the pseudoletter conditions. The suggestion was made above that there was something about the relationship between targets and distractors that contributed to this main effect. It could be that letter targets and symbol distractors were easily discriminated, making letters easy to identify. Alternatively, letter targets and pseudoletter distractors were very similar in appearance, which may have made the identification task more difficult compared to the symbol conditions. It is possible that these differences in discriminability contributed to subjects using strategy "S" and strategy "P". In other words, there was a default strategy used for each distractor category. When presented with a given distractor type, subjects naturally and without conscious effort adopted the given default strategy.

To further expand on this argument, research in the domain of human learning suggests that people tend to go about the same task differently as a function of level of task difficulty. Specifically, Blessing and Anderson (1996) pointed out that when asked to solve an algebraic problem, those who excel at math tend to skip steps and write down the solution immediately because they find the task easy. Conversely, those who are novices engage in the step-by-step process for solving for *x* because they find the task hard. Therefore, one could posit that subjects might go about the AB task differently in the more difficult pseudoletter conditions, where strategy "P" might be appropriate, compared to doing the AB task in the easier symbol conditions, where strategy "S" might be best.

Finally, the idea that letters are easier to identify when presented among a stream of symbols compared to among a stream of pseudoletters is supported by previous research (e.g. Chun & Potter, 1995; Kawahara, Enns, & Di Lollo, 2006; Visser et al., 2004). In the current study, there was a main effect of Block 2 Distractor for T1 performance, $F(1,76) = 211.732$, $p < .001$, $MSE = 6.704$, with symbols ($M = .886$) showing a much higher level of proportion correct than pseudoletters ($M = .682$). The data shown below in Figure 4b is consistent with Visser, et al. (2004; Experiment 3) who found that as target/distractor similarity increased, making target identification more difficult, performance for both T1 and T2 became gradually worse across the conditions.

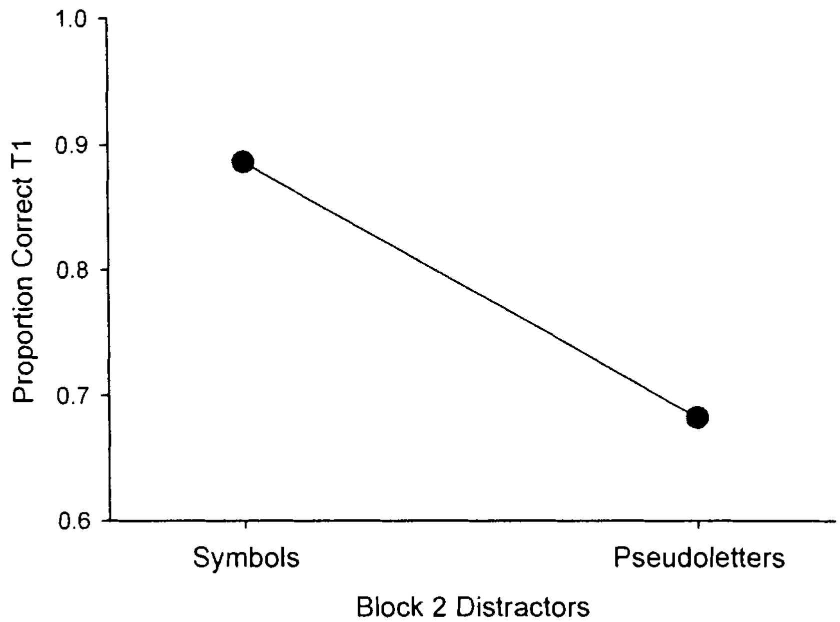


Figure 4b: Main effect Block 2 Distractor for T1

The Block 2 Distractor x Switch interaction is shown below in Figure 5. The data reveal that when the distractors in Block 2 were pseudoletters, whether or not there had been a switch in distractor type from Block 1 made no difference to T2 performance. On the other hand, when Block 2 distractors were symbols, T2 performance was worse in the switch condition compared to the no-switch condition; $t(318) = -3.584$, $p < .001$.

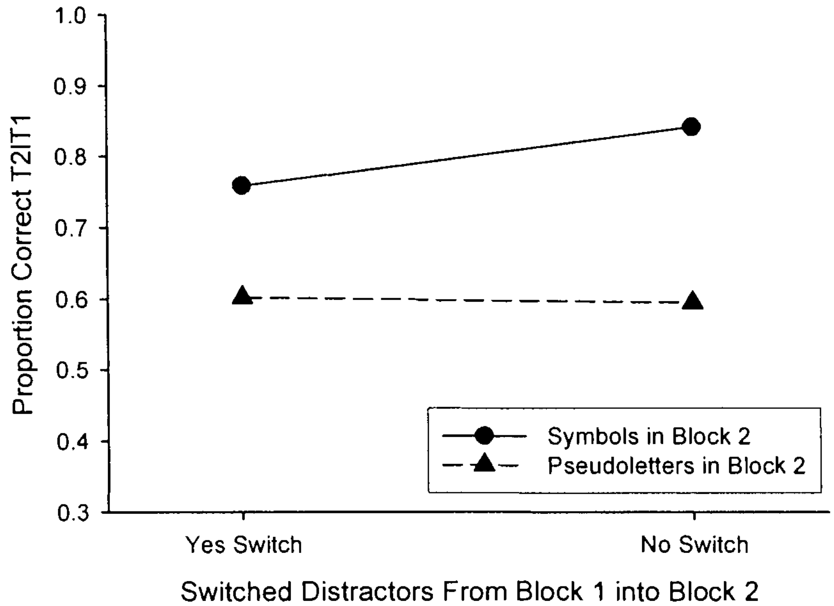


Figure 5: Block 2 Distractor x Switch interaction

These results appear to be consistent with the original two-strategy hypothesis set out in the introduction. In the Pseudo/Pseudo condition, subjects persisted with the optimal target-passing strategy from Block 1 into Block 2 because there was no switch in distractor category. But, in the Symbol/Pseudo condition, a switch in strategy would have occurred when there was a change in distractor category. The optimal distractor-rejection strategy used for symbols in Block 1 would most likely have resulted in rejecting the targets along with the distractors in Block 2 because of the high level of target/distractor similarity. Therefore, switching to the target-passing strategy would have been the best way to maximize T2 performance, if not necessary for performing the task. Since the same strategy would have been used for Block 2 in both the Pseudo/Pseudo and

Symbol/Pseudo conditions, there would have been no difference in performance between the two conditions.

On the other hand, in the Pseudo/Symbol condition, switching from pseudoletters in Block 1 to symbols in Block 2 could mean that even though the target-passing strategy was suboptimal for Block 2 symbols, the AB task could still be carried out using that method. In this case, the costs of maintaining a suboptimal target-passing strategy, namely, poor T2 performance, were less severe than the costs of switching to an optimal distractor-rejection strategy, namely, the effort of learning to ignore an entire set of distractors. Further, research shows that once subjects get used to using a particular strategy for a task, they tend to form a mental set (Luchins, 1942), getting 'stuck' with their original method and failing to recognize other more efficient methods for the task. Therefore, when compared to the Symbol/Symbol condition in which persisting with the optimal distractor-rejection strategy into Block 2 was likely, performance in the Pseudo/Symbol condition was significantly worse because of persistence with the suboptimal target-passing strategy.

However, there is a possible flaw in using the two-strategy hypothesis as set out in the introduction to explain the data in Figure 5. The interpretation is based on the assumption that subjects could have actively adopted either a distractor-rejection strategy or a target-passing strategy. The potential problem with making this assumption was revealed in the subsidiary analysis of the Lag x Block 2 Distractor interaction shown in Figure 4a, where, without Lag 1 the interaction disappeared. If the subsidiary analysis depicts the true relationship between the functions, then this means that whatever method subjects were using to carry out the AB task had no effect on the magnitude of the AB deficit across the conditions. Since it was predicted that engaging in a distractor-rejection strategy would lead to an attenuated AB curve, the absence of an interaction in the subsidiary analysis suggests that subjects may not have been adopting a distractor-rejection or target-passing strategy. It follows, then, that the Block 2 Distractor x Switch interaction shown in Figure 5 is also not necessarily a result of adopting one of the two aforementioned strategies.

Yet, there is the revised explanation of the two-strategy hypothesis to consider. It was suggested above that strategy "S" and strategy "P" could be default strategies that were adopted for symbols and pseudoletters, respectively. Using these strategies could still leave subjects vulnerable to the effect of mental set. Specifically, for the Pseudo/Symbol condition, in the same way that a mental set for the target-passing strategy may have persisted from Block 1 into Block 2, a mental set for strategy "P" may also have persisted. Further, one might consider that identifying letters among pseudoletters was a more effortful task than identifying letters among symbols. It is possible that a method that is optimal (i.e. strategy "P") for a more effortful task may still work for a less effortful task, but perhaps just not as efficiently.

In fact, Luchins (1942) demonstrated this very concept. In his study, the task was to measure out a specific amount of water using three water jugs (Jug A, Jug B, and Jug C) that already had a known and measured quantity of water in each. For example, if Jug A had 14 units of water, Jug B had 163 units of water, and Jug C had 25 units of water, how would one measure out 99 units of water? For the first six problems in that study, subjects could use the formula, Jug B – Jug A – 2JugC (B-A-2C). Subjects who established a mental set for solving the first six water-jug problems using this formula also solved the seventh and eighth problems in this manner. In actuality, the seventh and eighth problems were less complicated than the first six problems and could have been solved in a more efficient manner, using the formulas A+C and A-C, respectively.

Similarly, in the Pseudo/Symbol condition, using strategy "P" in Block 1 would have been optimal for the harder task. However, persisting with strategy "P" into Block 2 could have led to poorer T2 performance compared to the Symbol/Symbol condition in which the optimal strategy "S" persisted, simply because strategy "P" might not have been optimal for the easier symbol task.

Conversely, in the Symbol/Pseudo condition, just as persisting with distractor-rejection for Block 2 pseudoletters would have meant rejecting targets along with distractors, it could be that strategy "S" for the easy symbol block was not conducive to accomplishing the AB task in the harder pseudoletter block. In this case, mental set may have been disrupted by an inability to accomplish the AB task in Block 2, thus, leading participants to fall back into the default, and probably more efficient, strategy "P".

Referring back to Luchins (1942), his results showed that, indeed, mental set could be disrupted. Remember that problems one through six were solved with the formula B-A-2C and problems seven and eight were also typically solved using this more complicated formula even though an easier formula was more efficient. Luchins then introduced problem nine for which there was only one solution; A-C. Once the mental set for B-A-2C was disrupted at problem nine, participants were more likely to continue the experiment using the easier A-C solution even though using the more complicated solution would also have been successful. Therefore, performance for the Symbol/Pseudo condition, in which a switch to strategy "P" for Block 2 was necessary, would have been the same as performance in the Pseudo/Pseudo condition, in which strategy "P" was used for both blocks.

Finally, one must consider that the results in Figure 5 could be due to a combination of the practice effect shown in Figure 3 and type of distractor category. It has been noted above that letter targets among symbol distractors are easier to identify than letter targets among pseudoletter distractors. In fact, research has shown that letters are quite difficult to identify among pseudoletter distractors (e.g. Visser et al., 2004). The high level of difficulty in the pseudoletter conditions may have contributed to the lack of effect of practice across the Symbol/Pseudo and Pseudo/Pseudo conditions. Keeping in mind that not only are letters and pseudoletters very similar in appearance, but pseudoletters are also novel characters that subjects probably have never seen before. In this case, even two blocks of pseudoletters may not have afforded enough practice to lead to an improvement in performance for the Pseudo/Pseudo condition over the Symbol/Pseudo condition.

Alternatively, not only are symbols and letters less similar to each other then pseudoletters and letters, but symbols are also a known category of items that subjects probably see on a daily basis (e.g. computer keyboards, cell phones). Therefore, the better overall T2 performance in the symbol conditions compared to the pseudoletter conditions could be due to the fact that the AB task is easier with letter targets and symbol distractors. Further, having two blocks of symbols in the no-switch condition may have been enough practice with the easier task to lead to an improvement in performance over having only one block of symbols in the switch condition.

However, there are two problems with using distractor type and the practice effect to explain the data in Figure 5. First, the practice effect observed in the data shown in Figure 3 appears to be equal across both types of distractors. Specifically, the Lag x Position interaction means that regardless of type of distractor in Block 2, T2 performance was better during the last third of the block compared to the first third of the block. Therefore, it cannot be concluded that practice was effective across the switch and no-switch conditions with easy symbol distractors but was not effective across the switch and no-switch conditions with the more difficult pseudoletter distractors.

The second problem is that it seems logical that practice should affect harder tasks more than easier tasks and not the other way around, as was suggested above. This is because with an easy task, such as letters among symbols, performance starts off at a very high level, and so there is very little room for improvement before performance reaches the scale imposed ceiling. In contrast, performance on a more difficult task, such as letters among pseudoletters, would initially be at a lower level than the easy task and, therefore, would have more room for improvement as a result of practice. As seen in Figure 5, a small improvement in T2 performance can be observed between the Pseudo/Symbol and Symbol/Symbol conditions, suggesting that performance increased only slightly on the easy task when it had been preceded with practice on the same task. Although this finding is consistent with the practice effect prediction, there was no such difference in T2 performance between the Symbol/Pseudo and Pseudo/Pseudo conditions. If the practice effect was the only contributing factor to the results in Figure 5, then there should have been a much greater improvement in performance due to task repetition for the harder pseudoletter conditions as compared to the easier symbol conditions.

In summary, the significant Lag x Block 2 Distractor interaction shown above in Figure 4a suggests that, as hypothesized, engaging in a distractor-rejection strategy attenuated the AB deficit for the symbol conditions relative to the pseudoletter conditions. However, a subsidiary analysis cast doubt on this interpretation because the interaction disappeared when Lag 1 was dropped from the analysis. In this new analysis, only a main effect of Block 2 Distractor was observed. This left open the possibility that a ceiling effect led to the Lag x Block 2 Distractor interaction. In addition, besides the practice effect observed in Figure 3, there were no other significant interactions involving Lag in the ANOVA results. Given that by definition the AB is a lag effect, then this suggests that, contrary to the two-strategy hypothesis laid out in the introduction, the target-passing and distractor-rejection strategies may have had no effect on the magnitude of the AB deficit.

Other explanations that do not involve the two-strategy hypothesis also could not fully account for the pattern of results in Experiment 1. First, if the type of distractor were the only contributing factor to explain the pattern of data shown in Figure 4a and Figure 5, then one should have expected only main effects of Block 2 Distractor in the ANOVA results. Yet, there was a significant Block 2 Distractor x Switch interaction shown in Figure 5. This interaction suggests that while the type of distractor influenced T2 performance, this effect was modulated by whether or not a switch in distractor category occurred. Specifically, a switch in distractor category from Block 1 to Block 2 affected T2 performance for symbols but not for pseudoletters.

Second, while the Lag x Position interaction shown in Figure 3 suggests that, to some degree, a practice effect may have contributed to the results in Figure 4a and Figure

5, there was no interaction among Lag, Position and distractor type. This meant that the practice effect was most likely equal across distractor type and so cannot explain why Figure 5 shows an increase in performance between the two symbol conditions and no change in performance between the two pseudoletter conditions. Further, it seems logical that practice should affect harder tasks more so than easier tasks. That is, if performance in the easy task (i.e. letters among symbols) is near ceiling to begin with, practice will have a necessarily negligible effect: it will merely push performance up to ceiling. On the other hand, performance on a more difficult task (i.e. letters among pseudoletters) would initially be at a lower level than the easy task and so there would be more room for improvement as a result of practice. Therefore, while the results shown in Figure 5 for the Pseudo/Symbol and Symbol/Symbol conditions are in line with this prediction for the practice effect, the data for the Symbol/Pseudo and Pseudo/Pseudo conditions are not.

What can account best for the results in Experiment 1 is a revised version of the two-strategy hypothesis. In this revised hypothesis, there may still be two strategies available for doing the AB task, but they may not be distractor-rejection or target-passing. Instead, there could be a strategy "S" that is optimal for symbols and a strategy "P" that is optimal for pseudoletters. Because of distractor type and differences in level of target/distractor similarity between the symbol and pseudoletter conditions, participants might have gone about the AB task differently. It could be that the two strategies led to the same magnitude of AB deficit but, yet, a difference in overall level of T2 performance.

However, the question remains: is the Lag x Block 2 Distractor interaction shown in Figure 4a due to a ceiling effect? If this is the case, then the revised version of the two-strategy hypothesis holds merit. However, if the results are not due to a ceiling effect, then the interaction is consistent with subjects using a target-passing strategy for pseudoletters and a distractor-rejection strategy for symbols as would be predicted by the original two-strategy hypothesis outlined in the introduction. One way in which to tease apart these options is to use a single set of distractors that ensure that performance is not at ceiling and then specifically ask participants to do the task using either a target-passing or a distractor-rejection strategy.

Experiment 2

The purpose of Experiment 2 was to use a direct manipulation to test the two-strategy hypothesis laid out in the introduction. The validity of the manipulation used in the present experiment rests on the assumption that the processing that leads to the use of one of the two strategies is cognitively penetrable. That is, that subjects have the ability to consciously choose how they are going to process the stimuli, and in so doing could either adopt a target-passing or a distractor-rejection strategy. Based on this assumption, participants were explicitly instructed to use one specific strategy, either target-passing or distractor-rejection. In Experiment 1, the nature of the stimuli in the RSVP stream was manipulated, while the instructions remained the same, in order to covertly motivate subjects to adopt one particular strategy over another for a given distractor type. However, the results of Experiment 1 were ambiguous with regards to whether or not adopting a target-passing or distractor-rejection strategy affected the magnitude of the AB deficit. Therefore, for the current experiment, the RSVP stream stimuli remained constant and the instructions were manipulated.

Previous research has shown that overtly instructing participants to adopt different strategies can affect the results of the experiment. For example, Smilek, Enns, Eastwood, and Merikle (2006; Experiment 1) gave two groups of subjects the same visual search displays but with different instructions. One group received *passive* instructions and was told to "let the unique item "pop" into your mind" (p.548). The other group received *active* instructions and was told to "be as active as possible and to 'search' for the item" (p. 549). Subjects were asked to report which side of the target circle had a gap. There were two levels of task difficulty: easy and hard. In the Easy condition, the target circle had a large gap and was presented amongst distracting circles with small gaps on both sides. In the Hard condition, the target circle had a small gap and was presented amongst distracting circles with small gaps on both sides. The results showed that for the hard search task, participants who received the active instructions had slower reaction times than participants who received the passive instructions. However, for the easy search task there was no difference at all in reaction times between the two instruction groups.

More relevant for the present work because it illustrates how strategic instructions can modulate the AB is work by Olivers and Nieuwenhuis (2006). They conducted a between-subjects experiment in which two groups of participants were given a typical AB task and asked to identify two digit targets presented amid letter distractors. Both groups received two blocks of trials and the same instructions at the beginning of the experiment. They were all asked to concentrate hard on the RSVP stream and to identify the digits. For the second block of trials, however, one group received the same set of instructions to concentrate hard on the RSVP stream, while the other group received new instructions. This second group was told to concentrate less on the RSVP stream and to "pay a little less attention to the digits" (p. 373). The results showed that the group who received the same instructions for both blocks of trials did not improve their T2 performance from the first to the second block. But, the group that received a new set of instructions before commencing with the second block of trials did improve their T2 performance from the first to the second block.

The present experiment was designed to further test the hypothesis that observers could adopt either a target-passing or a distractor-rejection strategy based on the assumption that the processing leading to strategy choice is cognitively penetrable. In both conditions the trials contained identical stimuli so that the instruction manipulation would be the only independent variable. Because of the need to keep performance away from the response-scale ceiling and given that Smilek et al. (2006) have shown that the effect of instructions is a function of whether the task itself is easy or hard, digit distractors were used for this experiment for two reasons. First, based on the work of Chun and Potter (1995) and Visser et al. (2004) digits seem to be less similar to letter targets than are pseudoletters, but more similar to letter targets than are symbols. Second, digits should be more lumpable than are pseudoletters as well as being similar in lumpability to symbols (i.e. digits are a known and familiar category of characters). Therefore, the hope was to establish a difficulty level that would allow for performance to be able to move either higher or lower as a result of the instructional manipulation.

For this experiment, it was hypothesized that to the degree that strategy choice is cognitively penetrable, when two target letters were presented amid digit distractors, instructions encouraging a distractor-rejection strategy would result in an attenuated AB relative to when a target-passing strategy was encouraged.

Methods

Participants. Thirty male and female undergraduates with normal or corrected to normal vision participated for course credit. They were naïve to the purpose of the experiment and each observer took part in one condition.

Stimuli. The stimuli were the same as Experiment 1 except that digits (2-9) were used as distractors in both conditions (see Figure 6 below).

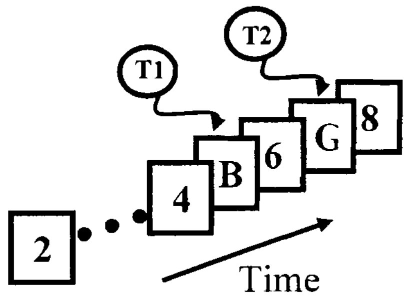


Figure 6: RSVP stream stimuli for both conditions in Experiment 2

Procedure. The procedure was the same as Experiment 1 except for the following changes. Once participants had read the given set of instructions, they were asked to explain the instructions to the experimenter in their own words. This was done to ensure that the instructions were clear to each participant. All subjects received 12 practice trials followed by one block of 120 experimental trials. Targets were always two letters and distractors were always digits. The participants were divided into two groups with the only difference in procedure being that they received different instructions before starting their task. In the Encourage-distractor-rejection group, participants were given the following set of instructions:

> Thank you for helping out today. In this experiment, you will see a cross in the centre of the screen. When your eyes are fixated on the cross, please press the spacebar. You will then see a string of items

> presented very quickly in the centre of the screen. Mixed in among those items will be two letters. Your task is to identify the two letters. It is important that you concentrate on actively stopping distracting items from entering your consciousness because they are not important for this task. Even though you will be asked to report the two letters, the best way to succeed at this task is to actively reject the distracting items, and let the two letters enter your eyes passively and without effort. At the end of each trial, you will be asked to type the two letters on the keyboard. Once you have entered a response for both items, the fixation cross will reappear to begin the next trial.

In the Encourage-target-passing group, participants were given a different set of instructions:

> Thank you for helping out today. In this experiment, you will see a cross in the centre of the screen. When your eyes are fixated on the cross, please press the spacebar. You will then see a string of items presented very quickly in the centre of the screen. Mixed in among those items will be two letters. Your task is to identify the two letters. It is important that you concentrate on searching only for the two letters. The best way to succeed at this task is to set your mind to looking for letters, and actively search for the two letters in the display. You will be asked to report both letters at the end of each trial by typing them on the keyboard. Once you have entered a response for both items, the fixation cross will reappear to begin the next trial.

Results and Discussion

Data is presented for T2 proportion correct performance given that T1 was also correctly identified (T2|T1), with an overall sample size of N = 30 and 15 participants in each condition. Overall mean T1 proportion correct performance for the Encourage-distractor-rejection condition was M = .94 and for the Encourage-target-passing condition, M = .93. A repeated measures analysis of variance (ANOVA) was performed on the proportion correct T2 scores for the entire block. Lag (1, 2, 3, 8) was the within subjects factor and Strategy (Encourage-distractor-rejection or Encourage-target-passing) was a between subjects factor.

The ANOVA yielded a significant main effect of Lag, $F(3,84) = 52.916$, $p < .001$, $MSE = .012$, which confirms the occurrence of the AB deficit. There were no other significant effects.

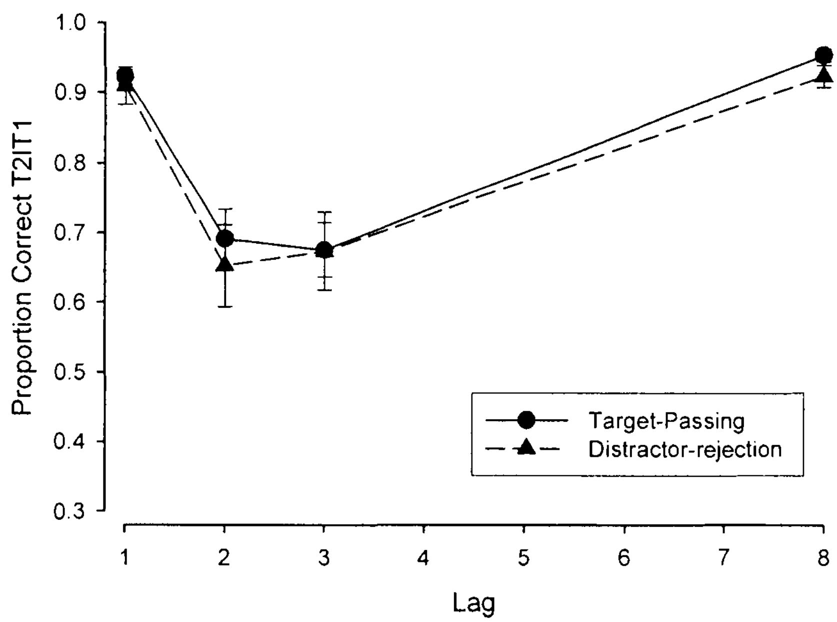


Figure 7: T2 performance for Experiment 2

As can be seen in Figure 7 above, both conditions yielded a typical AB deficit with very little difference in the shape or level of the two functions. Therefore, even though subjects were given explicit instructions on how to engage in a target-passing or a distractor-rejection strategy, not only was the AB deficit not affected, but T2 performance was also very similar across both conditions. One interpretation of these results is that strategy choice is not cognitively penetrable. This means that even though subjects were aware of the method they were supposed to be using to accomplish the task, they may not have been able to alter the way they processed the items. In other words, being told to use a distractor-rejection strategy did not necessarily lead to actively adopting the strategy, and, therefore, the AB was not attenuated. This suggests that the mechanisms that drive the strategies used for the AB task are not under participants' conscious control and are automatic instead.

The idea that strategy choice is not cognitively penetrable is in line with the revised version of the two-strategy hypothesis described in the discussion of Experiment 1. According to the revised two-strategy hypothesis, the strategy used will be determined by the RSVP stream items. So, just as with Experiment 1 where there may have been a default strategy "S" for symbols and a default strategy "P" for pseudoletters that could have led to differences in T2 performance but not AB magnitude, there may have been a default strategy adopted in Experiment 2. Given that the RSVP stream was identical in the two conditions, then it would not matter what instructions were given to participants, the strategy that was actually used would be a default one. Thus, if strategy choice is cognitively impenetrable and the same automatic strategy was employed in both conditions, then one would not expect to see a difference between the two AB curves.

Another possible interpretation of the results shown in Figure 7 is that, as stated in the introduction to Experiment 2, strategy choice is cognitively penetrable. This would mean that participants would have been able to follow the instructions and actively adopt the given strategy, but perhaps the Encourage-distractor-rejection group of subjects could not understand how to implement their strategy. If the subjects could not use the distractor-rejection strategy, then in order to do the task they may have adopted the perhaps more intuitive target-passing strategy that was explained to the other group. If this were the case, then one would not expect any difference between the two conditions because both groups ended up using the same strategy. However, based on the fact that participants were asked to explain the task in their own words prior to starting the experiment, it seems unlikely that they misunderstood the instructions.

Alternatively, and still in line with the idea that strategy choice is cognitively penetrable, it could be that the distractor-rejection strategy was not optimal for letter targets and digit distractors. Perhaps the level of target/distractor similarity was too high between letters and digits, leading to targets being rejected along with the distractors. Therefore, it would have been necessary to switch to a target-passing strategy in order to accomplish the AB task. If the realization that the distractor-rejection strategy was inadequate for digits occurred during the practice trials, then the Encourage-distractor-rejection group may have consciously switched to the same target-passing method as the other group before the experimental trials began. As such, if both groups were using the same target-passing strategy, then one could expect to see the results observed in Figure 7; very similar AB curves for both conditions.

In summary, the lack of a Lag x Strategy interaction in the ANOVA results presents a major problem for the assertion that strategy choice is cognitively penetrable. The two-strategy hypothesis as laid out in the introduction clearly states that adopting a distractor-rejection strategy would lead to an attenuated AB deficit. So, if strategy choice is under conscious control and there were specific instructions on how to go about using either strategy, then one would expect to see an attenuated AB curve in the Encourage-distractor-rejection condition compared with the Encourage-target-passing condition. However, there was no interaction, suggesting that instructions made no difference to AB magnitude because strategy choice may be cognitively impenetrable.

General Discussion

In the present work, I examined the two-strategy hypothesis as a possible explanation for differences in the magnitude of the AB deficit. I suggested that perhaps the assumption underlying the three major theories of the AB, implying that there is an input mechanism that is actively configured to recognize targets, is not entirely correct. If the visual system is malleable and dynamic, then it could be that not only can the input mechanism be configured to actively recognize targets and passively reject distractors, but perhaps it could also be configured to actively reject distractors and passively recognize targets.

The two-strategy hypothesis suggests that there may be an active target-passing strategy and an active distractor-rejection strategy that can be used to accomplish the AB task. Adopting a target-passing strategy would most likely lead to a typical AB deficit because of the effects of backward masking and target/distractor similarity. Specifically, backward masking has been shown to be a major contributing factor for producing the

AB deficit. As long as there are distractors following the targets, these distracting items will exert a backward masking effect on the targets, leading to impaired target identification. Further, the more similar targets and distractors are to each other, the stronger the backward masking effect will be (Fehrer, 1966). Also, the higher the level of target/distractor similarity, the more likely it is that a distractor could be mistaken for a target and be processed as one, thereby leading to impaired performance on subsequent targets. On the other hand, adopting a distractor-rejection strategy would be more likely to lead to an attenuated AB deficit. This is because it is possible for participants to learn to ignore the distracting items in the RSVP stream, and thus reject them as unimportant for the task. To the extent that these items can be ignored, the effects of backward masking and target/distractor similarity will be lessened. In turn, the AB deficit will be attenuated compared to using the target-passing strategy.

However, the strategy to be adopted may depend on the nature of the RSVP stream stimuli. Based on the principles of lumpability (the ease with which targets or distractors can be grouped together into one category) and target/distractor similarity, subjects may engage in a cost-benefit analysis for the purposes of adopting the best strategy with which to maximize their T2 performance. For example, under conditions of high distractor lumpability and low target/distractor similarity, the benefit of adopting the distractor-rejection strategy over the default target-passing strategy may be an attenuated AB deficit. However, the cost of distractor-rejection is that targets may be rejected along with the distractors. If the level of target/distractor similarity was to be increased, then the probability of rejecting a target might also increase, leading to very poor T2 performance. Therefore, under conditions of high target/distractor similarity, there would be a benefit to adopting a target-passing strategy; namely, improved T2 performance compared to distractor-rejection.

The purpose of Experiment 1 was to test the two-strategy hypothesis in a covert manner through manipulation of the nature of the RSVP stream stimuli. It was hypothesized that a target-passing strategy would be optimal for letter targets and pseudoletter distractors because of high target/distractor similarity and low distractor lumpability. On the other hand, the distractor-rejection strategy would be more likely to be optimal for letter targets and symbol distractors because symbols are easily lumpable and there is low target/distractor similarity. The hope was that when faced with a given set of stimuli in Block 1, participants would settle into the optimal strategy for those particular stimuli. Once Block 2 started, regardless of the strategy used in Block 1, subjects would adopt the optimal strategy for the given set of stimuli in Block 2.

However, the results of Experiment 1 were inconclusive. While the ANOVA yielded a significant Lag x Block 2 Distractor interaction (shown in Figure 4a), which was in line with the predictions of the two-strategy hypothesis, there was a possibility that the interaction was the result of a ceiling effect at Lag 1. By removing Lag 1 from the analysis, the interaction disappeared. This created a conundrum. If the data shown in Figure 4a was to be accepted as representing the true relationship between the two functions, then the two-strategy hypothesis held merit and could explain the data in Figure 4a and Figure 5. If the Lag x Block 2 Distractor interaction was due to a ceiling effect at Lag 1, then other explanations for the results may be more valid and could also explain the data in Figure 4a and Figure 5. In particular, a revised version of the two-strategy hypothesis was posited, which stated that perhaps target-passing and distractor-rejection strategies as stated in the introduction do not exist and instead, there were some other default strategies that were employed as a function of distractor type.

Experiment 2 was carried out with the purpose of resolving the ambiguity surrounding the data in Figure 4a and to further test the two-strategy hypothesis. The assumption was that strategy choice is cognitively penetrable, meaning that participants were able to consciously choose how they would process the incoming stimuli. So, given that strategy choice is cognitively penetrable and the two-strategy hypothesis outlined in the introduction was valid, then providing specific instructions for each strategy while keeping the RSVP stimuli constant should have yielded a reduced AB deficit for the group presented with the distractor-rejection instructions. However, this was not the case and in fact, the two AB functions were nearly identical. As such, it was concluded that perhaps the assumption that strategy choice is cognitively penetrable was invalid.

With regards to the original version of the two-strategy hypothesis laid out in the introduction, there can be no firm conclusions made about its feasibility as an explanation for differences in the magnitude of the AB for two reasons. First, if strategy choice is not cognitively penetrable, as was strongly suggested by the results of Experiment 2, then the mechanisms that drive the strategies used in the AB task are outside of conscious awareness. As such, subjects would not be able to gain access to those mechanisms for the purposes of actively engaging in either target-passing or distractor-rejection. In other words, neither a change in RSVP stimuli nor explicit instructions would allow for a conscious imposition of a specific processing strategy over top of the unconscious processes that were automatically triggered. Although, this is not to say that the target-passing and distractor-rejection strategies do not exist. It is entirely possible that these two strategies were engaged outside of conscious awareness as a function of the RSVP stream stimuli. However, by virtue of strategy choice being cognitively impenetrable, it is impossible to know for sure what processing mechanisms were being engaged.

Second, if strategy choice is cognitively penetrable, as was originally assumed, then the conundrum presented in Experiment 1 (i.e. is the Lag x Block 2 Distractor interaction due to a ceiling effect?) was not satisfactorily resolved in Experiment 2. This is because of the explanation that digit distractors presented in Experiment 2 may not have been conducive to using a distractor-rejection strategy, forcing subjects into adopting the alternative, target-passing strategy. As such, participants may never have actively engaged in a distractor-rejection strategy, leaving that particular aspect of the hypothesis untested.

Ultimately, it appears that the major objective of this work, which was to test the two-strategy hypothesis and draw conclusions about its viability as an account for the occurrence of differences in the AB deficit, was not achieved. It cannot be concluded that the two-strategy hypothesis either is or is not a valid explanation for the AB deficit.

Positive Outcomes

Despite the fact that the objective of this work was not accomplished, there were two interesting outcomes that deserve further consideration. First, there was a significant practice effect observed in Experiment 1 (see Figure 3) that appeared to be equal across distractor type and across switch and no-switch conditions. Specifically, T2 performance improved during the last third of Block 2 compared to the first third of Block 2 at Lags 2 and 3 for all conditions.

It is exceedingly rare for a practice effect to be reported in the AB literature. In one particular instance, Maki and Padmanabhan (1994) conducted research in which they trained their subjects on the RSVP task in order to acquire a baseline level of performance for further experiments. What is notable about their study is that after training subjects for an average of 15 days, a significant attenuation in the AB deficit on a target identification task (T1) and a probe detection task (T2) was reported. What is interesting to note is that the practice effect observed in Figure 3 of Experiment 1 in the current work occurred over the course of one experimental session that took less than half an hour. Further, since the practice effect appeared to be equal across distractor type and across switch and no-switch conditions, then it is possible that only one block of trials was needed for participants to improve to some degree on the target identification task.

In Maki and Padmanabhan's (1994) study, they hypothesized that the attenuation in the AB deficit after practice was due to the *consistent mapping* of targets and distractors. Consistent mapping was explained by Schneider and Shiffrin (1977; see also Shiffrin & Schneider, 1977) as a type of automatic processing that occurred when subjects were presented with numerous trials in which targets and distractors always came from mutually exclusive categories and there was a specific response expected for each category. To use an example from the current work, if targets were always letters and they were to be identified and reported and pseudoletters were always distractors and they were to be ignored, then eventually, each category of item would automatically be associated with a particular response. Over the course of the experimental blocks, participants may have engaged in automatic processing of the RSVP items to the extent that the appearance of a letter automatically triggered the 'identify and report' response and the appearance of a pseudoletter automatically triggered the 'ignore' response.

Consistent mapping could explain why, in this study, T2 performance improved across all conditions in Block 2 despite any switches in distractor type between blocks and despite the effects of backward masking and target/distractor similarity, which are known contributors to the AB deficit. The targets and distractors came from mutually exclusive categories; a letter was never a distractor and symbols or pseudoletters were never targets. Because subjects knew they were always looking for two letter targets, then perhaps over the course of the trials the letters automatically attracted attention while the distractors became a learned category that repelled attention. Shiffrin and Schneider (1977) found that, with no previous exposure to the stimuli sets in the experimental sessions, participants could learn to categorize sets of four arbitrary letters into a single meaningful group as long as the members of that group remained consistent across trials. Further, whether or not these groups of four letters were presented as targets or distractors did not matter, learning still occurred. Therefore, in the current study, it is possible that symbols and pseudoletters as completely arbitrary characters could have been categorized as one meaningful class; that of distractors. As such, the target features could have been consistently mapped and associated with the 'identify and report' automatic response while distractors were extraneous items to be ignored.

However, this same logic could be applied in the opposite direction. It is also possible that in a block with letter targets and symbol distractors, participants may have consistently mapped the features of symbols with the 'ignore' response and any other stimuli (i.e. letters) were extraneous items to which the automatic 'identify and report' response was attached. If this was the case, then a switch to pseudoletter distractors would have disrupted this consistent mapping. As such, there may not have been opportunity for improvement in T2 performance since the automatic responses would have needed to be developed again for different distractor item features (i.e. pseudoletters). The argument against this explanation is that if the distractor features were consistently mapped instead of the target features, then one would expect to see improvement in the no-switch conditions compared with switch conditions. But, as pointed out beforehand, T2 performance improved across Block 2 in all conditions.

However, the practice effect observed with consistent mapping in Maki and Padmanabahn (1994) was obtained over the course of thousands of trials presented in numerous sessions. In the current study, there were a total of 240 trials and only 120 trials in Block 2 with which to develop consistent mapping. It is entirely possible that consistent mapping could not be obtained in such a short amount of time. Further, one would expect consistent mapping to affect performance at all lags. That is, if T2 performance in the current study improved at Lags 2 and 3, then consistent mapping would predict that T2 performance at Lags 1 and 8 should also improve over the course of the same block of trials. However, this was not the case. Finally, with little to no report of a practice effect in the extant AB literature, there is no other experimental evidence to support the suggestion of consistent mapping as a contributing factor to the practice effect observed in the current study.

All three extant AB theories can explain a practice effect, so why it has not been considered in more detail before within the extant literature is up for debate. For the two-stage theory of the AB, Chun and Potter (1995) suggested that the difficulty of T1 detection has a direct effect on the magnitude of the AB deficit. They showed that when a letter T1 was followed by a digit distractor, then the AB was more pronounced than when a letter T1 was followed by a symbol. It was suggested that this resulted from letters and digits being harder to discriminate from each other than letters and symbols. The authors posited that the more a T1+1 item interferes with T1 processing (i.e. the greater the level of target/distractor similarity), then the longer it would take to process T1 for conscious report in the limited capacity Stage 2 of their model. The longer Stage 2 remains busy, keeping the bottleneck closed, then the less chance there would be for T2 to receive further processing before it decayed over time or was overwritten in Stage 1 by trailing stimuli.

However, if T1 processing took less time then the bottleneck would open up more rapidly, increasing the chances of T2 passing through into Stage 2 for processing and conscious report. Thus, the AB deficit should be attenuated as a function of the ease of T1 processing. Since the practice effect in the current study was equal across all conditions, then regardless of level of item discriminability, to the extent that subjects became better at processing T1 over the course of experimental trials, this should have reduced T1 processing time in Stage 2. Less time in Stage 2 for T1 meant that Stage 2 was available in plenty of time to allow T2 to be passed along for further processing and conscious report before being overwritten by incoming stimuli. This in turn would have reduced the AB deficit during the last third of any given block compared to the first third.

TLC theory can account for a practice effect in much the same way; the easier it is to process T1, then the AB deficit should be attenuated accordingly. The TLC model posits a central processor that sends maintenance signals to an input filter for the purposes of maintaining a configuration endogenously set to recognize target-defining features. Once a target arrives and passes through the input filter, the central processor disengages from sending maintenance signals to the filter and instead, becomes involved in target processing. This leaves the filter susceptible to being reconfigured by exogenous influences, namely, the subsequent items in the RSVP stream. Therefore, when the filter is reconfigured by a trailing distractor, it will no longer recognize the second target and an AB deficit results.

However, the central processor will only cease to send maintenance signals to the input filter for the duration of target processing. The practice effect suggests that subjects can become more adept at processing the targets. So, if T1 was more easily processed then maintenance signals to the filter would be resumed more quickly. This in turn would reconfigure the filter to recognize target-defining features and reduce the likelihood of T2 being lost at the earlier lags. Thus, as mentioned above, to the extent that subjects got better at the AB task over time by processing T1 more quickly, an attenuated AB deficit should occur.

With regards to resource depletion theory, of which interference theory is an example, accounting for the practice effect is not quite so simple but still possible. Much like TLC theory, interference theory posits the existence of a template that is configured to recognize target-defining features and against which RSVP stimuli are compared for the presence of a possible target. Items are admitted to VSTM on the basis of their match to this internal template. The better the match, the more resources are applied to the item and a heavier weight is assigned. Further, while T1 receives a significant portion of the available resources, the T1+1 item also receives resources because of its temporal proximity to T1. Since most of the available resources are engaged in assigning weights to the first target and its trailing item, then when T2 arrives, there are not enough resources left with which to assign a heavy weight as befits the target's match to the internal template. The AB deficit results when the heavier weighted T1 and T1+1 items win the competition for retrieval out of VSTM and are reported instead of the two targets (T1 and T2).

Within this framework, it is more difficult to explain a practice effect than for the previous two aforementioned theories. This is because in order for the AB deficit to be attenuated, T2 must receive enough resources with which it can be assigned a heavier weight than the T1+1 trailing item and so win the competition for retrieval out of VSTM. However, the theory is explicit in explaining that the T1+1 item slips through the sluggish attentional gate and therefore, always receives resources based on this temporal proximity. Therefore, as long as the T1+1 item slips through the attentional gate, it will take resources away from T2. And, as long as resources are scarce, then T2 will not receive a heavy weight and more often than not, will lose the competition for retrieval out of VSTM.

By definition, a practice effect implies improvement over time and can be applied to any AB task. Therefore, in order to account for a practice effect, this theory must somehow provide an explanation as to how the allocation of resources over the course of a particular experimental block could become more efficient. In other words, the pattern of resource distribution would need to change over time but within the constraints of one experimental block. Specifically, the new pattern would need to allow for T1 to receive a heavy weight and simultaneously deal with the arrival of the T1+1 item, but still leave enough resources to assign the requisite heavy weight to T2. This would then increase T2's chances of winning the competition for retrieval out of VSTM and lead to a corresponding attenuated AB deficit in the last part of the block compared to the first part of the block.

Perhaps with practice, subjects could learn to allocate resources more efficiently. Just as new drivers can learn to divide their attentional resources and become more adept drivers with practice, it could be that processing resources could also be allocated more efficiently to the items entering VSTM. In this new pattern of resource allocation, less resources would need to be applied to T1 and the T1+1 items for the purpose of assigning the appropriate weights as befits the target's template match or the T1+1 item's temporal proximity to T1. This would in turn leave more available resources to be applied to T2 and a heavier weight could be assigned to this target in comparison to the old pattern of resource distribution. As such, T2's chances of winning the competition for retrieval out of VSTM would increase at the end of a given experimental block compared to the beginning, resulting in a practice effect.

The second interesting outcome in this study was displayed in Figure 5. The results showed that for the two pseudoletter conditions, T2 performance did not change significantly whether or not there was a switch in distractor type from Block 1 into Block 2. However, the opposite was true for the two symbol conditions; T2 performance was much improved when there was no switch in distractor type between blocks compared to when there was a switch.

The fact that the two-strategy hypothesis laid out in the introduction to this work can neither be accepted nor denied does not preclude there being other possible strategies that were adopted for the task at hand (e.g. default strategies posited in the revised version of the two-strategy hypothesis). As such, one might consider that the results in

Figure 5 represented *asymmetrical switch effects* for the two classes of items. This term should not be mistaken for task-switching, which in the extant AB literature can refer to a switch in task between the two targets presented among distractors in an RSVP stream (e.g. reporting identity of T1 but reporting line orientation of T2) (e.g. Kawahara, Zuvic, Enns, Di Lollo, 2003). Instead, in the context of Experiment 1, one can think of asymmetrical switch effects as affecting T2 performance.

To explain asymmetrical switch effects, consider the following. In Figure 5, the data show performance across the two pseudoletter conditions as being very similar. In the case of the switch condition, a change in distractor type could have forced subjects to abandon the optimal distractor-rejection strategy for symbols because it may have led to rejecting targets along with distractors in the pseudoletter condition. Thus, the forced switch in strategy did not lead to a cost in T2 performance across the two groups because the optimal target-passing strategy would have been adopted in both pseudoletter conditions.

On the other hand, the data in Figure 5 for the two symbol conditions show a significant decrement in T2 performance for the switch group as compared to the no-switch group. In this case, the optimal strategy for pseudoletters may still have allowed for subjects to perform the task when the distractors were symbols. However, this particular strategy may have been sub-optimal when symbols were distractors as compared to pseudoletters. If, in the absence of a forced switch, subjects had perseverated in using the Block 1 strategy into Block 2 in the Pseudo/Symbol condition, then one could anticipate that T2 performance in Block 2 would be impaired compared to the Symbol/Symbol condition in which the optimal distractor-rejection strategy would have been used across both blocks.

Therefore, the data in Figure 5 demonstrate asymmetrical switch effects for T2 performance. If the task could not be done using a particular strategy then a switch to a different and more effective strategy had to occur. In the case of the data shown in Figure 5, subjects switched to the optimal strategy in the Symbol/Pseudo condition but not in the Pseudo/Symbol condition.

Future Directions

A couple of avenues for future research deserve some consideration. First, one could explore whether or not strategy choice for an AB task is cognitively penetrable. One way to do this could be to use the same stimuli sets as the current study but include conditions with and without explicit instructions on how to go about doing the AB task. For example, if performance in a symbol condition without instructions yielded a similar AB function as a condition with instructions, this could suggest that participants were not able to consciously choose how they processed the RSVP stimuli. This would be because if strategy choice was cognitively impenetrable, then despite the instructions, a conscious strategy choice could not replace the automatic processing mechanisms going on outside of conscious awareness.

If, on the other hand, evidence was found that supported the assumption that strategy choice for the AB task is cognitively penetrable, then this would allow for further testing of the two-strategy hypothesis. One way to do this could be to revisit the methods in Experiment 2 of the current study except change the RSVP stimuli. In Experiment 2, there was the possibility that letter targets and digit distractors created a higher level of target/distractor similarity than anticipated, leading subjects to adopt the target-passing strategy in both conditions. A condition with symbol targets and letter distractors would reduce the level of target/distractor similarity but it would also maintain a high level of distractor lumpability. In this way, a distractor-rejection strategy would be encouraged. This is because letters are an over learned category of items that could easily be lumped into one coherent semantic category to be rejected and also because letters and symbols are very dissimilar to each other in appearance. As such, an RSVP stimuli set of symbol targets and letter distractors could allow for T2 performance to move higher or lower as per the given set of instructions, but without creating a situation in which a distractor-rejection strategy could not be adopted.

Finally, further research could involve exploration of the practice effect in the occurrence of the AB deficit. Since studies that use an AB paradigm typically do not report such an effect, it is difficult to say whether there is always improvement in T2 performance over the course of a block of trials or only in certain circumstances. For example, in the current study, target and distractor categories were always mutually exclusive. However, if targets and distractors were to come from a single set of stimuli and each item could play the role of both a target and a distractor from trial to trial (not within a single trial), then this would encourage what Schneider and Shiffrin (1977) called *varied mapping*. In the case of varied mapping, no improvement in T2 performance would be expected because there would be no opportunity to develop an automatic response to any one category of stimulus item. However, if a practice effect occurred reliably in these circumstances (as opposed to the circumstances in the current study) then this could point toward a visual search mechanism that has not been previously considered as part of the AB phenomenon.

References

Bacon, W. F., & Egeth, H. E. (1994). Overriding stimulus-driven attentional capture. *Perception & Psychophysics, 55,* 485-496.

Blessing, S. B., & Anderson, J. R. (1996). How people learn to skip steps. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22(3)*, 576-598.

Brehaut, J. C., Enns, J. T., & Di Lollo, V. (1999). Visual masking plays two roles in the attentional blink. *Perception & Psychophysics, 61,* 1436-1448.

Chun, M., & Potter, M. C. (1995). A two-stage model for multiple target detection in rapid serial visual presentation. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 109-127.

Di Lollo, V., Kawahara, J., Ghorashi, S. M. S., & Enns, J. T. (2005). The attentional blink: Resource depletion or temporary loss of control? *Psychological Research, 69,* 191- 200.

Di Lollo, V., Smilek, D., Kawahara, J., & Ghorashi, S. M. S. (2005). System reconfiguration, not resource depletion determines the efficiency of visual search. *Perception & Psychophysics, 67,* 1080-1087.

Falcon, L. J. (2005). *Lag-1 sparing and the input mechanism in the attentional blink: Can the input filter be configured to detect more than one category of target in the RSVP stream?* Unpublished manuscript, Simon Fraser University: Burnaby, British Columbia.

Fehrer, E. (1966). Effect of stimulus similarity on retroactive masking. *Journal of Experimental Psychology, 71*, 612-615.

Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: HumanPerception and Performance, 18,* 1030-1044.

Giesbrecht, B. L., & Di Lollo, V. (1998). Beyond the attentional blink: Visual masking by object substitution. *Journal of Experimental Psychology: Human Perception & Performance, 24,* 1454-1466.

Harmon, L. D., & Julesz, B. (1973). Masking in visual recognition: Effects of two-dimensional filtered noise. *Science, 180(4091)*, 1194-1197.

Jolicoeur, P., Dell'Acqua, R., & Crebolder, J. M. (2001). The attentional blink bottleneck. In K. Shapiro (ed.), *The limits of attention: Temporal constraints in human information processing,* pp. 82-99. Toronto, ON: Oxford University Press.

Kawahara, J., Enns, J. T., & Di Lollo, V. (2006). The attentional blink is not a unitary phenomenon. *Psychological Research, 70,* 405-413.

Kawahara, J., Zuvic, S. M., Enns, J. T., & Di Lollo, V. (2003). Task switching mediates the attentional blink even without backward masking. *Perception & Psychophysics, 65,* 339-351.

Luchins, A. S. (1942). Mechanization in problem solving – the effect of Einstellung. *Psychological Monographs, 54(6)*, 195.

Maki, W. S., & Padmanabhan, G. (1994). Transient suppression of processing during rapid serial visual presentation: Acquired distinctiveness of probes modulates the attentional blink. *Psychonomic Bulletin & Review, 1*, 499-504.

Olivers, C. N. L., & Nieuwenhuis, S. (2006). The beneficial effects of additional task load, positive affect, and instruction on the attentional blink. *Journal of*

Experimental Psychology: Human Perception and Performance, 32, 364-379.

Potter, M. C., Chun, M. M., Banks, B. S., & Muckenhoupt, M. (1998). Two attentional deficits in serial target search: The visual attentional blink and an amodal task-switch deficit. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 979-992.

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance, 18,* 849-860.

Raymond, J. E., Shapiro, K. L., & Arnell, K. M.(1995). Similarity determines the attentional blink. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 635-662.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime User's Guide*. Pittsburgh: Psychology Software Tools Inc.

Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review, 84(1)*, 1-66.

Schubo, A., Schlaghecken, F., & Meinecke, C. (2001). Learning to ignore the mask in texture segmentation tasks. *Journal of Experimental Psychology: Human Perception and Performance, 27(4)*, 919-931.

Shapiro, K. L., & Raymond, J. E. (1994). Temporal allocation of visual attention: Inhibition or interference? In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory mechanisms in attention, memory and language* (pp. 151- 187). Toronto: Academic Press.

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review, 84(2)*, 127-190.

Smilek, D., Enns, J. T., Eastwood, J. D., & Merikle, P. M. (2006). Relax! Cognitive strategy influences visual search. *Visual Cognition, 14,* 543-564.

Theeuwes, J., Atchley, P., & Kramer, A. F. (2000). On the time course of top-down and bottom-up control of visual attention. In S. Monsell & J. Driver (Eds.), *Attention and Performance XVIII* (pp. 105-124). Cambridge, MA: MIT Press.

Visser, T. A. W., Bischof, W. F., & Di Lollo, V. (2004). Rapid serial visual distraction: Task-irrelevant items can produce an attentional blink. *Perception & Psychophysics, 66,* 1418-1432.

Whittlesea, B. W. A. (2002). False memory and the discrepancy-attribution hypothesis: The prototype-familiarity illusion. *Journal of Experimental Psychology: General, 131,* 96-115.