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### Previous attentional set can induce an attentional blink with task-irrelevant initial targets

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## Short article

# Previous attentional set can induce an attentional blink with task-irrelevant initial targets

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Identification of a second target is often impaired by the requirement to process a prior target in a rapid serial visual presentation (RSVP). This is termed the *attentional blink*. Even when the first target is task irrelevant an attentional blink may occur providing this first target shares similar features with the second target (*contingent capture*). An RSVP experiment was undertaken to assess whether this first target can still cause an attentional blink when it did not require a response and did not share any features with the following target. The results revealed that such task-irrelevant targets can induce an attentional blink providing that they were task relevant on a previous block of trials. This suggests that irrelevant focal stimuli can distract attention on the basis of a previous attentional set.

It has been suggested that the automatic capture of attention by stimuli in the visual field is, to a certain extent, controlled by the top-down attentional set of the observer. Folk, Remington, and Johnston (1992) proposed the contingent capture hypothesis, which states that observers will develop attentional control settings based on the goals of any given task. When completing this task any stimuli matching the control settings will capture attention, even if they are task irrelevant, providing they share a defining feature with the target. This research is based upon the notion of contingent capture; however, the interest here is not the effects of similarity between relevant and irrelevant items in the visual field, but rather how adopting an attentional set to complete

a certain task can influence a second task in which the set is no longer efficient.

According to Leber and Egeth (2006) if individuals have sufficient experience with one task set, when the task changes they may not evaluate the original set if the new task goals are being satisfied, even if a new set would improve performance. Using a rapid serial visual presentation (RSVP) they studied the influence of task-irrelevant distractors based on the attentional set that participants were induced to adopt. Two groups were asked to identify a coloured target in a RSVP; however, each group was encouraged to adopt either a feature search mode or a singleton detection mode of visual search in the first part of the experiment (Bacon & Egeth, 1994). In a

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training phase one group searched for a specific coloured target (feature group), amongst differently coloured nontargets. A second group searched for the uniquely coloured target (singleton group) amongst grey nontargets. In both groups 75% of the trials included peripheral distractors that matched the target colour, did not match the target colour, or were grey. Only distractors matching the target colour captured attention and interfered with accuracy in the feature group; however, in the singleton group any coloured distractor (except grey) disrupted performance.

A test phase followed in which all participants searched for a specific coloured target. Once again the two groups showed differential effects of the irrelevant distractors, as predicted from their respective attentional sets. Those who were originally in the singleton group showed evidence that all coloured distractors were capturing their attention, not just those that matched the target colour. Therefore when given a second task both groups continued to use the previously adopted attentional sets, even though this caused a detriment to performance as it increased the capture of attention by irrelevant distractors for those in the singleton group. These findings show that individuals do not always choose the most efficient attentional set for each task. Furthermore, the choice and implementation of any set is not purely based on the task demands and stimulus properties.

The present work aims to look at the influence of experience of an attentional set in much the same way as did Leber and Egeth (2006). The procedure used is also a RSVP, best known for demonstrating a finding referred to as the attentional blink (e.g., Reeves & Sperling, 1986; Weichselgartner & Sperling, 1987). The method involves presenting observers with a random succession of items in the same spatial location at a rate of approximately 10 items/s, from which they have to identify two or more targets. The temporal lag between the targets is varied, and results show that when a second target (T2) is presented during the first 500 ms following the first target (T1), identification of T2 is impaired

(Shapiro, Arnell, & Raymond, 1997). This effect is termed the attentional blink (AB). The magnitude of the blink varies as a function of the temporal lag, with the majority of studies finding that performance to T2 is high immediately following T1 (termed Lag 1 sparing), decreases between 180 and 270 ms stimulus onset asynchrony (SOA; Raymond, Shapiro, & Arnell, 1992), and then improves at later lags. The specific time deficit caused by the AB differs between studies but the general pattern of performance follows a U-shaped function (Visser, Zuvic, Bischof, & Di Lollo, 1999).

Folk, Leber, and Egeth (2002) utilized the AB to provide evidence for their contingent capture hypothesis. By presenting irrelevant peripheral distractors at a different spatial location to the central RSVP, at varying lags from T2 they were able to show whether such distractors could produce a spatial AB. Findings showed that the processing of T2 was only disrupted when the irrelevant items shared a target defining feature with T2. A further AB study carried out by Ghorashi, Zuvic, Visser, and Di Lollo (2003) found that the processing of a target was only disrupted by task-irrelevant distractors if they shared a defining characteristic with the target.

These studies show the modulation of involuntary capture of attention by top-down set; however, the present study utilizes the AB with the RSVP procedure to study the modulation of involuntary capture of attention by *previous* top-down set. The aim was to investigate whether the attentional set adopted by the observer has the potential to carry over to a second task in which it is no longer relevant. The AB effect was used to find evidence of a carry-over of top-down attentional set from one block to another block. Participants were randomly allocated to two groups; one group was required to monitor a RSVP and respond to Targets 1 and 2 in a first block, but only respond to Target 2 in a second block (even though Target 1 was still present). The second group was asked only to respond to Target 2 in both blocks (again Target 1 was still present). In this way the design manipulated prior experience of a task-relevant Target 1. It

was expected that if a carry-over effect does exist participants from the first group would show an AB not only in the first block, but also in the second block. This is due to the fact that they have developed an attentional set to search for both targets, and as this set is adopted and rehearsed it will be difficult to abandon. This therefore means that participants cannot ignore the first target when it subsequently becomes irrelevant as it still matches the attentional control settings.

The experiment aims to build upon the previous work of Leber and Egeth (2006) by attempting to show that the persistence of a top-down attentional set can occur under different conditions and by using different stimuli. Furthermore, the task-irrelevant items in this experiment are in the same spatial location as the task-relevant items; if they continue to capture attention based on a previous set despite being irrelevant, there will be evidence to show that a previous top-down set can influence the involuntary capture of peripheral and focal attention.

## Method

### *Participants*

A total of 60 participants (20 male and 40 female) took part in the experiment for a payment of £5; all were between the ages of 18 and 31 years, with a mean age of 22.12. All reported normal or corrected-to-normal vision.

### *Design*

A mixed design was used with two within-participants factors (lag and block) and one between-participants factor (set priming). Lag had five levels corresponding to four different SOAs between T1 and T2 and a negative lag in which T2 was presented before T1. In general AB experiments do not use a negative lag, and T2 only ever appears after T1; however, pilot studies showed that in a single-target block participants quickly learnt that if T2 always followed an irrelevant T1 they could use T1 to alert them to T2, therefore greatly increasing accuracy to T2 and overshadowing any potential carry-over from

Block 1 to Block 2. Lag refers to the temporal location of T2 in relation to T1; whilst T2 appeared immediately following T1 in a Lag 1 trial ( $T1 + 1$ ), T2 was the 3rd, 5th, and 7th post-T1 item in Lags 3, 5, and 7, respectively. This corresponds to four SOAs from T1 to T2: 100 ms (Lag 1), 300 ms (Lag 3), 500 ms (Lag 5), and 700 ms (Lag 7).

The factor of set priming referred to the experience that participants were given with a task-relevant T1. This was in an attempt to “prime” half the participants to develop an attentional set to respond to T1 and T2 in the first block. In Block 1, a total of 30 participants completed a dual-target block in which they had to respond to T1 and T2; this was the “set priming group”. The other 30 participants completed a single-target block that only required them to respond to T2 and ignore T1; this was the “no set priming” group. Following this first block all participants then completed a single-target block. The measures taken were accuracy to T1 and T2 in dual-target blocks and accuracy to T2 in single-target blocks.

### *Apparatus and stimuli*

The experiment was designed and run using E-Studio on a Viglen Contender P3 computer, with a 17" monitor. Participants were seated 60 cm from the screen, and head movements were minimized with the use of a chin rest. T1 was one of five numbers (2, 3, 4, 5, and 6). All 26 letters of the alphabet were also used, with 5 T2s (vowels), and 21 distractors (consonants). All letters were presented uppercase, and all letters and numbers were presented in black on a white background, in Verdana typeface, size 30, subtending  $1.43^\circ$  of the vertical visual angle and a maximum of  $1.19^\circ$  of the horizontal visual angle. All stimuli were presented at the centre of the screen.

### *Procedure*

The experiment was divided into two blocks. Each block took 25 minutes to complete, and there was a 5-minute break between the two. For each block participants completed 200 trials (after an initial 10 practice trials), consisting of 100 negative lag

trials and 25 trials for the four positive lags. In the positive lag trials this allowed every vowel to be shown once with every number at each lag; for the negative lag trials every vowel was shown five times with every number. Each trial began by showing a black fixation cross in the centre of the screen for 500 ms, and then a series of between 10 and 20 distractors were shown followed by T1 (in positive lag trials). T2 would then be shown immediately after T1 in a Lag 1 trial, or after 2, 4, or 6 distractors following T1 for Lags 3, 5, and 7 respectively. After T2 a further 10–15 distractors were shown before the trial ended. In a negative lag trial T2 was presented after 10–15 distractors, followed by a further 10–15 distractors before T1 appeared, and 10–15 more distractors before the end of the trial (Figure 1). Distractors, T1, T2, and lag were chosen randomly by the computer. All stimuli were shown for 50 ms with an interstimulus interval (ISI) of 50 ms (a rate of 10 items/s). The rate of presentation follows previous studies; however, the ISI in this experiment is fairly short in comparison. This was because participants had to detect and discriminate targets, making the task more difficult. Showing each item for longer would make the task easier; therefore any AB found would be particularly robust.

Participants were instructed to attend to the series of letters in the centre of the screen and to look for a vowel appearing. They were told that

Negative lag trial –

T2                      T1  
 ↓                            ↓  
 + ... S Q X L P Y E ... W N B T R ... 5 V M C Z F ...

Positive lag trial (example using lag 3) –

T1    T2  
 ↓    ↓  
 + ... R V L Y Q 2 D H A W Z F J P ...

**Figure 1.** Sequences of stimuli presented serially at fixation. Both blocks (dual target and single target) are identical, however in a single-target block participants are told to ignore T1 as it holds no relevance to the task.

at least one vowel would be shown in every trial; if they did not see a vowel they were asked to make a guess as there was no option to state that they had not seen one. They were told that there could be more than one vowel in each trial, and they should report the most recent (although only one vowel was shown in each trial). This was to ensure that participants would not try to use T1 in a single-target block to alert them to T2 if T2 had not already appeared. By expecting more than one vowel they would hopefully assume that using T1 as a cue would not be beneficial. Participants were also told that a number would be shown in each trial, but they were only asked to respond to this in the dual-target blocks and ignore it in the single-target blocks. At the end of each trial in the single-target block participants were asked which vowel they had seen (A, E, I, O, or U). At the end of each trial in the dual-target block they were asked which number they had seen (2, 3, 4, 5, or 6) and were then asked which vowel they had seen. Participants responded verbally, and the experimenter recorded all responses. On-screen feedback was given, but the experimenter was unaware of accuracy.

## Results

Participants in the set priming group took part in one dual-target block followed by a single-target block, and those in the no set priming group took part in two single-target blocks. In the first block participants in the set priming group had to respond to T1 and T2, and in the following block they only responded to T2. In the no set priming group participants responded to T2 in both blocks, and T1 was task irrelevant. Analysis consisted of two  $2 \times 4$  analyses of variance (ANOVAs), where four levels of lag were compared across the two groups for each block. Results calculated were accuracy levels to T2. Any trials in which T1 was incorrect were filtered out and were not entered into the analysis.

Prior to carrying out the analyses on the positive lags in each condition a  $1 \times 4$  ANOVA was conducted to check performance in the negative lag trials. Results showed no significant differences

between blocks showing that the experimental condition did not affect accuracy in a negative lag. No further analysis was carried out on the negative lag trials as they were present in the experiment purely for the purpose of removing any facilitation effects.

#### *Comparison of the first block between groups*

The set priming group responded to both T1 and T2 in the first block. Overall mean accuracy to T1 was 89.87%, and a  $1 \times 4$  ANOVA showed that accuracy to T1 did not vary according to the condition of lag. Degrees of freedom were adjusted according to the Greenhouse–Geisser epsilon as analysis showed problems with sphericity, however this did not change the pattern of the results, and therefore the original degrees of freedom are reported. In terms of accuracy to T2, when comparing the positive lags from the first block completed by the set priming group with the first block completed by the no set priming group results showed a main effect of lag,  $F(3, 174) = 18.258$ ,  $MSE = 118.052$ ,  $p < .001$ . There was also a lag by group interaction,  $F(3, 174) = 15.468$ ,  $MSE = 118.052$ ,  $p < .001$ . In the no set priming group there was no significant effect of lag as performance at each SOA varied very little between 66.67% and

70.14%. However, in the set priming group, when participants had to respond to both T1 and T2, performance varied from 44.46% at Lag 3 to 71.71% at Lag 7. These results demonstrate an AB in the dual-target block completed by the set priming group with the greatest detriment in performance at 300-ms SOA (see Figure 2).

#### *Comparison of the second block between groups*

In order to determine the precise nature of any effect of an irrelevant T1 that was previously relevant, performance in the final block was compared between groups (see Figure 2). In this case those in the no set priming group would have no experience of a relevant T1 but would have the same amount of experience and practice with the stimuli. Any similar interaction between group and lag would therefore signal that the previously relevant T1 was still affecting identification of T2 in the second block completed by the set priming group. The analysis of these conditions showed a significant effect of lag,  $F(3, 174) = 3.718$ ,  $MSE = 76.480$ ,  $p < .01$ , and an interaction between group and lag,  $F(3, 174) = 3.362$ ,  $MSE = 76.480$ ,  $p < .05$ . Although accuracy has increased for both groups compared to Block 1 (from a mean of 68.37% in Block 1 for the no set priming group to 73.17% in Block 2, and 59.68% to 70.33% for

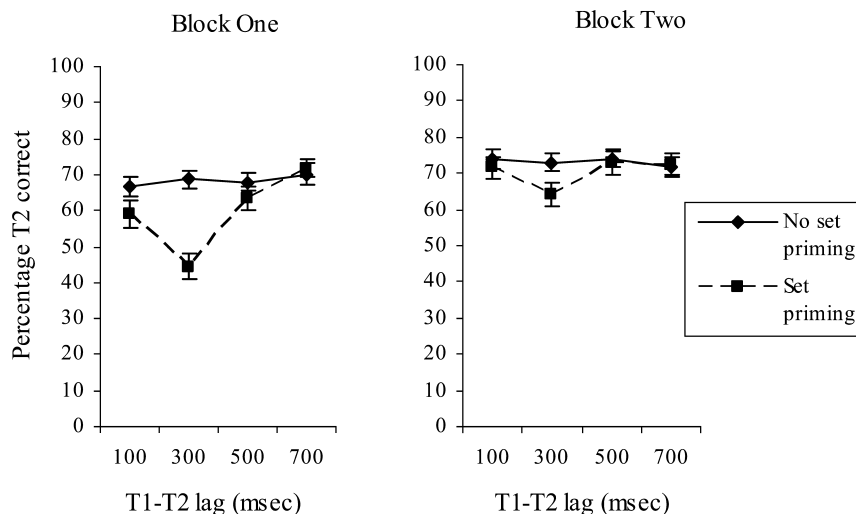


Figure 2. Mean accuracy to T2 for the set priming and no set priming groups in Blocks 1 and 2.

the set priming group) participants who had previously been responding to T1 were still showing an AB effect. As before the detriment in performance fell at Lag 3 with a mean accuracy of 64.27%, showing the familiar U-shaped function found in AB studies.

## Discussion

The current experiment aimed to determine whether there was any evidence that a previous top-down attentional set can persist to a second task in which it is no longer relevant. To test this theory the AB paradigm was utilized with a RSVP. The idea was to compare performance when participants were asked to respond to two targets within the RSVP (dual-target condition) to that when they only respond to one target but the other target is still present (single-target condition). The amount of experience that participants were given with a relevant T1 was manipulated prior to taking part in a task with an irrelevant T1. This was to determine whether the distraction of attention by irrelevant onsets could be modulated by previous attentional set.

As expected from a standard AB procedure, when participants were asked to respond to T1 and T2, identification accuracy of T2 was severely impaired in relation to lag (e.g., Raymond et al., 1992). A traditional AB effect was found in the dual-target condition, with Lag 1 sparing followed by a decrease in performance at Lag 3 and an improvement in performance at Lags 5 and 7. This showed that the stimuli involved in the experiments were able to provoke an AB in a dual-target RSVP. When participants completed a single-target block immediately after a dual-target block, performance followed a pattern similar to that found in an AB (albeit with less magnitude than a dual-target block). This demonstrates that a task-irrelevant target is capable of distracting attention away from the primary task. However, this distraction by irrelevant targets is contingent upon the target having been task relevant in the previous block; the task-irrelevant T1 did not capture attention in the single-target blocks completed by the no set priming group.

This effect has implications for standard attentional blink experiments. In general past studies either have focused upon the experimental condition (respond to two targets), and have not included a control condition (respond to T2 only), or have tested the two conditions between groups. However, some studies tested the conditions within participants (e.g., Raymond et al., 1992) but counterbalanced the two sessions. Counterbalancing will overshadow the effect of any carry-over from a dual-target condition to a single-target condition, but it will not remove the effect. As a result the magnitude of the AB in such studies may be underestimated, as accuracy in the control condition for half the participants (who completed a dual-target block first) may have brought down overall accuracy for the control condition. This is because they may have experienced carry-over of their attentional set from the dual-target to the single-target block, and the now irrelevant (but previously relevant) T1 may still be capturing attention because it still matches the top-down set. The consequence of this would be a decrease in performance at the most critical SOAs. The AB is a very robust effect, but perhaps the extent of it may have been masked in past studies. The current finding of carry-over is therefore an important one to consider when choosing the experimental design for an AB study.

The results reported not only have implications for attentional blink experiments, they are also relevant to the findings of contingent capture. The contingent capture hypothesis of Folk et al. (1992) states that task-irrelevant items will capture attention only if they match the top-down control settings. Specifically if distractors share target-defining features with the targets they will attract attention. Although the results outlined here support the notion of contingent capture, the fact that task-irrelevant stimuli captured attention was not based on the similarity between the task-relevant and task-irrelevant items. First, T1 and T2 did not share any similarities over and above the similarities they both shared with the distractors. In addition to this, if the similarity of the two targets was causing the AB effect when T1 was no longer relevant, an AB would be found in every single-target block; yet

this was not the case, and only a single-target block completed after a dual-target block showed such an effect. The persistence of the AB effect to a block in which T1 was no longer relevant was due to the persistence of the attentional set initially adopted to search for T1 and T2 and to ignore the irrelevant distractors. As participants rehearsed this set it was continually being activated and therefore was not evaluated when the task demands changed. As the set remained the same the task-irrelevant T1 still matched the top-down control settings and so was still able to capture attention.

The current findings can therefore provide evidence that the practice and rehearsal of an attentional set can result in the subsequent incorrect application of this set, as it has become unavoidable. Like the previous findings of Leber and Egeth (2006), the current results show that once a top-down attentional set is adopted the individual will not always re-assess this set when a second task ensues and will continue to use the original set, despite the fact that it may no longer maximize performance.

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