Vision Research 76 (2013) 68–76

Contents lists available at SciVerse ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

The role of preparation time in the attentional blink

Nicholas A. Badcock[a,b,*], David R. Badcock[b], Janet Fletcher[b], John Hogben[b]

[a] *ARC Centre of Excellence in Cognition and its Disorders, Macquarie University, North Ryde, Australia*
[b] *School of Psychology, University of Western Australia, Crawley, Western Australia, Australia*

A R T I C L E I N F O

Article history:
Received 28 March 2012
Received in revised form 7 October 2012
Available online 30 October 2012

Keywords:
Attentional blink
Preparation
Perceptual set
Foreperiod

A B S T R A C T

This research investigated the effect of foreperiod predictability in the *Attentional Blink* (AB). The AB, a cost in processing the second of two targets presented in close temporal proximity, was estimated using a minimalist procedure consisting of two letter targets and two letter fragment masks. In a four-step procedure, differences in foreperiod duration, target exposure duration, and inter-target interval were controlled in order to estimate the AB. Foreperiod was manipulated in three experiments. The AB effect was reduced when a single and relatively long foreperiod value was used ($M = 880$ ms, Experiment 2) in comparison to randomized (250–750 ms, Experiment 1) and single but relatively short foreperiods ($M = 273$ ms, Experiment 3). The results are discussed in the context of resource-sharing and preparation of a perceptual-set pertaining to physical target features including modality and intensity, as well as spatial and temporal predictability. It is concluded that foreperiods that are too brief for an individual observer or temporally unpredictable contribute to the AB.

1. Introduction

The ability to respond to a stimulus is affected by the opportunity to prepare for the response. The impact of foreperiod, that is, the duration of time from a cue signalling task onset to the presentation of a target stimulus, has been well documented with respect to reaction time performance (for a review see Niemi & Näätänen, 1981). Where reaction time is concerned, and foreperiod is constant within experimental blocks, longer foreperiods are associated with faster and more accurate responding. An interesting effect in this research is that when observers are presented with a range of foreperiods randomised over successive trials, reactions are faster to stimuli at the longest foreperiod, independent of the distribution of foreperiods. For example, if presented with foreperiods ranging from 500 ms to 3 s versus foreperiods ranging from 500 ms to 1 s, responses will be fastest to 3 and 1 s foreperiods respectively. Thus it would appear that the observers accumulate knowledge of the distribution and bias their response preparation to peak at the longer intervals (Vallesi & Shallice, 2007). As well as this cumulative effect, there is a also a trial by trial influence whereby reaction times will be slower if the current foreperiod is longer than the previous (Vallesi & Shallice, 2007; Van der Lubbe et al., 2004). Foreperiod effects have also been demonstrated to affect perceptual processing (Bausenhart, Rolke, & Ulrich, 2008; Rolke & Hofmann, 2007). The current investigation is concerned with how the foreperiod affects dual-target tasks, specifically those susceptible to the *Attentional Blink* (AB).

Visual dual-target tasks are often examined in a rapid serial visual presentation (RSVP) in which multiple stimuli, commonly letters or numbers, are presented in brief (stimulus onset asynchrony of 100 ms) succession at the same spatial location. Observers are then asked to identify or detect specified target items. With respect to letters, it may be the task of identifying two red letters in a series of black distracter letters. When the temporal separation between two targets is greater than about 500 ms, reporting accuracy for both targets is high. However, when two targets are presented within a 500 ms window, accuracy in reporting the second target (T2) is significantly reduced. This phenomenon has been labelled the AB, originally considered analogous to an eyeblink with respect to the processing of new information: whilst the eye is closed, no new information can be processed (Raymond, Shapiro, & Arnell, 1992). In light of more recent evidence, the AB might be considered a blink in conscious awareness given that there are electrophysiological responses to missed targets (Vogel, Luck, & Shapiro, 1998).

Models of the AB fall into two major categories: resource limitations and selection accounts. Both accounts consider two basic stages of RSVP processing. The first provides a subconscious sensory representation of all items and the second provides a conscious, reportable representation of the targets. It is considered that a capacity-limited set of resources is required for target processing and when two targets appear within 500 ms, resources can only be applied to one target, usually the first (Chun & Potter, 1995). A critical sub-theory in the resource limitation category is

---

* Corresponding author at: CCD, Macquarie University, Balaclava Road, North Ryde, New South Wales, Australia.
E-mail address: nicholas.badcock@mq.edu.au (N.A. Badcock).

0042-6989 Crown Copyright © 2012 Published by Elsevier Ltd. Open access under CC BY-NC-SA license.
http://dx.doi.org/10.1016/j.visres.2012.10.010

that of resource sharing (Jolicœur, 1998). Rather than a serial processing of one target and then another, this variation posits that resources are shared between targets, predominantly emphasising the first target (T1). For selection accounts, discriminating targets from distracters is the limiting factor. An example of a selection account comes from Di Lollo and colleagues (Di Lollo, Kawahara, et al., 2005; Di Lollo, Smilek, et al., 2005) who suggest that, in order for the targets to be consciously reported, the sensory representations must pass through a filter attuned to target features. For successful target filtering, this filter must be under endogenous control, that is, an attentional focus driven by the observer. This is in contrast to exogenous control in which attentional focus is driven by the stimulus (Monsell, 1996). The selection account proposes that the presence of distracter items following T1 forces the system into an exogenous state and it is not until endogenous control is regained that subsequent target processing can occur. During this loss of control, the representation of T2 may decay beyond that required for accurate report.

In the task-switching literature which uses a similar dual-target paradigm to that of the AB, increasing foreperiod length is considered to enhance task preparation reducing the cost of switching between tasks (Monsell, 2003). Although temporal orienting to T2 has been examined in the AB (Martens, Elmallah, et al., 2006; Martens & Johnson, 2005), specific effects of T1 foreperiod have not been considered. The aim of the current investigation is to determine whether the magnitude of the AB is reduced when adequate foreperiod durations are provided.

Rolke and Hofmann (2007) examined how foreperiod affected the sensitivity of a backward masked Landolt square to which observers were required to make a left–right judgment about the location of a gap in the square. Critically, sensitivity was higher in the longer foreperiod condition (2400 ms) compared with the shorter foreperiod condition (800 ms). They suggest that temporal uncertainly in target appearance reduces perceptual processing, therefore it is plausible that this effect may impact upon the AB. Single-target RSVP accuracy has been shown to be higher at longer foreperiods (Ariga & Yokosawa, 2008) and Martens et al. have manipulated temporal knowledge of T2, suggesting that temporal cueing reduces the magnitude of the AB (Martens, Elmallah, et al., 2006; Martens & Johnson, 2005).

The role of temporal orienting in the aforementioned research has been made using a full RSVP, including targets and distracters. Distracters in AB experiments are demonstrated to cause interference. Properties known to affect the AB include visual similarity (Maki et al., 1997), phonological similarity (Coltheart & Yen, 2007), and conceptual similarity (Dux & Coltheart, 2005). Implementing number distracters and letter targets, considered to be visually similar (Chun & Potter, 1995), may introduce an additional source of error which would be best excluded. We therefore implemented a minimalist procedure consisting of two targets and two visual masks, previously shown to be suitable for AB investigation (Duncan, Ward, & Shapiro, 1994; McLaughlin, Shore, & Klein, 2001; Rolke, Bausenhart, & Ulrich, 2007; Shore, Mclaughlin, & Klein, 2001; Ward, Duncan, & Shapiro, 1997). This minimalist procedure removes the influence of distracter items, allowing the effect to be more clearly underpinned by target processing. Recent research suggest that visual masks, formerly considered crucial to observing the AB effect (e.g., Raymond, Shapiro, & Arnell, 1992), are not required (Jannati, Spalek, & Di Lollo, 2011; Jannati et al., 2012). Therefore, the inclusion of backward masks in the current investigation merely provides a mechanism to control for target sensitivity and ensure that the results are free from ceiling effects.

To examine the effect of foreperiod on the AB, one option would be to set the same short and long foreperiods (e.g., 300 and 900 ms) for all individuals and compare the results. The weakness of this procedure is the assumption that the length of foreperiod has the same effect in all individuals. This is unlikely to be the case. It is more plausible that at 300 ms, some individuals may be less prepared and some more prepared. Therefore, the one-size-fits-all approached fails to adequately provide an equivalent manipulation of foreperiod between individuals. In order to control for foreperiod length, a methodology to enable careful control for individual differences in target and AB sensitivity was employed. Our minimalist procedure included a fixation cross, a blank foreperiod interval, T1 and a backward mask, a blank inter-target interval (ITI), followed by T2 and then a backward mask. This is depicted in Fig. 1. Utilising the minimalist display, psychophysical procedures can be used to estimate individually equated values of foreperiod, target exposure duration, and the length of the AB effect. With these values ascertained, the AB itself can then be measured. The AB effect itself refers to accuracy of detection across a number of ITIs.

We introduce a four-step procedure that utilises previous step estimates in order to equate for individual differences and control for their influence in subsequent steps. Step 1 involves estimating foreperiod. As mentioned with respect to reaction time at a range of foreperiod values, pilot testing indicated that exposure duration thresholds are lowest at longer foreperiods (for an example see Fig. 2) consistent with existing literature (Bausenhart, Rolke, & Ulrich, 2008; Rolke & Hofmann, 2007). Here we estimated the T1 exposure duration required for 75% correct identification at multiple foreperiods. An exponential decay function can then be fitted to exposure duration thresholds as a function of foreperiod length to estimate individually equivalent foreperiod values based on the half-life of this function (see Fig. 2 and Method for details). This individually fixed level of foreperiod is then implemented in Step 2 to determine exposure duration required for 75% T1 reporting accuracy. The foreperiod and exposure duration are then utilised in Step 3 in which the ITI is manipulated to determine an interval at which T2 is reported at 60% accuracy.[1] Finally, these three pieces of information are included in Step 4 in order to estimate the AB effect after controlling for individual differences in foreperiod, exposure duration, and ITI.

2. Experiment 1

In the first experiment we demonstrate the four-step procedure but do not use the foreperiod estimate for subsequent steps, using instead a randomized foreperiod (250–750 ms) to establish baseline AB pattern using this methodology. Previous experiments using the minimalist design have used foreperiod durations of 0 to 1000 ms with intervals (i.e., the minimum to maximum difference; e.g., 600–1000 = 400) ranging from 300 to 500 ms (Duncan, Ward, & Shapiro, 1994; McLaughlin, Shore, & Klein, 2001; Rolke, Bausenhart, & Ulrich, 2007; Shore, Mclaughlin, & Klein, 2001; Ward, Duncan, & Shapiro, 1996, 1997). The foreperiod range employed in Experiment 1 provides a baseline in the middle of the range used in existing research. Despite not using the foreperiod estimate, it is important that this step is included so that the procedure was equivalent in all experiments we wish to compare.

3. Materials and methods

3.1. Participants

There were 16 university students in Experiment 1. The mean age was 26.3 (SD = 6.09, min = 21, max = 42) and 5 were male. All

---

[1] The exposure duration of T1 and T2 is equivalent throughout: when T1 is adjusted, T2 is also adjusted. If Step 2 is successful, then the maximum expected accuracy for both targets is 75% in steps 3 and 4. In order for the adaptive procedure to operate, accuracy above and below the required threshold must be achievable, therefore, a lower threshold must be used in Step 3 and we selected 60%.