The Attentional Blink at 20 items/sec, Model Prediction and Empirical Validation of Lag-2 Sparing

Bradley P. Wyble (bw5@kent.ac.uk)
Centre for Cognitive Neuroscience and Cognitive Systems, University of Kent
Canterbury, UK CT2 7NF

Howard Bowman (h.bowman@kent.ac.uk)
Centre for Cognitive Neuroscience and Cognitive Systems, University of Kent
Canterbury, UK CT2 7NF

Introduction

The Attentional Blink (AB) paradigm uses a Rapid Serial Visual Presentation (RSVP) stream, with two targets (denoted T1 and T2). There is a period of approximately 500 msec during which processing of T1 seems to impair the ability to detect and report T2 (Raymond, Shapiro and Arnell 1992). This suggests that the deployment of attention to processing T1 has a temporal window of a little over half a second. This interpretation is complicated by *lag 1 sparing*, which is the robust finding of almost unimpaired performance on T2 when it immediately follows T1.

Early theories of the AB have posited that the blink is the result of interference between the T1, T1+1, T2 and T2+1 items (Raymond, Shapiro and Arnell 1992). In this formulation, the existence of distractors is key to producing the particular U shape of the AB curve. Specifically, it is the T1+1 distractor that reduces the accuracy of a lag-2 T2 by entering the visual buffer along with the T1.

Another theoretical account posits the AB as the result of the interaction of two stages of processing (Chun and Potter 1995). Consolidation of the T1 in the second stage prevents the processing of T2. T1+1 items are important in causing the blink in that they make T1 processing more difficult

We have implemented a model of the AB, which combines this two-stage architecture with a token-based account of working memory (Kanwisher, 1987). This model makes explicit the prediction that it is the temporal characteristics of the token binding process that determines the shape and time course of the blink, and not the sequential arrangement of targets. Specifically, our model predicts that the shape of the blink curve will be constant with respect to time, such that at a presentation rate of 20 items/sec, the maximal depth of the blink will be obtained at lags 4-6, recovery will occur by lags 10-12, and there will be strong lag-2 sparing. This paper will then describe an experiment that confirms these results empirically. These results are generally incompatible with the intereference theory of Raymond, Shapiro, and Arnell (1992).

Modelling the AB

A complete description of this model is beyond the scope of this submission format. Accordingly, this text will focus on the general architecture of the model. A full specification can be found online at http://www.cs.kent.ac.uk/projects/cncs/online/bw5/iccm2004/.

This model uses a continuous firing rate representation of neural units, arranged in a series of layers representing a series of processing steps from early visual traces, through semantic processing and eventually leading to consolidation in working memory through recurrent sustained activation of working memory tokens. All units are connected by fixed inhibitory and excitatory connections.

Our implementation is strongly influence by the two-stage model of Chun (1997) in which the first stage performs low level visual and semantic processing of the RSVP stream. This stage can hold multiple items simultaneously, each in a localist fashion. However, lateral and feedforward inhibition effects cause weak activation traces for masked items, which is the case for all items in an RSVP stream. This feature sets the stage for T1+1 blanks attenuating the blink (Chun and Potter 1995), which is not described here. Representations in this first stage are akin to *Types* in the *Types-Tokens* distinction of Kanwisher (1987)

The second stage implements a *token* system that binds working memory *tokens* to the *type* information in the first stage. This system is capacity limited in that it can only bind one *token* at a time. In order to protect the integrity of this binding process, a transient attentional mechanism is deactivated during token binding. The unavailability of this resource makes it difficult for a T2 to reach an activation level sufficient to undergo tokenization at a relative lag of 200-500 msec following the T1.

Critically, in this model, it is the temporal dynamics of the *token* binding process that determine the shape of the blink. If the T2 follows closely enough after the T1, it receives a strong benefit from the transient attentional episode triggered by the T1, and is capable of being included in the T1's *token* binding process. The time course of this attentional transient is relatively unaffected by either the strength of the targets, or the number of distractors, that intervene between T1 and T2. Consequently, this model predicts that at a much faster presentation rate, lag 2 sparing should be strongly evident.

The duration of the blink is also independent of the number of items, being instead a function of the time between T1 and T2. The presentation of input to the model assumes that some letters are more visible through the stream of distractors than others, and this is modeled by presenting inputs at varying strengths to the input layer. The result of this variance is such that weaker traces caused by the faster presentation rate affect the depth of the blink and the baseline performance, rather than the duration.

In this work, this model was presented with streams at 10 and 20 items/sec (100 and 50 msec SOA's). The task is similar to that of Chun and Potter (1995), in which targets are categorically distinct from distractors (e.g. letters in a digit stream). For the 20 item/sec presentation rate, it was necessary to increase the strength of bottom-up connections so that higher layers were excited above threshold by the 50 msec stimuli. This modification represents the presumed adaptation of low level feature detectors to the more rapid presentation rate.

Figure 1 illustrates the output of the model in the 10 and 20 item/sec rates. Note that for the faster rate, the leftmost position in the graph represents lag-2, the next lag-4, etc up to lag 16. For the slow rate, data points represent lags 1-8. Criticially, in this model, distractors serve primarily as low level feature masks, as supported by recent data from Maki et al (2003). Distractors are capable of evoking traces in the semantic layer of the network, but these traces are suppressed by a task demand system prior to entry into the token binding system.

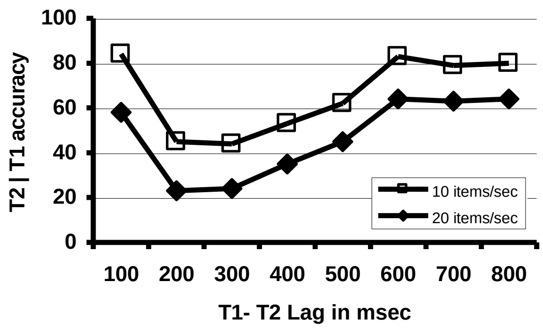
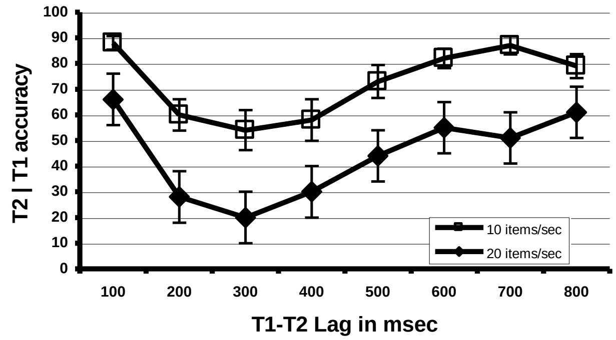


Figure 1: Model data for fast and slow rates.

Empirical Results

Empirical studies of human volunteers were undertaken to test the results of the model in comparing the AB from 10 and 20 item/sec presentation rates in two experiments. In the first, 14 volunteers were presented with two blocks of a task similar to that of Chun & Potter (1995) as described above. Items were 93 msec in duration with no intervening blank space and presented in black on a white background. RSVP streams were 17-21 items in length with the T1 appearing from positions 5-9 and the T2 appearing 1-8 positions later. For the faster presentation rate, items were presented for 53 msec and all RSVP parameters were doubled, presenting a similar temporal profile between T1 and T2. Results are depicted in Figure 2. Results closely match that of the model, with impaired performance for the faster rate, but a blink curve of a nearly identical shape.

Figure 2: Empirical data for fast and slow rates. Bars



represent standard error.

Conclusions

In conclusion, this work presents computational evidence and empirical validation that the AB shape is dictated by the temporal lag between T1 and T2, rather than the sequential arrangement of the targets in between. Consequently, clear Lag-2 sparing exists for a presentation rate of 20 items/sec. This result stands against the predictions of existing formulations of the interference model but is well explained by the two-stage model of Chun & Potter (1995) and Chun (1997). In our formulation, a token binding system serves as the second stage, and the temporal requirements of binding the T1 to a token determine the shape of the blink. If T2 arrives within 100 msec of the T1, it is spared, regardless of intervening distractors, which primarily serve as visual masks in initial stages of processing.

Acknowledgements

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