The Attentional Blink at 20 items/sec, Model Prediction and Empirical Validation

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The Attentional Blink

- The AB paradigm presents subjects with a Rapid Serial Visual Presentation (RSVP) stream, conventionally at 10 items/sec, with two marked targets (T1 and T2) hidden within 20 distractors (Raymond et al 1992).
- Subjects are impaired at reporting the second target when it follows the first target by 200-500 msec.
- A common finding in this task is lag-1 sparing: T2 performance is often unimpaired when it follows T1 directly.
- The interference theory posits that items in the T1, T1+1, T2 and T2+1 slots compete in short term memory, causing the T2 deficit, except at lag 1 in which the T1+1 item is T2. (Raymond et al 1995)
- The two-stage model posits that consolidation into working memory is primarily a serial process; T2 must wait for T1 to finish this process before being encoded. At lag-1, the T2 slips into the consolidation process with the T1. (Chun and Potter, 1995)
- We have implemented a functional version of this two-stage model that describes the lag-1 sparing window as precisely temporal. At 20 items/sec, lag-2 sparing should be evident. This prediction is counter to the description of the interference theory, which posits that only lag-1 sparing obtains regardless of presentation rate.
- This report describes first the model, then empirical validation of this prediction.

The Two-Stage Model

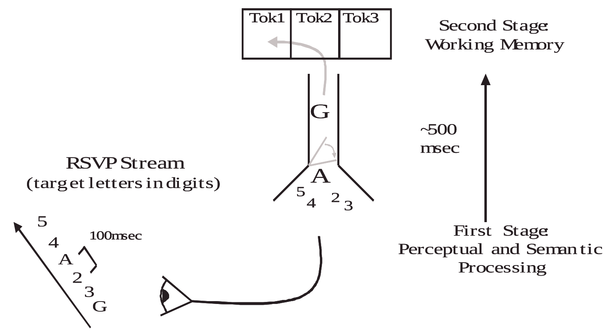
This model is an implementation of the Two-Stage model described in Chun and Potter (1995). In the task used here, subjects are to select letters from a digit stream.

In this model, the first stage contains early visual, lexical and semantic processing. It can represent multiple items for 300-500 msec.

For longer term memory, a tokenization system assigns task relevant items to tokens to store them in working memory (Kanwisher 1987).

This is a time intensive process, particularly if the item is heavily masked. During this process, other targets are denied access to the tokens, creating a bottleneck.

While waiting to be tokenized, items in the first stage are vulnerable to decay.



Methods

The model represents items using localist, continuous firing rate representations which compute the membrane potential of neuron *j* in layer *i* at time *t* using excitatory, inhibitory and leak currents according to the following formula:

$$MP_{(i,j,t)} = MP_{(i,j,t-1)} + DT\_VM_{(j)} * ((Bias_{(j)} + Excite_{(i,j,t-1)}) * (EE_{(j)} - MP_{(i,j,t-1)}) + Inhib_{(i,j,t-1)} * (EI_{(j)} - MP_{(i,j,t-1)})) + Leak_{(j)} * (EL_{(j)} - MP_{(i,j,t-1)}))$$

Output of each neuron is computed by a threshold function according to the following equation which roughly approximates sigmoid behavior:

$$Out_{(i,j,t)} = \frac{[MP_{(i,j,t)} - \vartheta_{(j)}]_+ * \vartheta_{(j)}}{[MP_{(i,j,t)} - \vartheta_{(j)}]_+ * (\vartheta_{(j)} + 1)} \quad \text{Where } [x]_+ = \begin{matrix} x & if & x > 0 \\ 0 & otherwise \end{matrix}$$

Elements of the Model

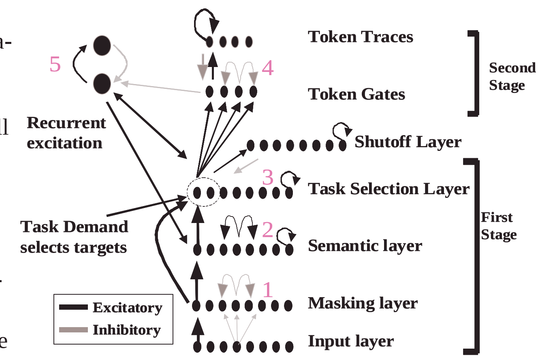
Items from a simulated RSVP stream are presented to the model starting at the input layer and processed by subsequent stages.

1. Masking layer: lateral and feed-forward inhibition produces an asymmetric combination of backward and forward masking reducing activation traces equally for targets and distractors.

2. Semantic Layer: Input evokes prolonged activation traces. Weak lateral excitation allows semantic priming. Weak self excitation prolongs duration of traces. Both targets and distractors are processed to a semantic extent, even during the blink. No distinction is made between targets and distractors at this stage.

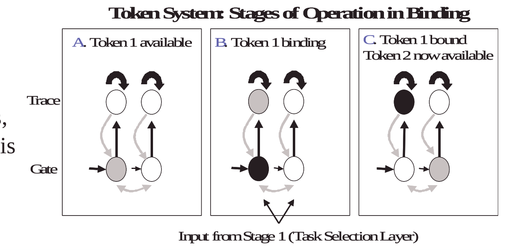
Elements of the Model (Continued)

3. Task Selection Layer: Cognitive control foregrounds targets and inhibits distractors. Self excitation allows traces to self sustain under concurrent semantic layer input. After a sufficient period of activity, a shutoff neuron unique to each neuron will strongly inhibit it for a period of several hundred milliseconds. This shutoff process is critical to reduce encoding interference.



4. Token system: Active items in the Task Selection Layer can be bound to the available token(**A**). During binding (**B**), a link is created from the active token to the active item(s). This link is used at retrieval to recall the item from working memory. After the binding link is established, the trace neuron reaches threshold, and suppresses that token, making it unvailable for further binding (**C**). The next token in the line is then freed from lateral inhibition and becomes available. During binding, new targets entering the first stage are supressed by inhibition of attentional resources (described below) and weak lateral inhibition in the Task Selection Layer.

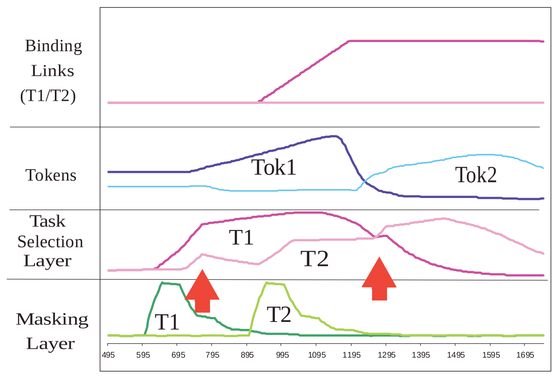
5. Generalized Transient Attentional Resource: A rapid pulse of recurrent excitation is generated by activity in the Task Selection Layer as suggested by data in Chua et al (2001). This pulse affects all items, whether or not they are active. Initiation of this pulse is strongly suppressed while a token is being bound. Thus, the duration of the tokenization process is the cause of the blink.



Blinking

Activation traces produced by the model for T1 and T2 at lag 3. The T2 trace (light pink) is not able to reach full activation during tokenzation of T1. After token 1 is completed, binding of T2 to token 2 begins, but T2 decays before the token is finished. This T2 is thereby missed.

The red arrows represent the short pulses of excitation, triggered by activity in the task selection layer.

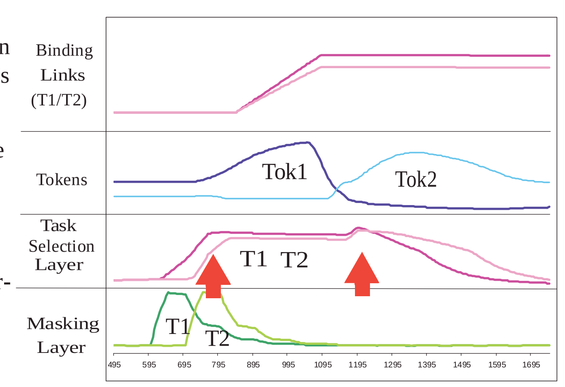


Lag-1Sparing

Lag-1 sparing occurs when T1 and T2 are close enough in time that T2 benefits from the attentional excitation and is bound into token 1.

Sparing is a **breakdown** of a system intended to produce discrete elements in working memory. In our model, a retrieval process is assumed to disambiguate these dual-bound tokens.

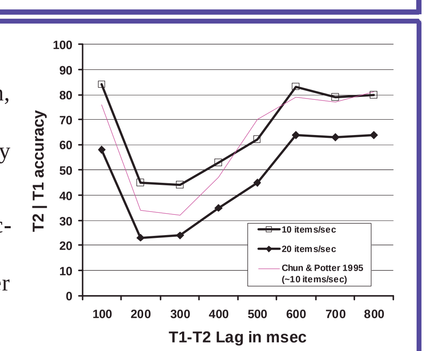
Note that T2 is also bound partially to Token 2. This partial binding is used to disambiguate the order of T1 and T2 at retrieval. At lag1, swaps occur about 30% of the time.



The Attentional Blink at 10 and 20 items/sec

When presented with a series of inputs for T1 and T2 of varying strength, the model reproduces the standard U shaped AB curve. The example used here is from Chun & Potter (1995). Data is presented as T2 accuracy conditional on successful T1 retrieval.

If the presentation rate is doubled, the blink obtained by the model is dictated by the target SOA, not the number of intervening distractors. One obtains lag-2 sparing, and recovery by lag 12. To accomodate the shorter trace duration, input strengths were increased.



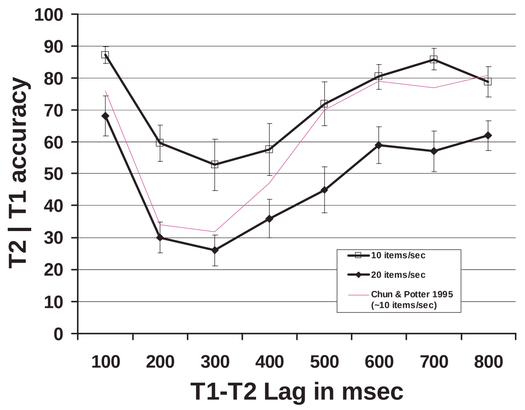
Experiment

AB Experiments were conducted on subjects at 10 and 20 item/sec rates. The paradigm was similar to that of Chun and Potter (1995). Methods are described below.

Results

In the 10 item/sec condition results generally replicated those of Chun & Potter. In accordance with the model, doubling presentation rate left the shape of the curve unchanged with respect to time and there was a general decrease in baseline performance. Data were collected for even numbered lags (2, 4, etc) in the 20 items/sec condition. Error bars indicate standard error.

Order inversions of T1 and T2 were also highly similar at the same time at 25% and 28% at lag 1 and lag 2 of the slow and fast presentation rates respectively.



Discussion

- Our work involves invokes a computational implementation of a Two-Stage model of visual attention similar to that described in Chun and Potter(1995)
- Distractors and targets are processed to a semantic level even during the blink, fitting the data concerning the N400 (Vogel et al 1998), the breakthrough of emotional words (Anderson and Phelps 2001) and distractors priming targets (Chua et al 2001).
- In this model, the temporal dynamics of token binding and general attentional enhancement determine the shape and size of the blink.
- These dynamics are determined by parameter fitting of various data sets, including the effect of T1+1 blanks and T2 as end of stream manipulations. The model also fits data for T1 performance impairments and temporal order inversions at lag 1.
- Sparing in this model is a function of the T1 and T2 occuring closely enough that both receive the benefit of the attentional transient and are bound to the same token.
- Task demand prevents distractors from reaching the token layer.
- Thus, this model predicts that lag-2 sparing will be obtained at double the conventional presentation rate (20 items/sec).
- Empirical data confirms this prediction
- In theory this model predicts lag-10 sparing at 100 items/sec, but in practice the strong masking effects of a 10 msec SOA make this unlikely.

References

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Methods

All experiments were conducted with MATLAB R13 using the Psychophysics toolbox (www.psychtoolbox.org) on a Windows 2000 platform. Targets were capital letters excluding I, M, O, Q, S, W, X, Y, and Z in 180 point HE Terminal font. Distractors were single digits excluding 1 and 0. The stream was presented in black on a white background centered on a 17" monitor with a viewing distance of approximately 10-15 " and preceded by a fixation cross for 400 msec. 14 subjects were used in the slow (10/item sec) condition and 10 were used in the fast (14/item sec) condition. All subjects had normal or corrected version and were between 18 and 45 years of age.

Slow streams were 18 items in length presented at 92 msec SOA with no gaps between items. Streams were presented in 2 blocks of 158 trials, 14 were 1 target lures, and the rest in a two factor 8 x 3 arrangement with 6 repetitions. The first factor were the lags 1-8, and the second included standard streams, and T1+1 blank and T2+1 blank conditions (data for the latter two conditions were not considered in this report).

Fast streams were 40 items in length, presented at 53 msec SOA with no gaps between items. Streams were presented in 2 blocks of 106 trials, of which 10 were 1-target lures and the rest divided among 8 lag conditions (2,4,6,8,12,14,16).