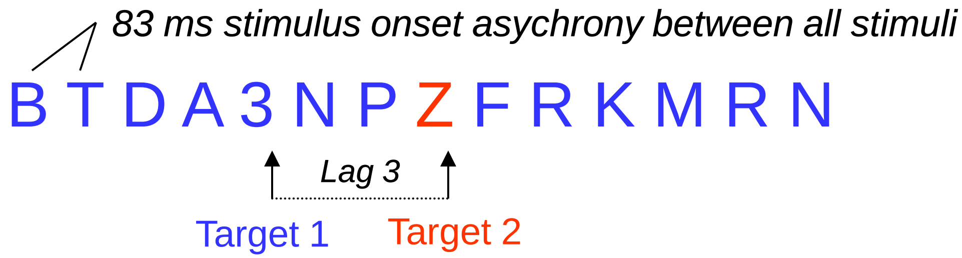
Attentional Blink Paradigm

ATTENTIONAL BLINK



After detection of a target in a rapid stream of visual stimuli there is a period of 300-600 ms during which subsequent targets are missed.

Use ERPs to delineate which processing stage(s) are affected by the Attentional Blink (AB).

Vogel and Luck (1998): Experiment 1

Aim: Test the hypothesis that the attentional blink reflects a suppression of sensory processing.

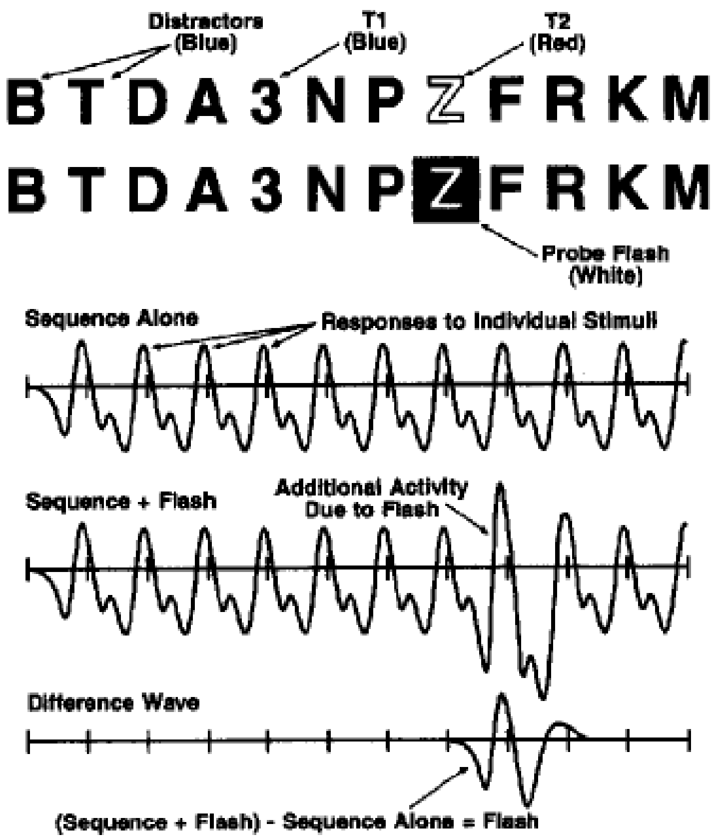
Dependent measure: P1 and N1 components

These early visual components reflect sensory processes and are primarily sensitive to the physical characteristics of the eliciting stimulus, such as brightness, and are also sensitive to visuospatial selective attention.

Hypothesis: If attentional mechanisms are responsible for attentional blink, expect smaller P1 and N1 waves for stimuli during attentional blink period than outside of it.

Vogel and Luck (1998): Experiment 1

Need to modify AB paradigm for ERP methodology to overcome difficulties due to overlap of ERPs to individual items in the RSVP stream – i.e., to isolate ERP for stimulus of interest.



Used **irrelevant probe flash** technique

Task-irrelevant white square flashed behind T2 was used as a measure of sensory processing at the time of T2.
ERP to 50% of trials without probe flash was subtracted from 50% of trials with a probe flash.

19 letters and one digit per stream
88 ms/character (33 ms duration)
2 targets
 - T1: blue digit (w/ blue nontarget letters)
 - T2: red letter, at lag 1, 3, or 7 after T1

T1 even or odd?
T2 vowel or consonant?
On dual task both decisions, on single only T2

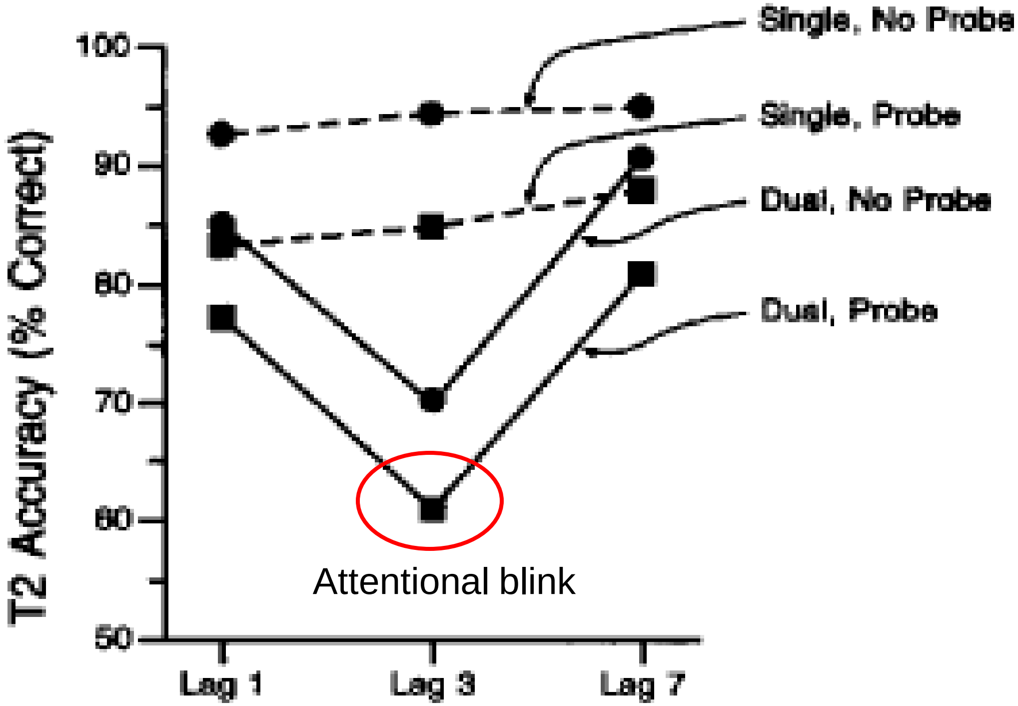
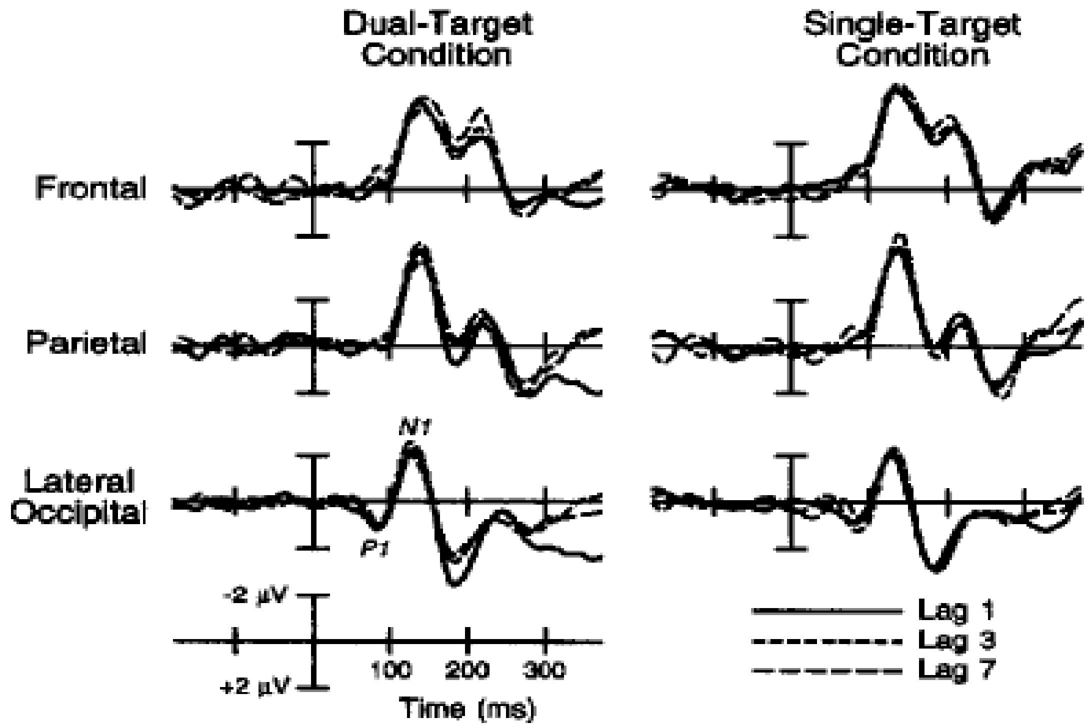


Figure 3. Mean accuracy for identifying the second target (T2) letter in Experiment 1 as a function of lag and probe presence.



P1 and N1 amplitudes to the probe flash (that appeared concurrently with T2) were the same at all lags. ***Thus, it seems that there was no suppression of the P1 and N1 components during the attentional blink***.

This is consistent with the hypothesis that the attentional blink does not reflect the suppression of information at a perceptual stage, and is post-perceptual.

Vogel and Luck (1998): Experiment 3

Aim: To provide an upper bound on the stage of processing at which processing is impaired during the attentional blink.

Dependent Measure: centro-parietal P3b component that is sensitive to perceptual manipulation, elicited by stimuli that have reached the level of working memory.

Hypothesis: If P3 is elicited during attentional blink, then AB occurs after information reaches working memory. If P3 is suppressed during attentional blink then AB occurs at or before the stage of encoding into working memory – i.e., working memory updating.

Vogel and Luck (1998): Experiment 3

19 letters and one digit per stream
88 ms/character (33 ms duration)
2 targets
- T1: black digit (w/ black nontarget letters)
  even or odd?
- T2: white, at lag 1, 3, or 7 after T1
  - letter E on 15% trials, respond
  - not E on 85% trials, no response

Single target condition: respond only to T2
Dual target condition: respond to T1 and T2

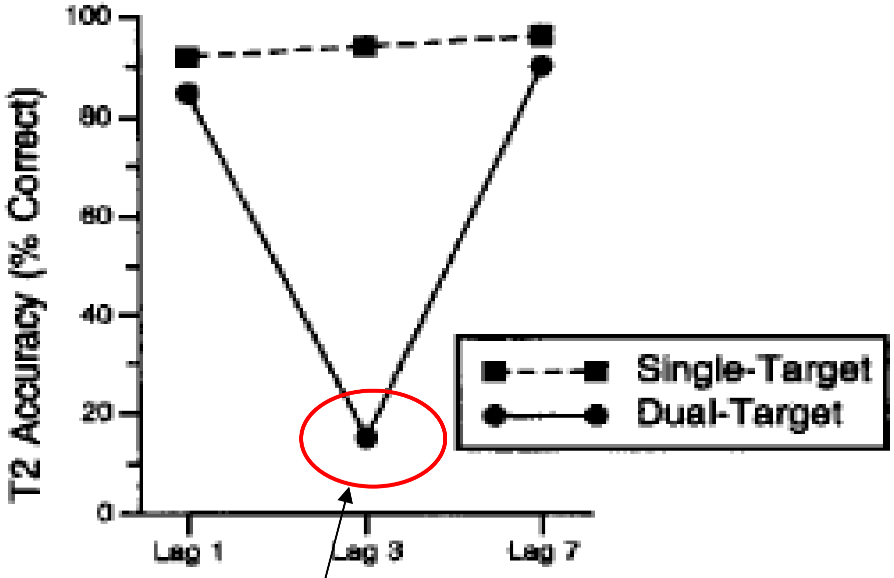


Figure 8. Mean discrimination accuracy for the second target (T2) as a function of lag for the single- and dual-target conditions in Experiment 4.

Attentional Blink

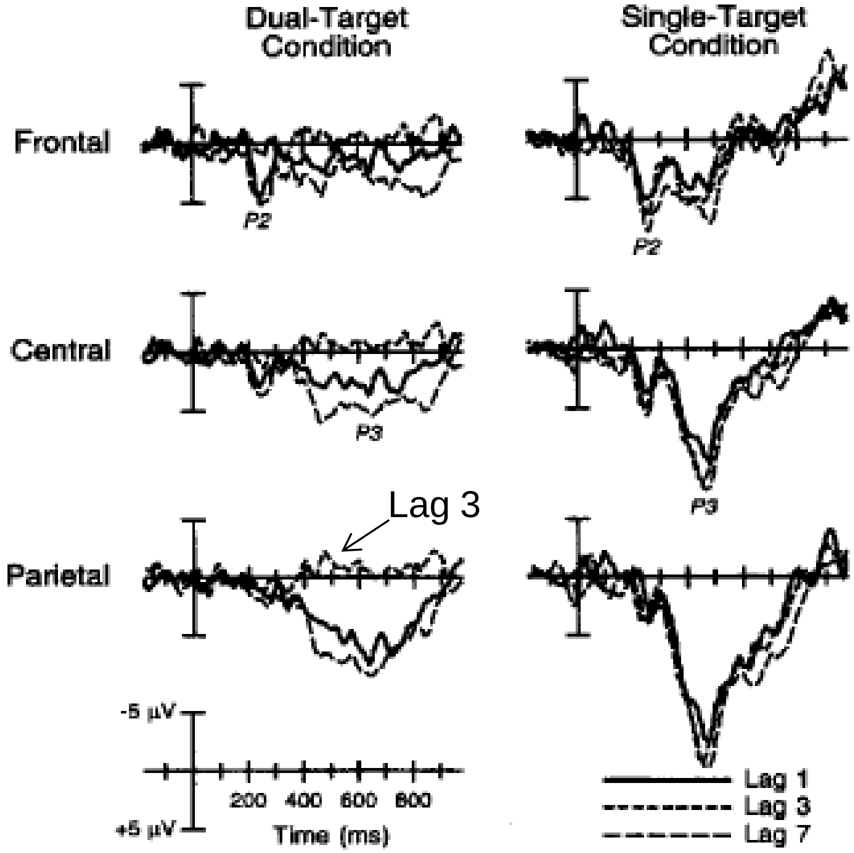


Figure 9. Grand average event-related potential difference waveforms from Experiment 4, formed by subtracting trials with the frequent second target (T2) stimulus from trials with the rare T2 stimulus. These waveforms were recorded at midline electrode sites and were averaged across participants. Negative is plotted upward.

Effect of lag on P3 in single target condition?

Effect of lag on P3 in dual target condition?

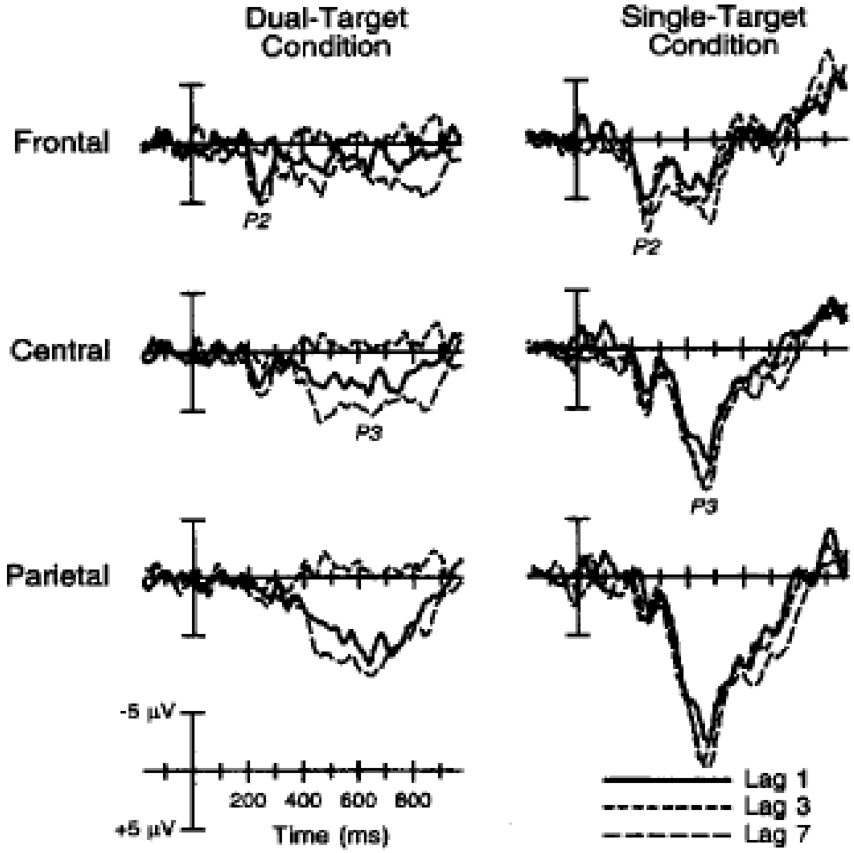


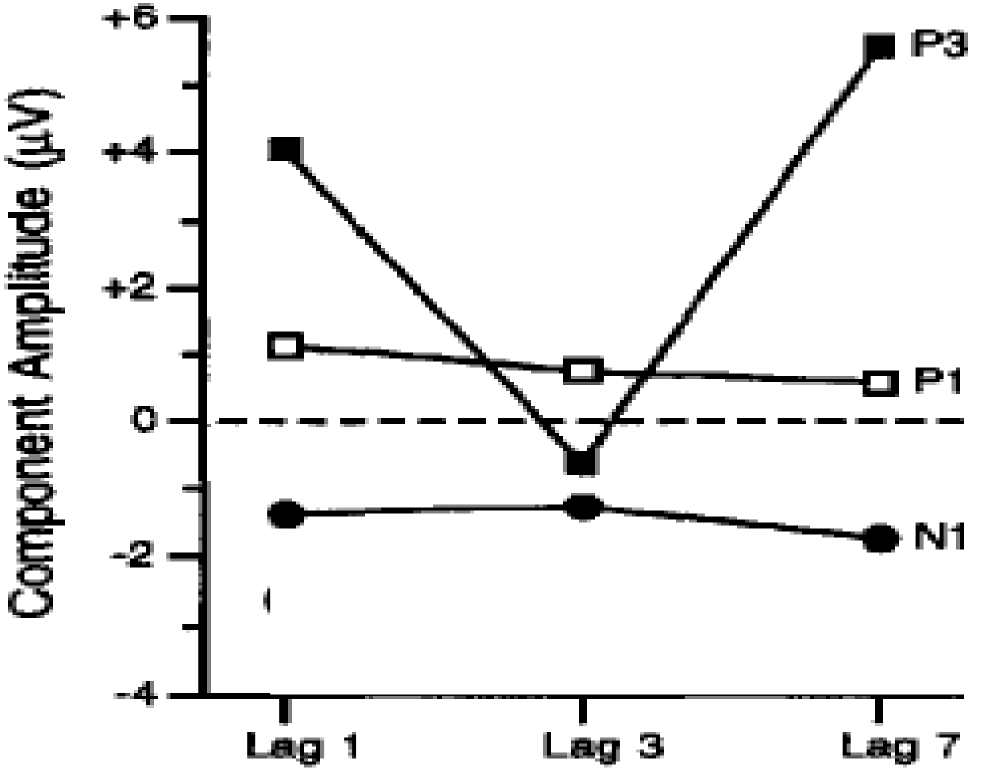
Figure 9. Grand average event-related potential difference waveforms from Experiment 4, formed by subtracting trials with the frequent second target (T2) stimulus from trials with the rare T2 stimulus. These waveforms were recorded at midline electrode sites and were averaged across participants. Negative is plotted upward.

P3 amplitude unaffected by lag in single target condition

P3 suppressed in dual target condition at lag 3 (i.e., within AB)

Thus, attentional blink operates before or during the process of forming a stable representation of the stimulus in working memory.

Summary: ERP components and attentional blink



Attentional blink operates at post-perceptual stages, but before or during the consolidation into working memory

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Delayed working memory consolidation during the attentional blink

EDWARD K. VOGEL and STEVEN J. LUCK
University of Iowa, Iowa City, Iowa

After the detection of a target (T1) in a rapid stream of visual stimuli, there is a period of 400–600 msec during which a subsequent target (T2) is missed. This impairment in performance has been labeled the *attentional blink*. Recent theories propose that the attentional blink reflects a bottleneck in working memory consolidation such that T2 cannot be consolidated until after T1 is consolidated, and T2 is therefore masked by subsequent stimuli if it is presented while T1 is being consolidated. In support of this explanation, Giesbrecht & Di Lollo (1998) found that when T2 is the final item in the stimulus stream, no attentional blink is observed, because there are no subsequent stimuli that might mask T2. To provide a direct test of this explanation of the attentional blink, in the present study we used the P3 component of the event-related potential waveform to track the processing of T2. When T2 was followed by a masking item, we found that the P3 wave was completely suppressed during the attentional blink period, indicating that T2 was not consolidated in working memory. When T2 was the last item in the stimulus stream, however, we found that the P3 wave was delayed but not suppressed, indicating that T2 consolidation was not eliminated but simply delayed. These results are consistent with a fundamental limit on the consolidation of information in working memory.

T2 cannot be consolidated until after T1 is consolidated, so if T2 comes while T1 is being consolidated then it must wait for consolidation; as a consequence, it is masked by any subsequent stimuli in stream.

Vogel and Luck (2002)

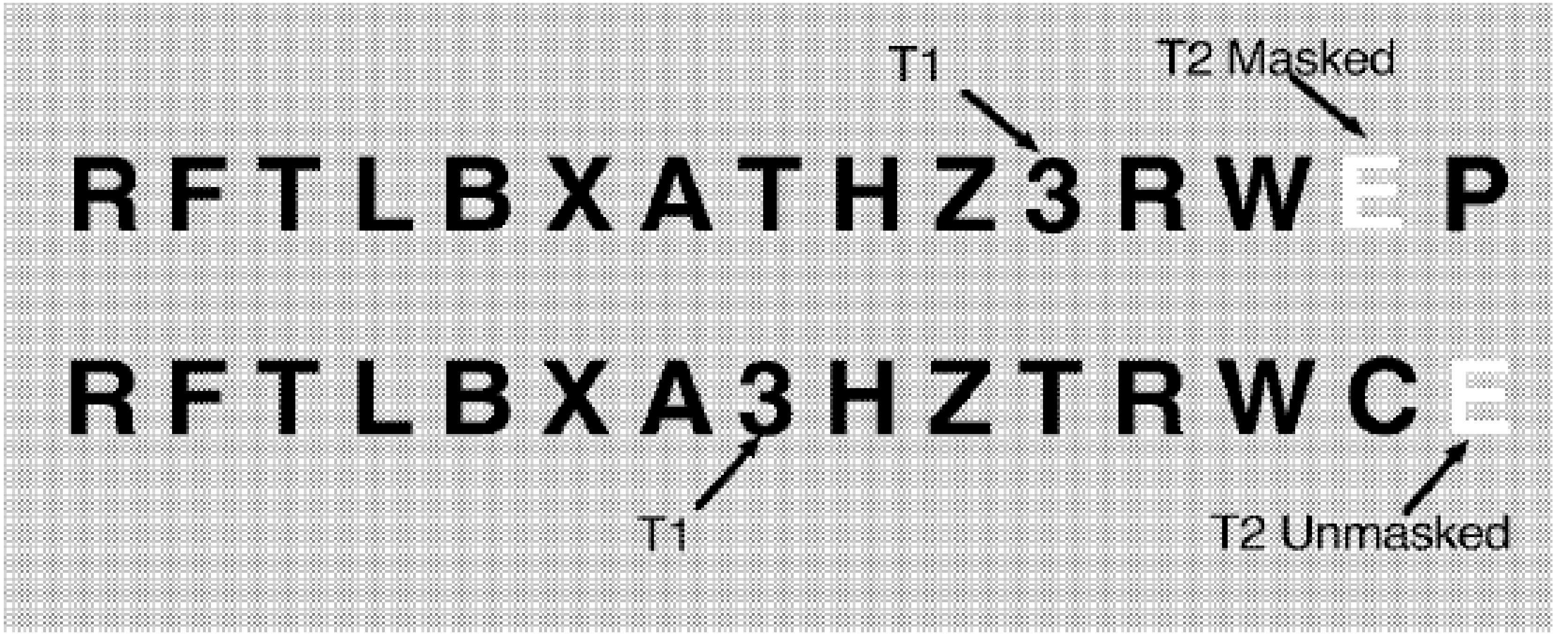


Figure 1. Sequences of stimuli presented serially at fixation. The upper row displays a lag 3 masked trial. The lower row displays a lag 7 unmasked trial.

Vogel and Luck (2002)

TASK: Report two target items.
First target was a number.
The second target was either the letter E (25%) or some other letter (75%). Subjects reported whether the second target was an E or not.

Why use low probability target? The P3 will be larger for the infrequent E stimuli. Difference between target and non-target trials will yield a large – measurable -- P3 difference wave.

T2 appeared either as 3rd item after T1, or 7th item after T1

- T2 was either followed by one other item (masked)
- or, it was not followed by any other items (not masked)

Vogel and Luck (2002)

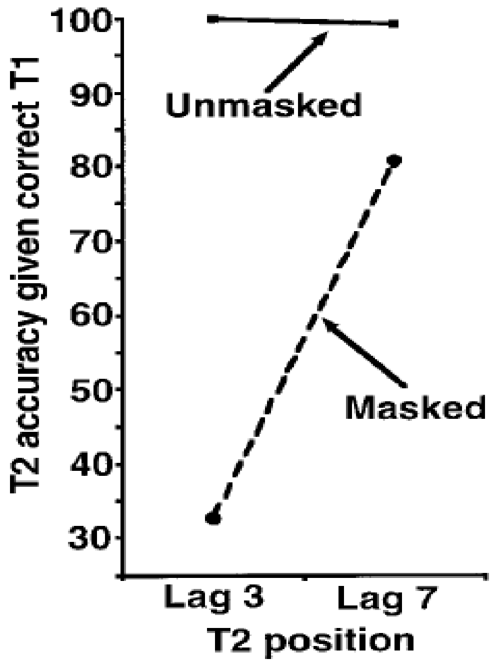


Figure 2. Accuracy for the second target (T2) as a function of lag for the masked and unmasked conditions.

Effect of lag on accuracy of T2 report when T2 is not masked?

Effect of lag on accuracy of T2 report when T2 masked?

Vogel and Luck (2002)

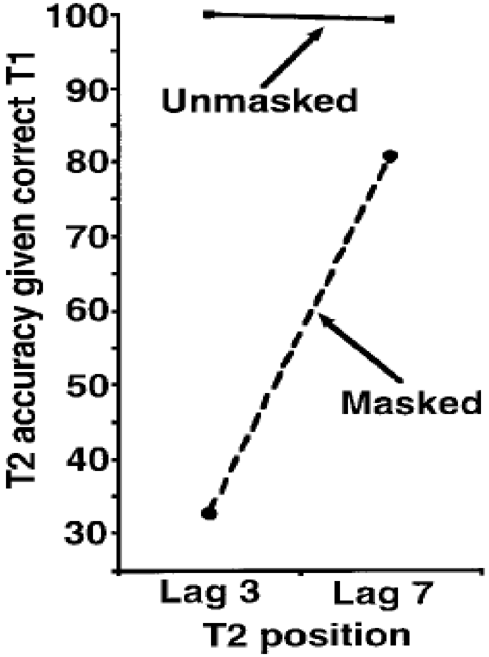


Figure 2. Accuracy for the second target (T2) as a function of lag for the masked and unmasked conditions.

In masked condition, accuracy of T2 report was poor at lag 3 and good at lag 7.
In unmasked condition, accuracy of T2 report was quite good at lag 3 and lag 7.

Vogel and Luck (2002)

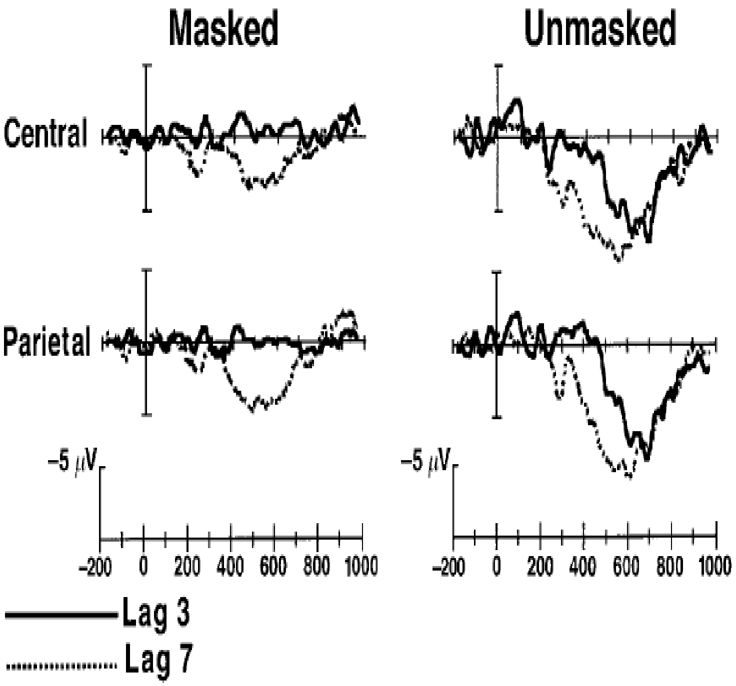


Figure 3. Grand average difference waveforms (infrequent T2 minus frequent T2) for two electrode sites (Cz and Pz) for each of the conditions. Note that negative voltage is plotted upward.

Effect of lag on P3 amplitude when T2 masked?

Effect of lag on P3 amplitude and latency when T2 is not masked?

Vogel and Luck (2002)

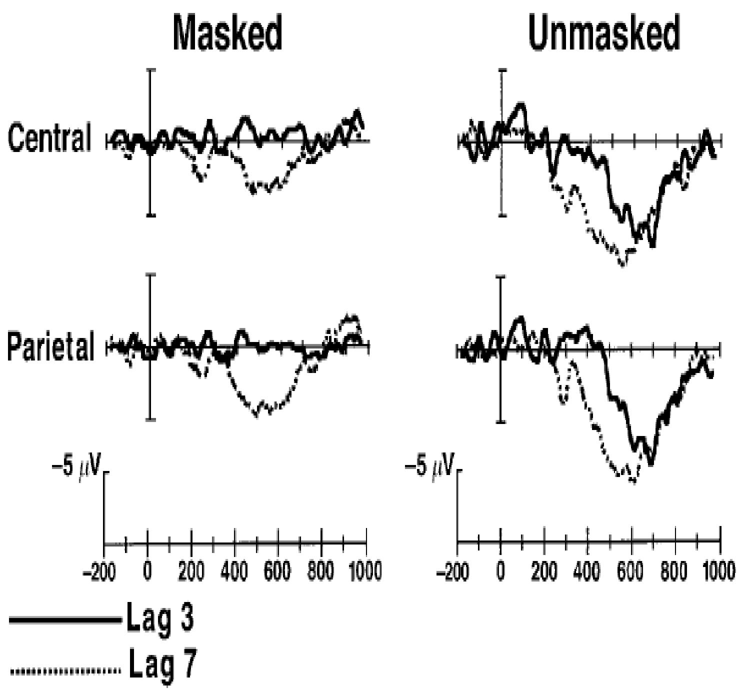


Figure 3. Grand average difference waveforms (infrequent T2 minus frequent T2) for two electrode sites (Cz and Pz) for each of the conditions. Note that negative voltage is plotted upward.

In the masked condition, no P3 at lag 3, and large P3 at lag 7.
In the unmasked condition, large P3 seen for lag 3 and lag 7, however the P300 at lag 3 is substantially delayed in latency.

Vogel and Luck (2002)

These results are consistent with ***two-stage model*** of the attentional blink.

The absence of a P3 to T2 at short lags under masked conditions suggests that it is overwritten by a subsequent stimulus before it can consolidated into working memory (as this process takes time). We can see this in the delay of the P3 to T2 at short lags under the unmasked condition – where there is a P3 indicating that the stimulus is consolidated in WM, but this process happens later when the system is still processing a recent stimulus.

The pattern of results is inconsistent with ***interference model*** according to which T2 suppression results from a confusion between T1 and the +1 stimulus

“The main difference between these models is that the two-stage model proposes that there is a specific process that cannot be applied to T2 during the attentional blink and that T2 consequently fails to reach working memory, whereas the interference model proposes that T1 and T2 both enter working memory but that T2 is lost because of interference caused by T1 (Vogel and Luck, 1998).

RESEARCH PROPOSAL

Introduction

- what's the general issue/specific question being addressed
  can be a new question or a variant on an existing study
- provided relevant background to set up the problem
- why ERPs are good dependent measure in general and
  more specifically why for the particular measure/paradigm that
  you propose.

Methods

- what is experimental design? What are you going to do to address the question?

Results & Discussion of Possible Outcomes

- what are some of the possible expected outcomes? e.g., if the pattern of results comes out exactly as you hypothesize (anticipate) what would that pattern be, and what would you infer from it about your hypothesis? What alternative outcomes might there be and what would they mean? You needn't describe all possible outcomes but at least two or three possibilities.

MEMORY

Many different ways of thinking about memory…

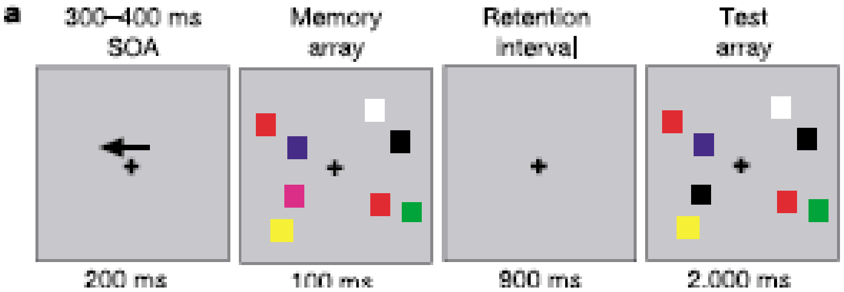
e.g., How long it lasts

- ***sensory memory*** (echoic, iconic) – seconds
  MMN

- ***working memory/short term memory*** – seconds to minutes
  memory search paradigms w/ slow waves, P3b latency,

- ***long term memory*** – years, perhaps forever?
  semantic – general knowledge (context independent)
  episodic – specific episodes (context dependent, what, where, with whom)
  Dm, ERP repetition effects, P3b, various ERP old-new effects, slow potentials

VISUAL SHORT TERM MEMORY



Task: remember items in one or other hemi-field, as indicated by arrow cue. 900 ms later (retention interval), indicate whether test array is identical or differs in one color element.

Vogel lab

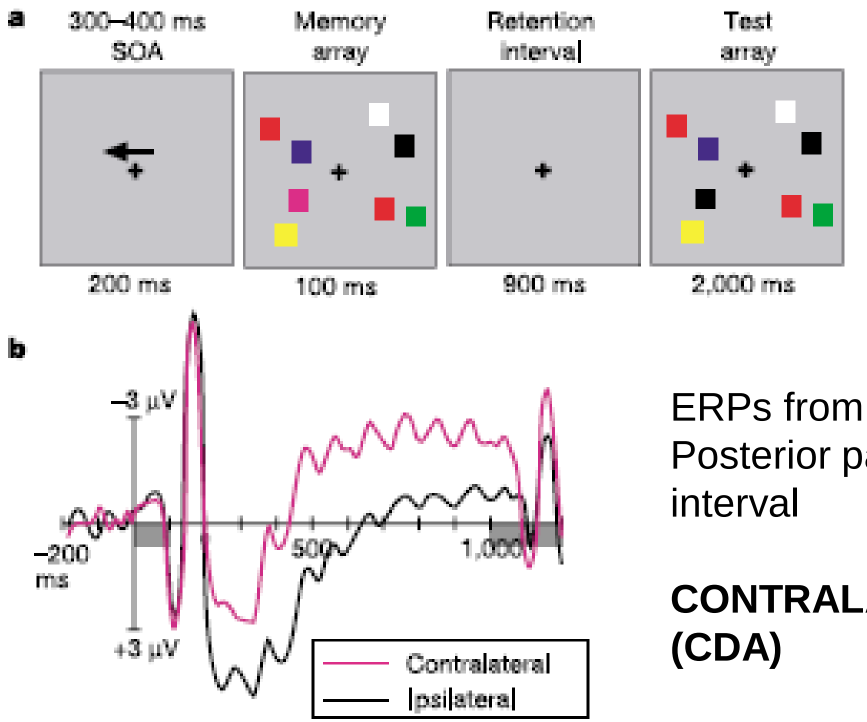
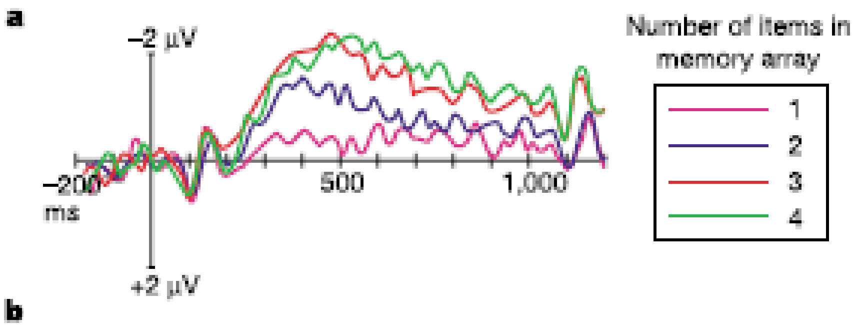


Figure 1 Stimuli and results from experiment one. a, Example of a visual memory trial for the left hemifield. SOA, stimulus onset asynchrony. **b**, Grand averaged ERP waveforms time-locked to the memory array averaged across the lateral occipital and posterior parietal electrode sites in experiment one. The two grey rectangles reflect the time periods for the memory and test arrays, respectively. Note that, by convention, negative voltage is plotted upwards.

ERPs from Lateral occipital/ Posterior parietal sites during retention interval

CONTRALATERAL DELAY ACTIVITY (CDA)

There is a negativity during the retention interval larger contralateral to the remembered visual field. What does ERP effect reflect: Maintenance of Object representations from memory array? Executive processes? Effort?



Result: amplitude of negativity varies with number of items in the array.

Hypothesis/explanation: maintenance of object representation or difficulty/arousal?

Manipulate number of items in array: how many should there be???

Potential outcomes:

If CDA negativity reflects maintenance of object representation

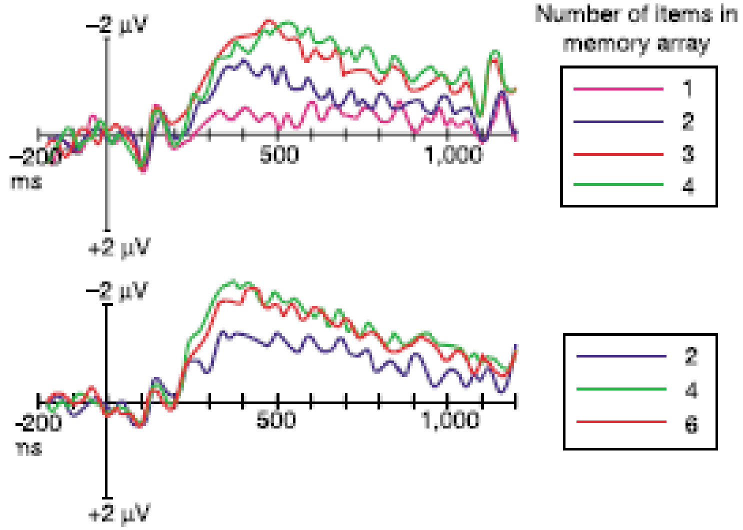
If CDA negativity reflects difficulty

Manipulate number of items in array: how many should there be???

Potential outcomes:

If CDA negativity reflects maintenance of object representation (assuming capacity limited system: 8=6, but then 4>3>2>1)

If CDA negativity reflects difficulty: 8> 6>4>2>1 a



−2 μV
+2 μV
−200 ms
500
1,000
Number of items in memory array
1
2
3
4
−2 μV
+2 μV
-200 ms
500
1,000
2
4
6

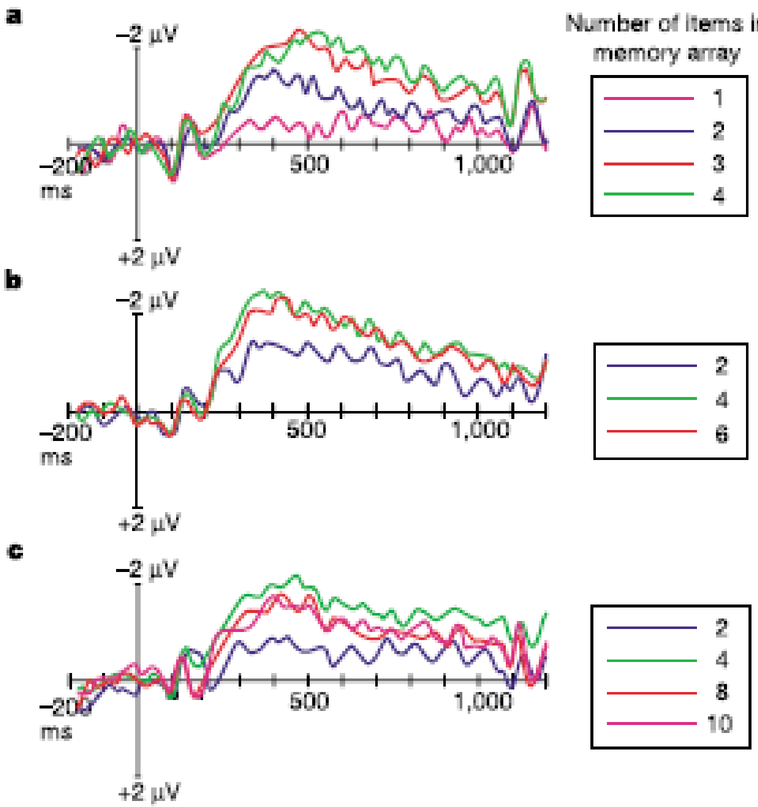
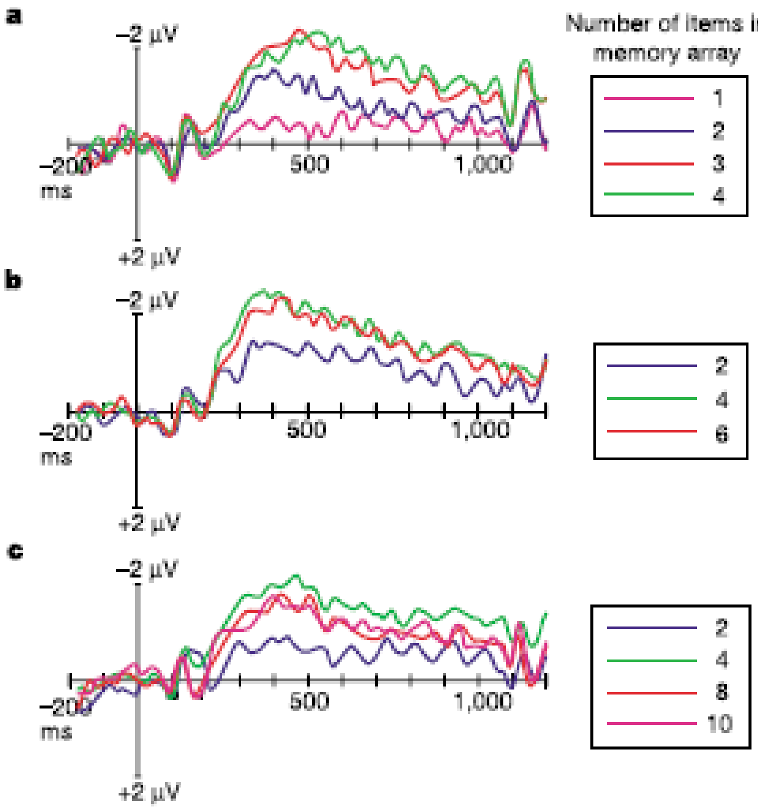


Figure 2 ERP difference waves at lateral occipital and posterior parietal electrode sites for experiments two, three and four, respectively. **a**, Pairwise comparisons yielded significant differences in amplitude between array sizes of one, two and three ($P < 0.001$), but no difference between three and four items ($P > 0.20$) in experiment two. **b**, **c**, No significant differences in amplitude were observed between arrays of four, six, eight or ten items ($P > 0.25$ in all cases) in experiments three and four.



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Contralateral ERP activity (CDA) during retention interval reflects maintenance of representations in visual memory i.e., the currently active representations maintained in visual working memory!

correlation between negativity increase in memory set size from 2 to 4 and memory capacity

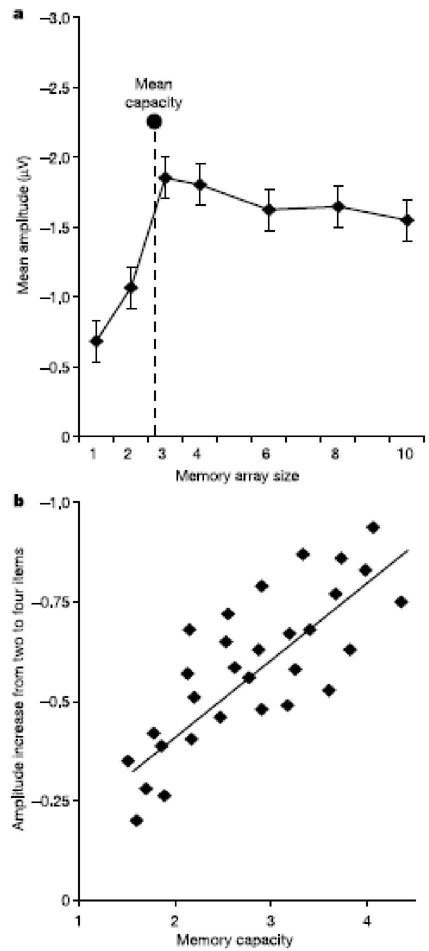


Figure 3 Mean amplitude and visual memory capacity. **a**, Mean amplitude and visual memory capacity across experiments two, three and four. Error bars reflect 95% confidence intervals. **b**, The correlation between an individual subject's memory capacity and the increase in amplitude of delay activity between two- and four-item arrays.

These data offer an ERP predictor of visual memory capacity!

Many different ways of thinking about memory…

Encoding – how information gets placed into and stored in memory

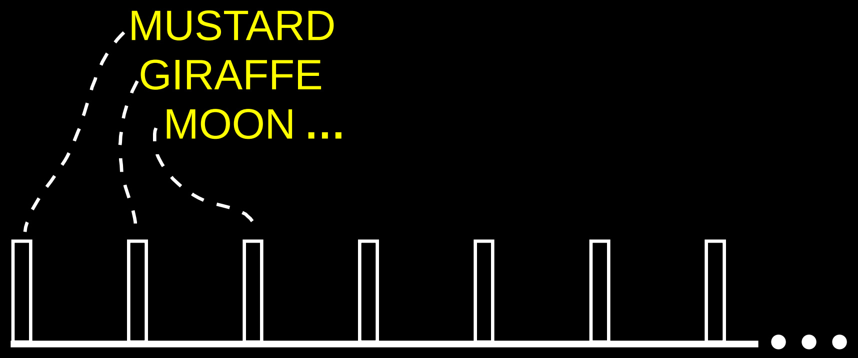
Retrieval – how information is accessed/retrieved from memory

- **Explicit** – conscious recollection
- **Implicit** – facilitation derived from prior exposure without conscious recollection
  e.g., priming

A major advantage of ERP approach is that it allows us to look at processes and time course of processes during encoding. This contrasts with behavioral studies which manipulate encoding and infer consequences from differences in performance.

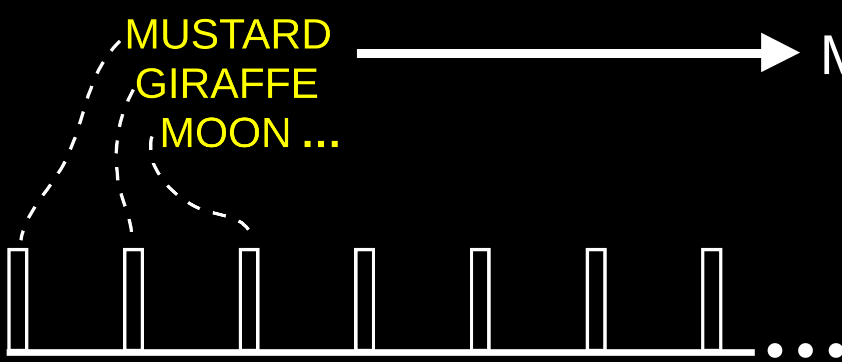
Neural Measures of Memory Formation

Learning



Neural Measures of Memory Formation

Learning



Remembering

Memory test
for events

Neural Measures of Memory Formation

Learning

MUSTARD
GIRAFFE
MOON ...

Remembering

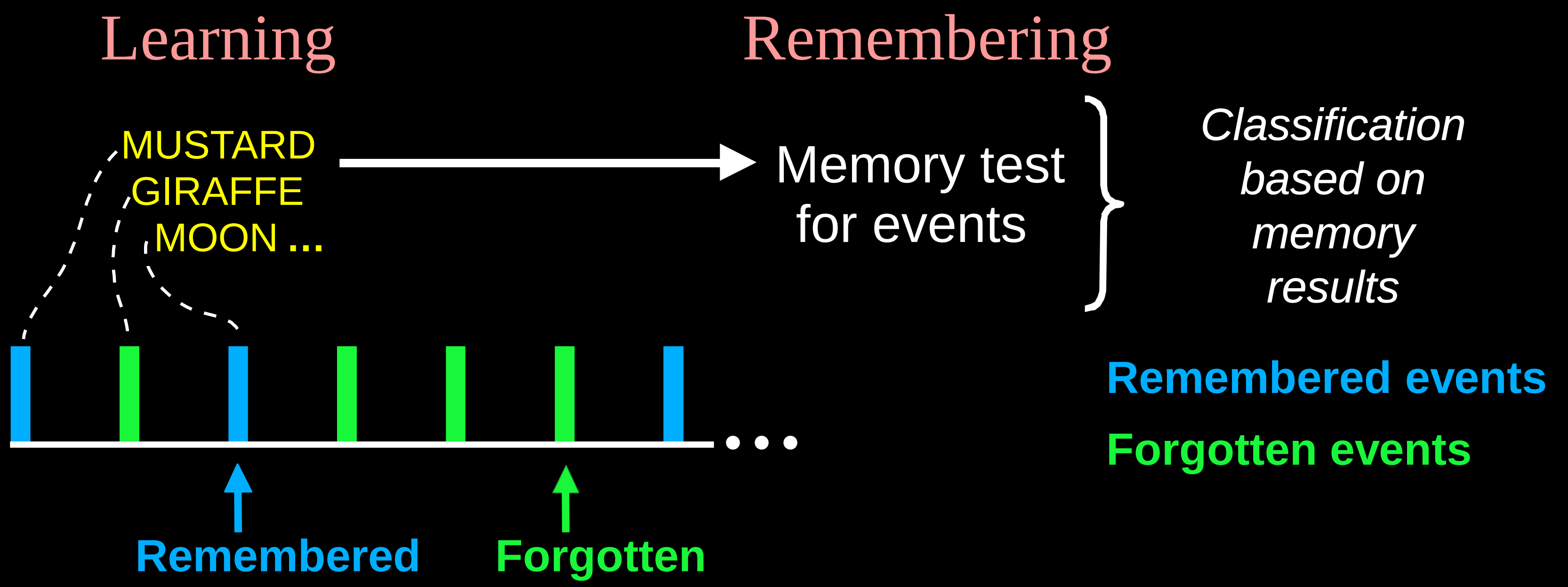
Memory test for events

Classification based on memory results

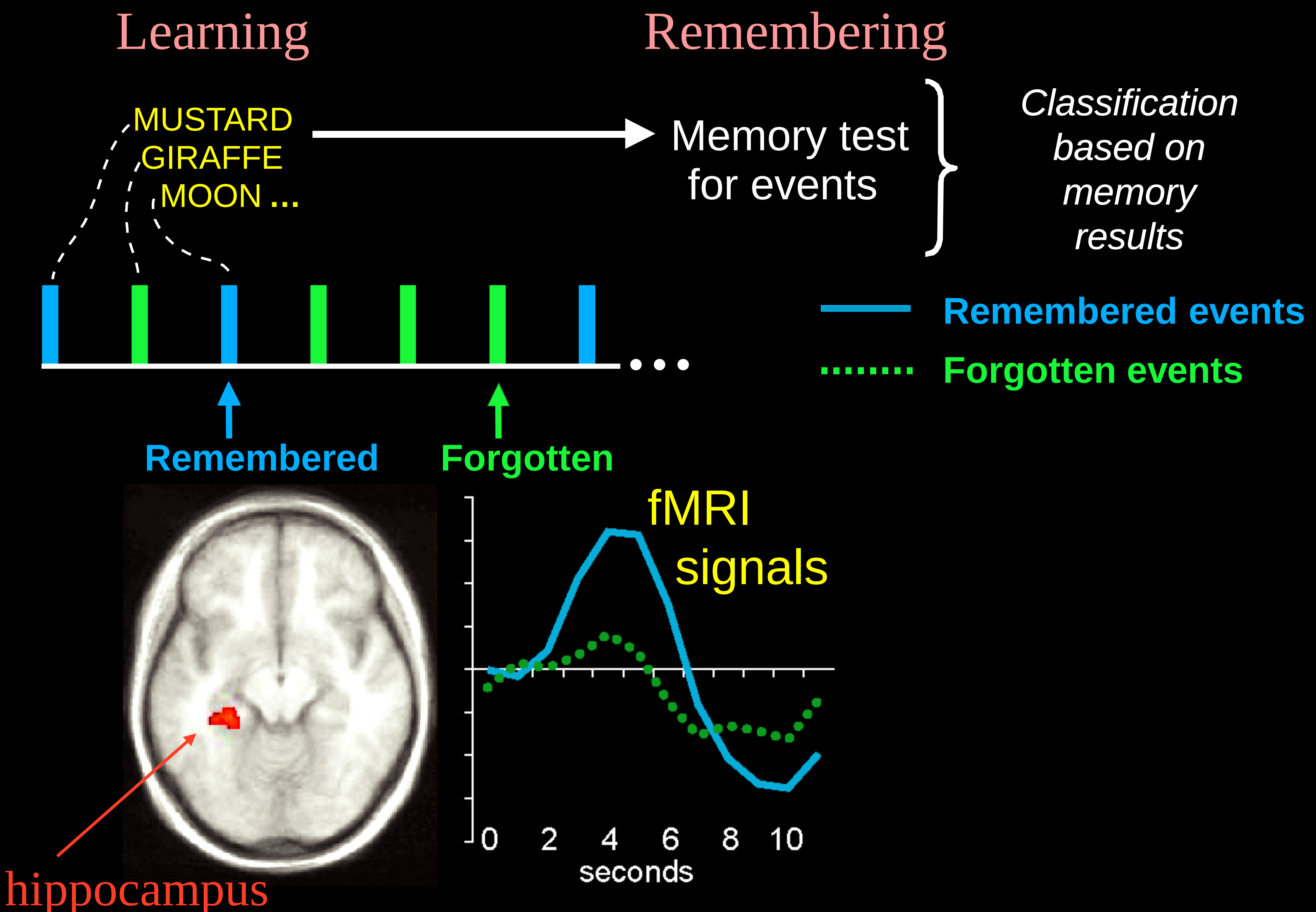
Remembered events

Forgotten events

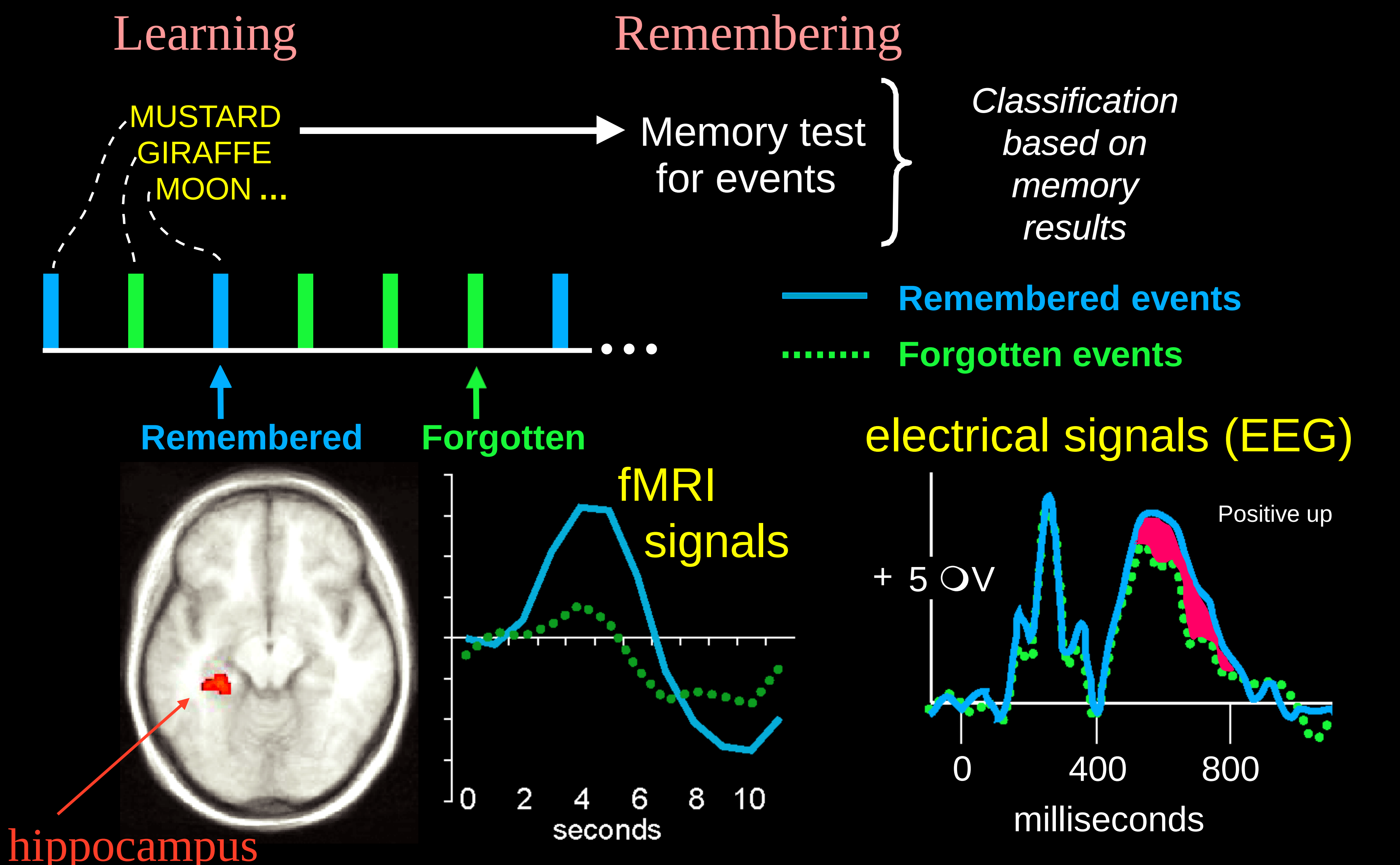
Neural Measures of Memory Formation



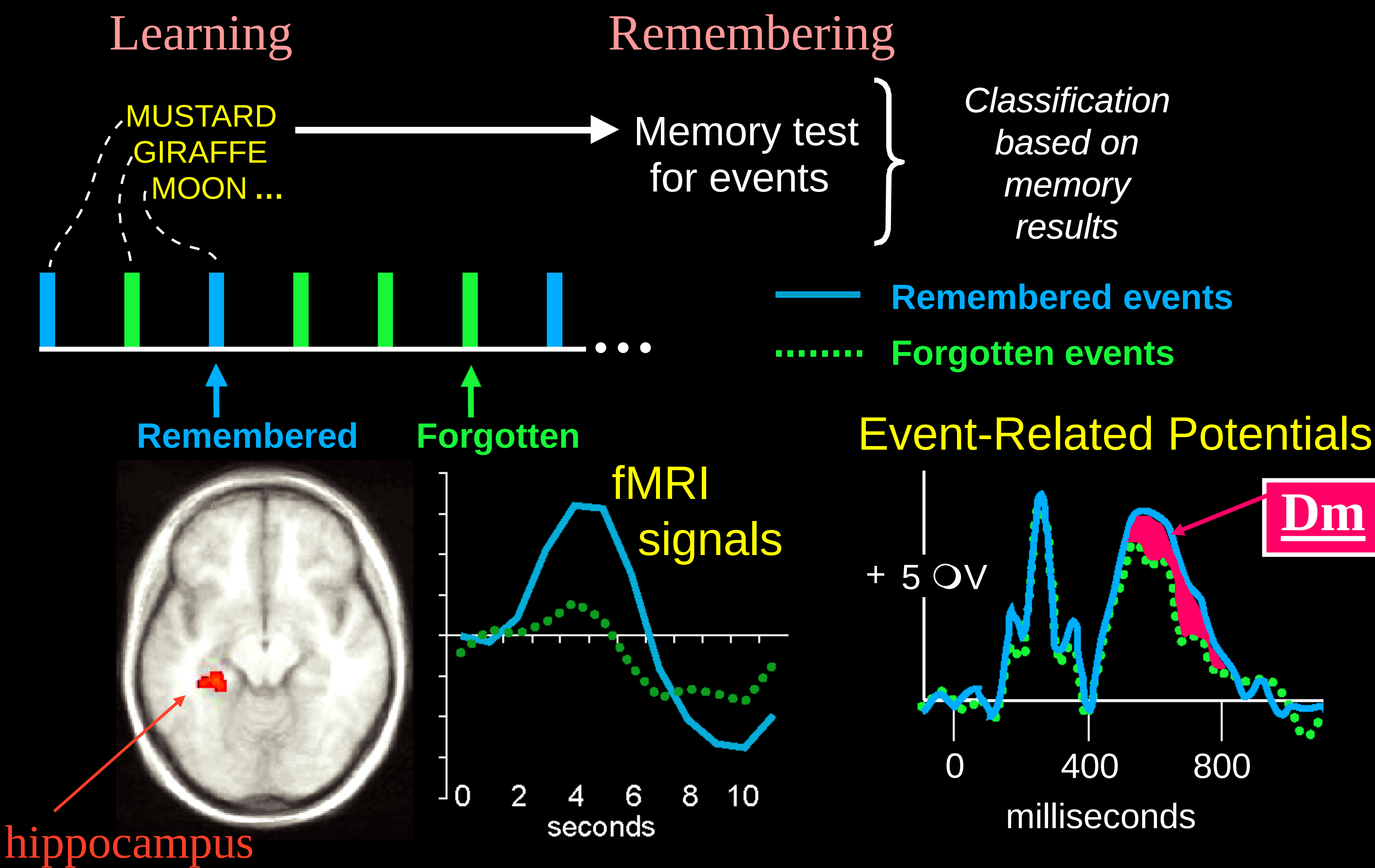
Neural Measures of Memory Formation



Neural Measures of Memory Formation



Neural Measures of *D*ifferential *m*emory encoding (*Dm*)



Dm is difference due to memory or different in subsequent memory

Dm is a difference ERP calculated for ERPs during encoding (i.e., at study, upon initial exposure)

Dm = (ERPto item subsequently remembered – ERP to item subsequently forgotten)

Positive up

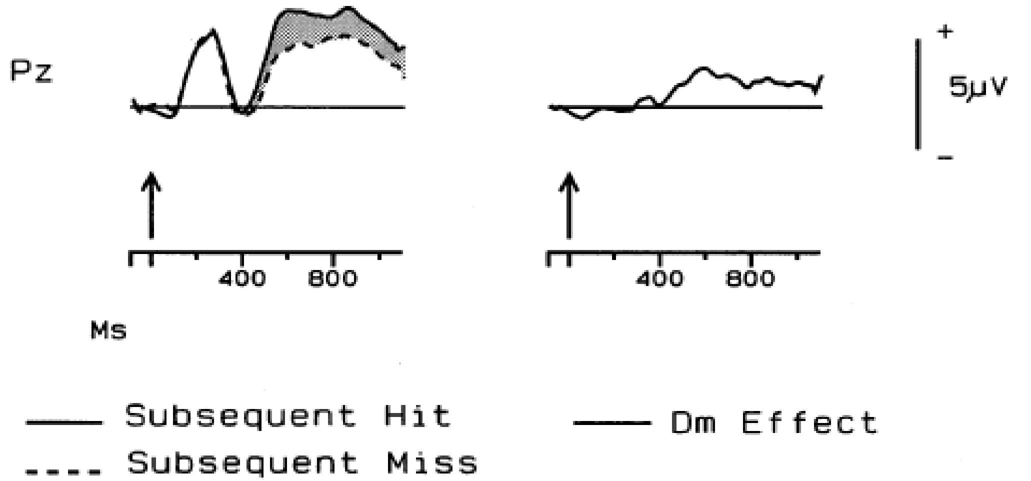


Fig. 1. Grand mean ERPs elicited by words during a study phase averaged according to whether they were subsequently correctly recognized (i.e. hit) or not recognized (i.e. miss) during the subsequent test phase. Shading between the waveforms indicates the Dm or subsequent memory effect. The difference waveform (subsequently hit-subsequently missed) is depicted to the right of the unsubtracted waveforms. Arrows mark stimulus onset, with time lines every 200 ms.

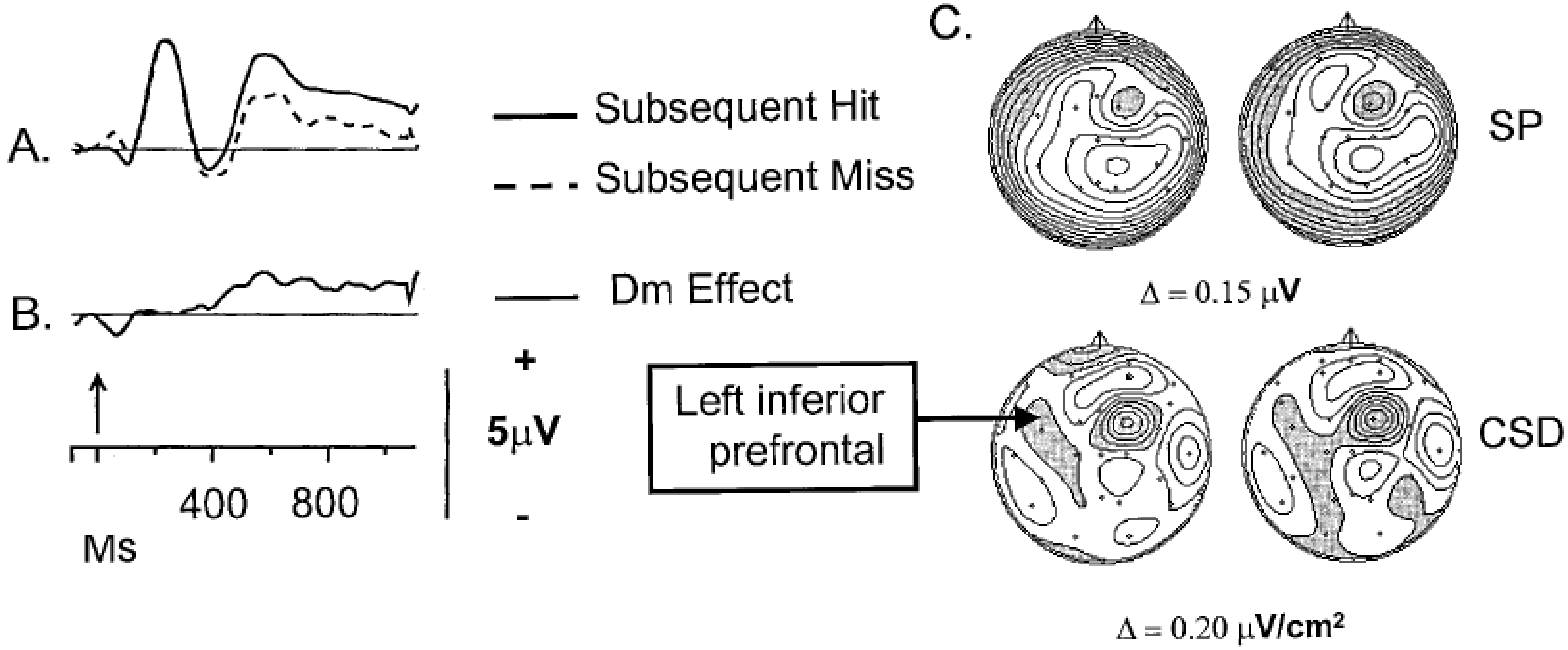


Fig. 2. **A:** Grand mean ERPs elicited by study items that were (Hit) or were not (Miss) subsequently recognized. **B:** Grand mean Dm effect, i.e., difference waveform obtained by subtracting the subsequent miss waveform in A from the subsequent Hit waveform in A. **C:** Voltage or Surface Potential (SP; first row) and current source density (CSD; second row) maps for two measurement windows (500–800; 810–1,100 ms) for the ERP data depicted in B. Data in A and B recorded at a left inferior prefrontal scalp site.

ALL OLD
Remember – retrieval based on recollective experience, context
Know – retrieval without recollective experience
Miss - forgotten

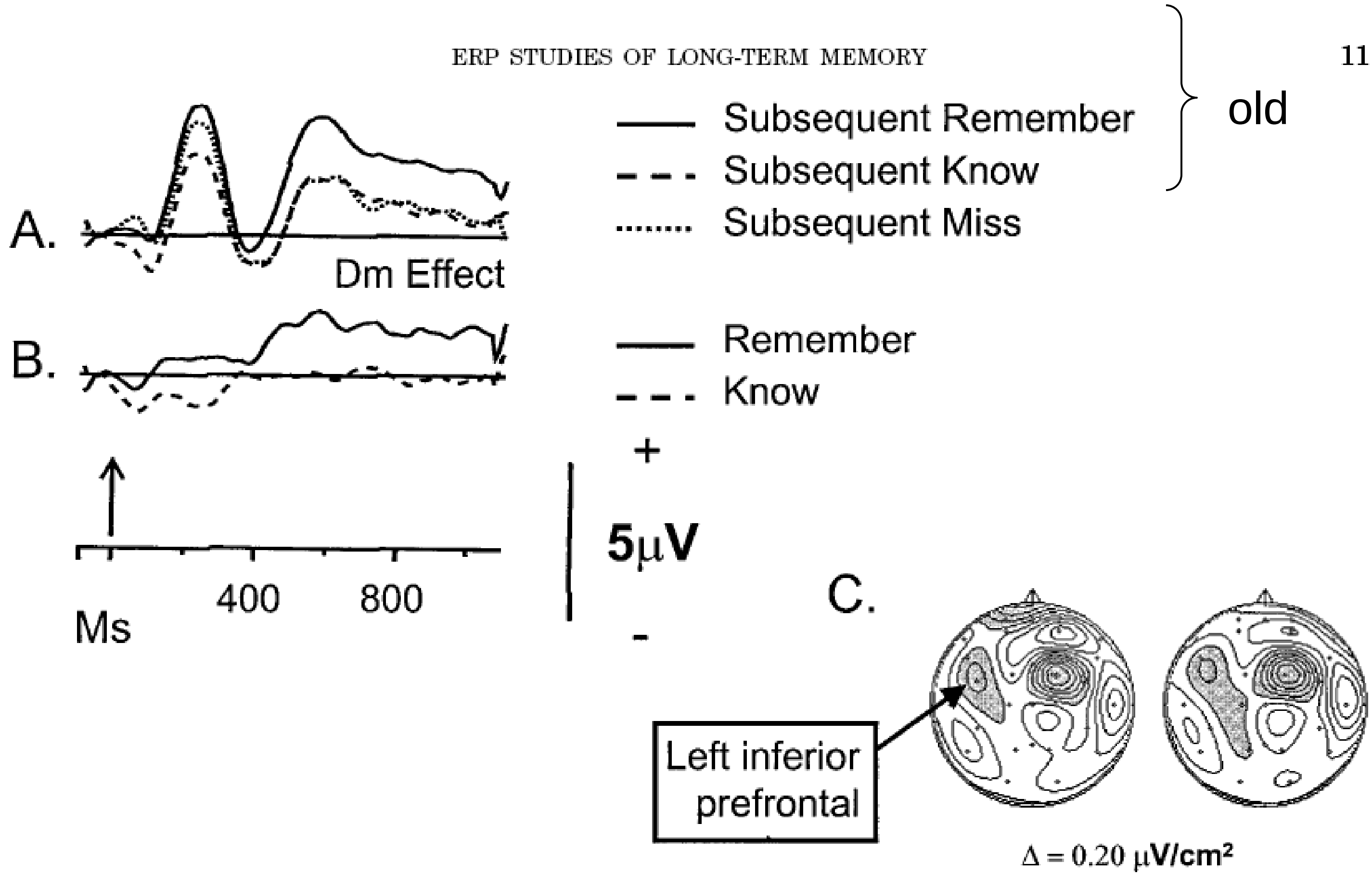


Fig. 3. **A:** Grand mean ERPs elicited by study items that were subsequently associated with remember or know judgments (hits) or were unrecognized (misses) during the subsequent recognition test. **B:** Grand mean difference waveforms computed by subtracting the ERPs to study items subsequently missed from those that were subsequently associated with either a remember or know judgment (Modified from Friedman and Trott, 2000). **C:** CSD maps for 2 intervals (500–800; 810–1,100 ms) measured in the Dm waveform associated with a subsequent Remember judgment. Data in A and B recorded at a left inferior prefrontal scalp site.

Largest DM for most "deeply" encoded items.