P3b latency and stimulus evaluation time

Varies with difficulty of categorization task

Is correlated with but dissociable from reaction times

Is more sensitive to perceptual-conceptual (stimulus related/evaluation) processes than response-related processes, i.e., ***P3 latency is not (well-)correlated with variance in RT due to response-related processes***

Dual Task Paradigm

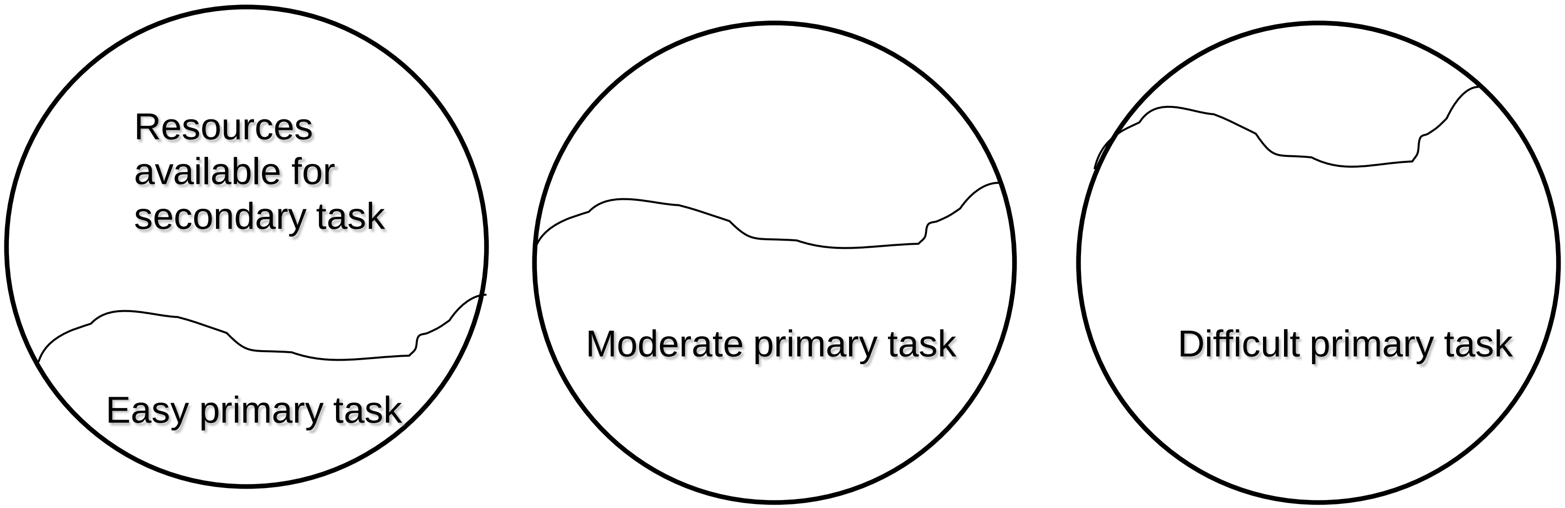
P3b amplitude related to stimulus encoding, esp. perceptual/conceptual resources

P3b is related to stimulus evaluation processes and to working memory processes (capacity-limited).

Resource Allocation Theory

P3 amplitude and cognitive resources?

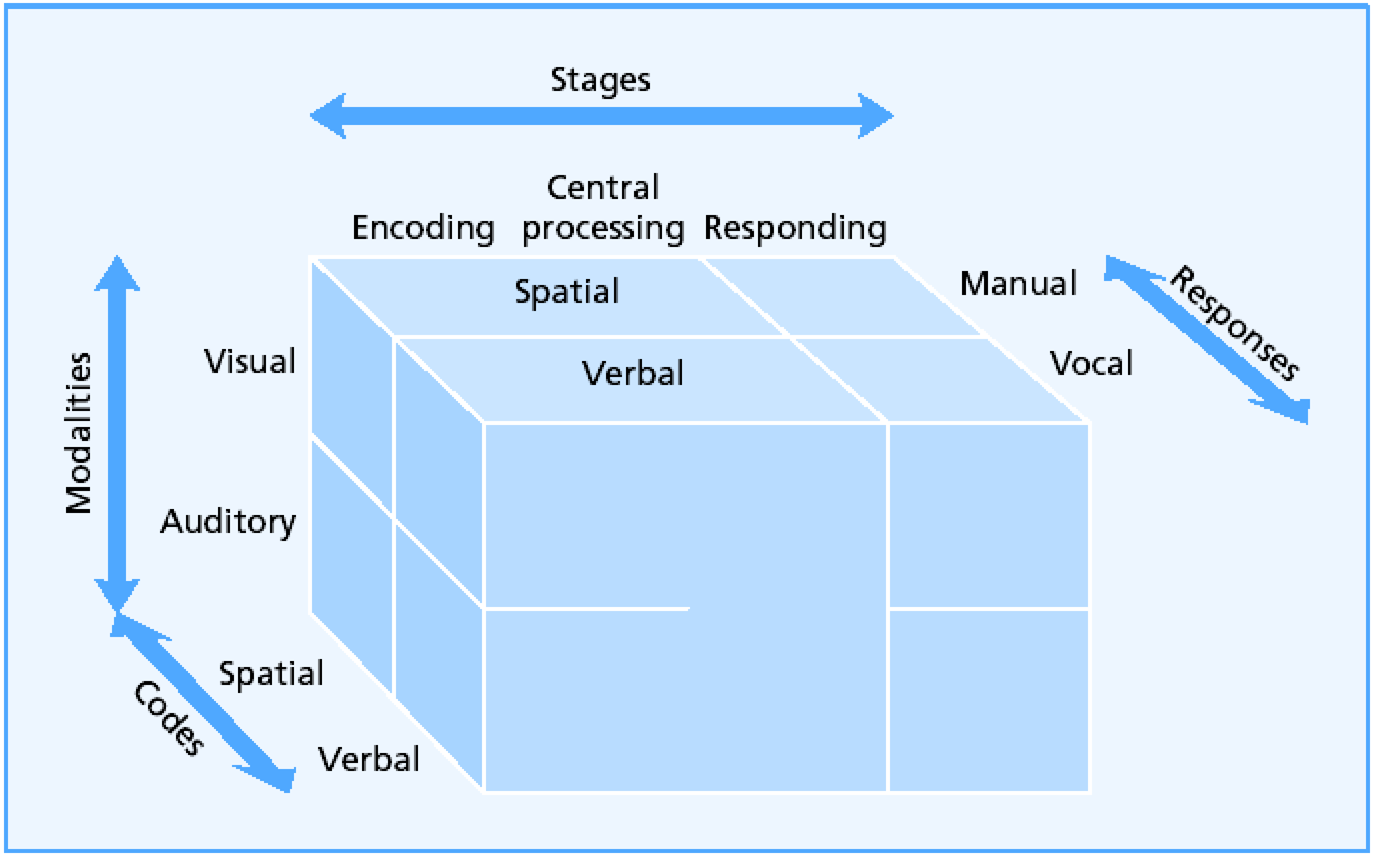
Capacity Limited Resource



When 2 tasks time share, levels of performance of each is worse than when either task is performed alone; if one uses more resources, the other uses less (i.e., reciprocal relationship).

Demands imposed by primary task can be assessed by monitoring performance on secondary task, such that performance on secondary task can be taken as index of difficulty of primary task.

Multiple-resource Theories



Wickens (1984). A proposed dimensional structure of human processing resources. From *"Processing resources in attention" by Wickens, C.D. in Varieties of Attention* edited by R. Parasuraman and D.R. Davies © 1984 by Academic Press. Reproduced by permission of Elsevier.

Primary task: visuo-motor tracking (track 1D-horizonal; track 2D-horizontal & vertical
Secondary task: auditory oddball

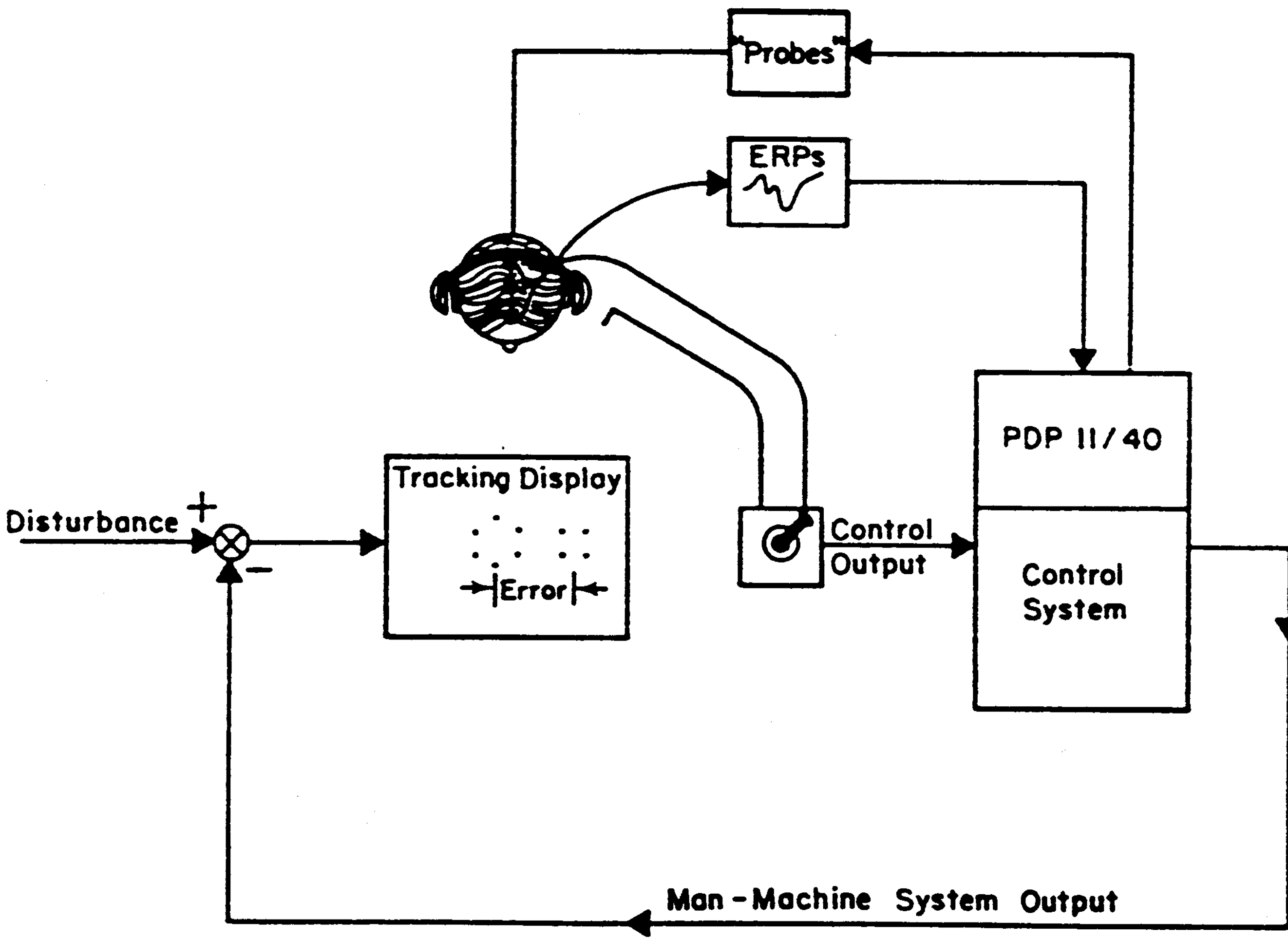
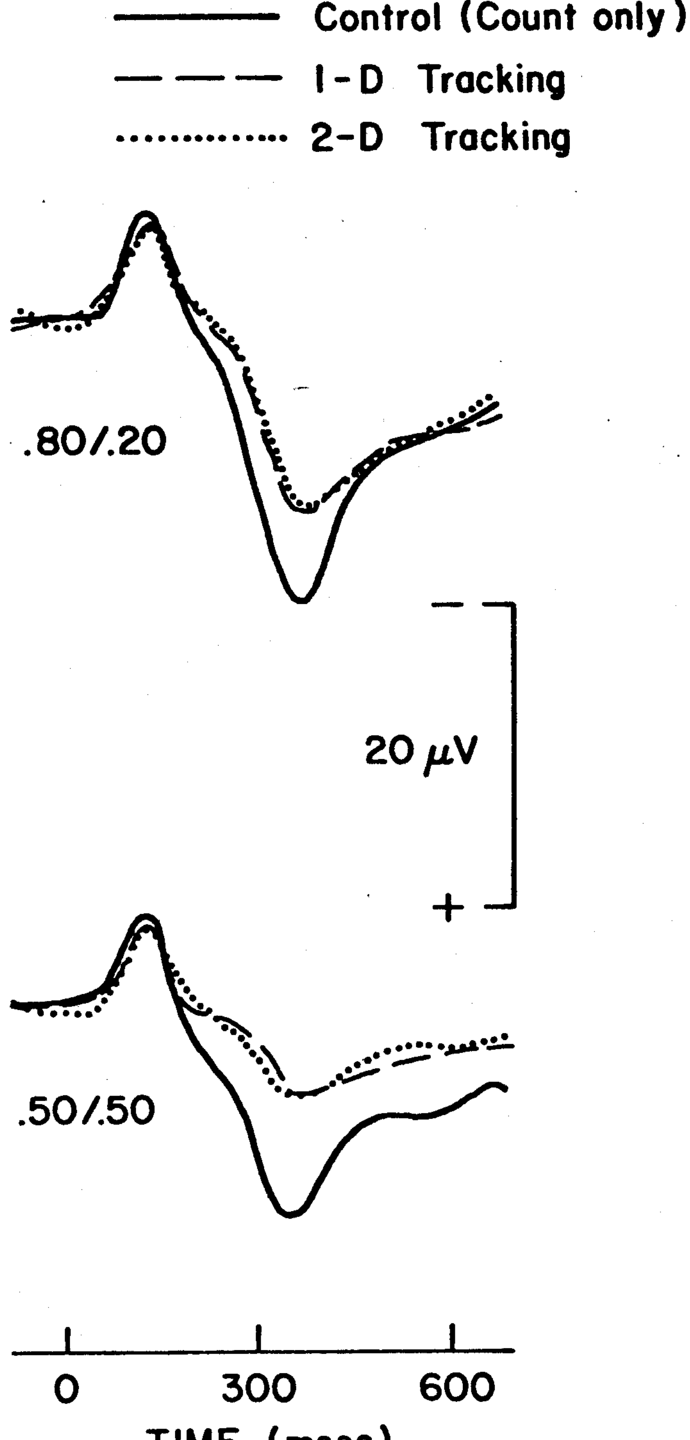


Figure 26-5. An illustration of the experimental paradigm employed in the analysis of the utility of the ERP as a workload measure.


Control (Count only)
1-D Tracking
2-D Tracking
.80/.20
20 μV
.50/.50
0
300
600

Increased levels of difficulty by changing the bandwidth of the forcing function

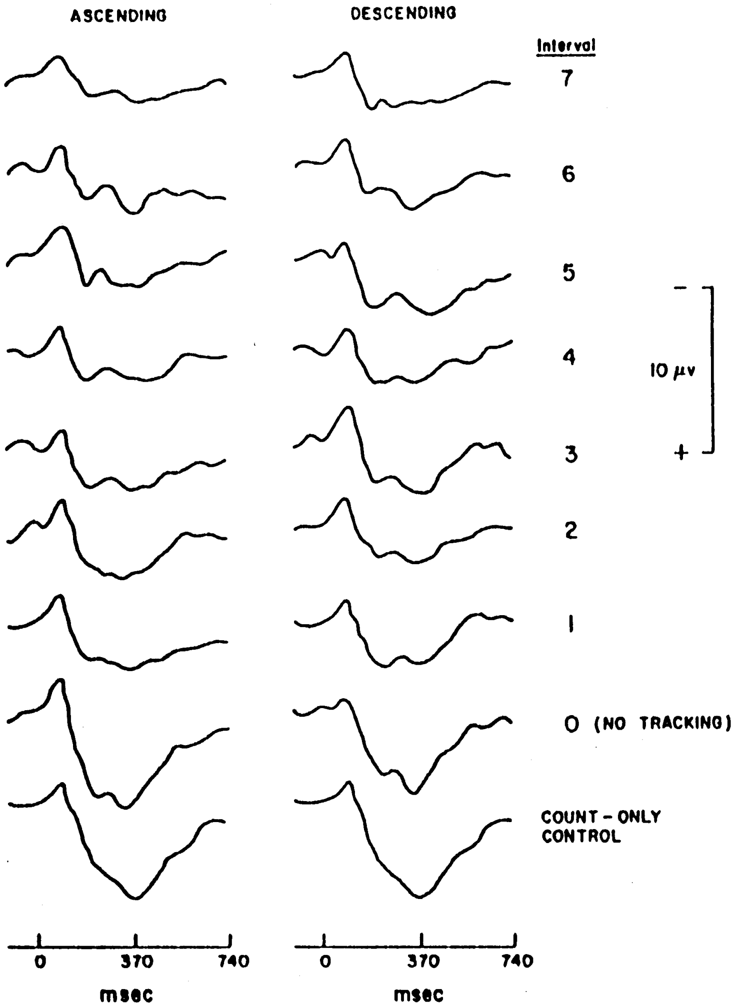


Figure 26-6. Average parietal ERPs, elicited by equiprobable counted tones, for each bandwidth interval and count-only control conditions, for ascending and descending blocks of trials. Bandwidth increases from 1 to 7. (Copyright 1980, The Society for Psychophysiological Research. Reprinted with permission of the publisher from "P300 and Tracking Difficulty: Evidence for Multiple Resources in Dual-Task Performance" by J. B. Isreal, G. L. Chesney, C. D. Wickens, and E. Donchin. *Psychophysiology*, 1980, 17, 259-273.)

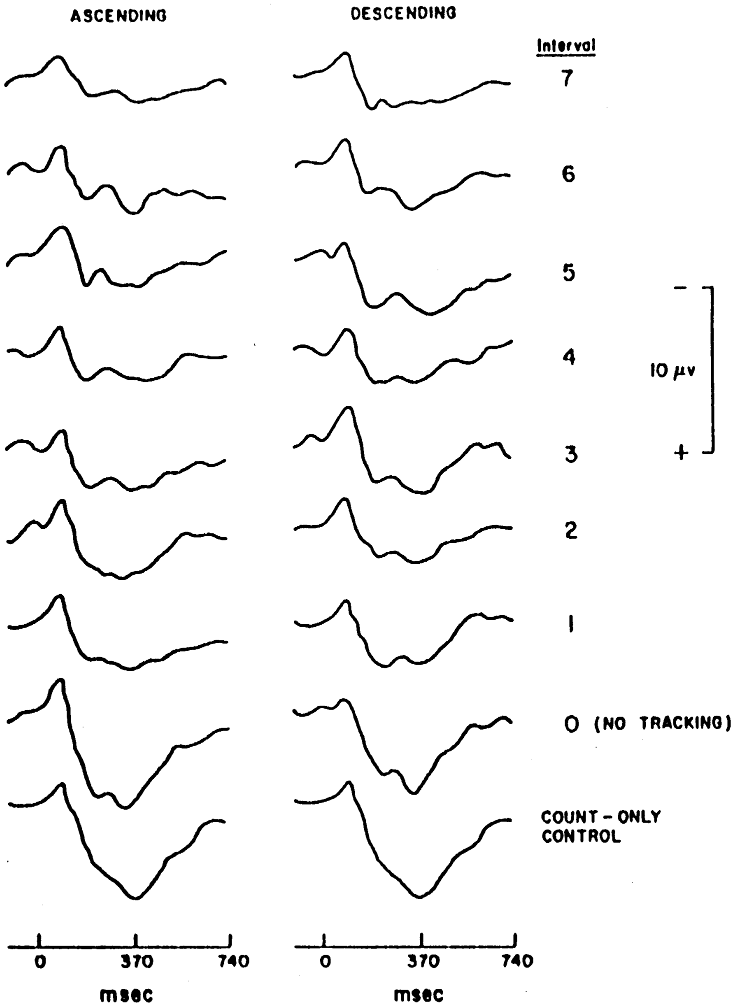
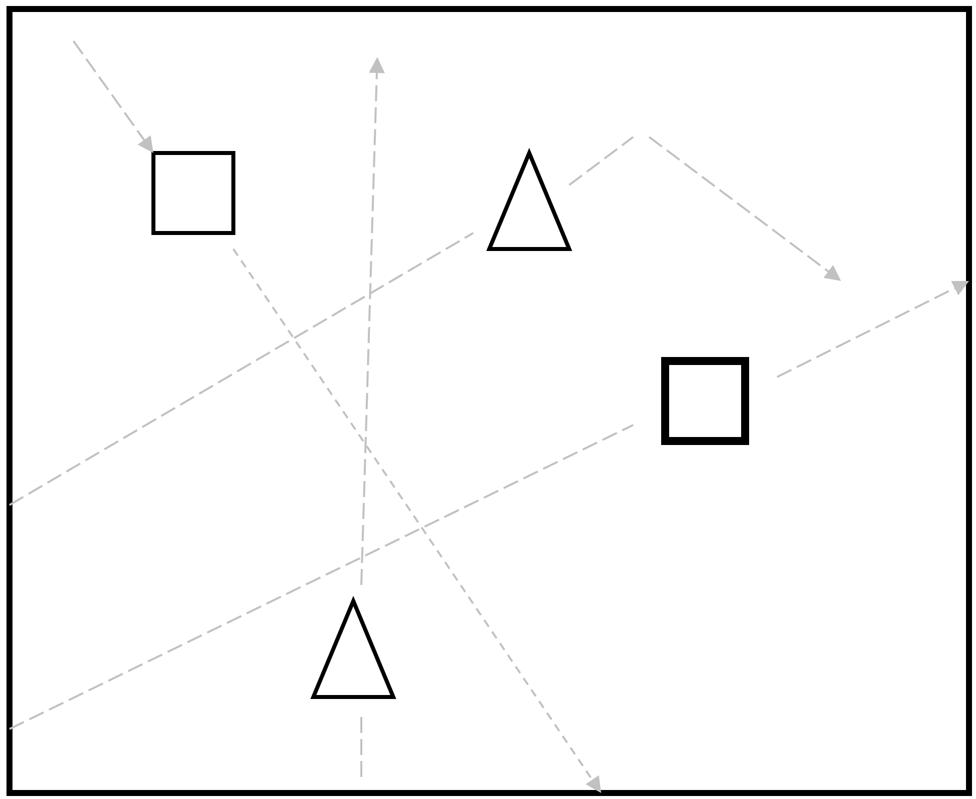


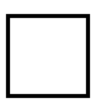
Figure 26-6. Average parietal ERPs, elicited by equiprobable counted tones, for each bandwidth interval and count-only control conditions, for ascending and descending blocks of trials. Bandwidth increases from 1 to 7. (Copyright 1980, The Society for Psychophysiological Research. Reprinted with permission of the publisher from "P300 and Tracking Difficulty: Evidence for Multiple Resources in Dual-Task Performance" by J. B. Isreal, G. L. Chesney, C. D. Wickens, and E. Donchin. *Psychophysiology*, 1980, 17, 259–273.)

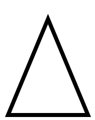
Introduction of tracking task reduced P3 amplitude to oddball, but no reliable change in P3 amplitude with increased tracking difficulty.

Why??

VISUAL DISPLAY



 target

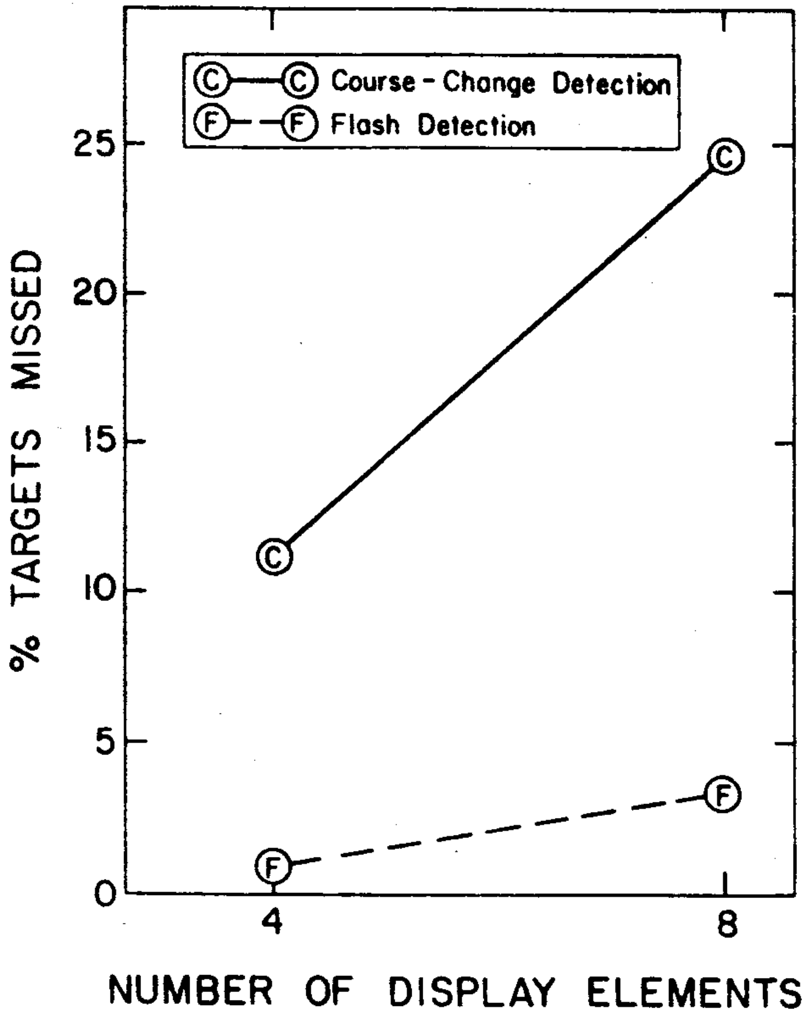
 Non-target “noise” element

Monitor for course change
Monitor for increase in intensity

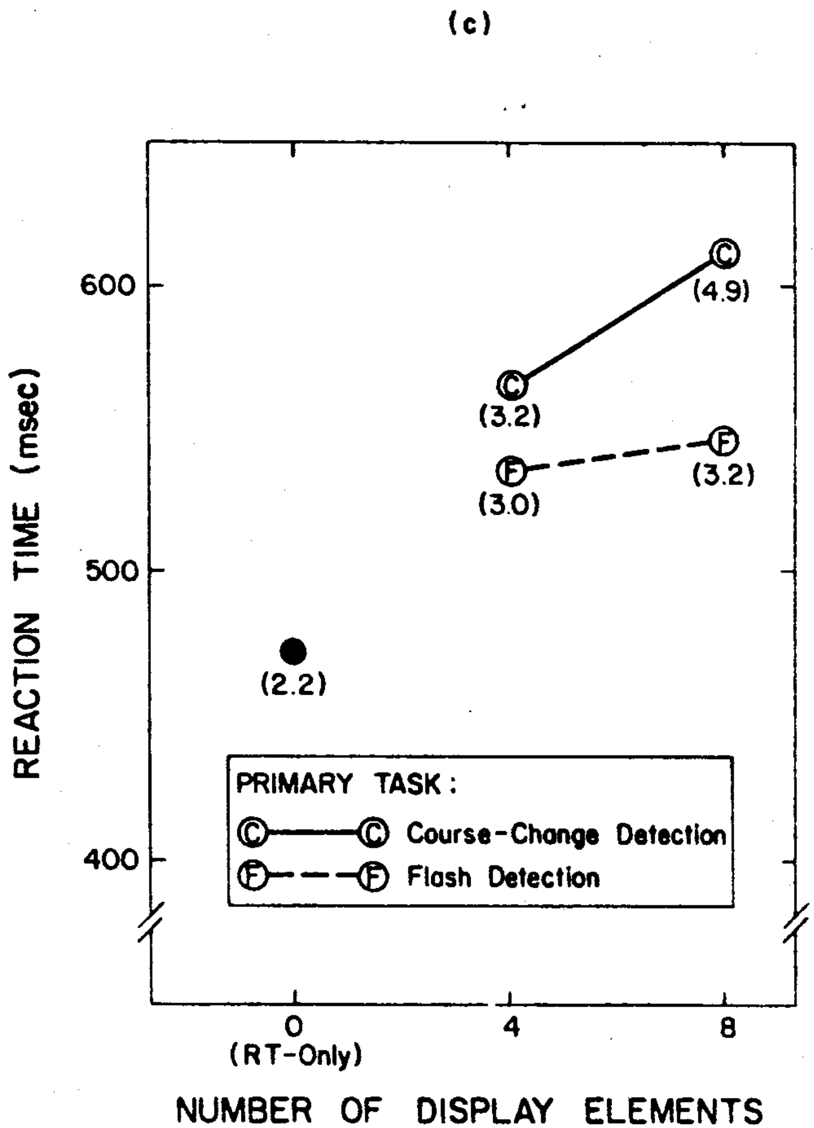
Vary number of visual elements

Accuracy of Target Detection

(b)



Speed of Target Detection



P3b to secondary task tones
in oddball task

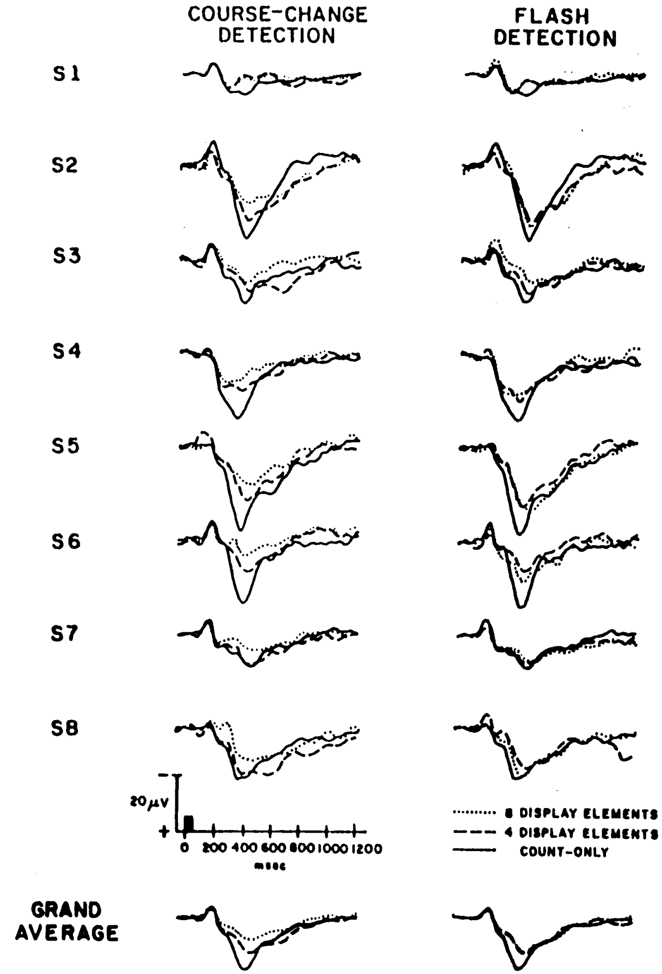
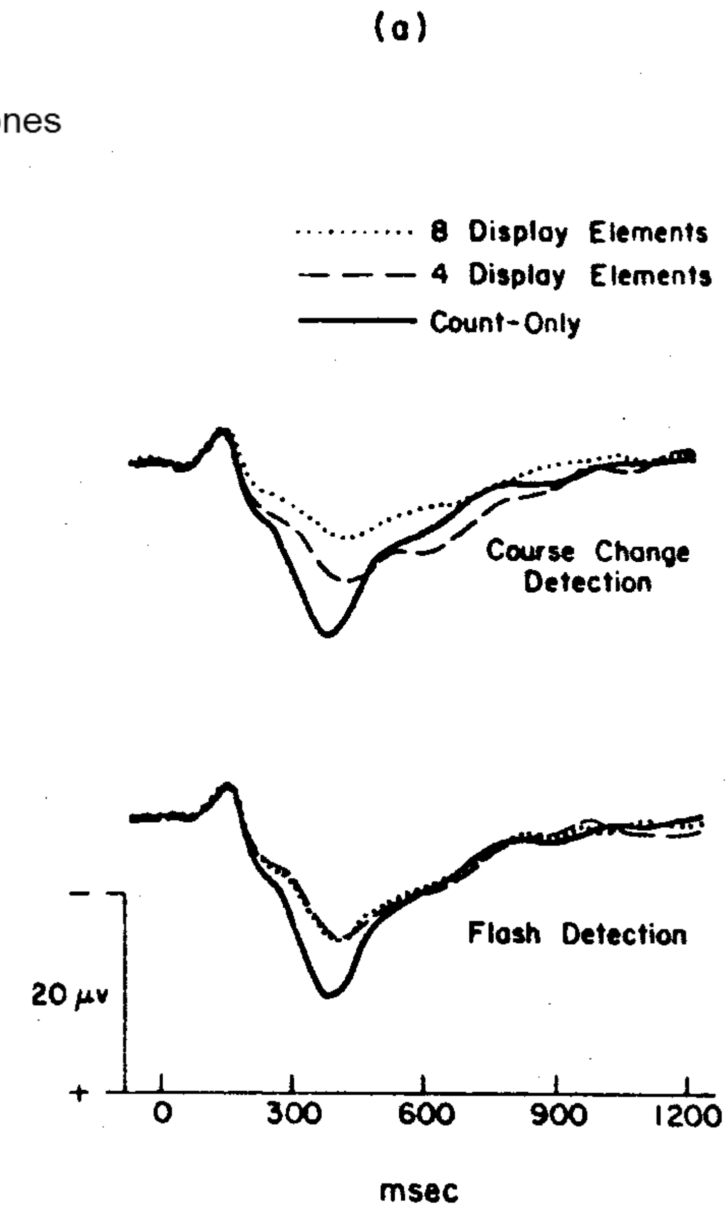


Figure 26-7. Single-subject and average ERPs elicited by infrequent, counted tones presented concurrently with each of two monitoring tasks. Two monitoring conditions as well as a count-only control condition are presented. All waveforms displayed were recorded at the parietal electrode. (From "The Event-Related Brain Potential as an Index of Display Monitoring Workload" by J. B. Isreal, C. D. Wickens, G. L. Chesney, and E. Donchin. *Human Factors*, 1980, 22, 212–224. Copyright 1980, by The Human Factors Society, Inc. and reproduced by permission.)

P3b to secondary task tones
in oddball task



Reciprocity between P3 amplitude for primary and secondary task

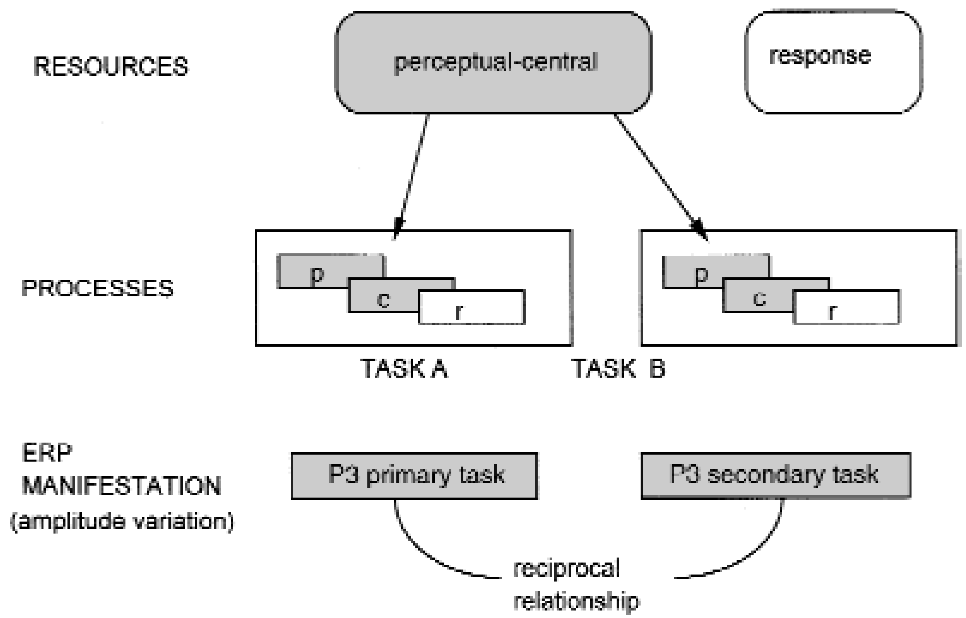


Figure 3. Schematic representation of the way perceptual-central resources (represented as a separate pool of resources that are differentiated from response-related resources) affect processing stages and P3 amplitude in dual-task settings, according to investigators who varied the difficulty of the primary task (p = perceptual, c = central, and r = response processes). Dark areas represent the resources and associated processes presumed to be specifically involved in P3 generation. Amplitudes of P3 elicited in primary and secondary were shown to have a reciprocal relationship

Hypothesis: *increase in difficulty of primary task diverts processing resources from secondary task*

Pursuit tracking task
- every 3 seconds, cursor moved; task keep cursor on target
- difficulty varied by varying predictability of movements
  - high predictable, left-right alternation
  - low predictable, random direction of movement

(magnitude of movement unpredictable in all cases)

Conditions of increasing difficulty

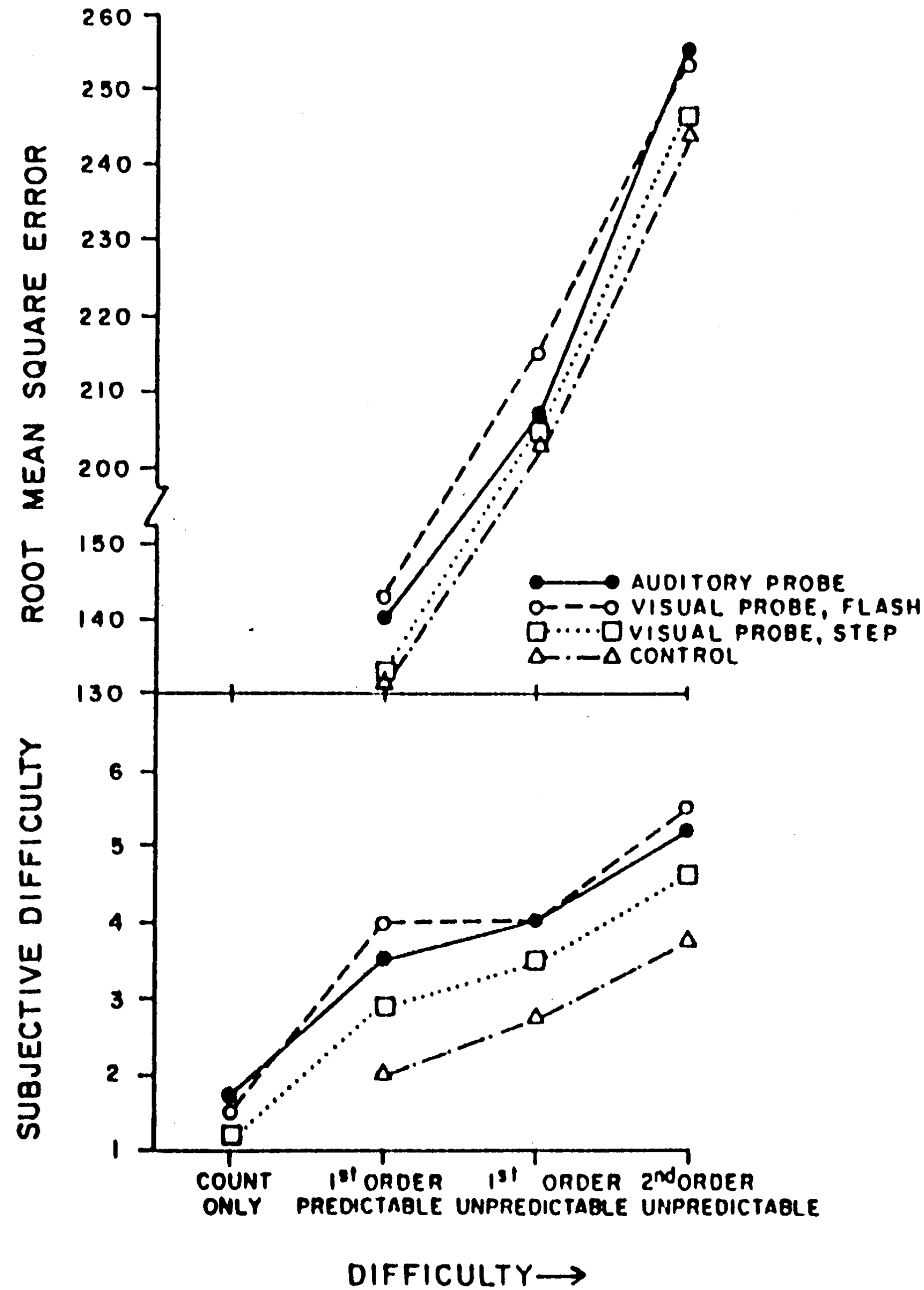
-1st order control of predictable input

-1st order control of unpredictable input

-2nd order control of unpredictable input

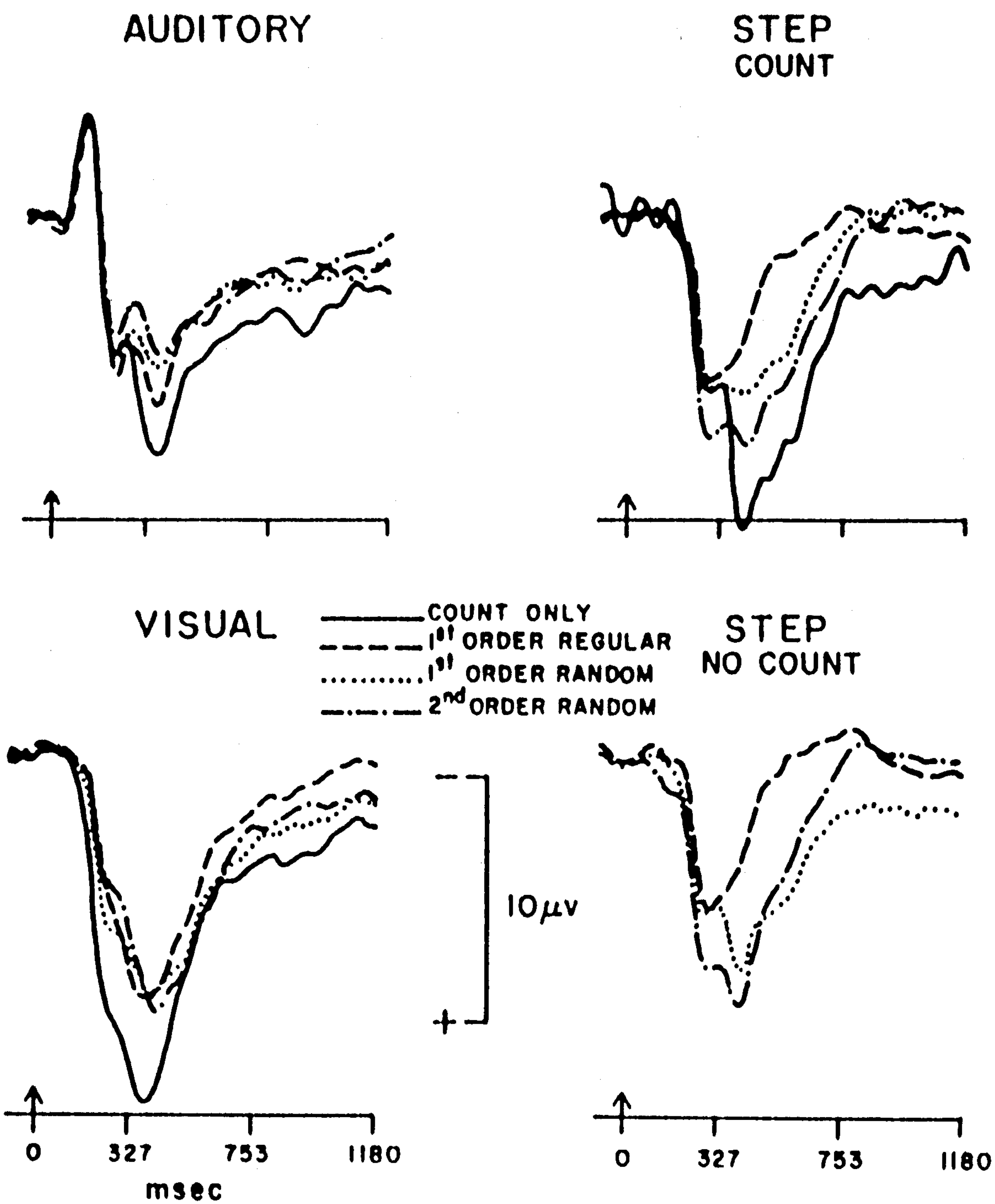
3 probe types
- auditory secondary task: auditory oddball, count infrequent low tones
- visual secondary task: count dimmer of two flashes
- primary task: count number of step tracking changes to left

Control conditions
- count only (no tracking)
- tracking only (no probes)



ROOT MEAN SQUARE ERROR
260
250
240
230
220
210
200
150
140
130
AUDITORY PROBE
VISUAL PROBE, FLASH
VISUAL PROBE, STEP
CONTROL
SUBJECTIVE DIFFICULTY
6
5
4
3
2
1
COUNT ONLY
1st ORDER PREDICTABLE
1st ORDER UNPREDICTABLE
2nd ORDER UNPREDICTABLE
DIFFICULTY→

SECONDARY TASKS PRIMARY TASKS



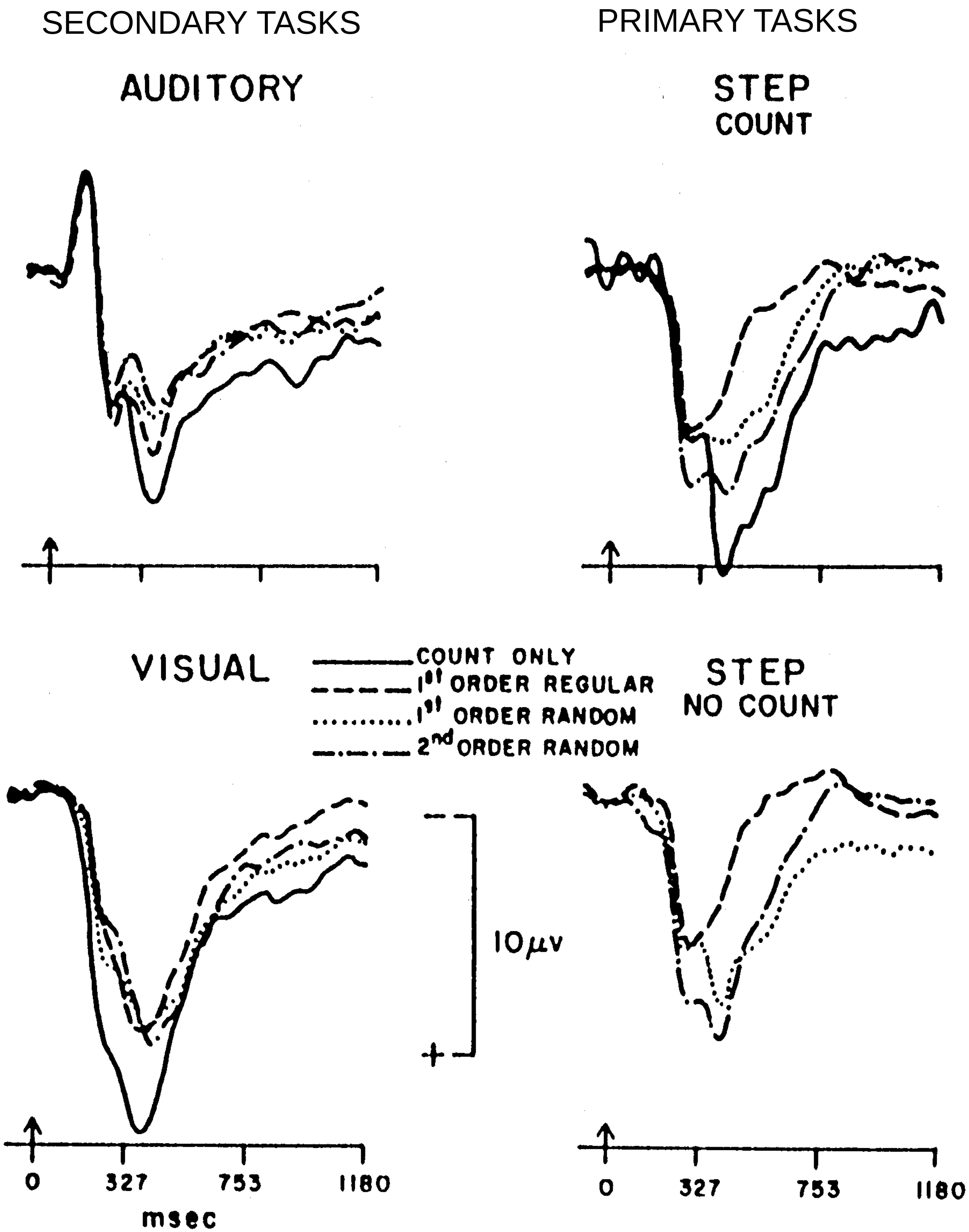
Count only versus other conditions?

Consequence of introducing secondary task?

Consequence of increasing primary task difficulty on P3 amplitude on secondary task probe?

Consequence of increasing primary task difficulty on P3 amplitude to primary task probe when counted and when not counted?

Relationship between P3 amplitude to primary and secondary task probes?



Largest P3 is in count only condition in all conditions (auditory, step count, visual).

Introduction of secondary task leads to P3 decrease (auditory, visual, step count).

For visual but not auditory secondary task, continued reduction in P3 amplitude as primary task becomes more difficult.

For primary task (step count), the more difficult it is, the larger the P3 elicited, whether or not it is counted.

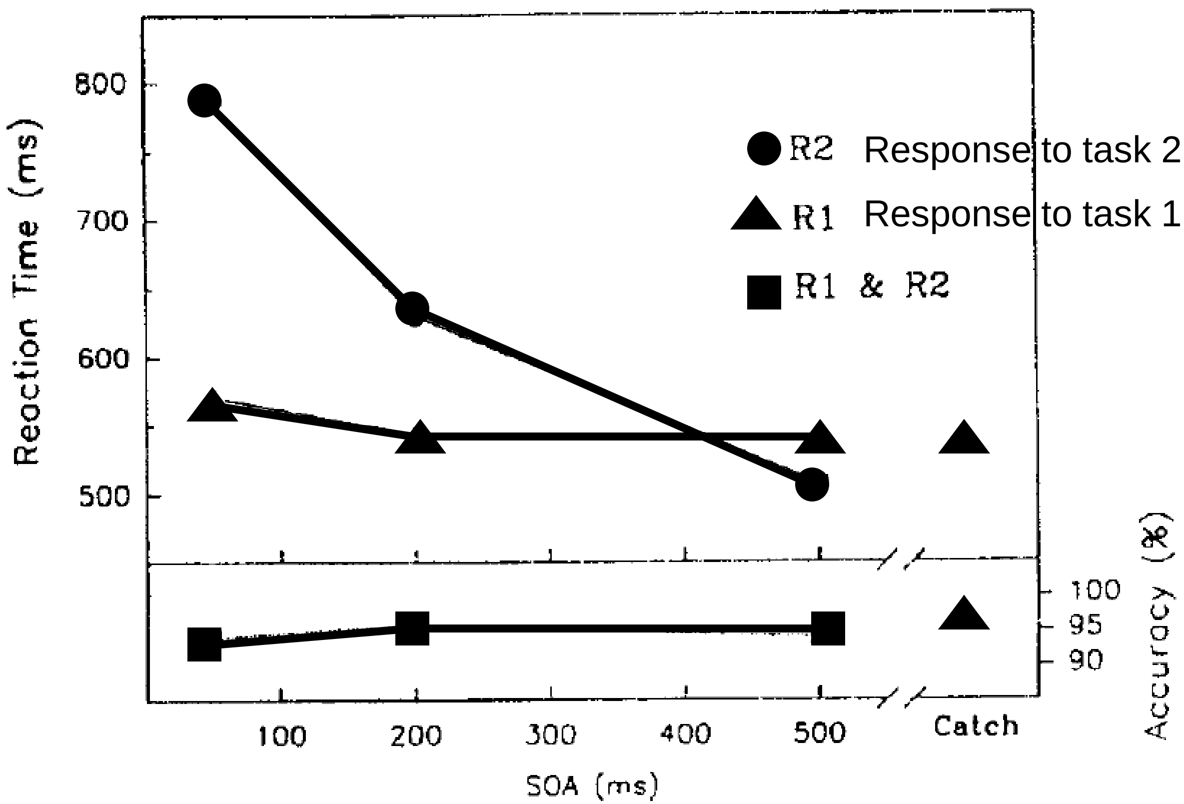
Note reciprocal relationship between Auditory and Step count P3 amplitudes as a function of increasing task difficulty.

Using the P3b to analyze locus of interference in dual task situations

Psychological Refractory Period (PRP)

Attentional Blink (AB)

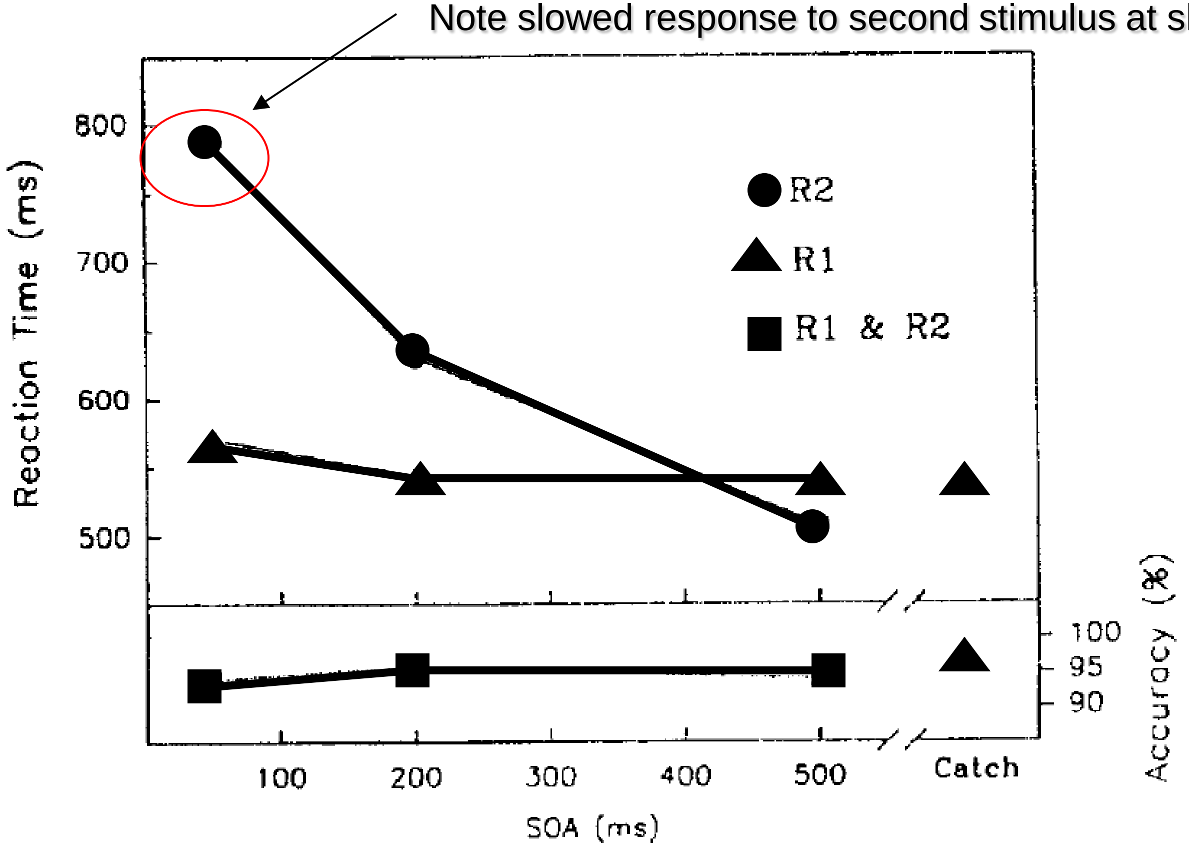
PSYCHOLOGICAL REFRACTORY PERIOD (PRP)



For two tasks in quick succession,
PRP effect refers to the increase in RT to the second of two successive response signals (RT2) as the interval between the signals (SOA) is decreased.

PSYCHOLOGICAL REFRACTORY PERIOD (PRP)

Note slowed response to second stimulus at short SOA



PRP effect refers to the increase in RT to the second of two successive response signals (RT2) as the interval between the signals (SOA) is decreased.

Psychological Refractory Period (PRP) refers to the increase in RT to the second of two successive response signals as the interval between the signals (i.e., SOA) decreases.

Within single channel models, where is the bottleneck (proposals from early to late)?

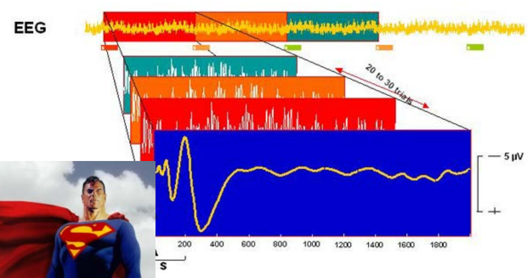
- Stimulus identification (Broadbent, 1958)
- More central decision/ stimulus-response translation process (McCann, Johnston, Pashler, Welford)
- Response initiation (Keele, 1973)
- Response execution, only after the point of no return for the first reaction (Logan & Burkell, 1986)

There is a bottleneck somehwere – a mechanism that can only handle one process at a time. Until the bottleneck is encountered, processes can go on in parallel but at some point first reaction must clear bottleneck before second can continue. Where is that bottleneck?

Behavioral PRP findings

PRP independent of modality or response suggesting interference is central rather then peripheral, but where?

Can use ERPs to locate focus/foci of bottleneck



Journal of Experimental Psychology:
Human Perception and Performance
1993, Vol. 19, No. 6, 1292-1312

0096-1523/93/$3.00

The Locus of Dual-Task Interference: Psychological Refractory Effects on Movement-Related Brain Potentials

Allen Osman and Cathleen M. Moore

We sought to measure separately the motor potentials for each of 2 concurrent tasks and to use these measurements to identify the locus of dual-task interference. Lateralized readiness potentials (LRPs) were measured in the psychological refractory period paradigm, in which a separate response is required to each of 2 successive signals. As the interval between the signals decreased, the 2 reaction time (RT) tasks increasingly overlapped and the 2nd RT was prolonged. The LRP for the 2nd task was also delayed but maintained a constant temporal relation with the 2nd RT and sometimes preceded the 1st-task RT. The results indicate that (a) independent measures of the LRP can be obtained for each of 2 concurrent tasks, (b) slowing of the 2nd task was caused by a delay in processes that precede LRP onset, and (c) the 1st task may cease to interfere with the 2nd considerably before producing an overt response.

PRP & LRP (Osman & Moore, 1993)

Aims:

Measure separately concurrent LRP to two targets in order to determine ***whether bottleneck begins before or after LRP***.

Experimental Paradigm:

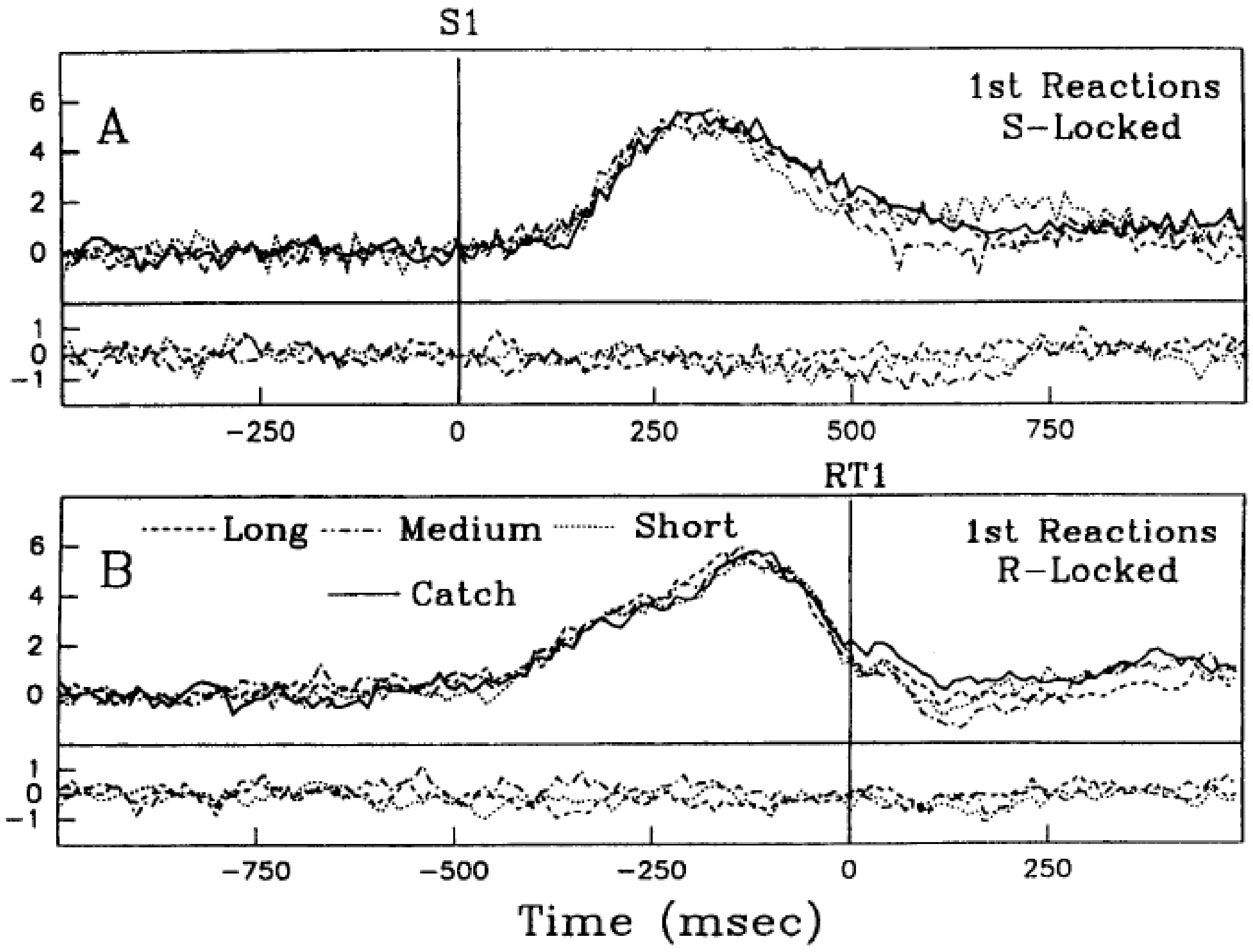
– S1: tone, R1: left / right finger (or foot)

– S2: visual, R2: left / right finger

– 3 SOAs: short, medium, long

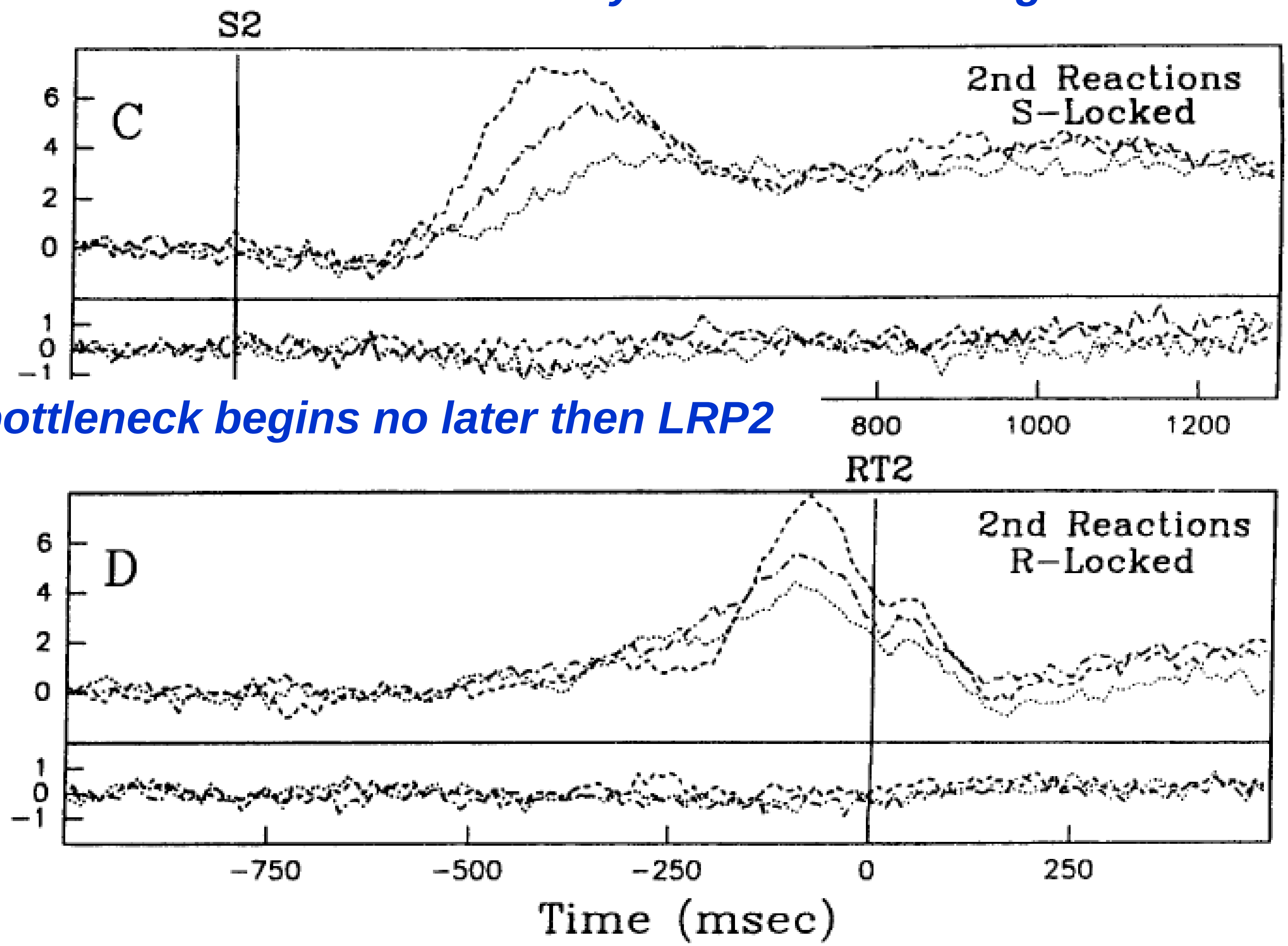
LRPs time-locked to T1, RT1

LRP of first response isn't affected by S2



LRPs time locked to T2, RT2

LRP2 delayed with decreasing SOA



Thus, bottleneck begins no later then LRP2

Main Conclusion from LRP data

Bottleneck begins at or before (i.e., no later than) LRP processes (response preparation / response selection?) to 2^{nd} task.

But how ***far*** before LRP does interference occur?

PSYCHOLOGICAL SCIENCE

Research Report

SOURCES OF DUAL-TASK INTERFERENCE:
Evidence From Human Electrophysiology

Steven J. Luck
University of Iowa

Aim: Use P3 to delimit the bottleneck by distinguishing between response selection and earlier stages such as target categorization.

Useful characteristics of P3b (parietal P3 component) to this end:

- Greater for improbable targets (Johnson 1986)
- Latency increases with categorization difficulty (Kutas et al, 1977)
- Smaller when perceptual resources are diverted (Isreal et al, 1980)
- Unaffected by response selection difficulty (Kramer et al, 1983)

P3 Latency offers a measure of perception & categorization time

P3 amplitude offers a measure of available cognitive resources for target perception and categorization.

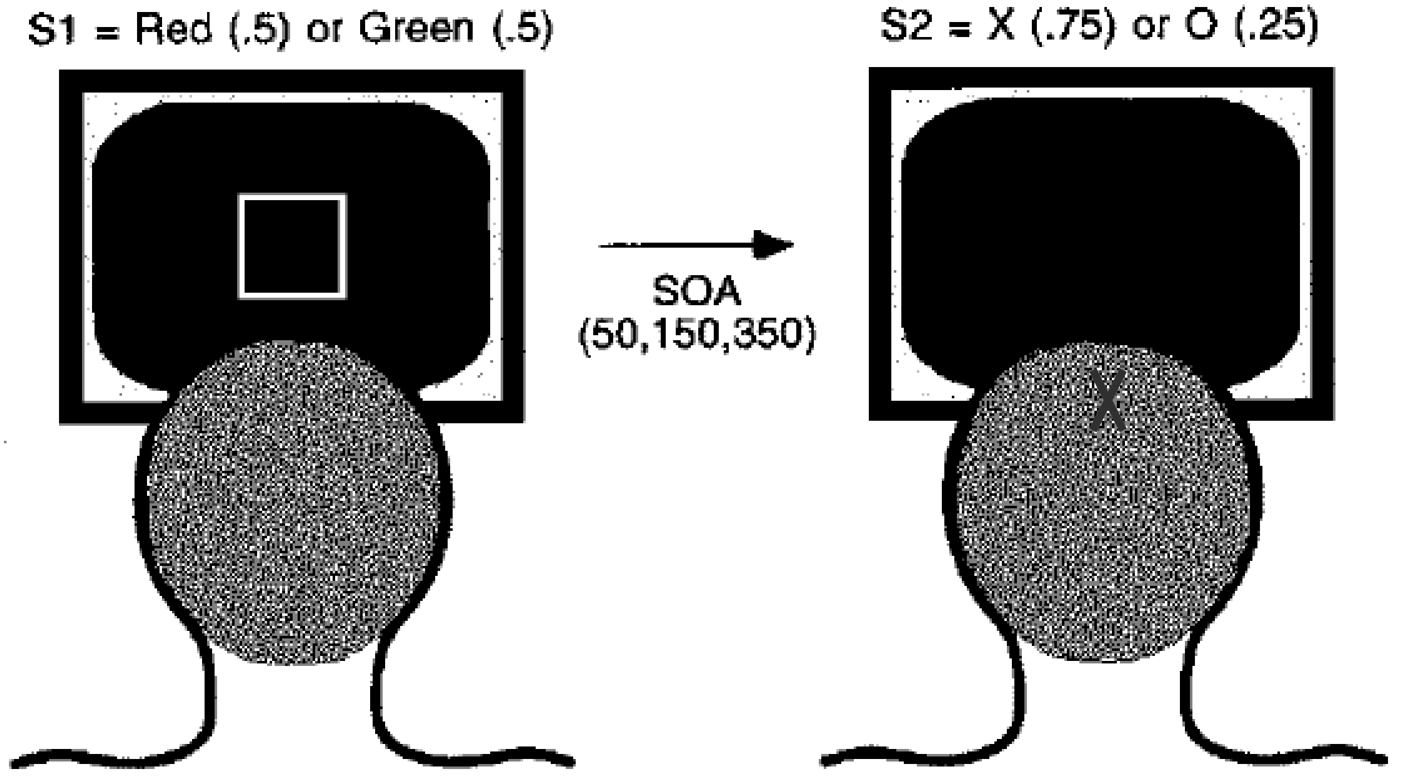
Pashler’s Model

Main bottleneck leading to PRP is in the stage of response selection stage – i.e., response selection for RT2 is postponed.

Predictions:

1. Unlike RT, P3 latency to stimulus in T2 should not be increased at short T1-T2 SOAs.

2. some limitations in identification and categorization of T2 when processed concurrently with T1, predicts modest reduction in P3 amplitude

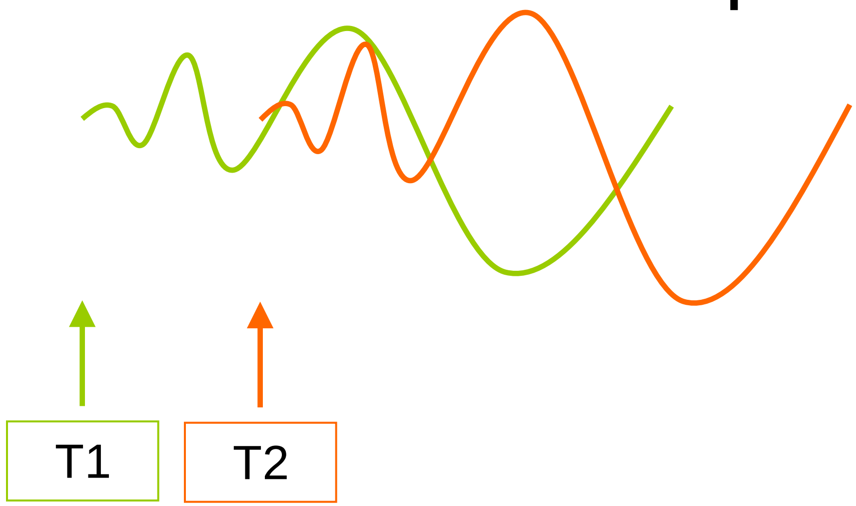


S1 – red or green box, equiprobable
S2 – letter X or O with one less probable than other

2 buttonpresses on each trial based on color for S1 and form for S2

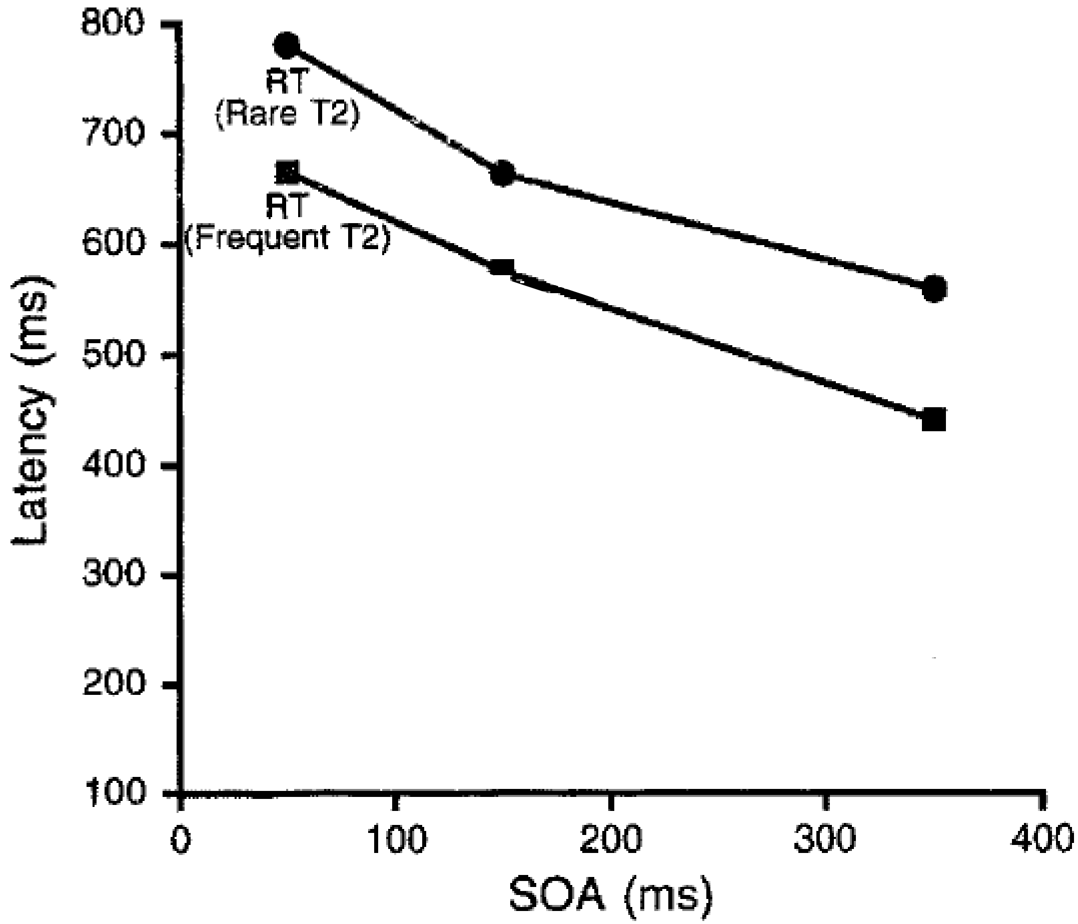
Why different probabilities for T2?

- Elicit robust P3 for infrequent stimulus
- Overcome overlap of T1 and T2:

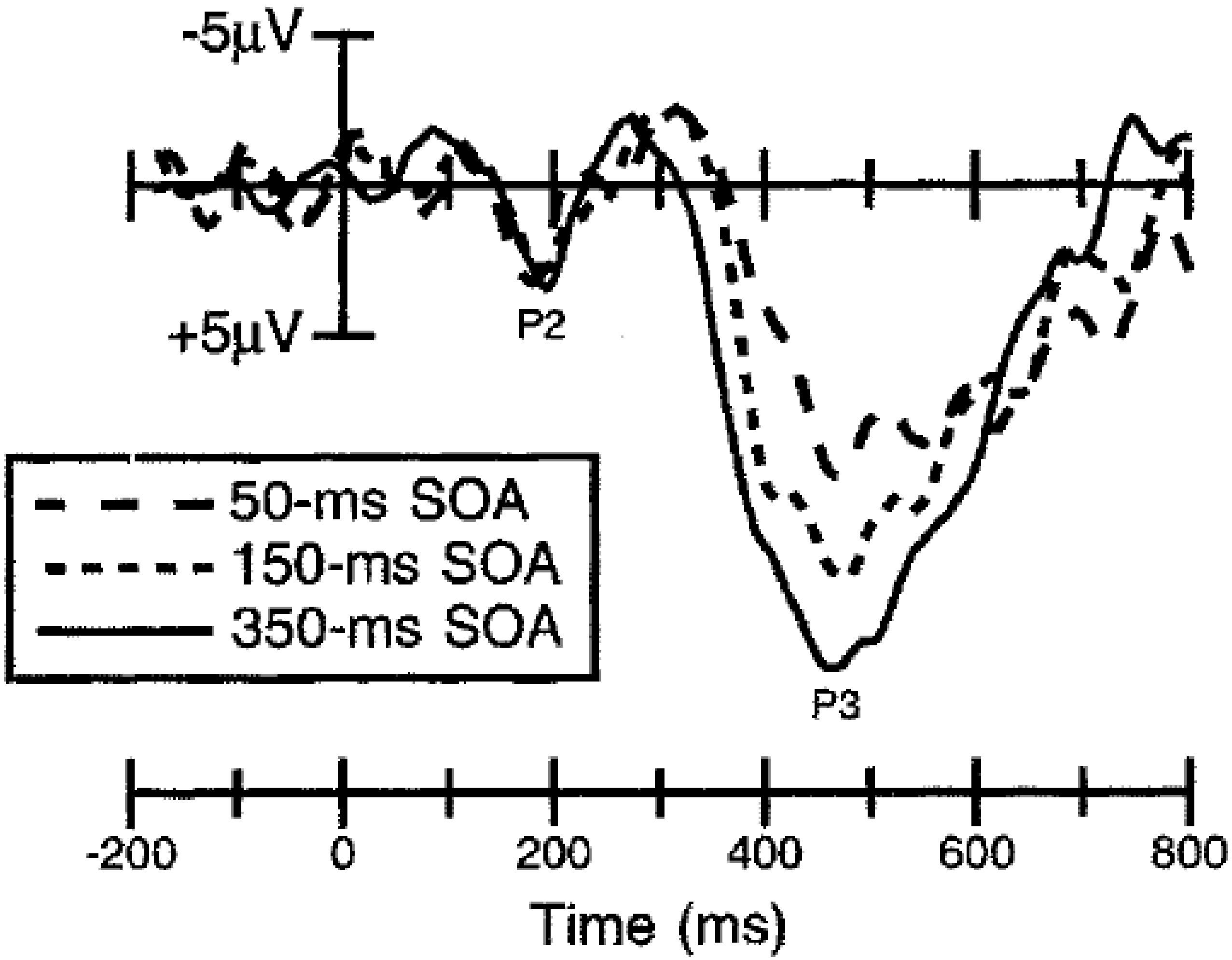


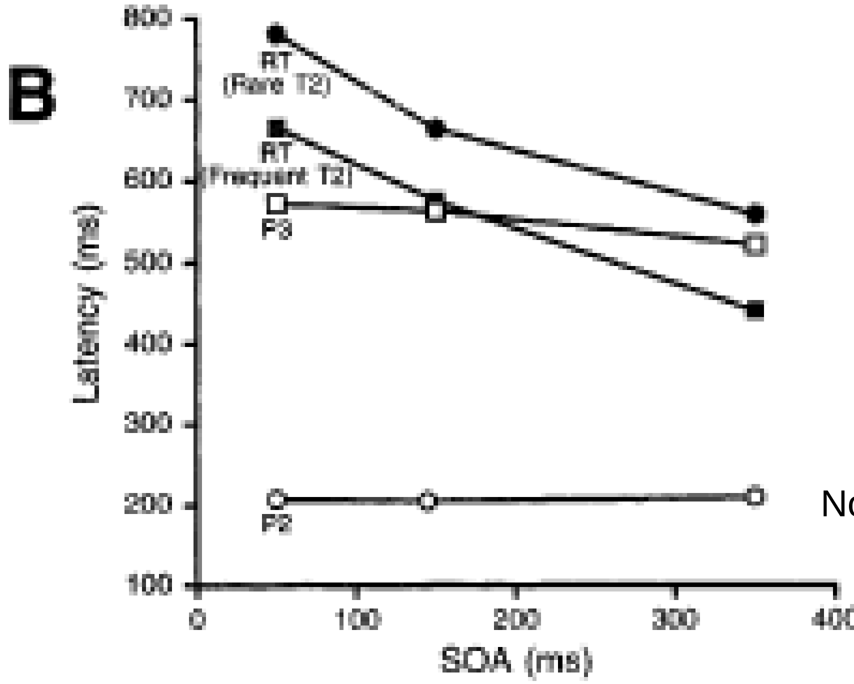
Create difference wave (infrequent from frequent ERP); all that is left are parts of ERP to T2 that are sensitive to probability (P2, N2, and especially P3).

RT PRP EFFECT



P3 difference (infrequent-frequent)





Effect of SOA on P3 latency much less than on RT

No effect of SOA on P2 amplitude

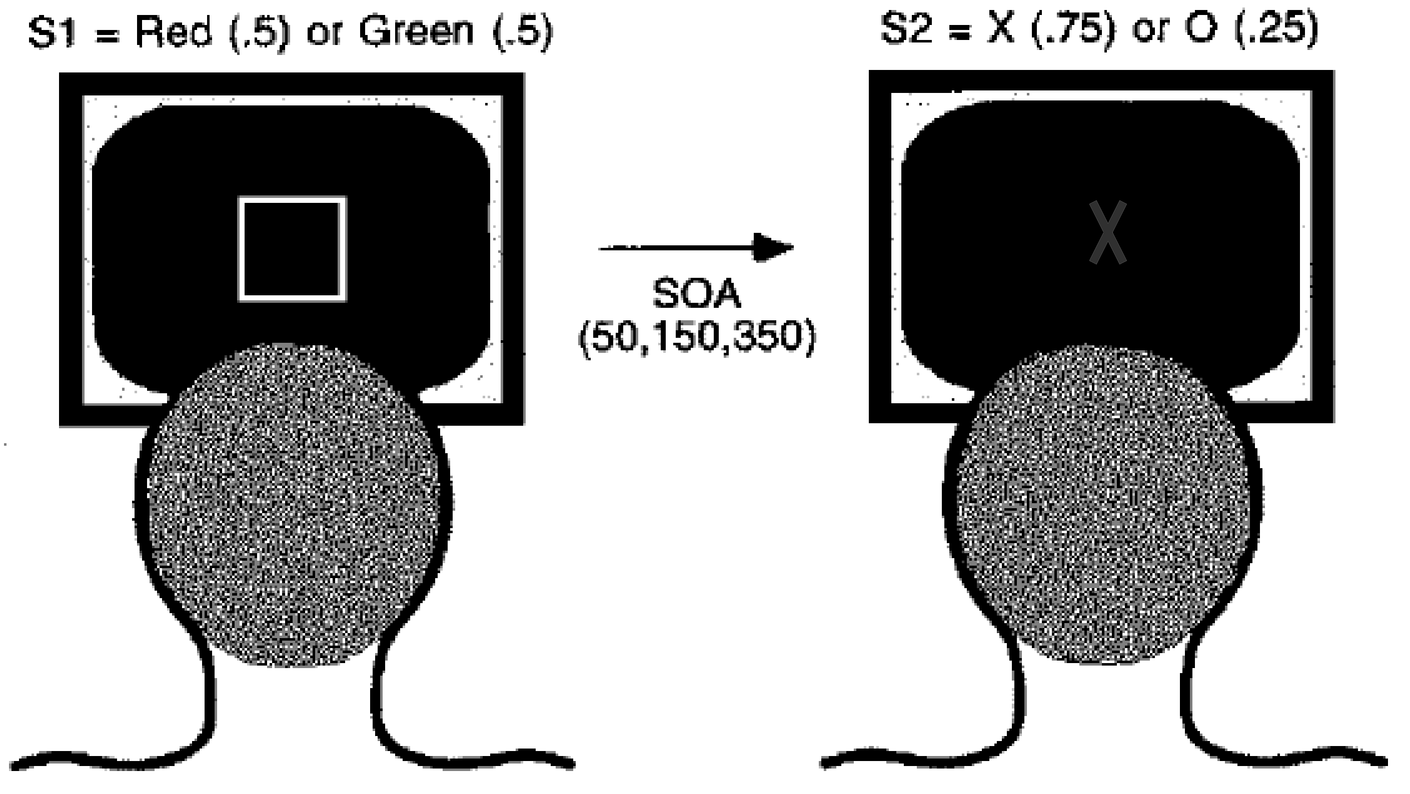
Summary for Experiment 1

RT2 decreases with SOA
RT2 longer for infrequent
P3 amplitude increases with SOA
P3 latency decreases very slightly with increasing SOA
P2 amplitude and latency are unaffected by SOA

Absence of an SOA effect on early sensory processing (P2). SOA effects come later on P3 amplitude (reduction in cognitive resources for ID/categorization), with only a modest effect of SOA on P3 latency. These ***findings seem to support Pashler's hypothesis that primary locus of interference leading to PRP may be at relatively late stage - response selection.***

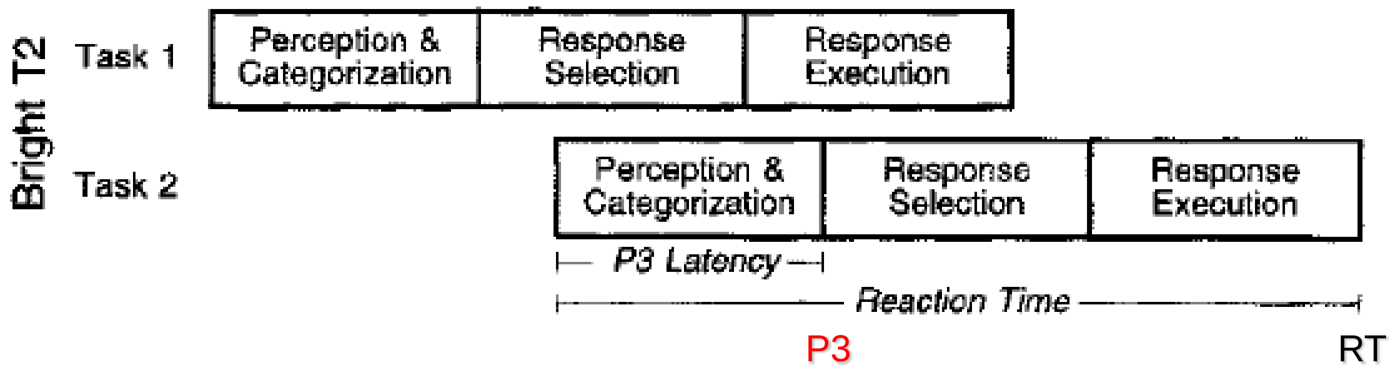
However, since P3 latency was affected by SOA manipulation, albeit less than RT, it could be that small effect on P3 reflects lack of sensitivity or power.

Experiment 2: direct maniplation of perceptual difficulty of T2 (bright, dim)

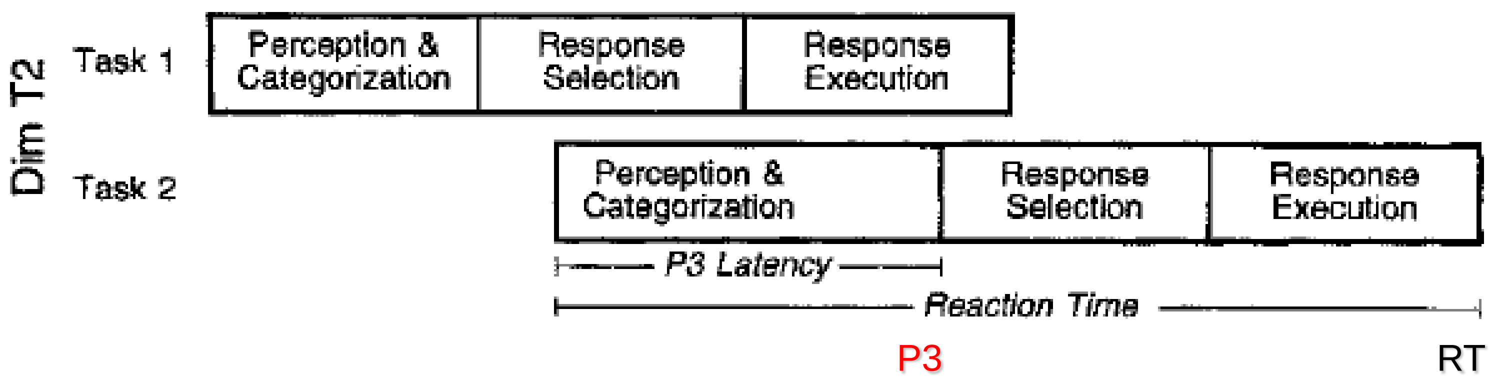


Bright. dim

Long SOA

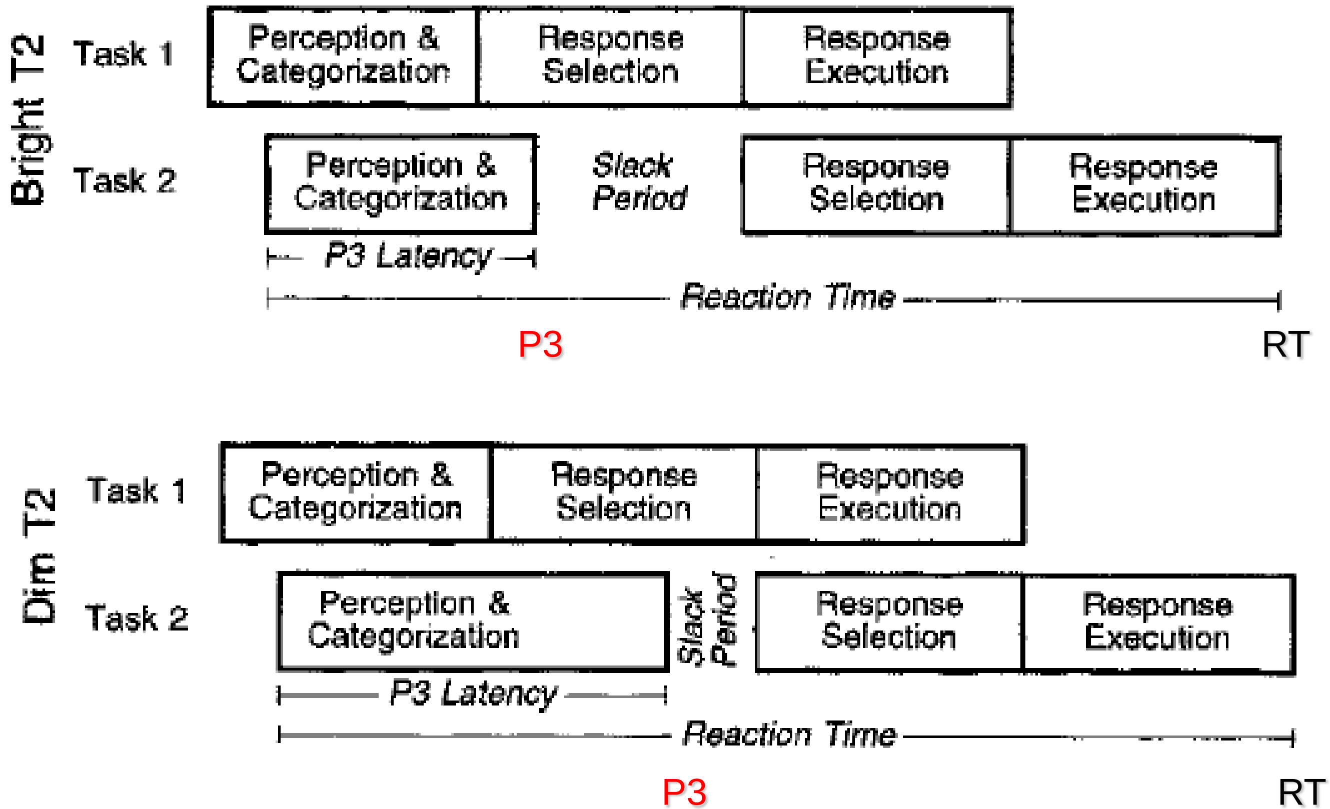


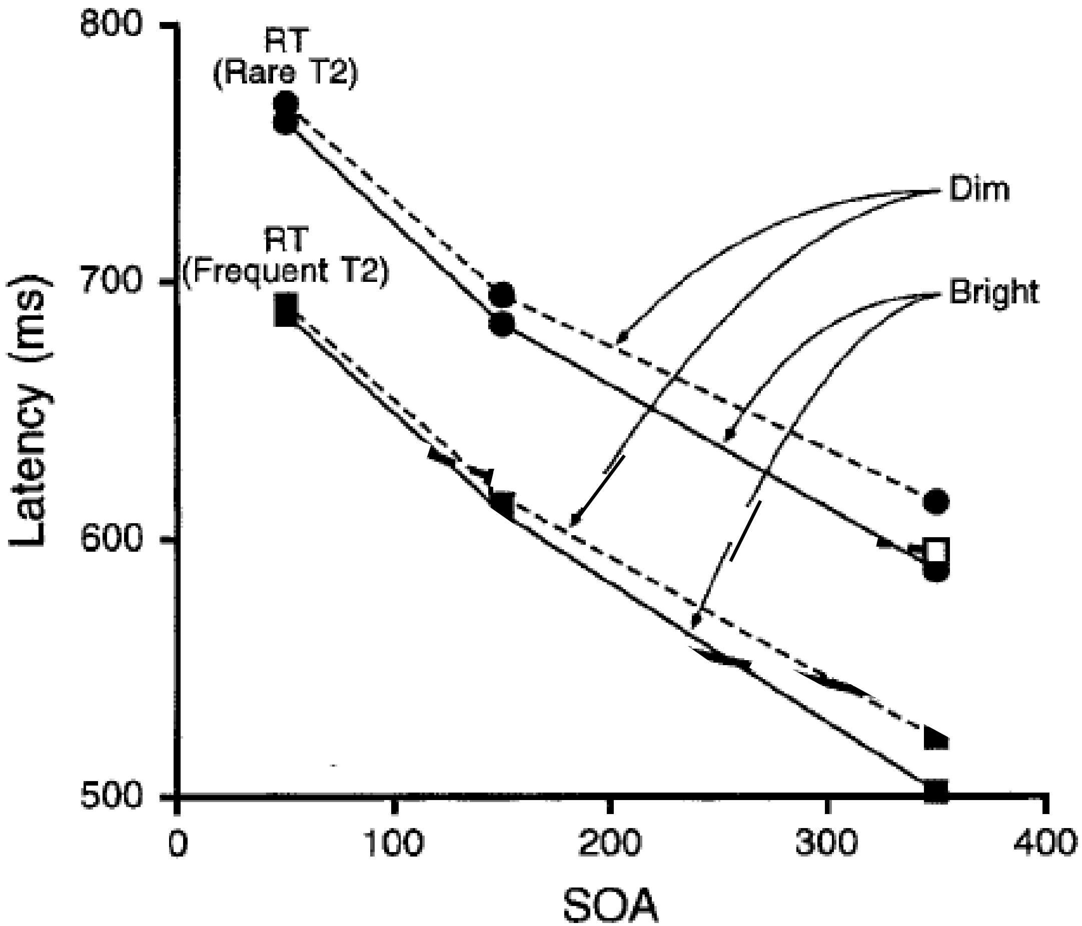
Bright T2
Task 1
Perception & Categorization
Response Selection
Response Execution
Task 2
Perception & Categorization
Response Selection
Response Execution
P3 Latency
Reaction Time
P3
RT



Dim T2
Task 1
Perception & Categorization
Response Selection
Response Execution
Task 2
Perception & Categorization
Response Selection
Response Execution
P3 Latency
Reaction Time
P3
RT

Short SOA

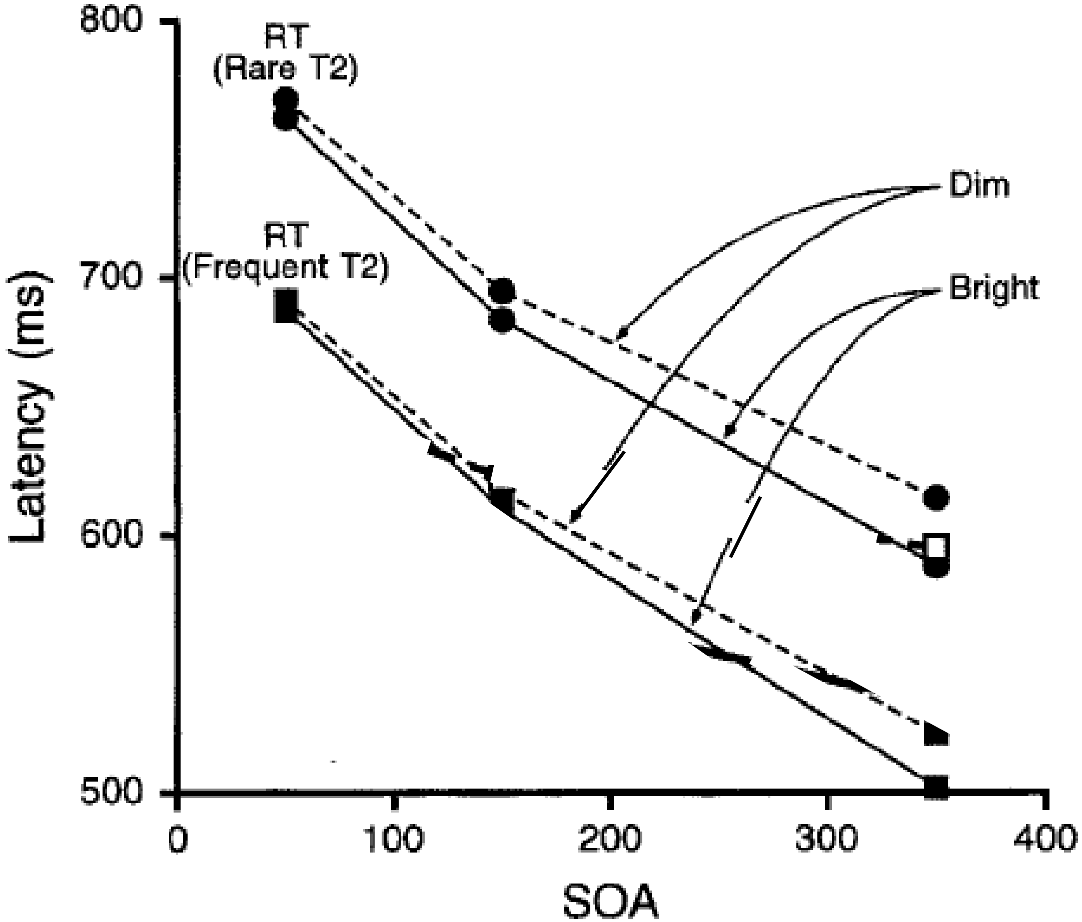

Bright T2
Task 1
Perception & Categorization
Response Selection
Response Execution
Task 2
Perception & Categorization
Slack Period
Response Selection
Response Execution
P3 Latency
Reaction Time
P3
RT
Dim T2
Task 1
Perception & Categorization
Response Selection
Response Execution
Task 2
Perception & Categorization
Slack Period
Response Selection
Response Execution
P3 Latency
Reaction Time
P3
RT



RT2 for rare vs frequent?

RT2 as function of SOA?

RT2 for dim vs bright T2?



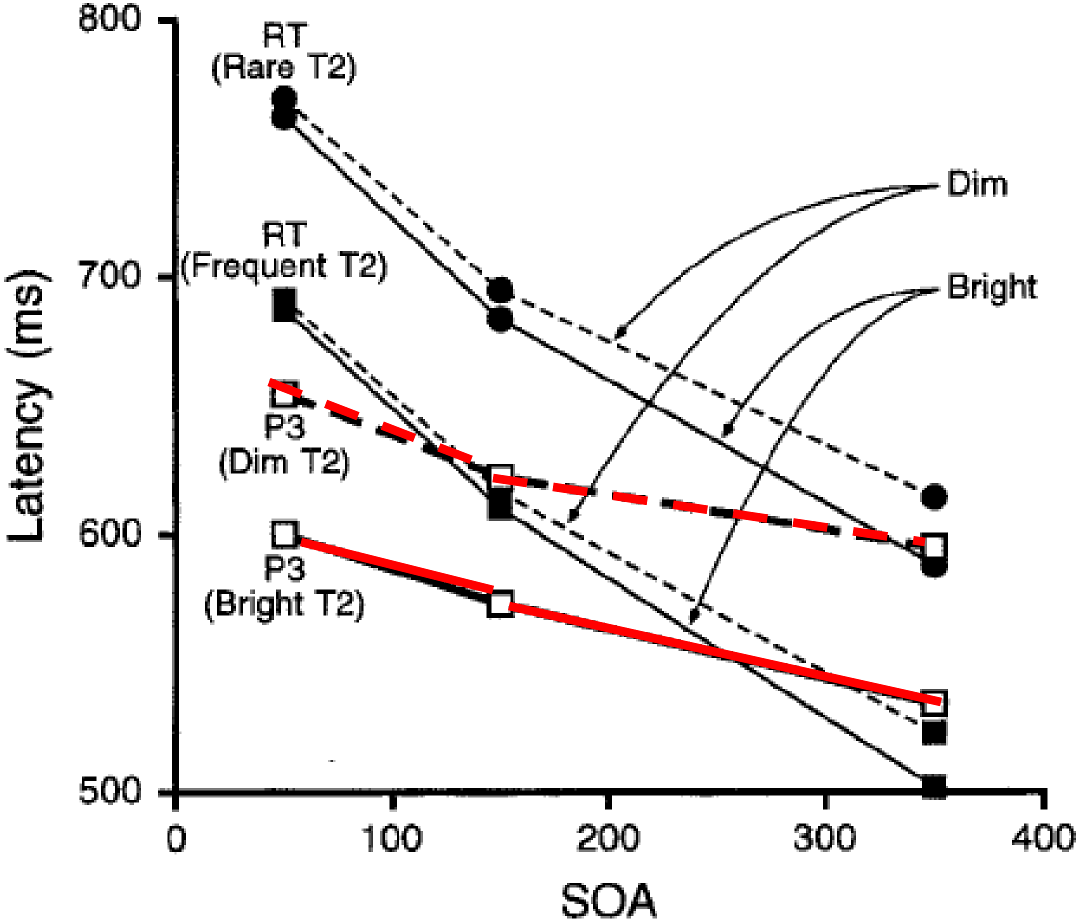
RT results

RTs longer for rare than frequent T2

RT to T2 decreases as SOA increases

RT to T2 longer for dim than bright stimuli T2, more so at longer than shorter SOAs

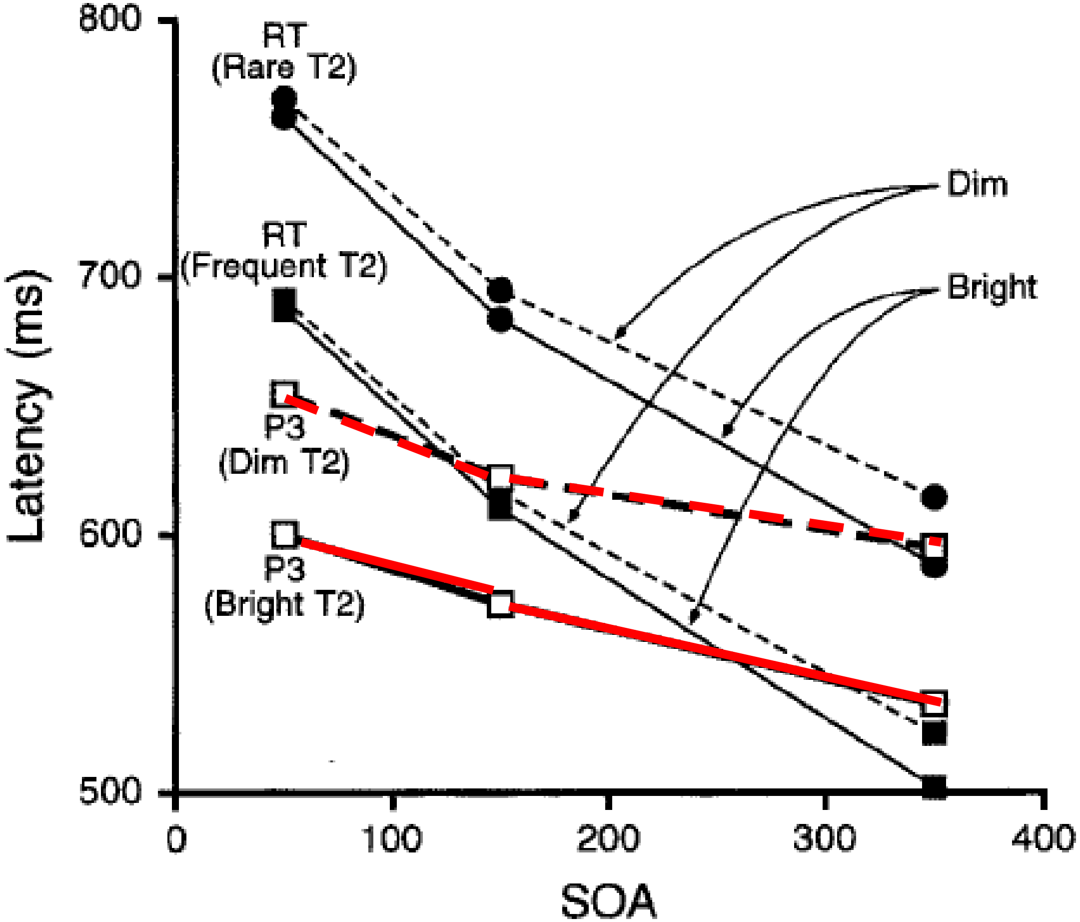
Results consistent with hypothesis that delay in RT2 at short SOAs reflects a postponement in a relatively late process, such as response selection.



P3 for dim vs bright?

P3 as function of SOA?

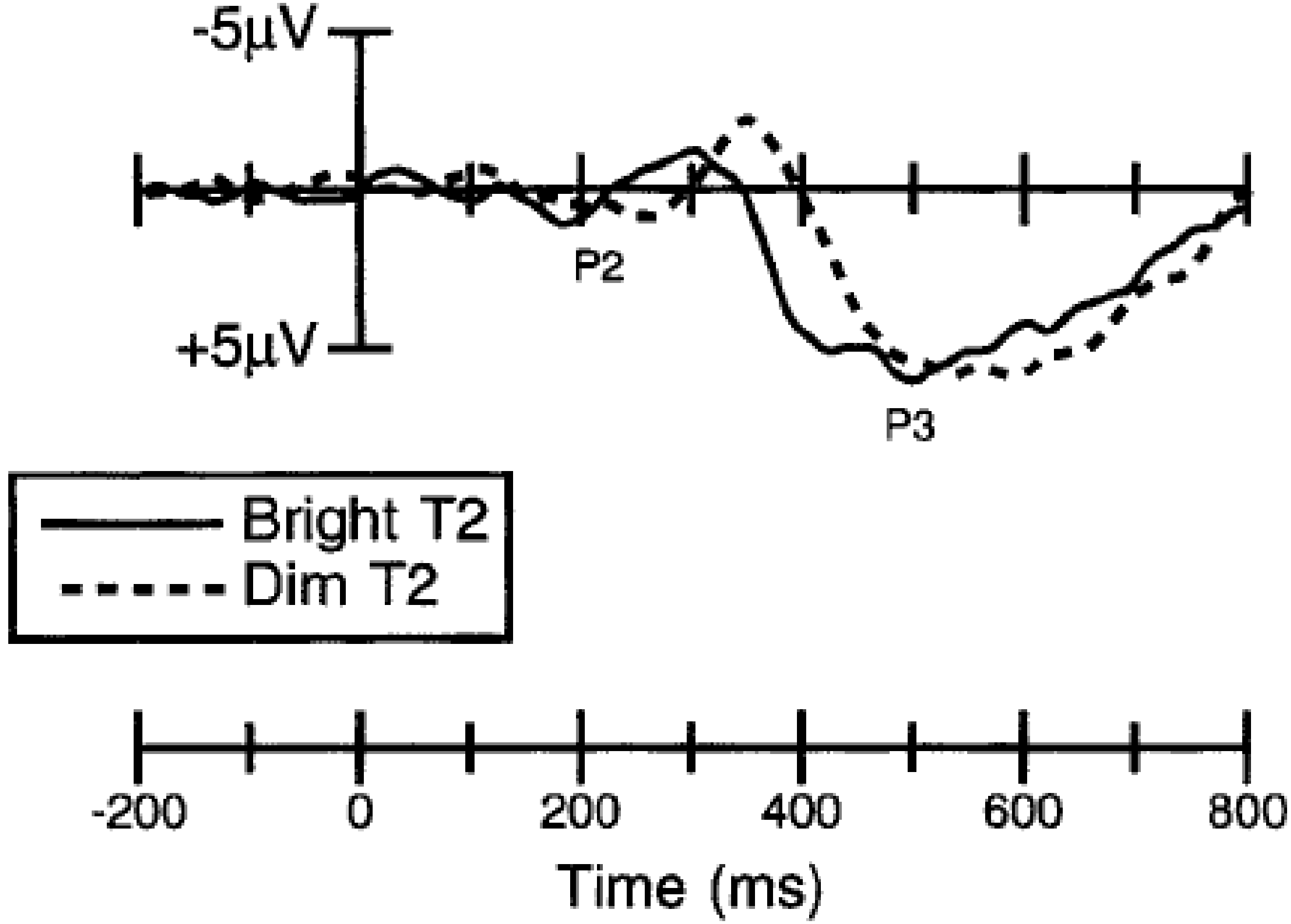
P3 latency results & inference

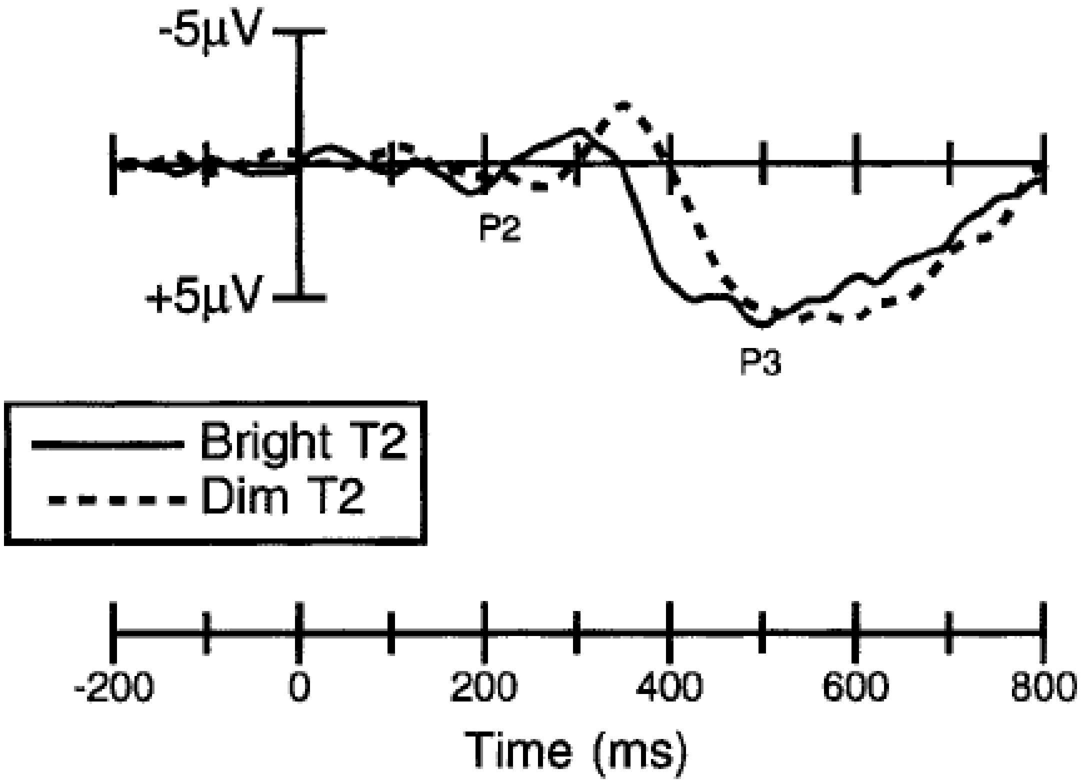


P3 later for dim than bright T2 (~60 ms)

P3 delayed with short SOA,
but much less than RT2, and dim effect

Slowing RT2 is primarily after perception


-5μV
+5μV
P2
P3
Bright T2
Dim T2
-200
0
200
400
600
800
Time (ms)



Other P2 and P3 results

P3 slightly smaller at shorter SOA
P2 later for dim than bright
P2 unaffected by SOA

Conclusions

Delay in RT2 at short T1-T2 SOAs occurs in a process that follows the identification and categorization of T2 – perhaps response selection

Also some interferences in an earlier stage, after P2 which was unaffected by SOA, around P3 which is slightly smaller and slightly delayed at shorter SOA. ***Thus, T2 was identified (normal P2), but process of cagorization was partially affected***.

Psychonomic Bulletin & Review
2004, 11 (1), 77-83

Dissociating sources of dual-task interference using human electrophysiology

KAREN M. ARNELL, ALICIA M. HELION, JESSICA A. HURDELBRINK, and BRIAN PASIEKA
North Dakota State University, Fargo, North Dakota

In the psychological refractory period (PRP) paradigm, two unmasked targets are presented, each of which requires a speeded response. Response times to the second target (T2) are slowed when T2 is presented shortly after the first target (T1). Electrophysiological studies have previously shown that the P3 event-related potential component is not delayed during T2 response slowing in the PRP paradigm, but that the lateralized readiness potential is delayed, which suggests a bottleneck on response selection operations but not on stimulus identification. Recently, researchers (Arnell & Duncan, 2002; Jolicœur & Dell'Acqua, 1999) observed T2 response slowing in an encoding–speeded response (ESR) paradigm where T2 followed a masked T1 that required identification but not a speeded response. T2 response slowing in the ESR paradigm is often indistinguishable from that in the PRP paradigm, prompting some researchers to postulate a common processing bottleneck for the two paradigms. With the use of the ESR paradigm, we observed T2 response slowing and, in contrast to the PRP paradigm, we also observed corresponding P3 delays. The results suggest that dissociable bottlenecks underlie the dual-task costs from the two paradigms.

Encoding-speeded response or ESR: T2 follows a masked T1 that requires identification but not a speeded response.

Encoding-Speeded Response (ESR) Paradigm

Similar to PRP but T1 is masked and requires identification for a later response; only T2 requires speeded response.

e.g., T1- masked visual digit, T2- unmasked tone, report pitch of tone asap, then report identity of T1 at trial's end.

T1 (masked) ---SOA – T2 – RT2, then report T1 identity

Typical finding: response to T2 is slow at short T1-T2 SOAs.

Question: does T2 slowing in ESR paradigm result from bottlenecks at same stage of processing as PRP or at different stages?

Arnell et al (2004): ESR Paradigm

T1: masked visual target requiring unspeeded response
T2: unmasked auditory target requiring a speeded response

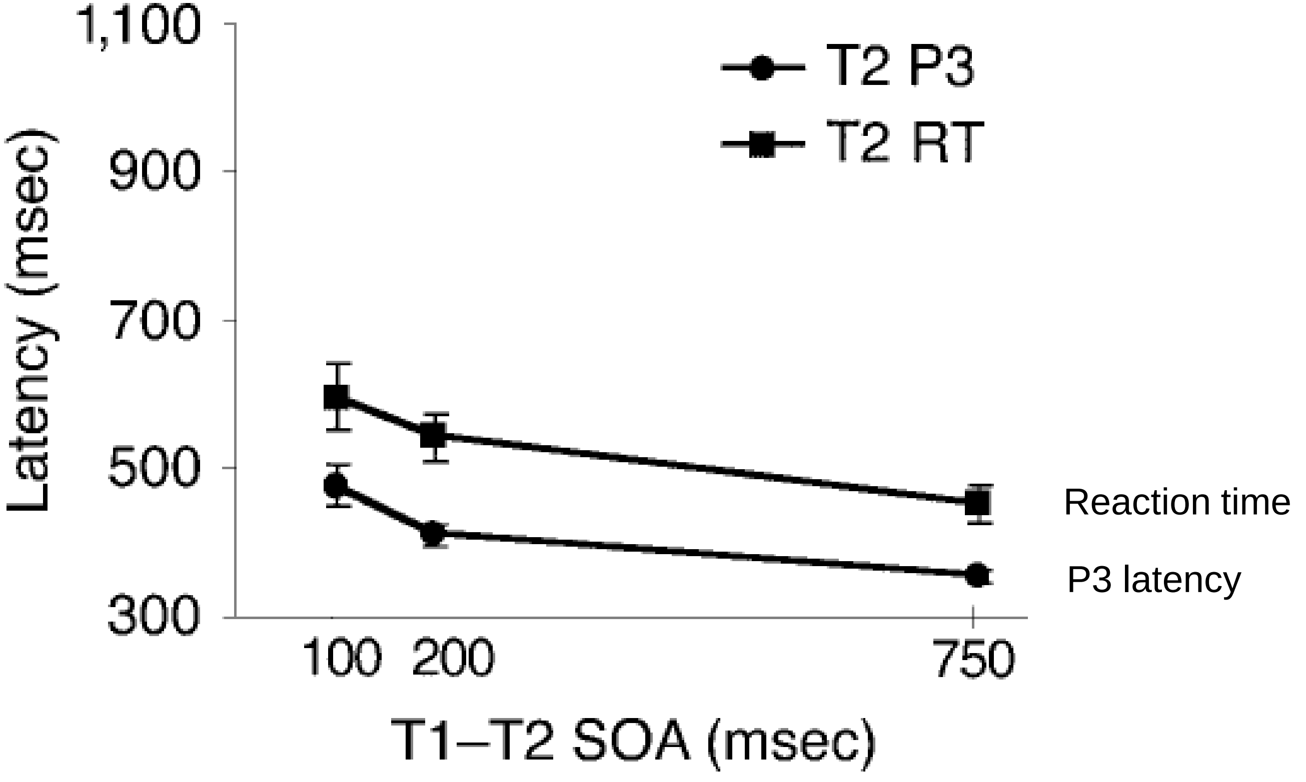
Trial Design:
T1: digit, followed by visual mask
T1-T2 SOA: 100, 200 or 750 ms
T2: word spoken in high or low pitch
R2: speeded keypress for pitch
R1: prompted 1000 msec after trial, digit ID

Expected outcomes:
Slowed RTs to T2 with decreasing T1-T2 SOA

If T2 slowing is due to bottleneck before or at identification or categorization, then P3 will be delayed at short SOAs.

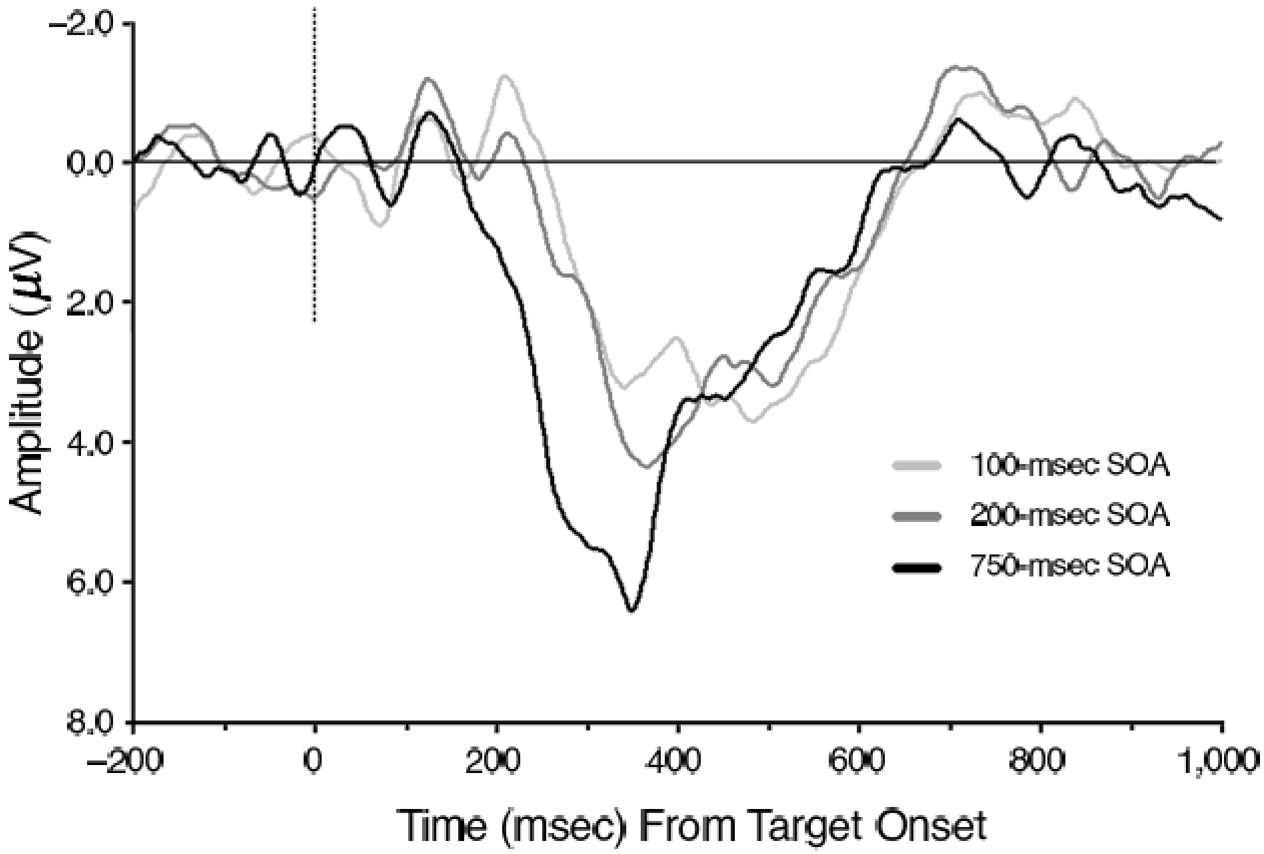
If T2 slowing is due to bottleneck after identification or categorization (e.g., response selection), then P3 latency should not be affected or affected as much as RT by SOA manipulation; this is the pattern seen in PRP.

RTs and P3 latencies to T2

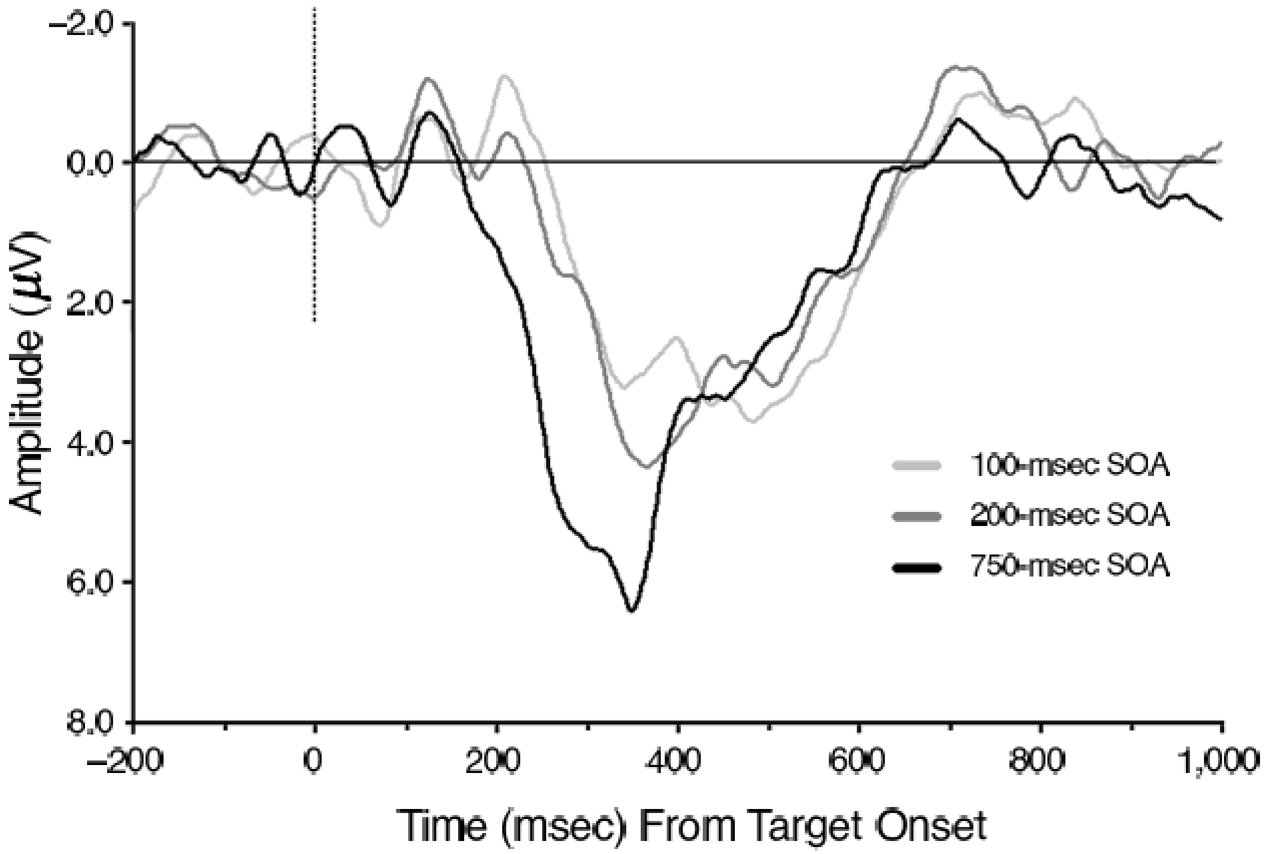


P3 latency and RT behave similarly; they are equally later at shorter (relative to longer) SOAs.

P3 difference (infrequent-frequent)



P3 difference (infrequent-frequent)



P3 latency is increased and P3 amplitude is decreased a shorter T1-T2 SOAs.

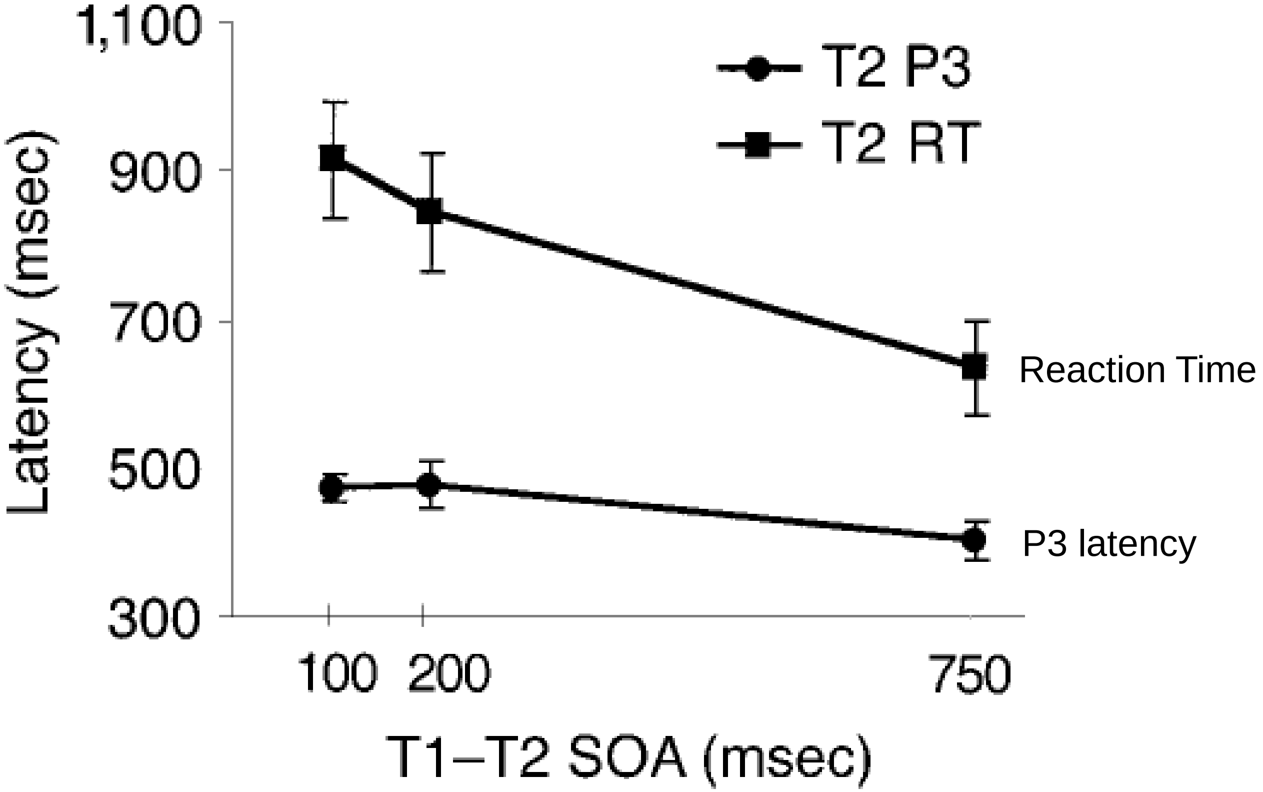
Majority of interference underlying response delay occurs before or at stage of stimulus identification and categorization

Psychological Refractory Period (Arnell et al 2004)

Same as Experiment 1, except T1 is not masked, and requires a speeded response (i.e., PRP paradigm)

T1: visual digit, no mask
R1: speeded key press for digit
T1-T2 SOA: 100, 200, or 750 ms
T2: spoken word, high or low pitch
R2: speeded key press for pitch

RTs and P3 latencies to T2



Reaction time slower than P3 latency

Reaction time is slower with decreasing T1-T2 SOA

P3 latency is only slightly slower with decreasing T1-T2 SOA

Summary

T2 response slowing is observed when T1 is masked and requires a delayed response and when T1 is unmasked and calls for an immediate response, i.e., in ESR and PRP, respectively.

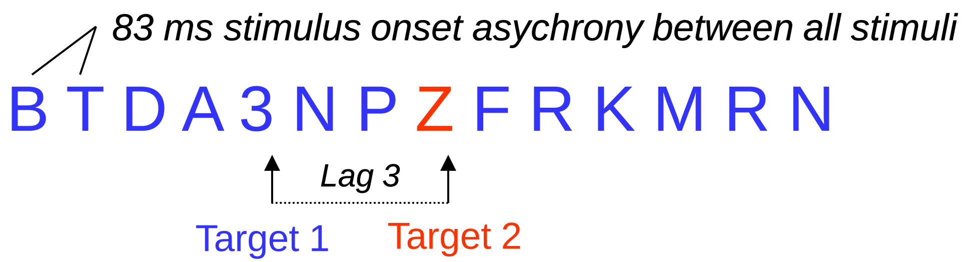
Although RT slowing looks the same – in fact, indistinguishable in pattern - ERP data suggest that the cause of the slowing occurs in different stages of processing in this two paradigms. In the PRP paradigm, In the ESR paradigm, according to P3 latency data, interference occurs pre-stimulus identification and categorization. Hypothesis is that conscious identification is bottlenecked because both targets must be identified online, while there is no bottleneck on response selection operation, as no speeded response to T1 is called for. In the PRP paradigm, by contrast, both identification and response selection processes are bottlenecked, the latter more than the former.

In short, RT delays at short SOAs in ESR are due to processing delays on stimulus identification/categorization/encoding while those in PRP are due to processing delays mostly in response selection processes but also somewhat in stimulus identification/categorization/encoding into working memory.

Attentional Blink Paradigm

Look for blue T followed by X.

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.

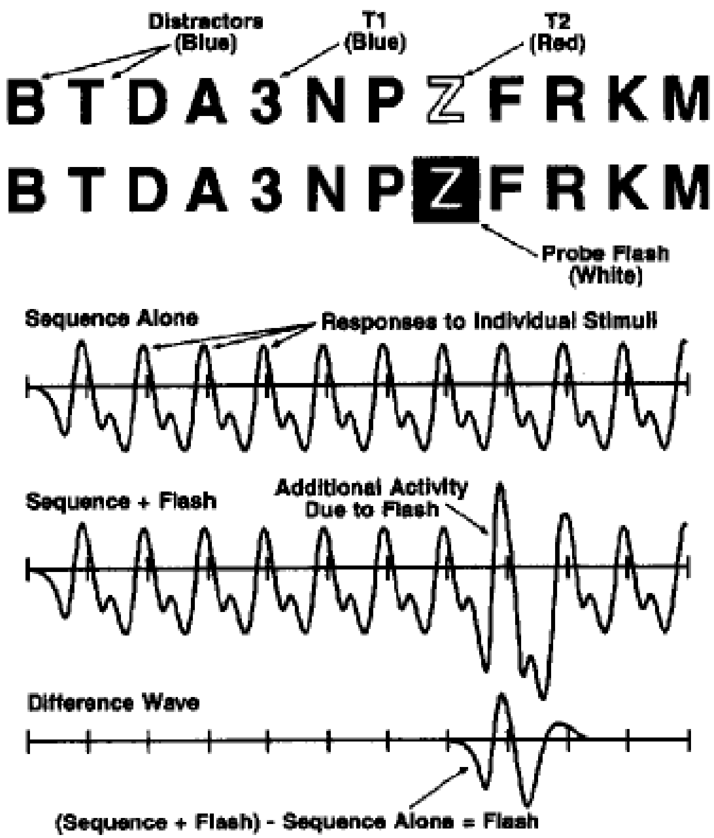
Dependent measure: P1 and N1 components

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

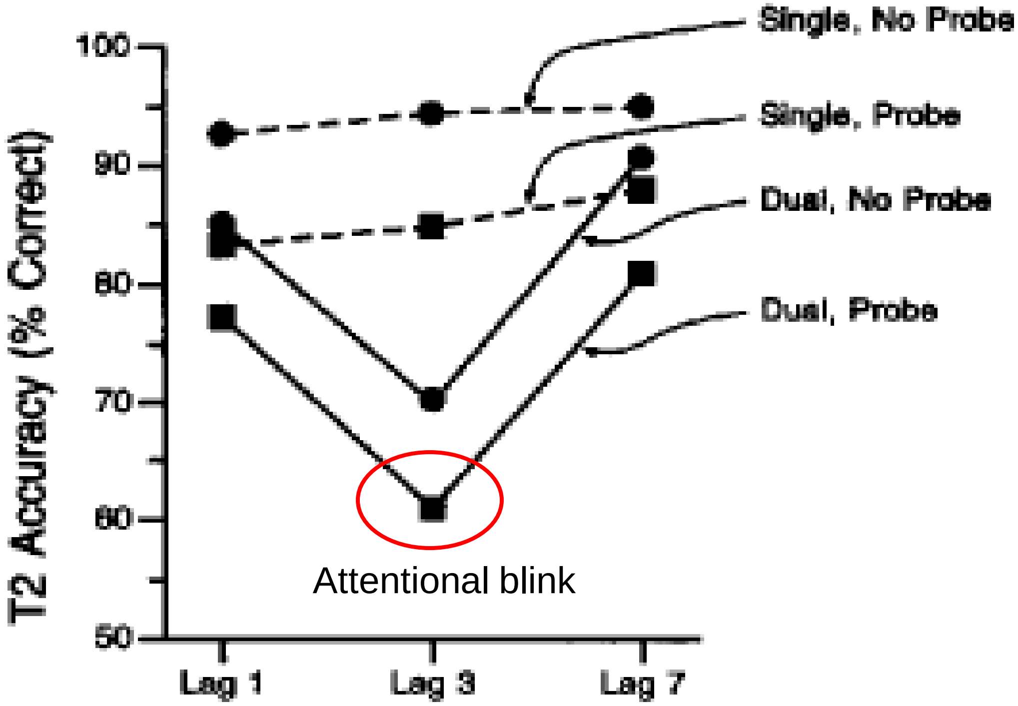
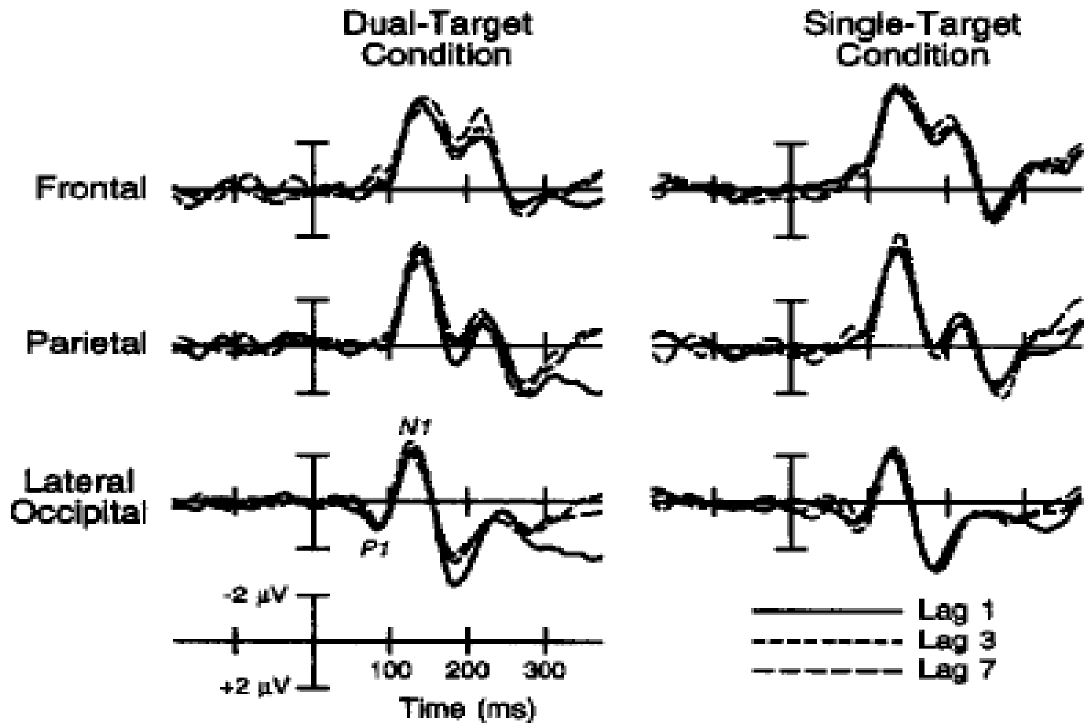


Figure 3. Mean accuracy for identifying the second target (T2) letter in Experiment 1 as a function of lag and probe presence.



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

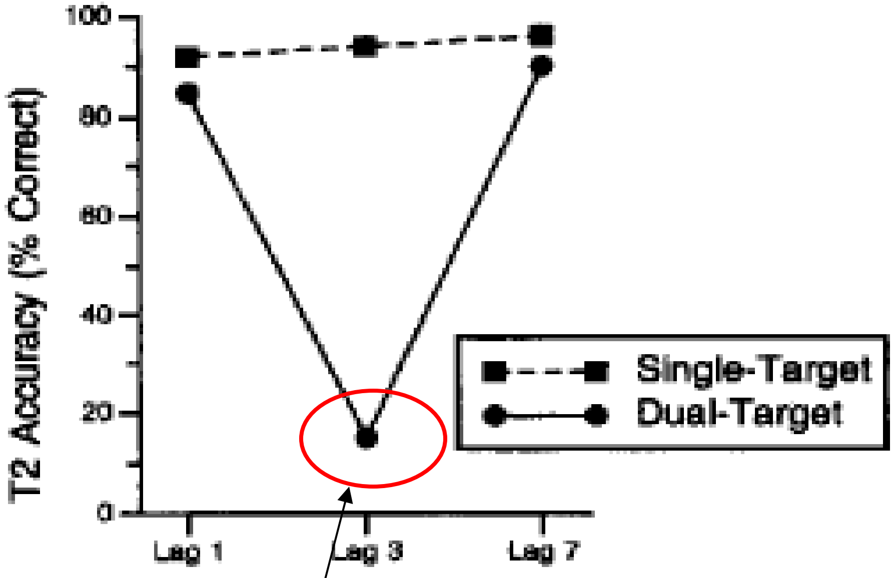


Figure 8. Mean discrimination accuracy for the second target (T2) as a function of lag for the single- and dual-target conditions in Experiment 4.

Attentional Blink

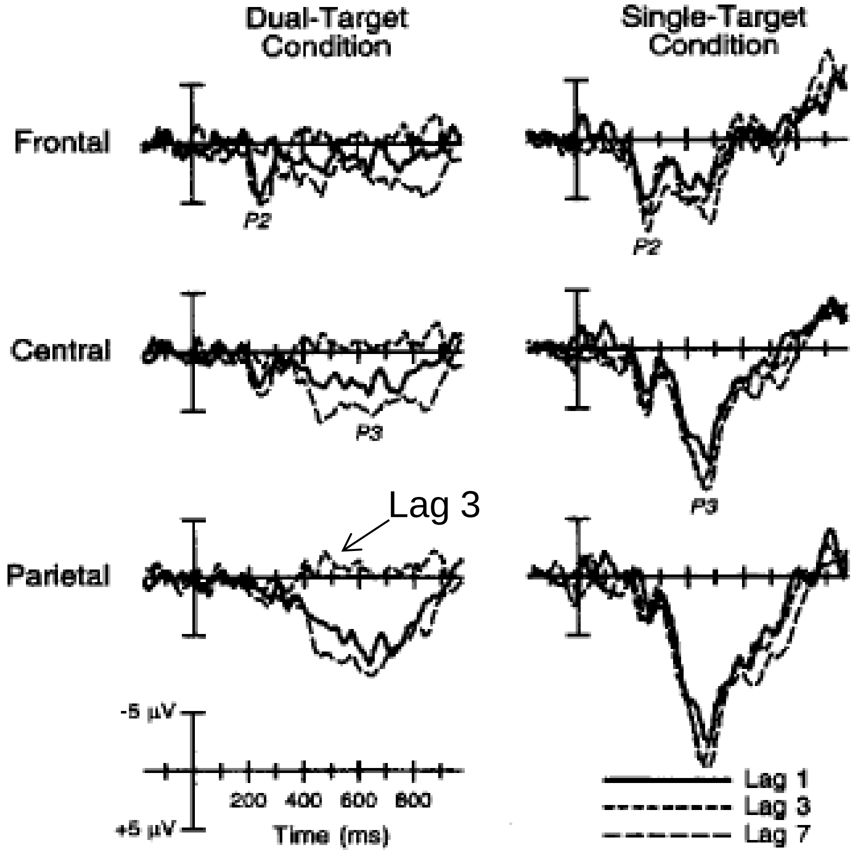


Figure 9. Grand average event-related potential difference waveforms from Experiment 4, formed by subtracting trials with the frequent second target (T2) stimulus from trials with the rare T2 stimulus. These waveforms were recorded at midline electrode sites and were averaged across participants. Negative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

Effect of lag on P3 in single target condition?

Effect of lag on P3 in dual target condition?

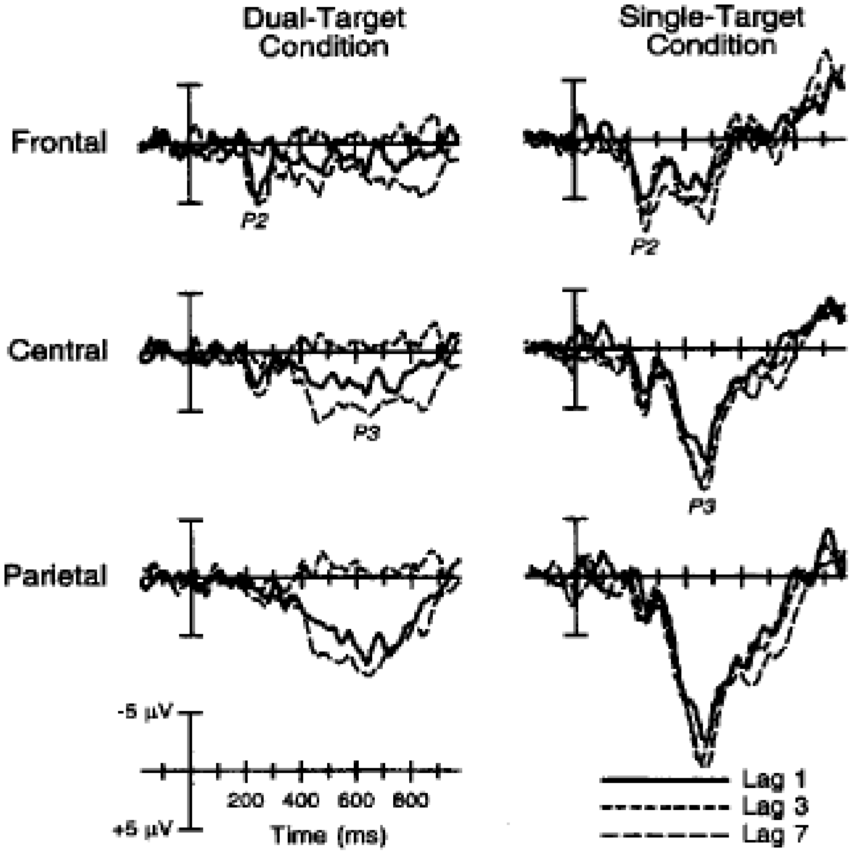


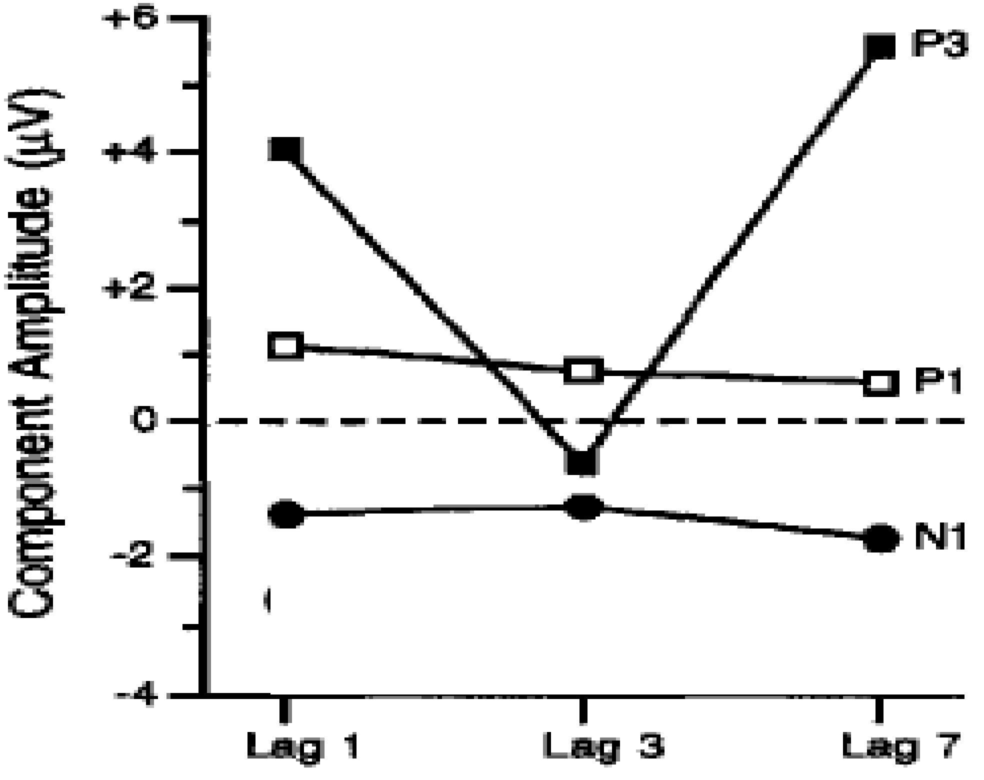
Figure 9. Grand average event-related potential difference waveforms from Experiment 4, formed by subtracting trials with the frequent second target (T2) stimulus from trials with the rare T2 stimulus. These waveforms were recorded at midline electrode sites and were averaged across participants. Negative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

Psychonomic Bulletin & Review
2002, 9 (4), 739-743

Delayed working memory consolidation during the attentional blink

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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.

Vogel and Luck (2002)

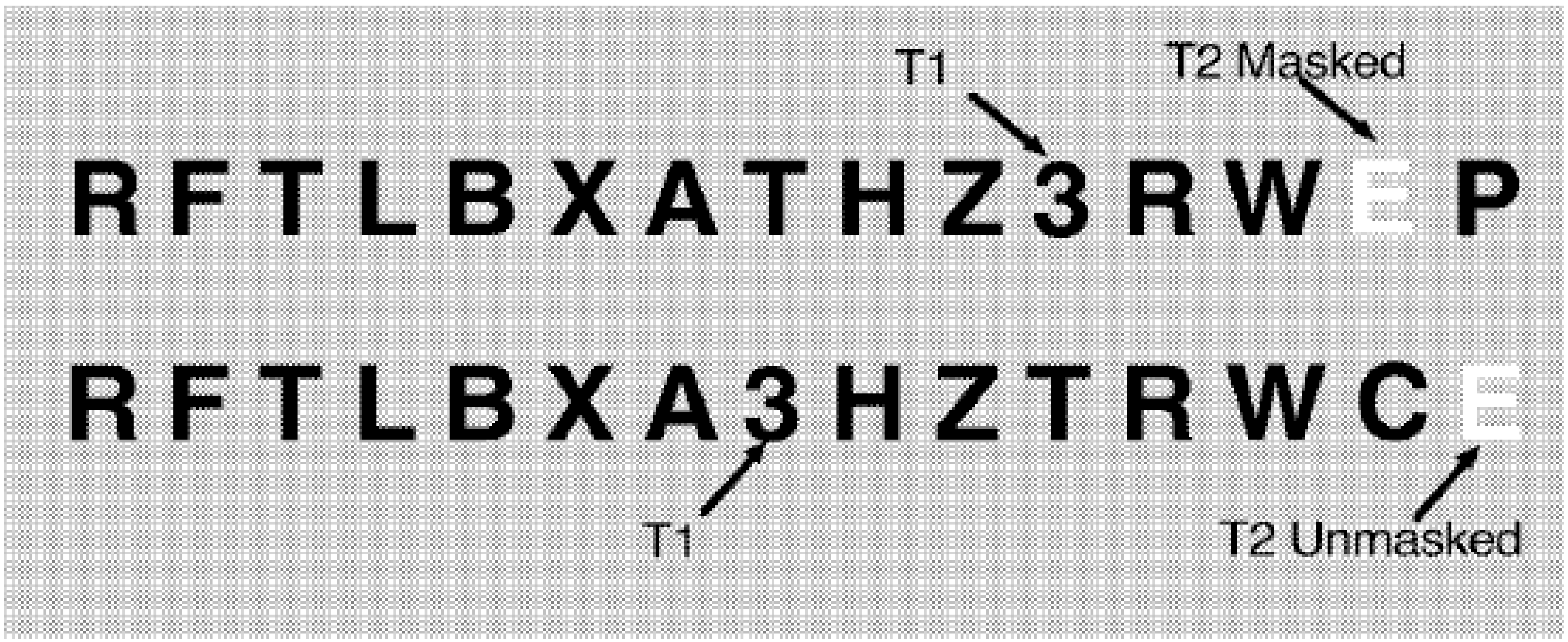

Figure 1. Sequences of stimuli presented serially at fixation. The upper row displays a lag 3 masked trial. The lower row displays a lag 7 unmasked trial.

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)

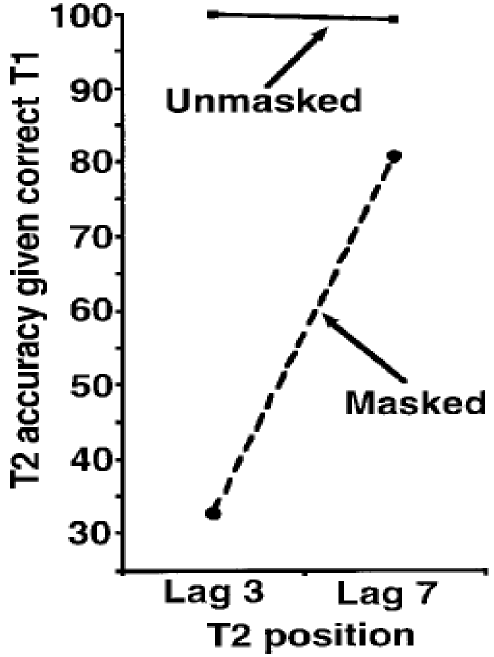

Figure 2. Accuracy for the second target (T2) as a function of lag for the masked and unmasked conditions.

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)

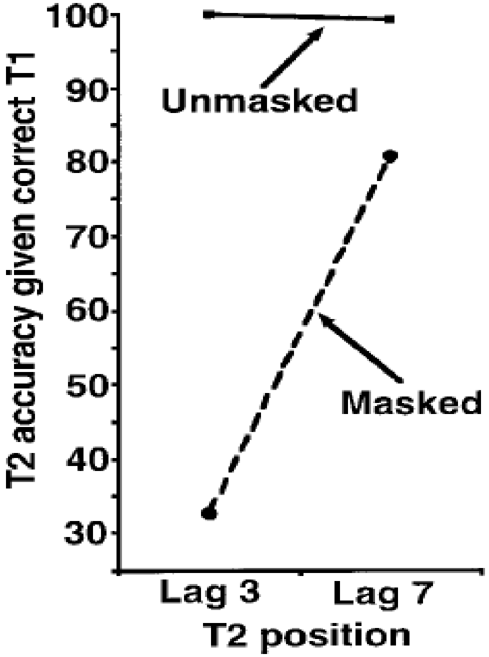

Figure 2. Accuracy for the second target (T2) as a function of lag for the masked and unmasked conditions.

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)

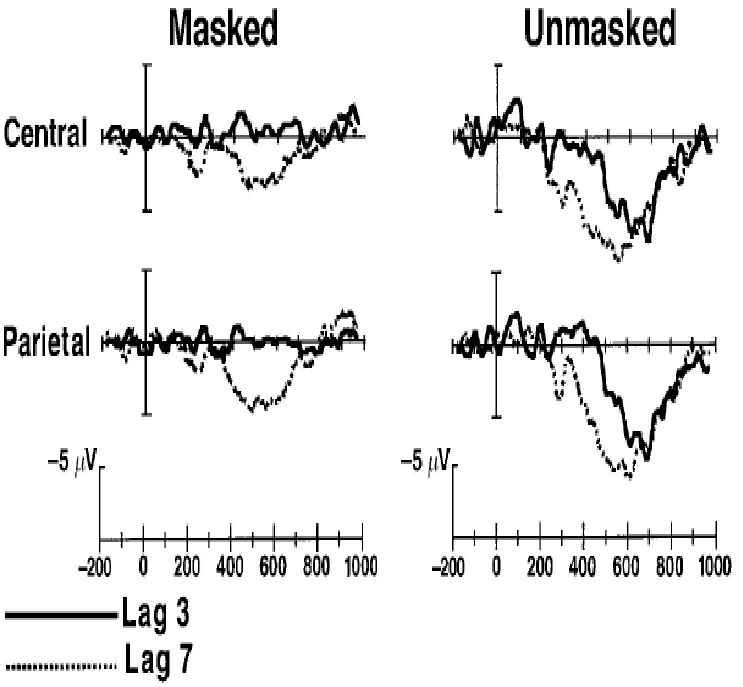

Figure 3. Grand average difference waveforms (infrequent T2 minus frequent T2) for two electrode sites (Cz and Pz) for each of the conditions. Note that negative voltage is plotted upward.

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)

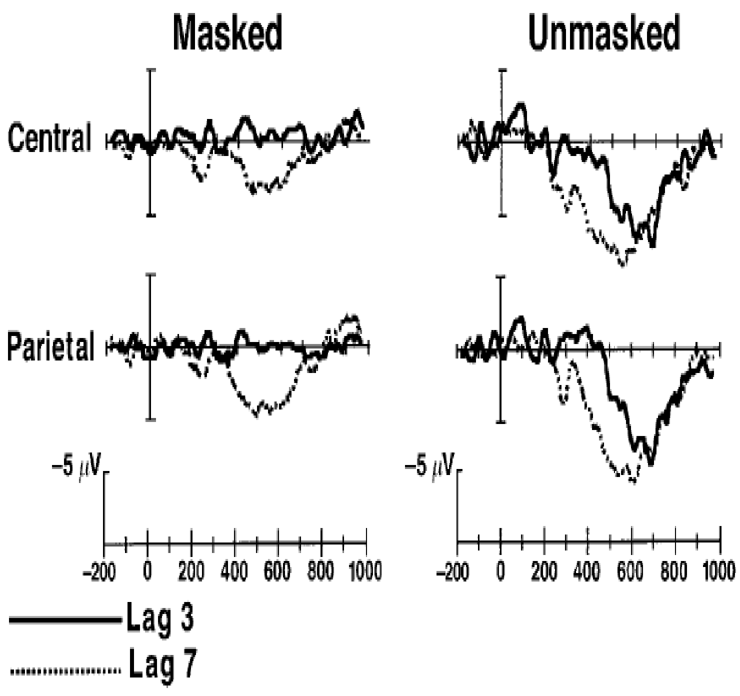

Figure 3. Grand average difference waveforms (infrequent T2 minus frequent T2) for two electrode sites (Cz and Pz) for each of the conditions. Note that negative voltage is plotted upward.

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. On this model masking of T2 is not irrelevant to the attentional blink.

TWO ALTERNATIVE ACCOUNTS

Interference Model (Raymond, Shapiro, & Arnell,1992)
Presentation of a new item (T2) soon after T1 but before T1 processing is complete provides attentional mechanism with confusing information, as features of T1 and T2 are both available. The processing system thus engages a suppressive mechanism, which suppresses stimuli that occur further down the stream in order to eliminate further confusion. AB is a consequence of this suppression.

Two stage model (Chun and Potter, 1995)
Stage 1. All items in the stimulus stream are processed to the point of conceptual representations without attention.

Stage 2. Attention is used to consolidate these representations into durable and reportable form.

The attentional blink is seen as a failure of T2 to receive stage II processing when stage II is still occupied with T1. i.e., T2 is not consolidated into working memory.

“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).

Overall, P3 amplitude is presumed to reflect demands on perceptual-central resources