

# Inferences2

<http://www.cogsci.ucsd.edu/~coulson/cogs179/>

# Announcements

- Homework due Thursday (not today)
- Course Reader available Thursday
- Library Reserves (not currently available, but hopefully soon)

# Inferential Limitations

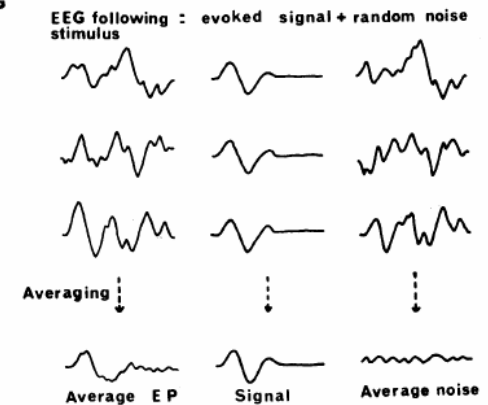
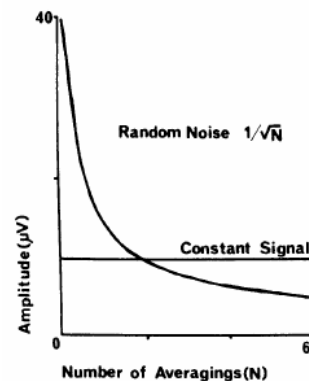
- Null Results
- Scalp Distribution
- Polarity
- Intracerebral Sources
- Amplitude
- Time Course
- Correlation vs. Causation
- Interdomain Mapping

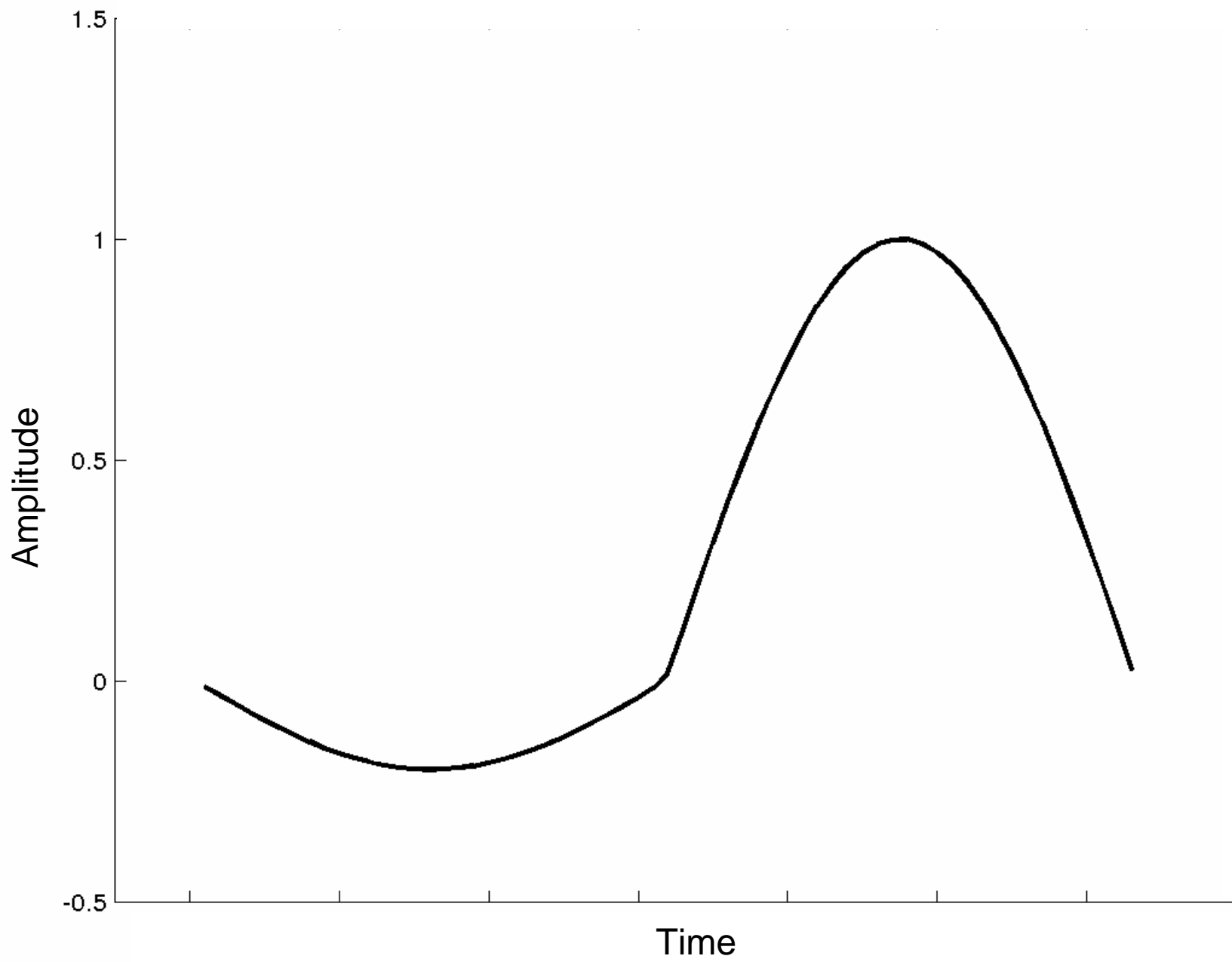


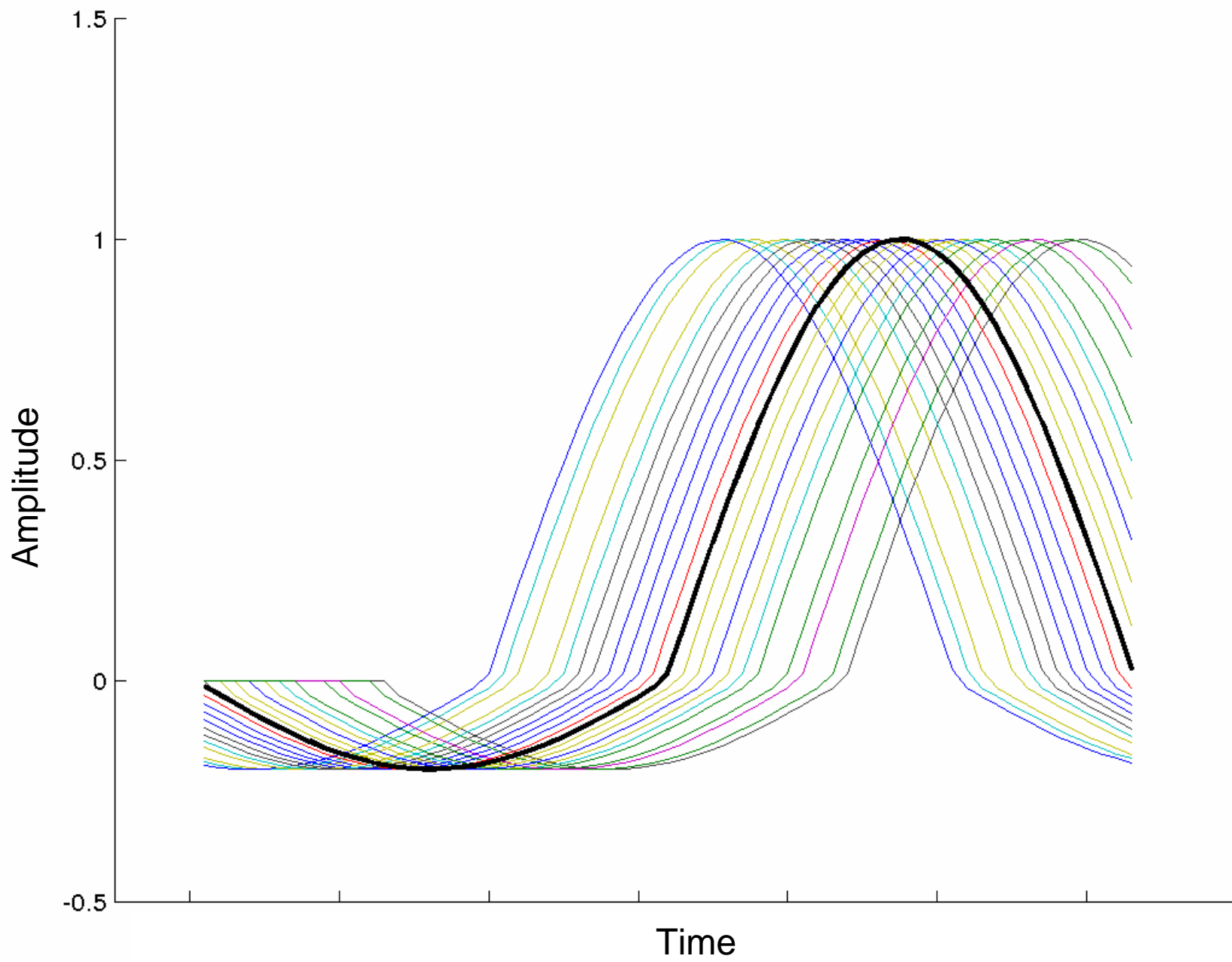
# Amplitude

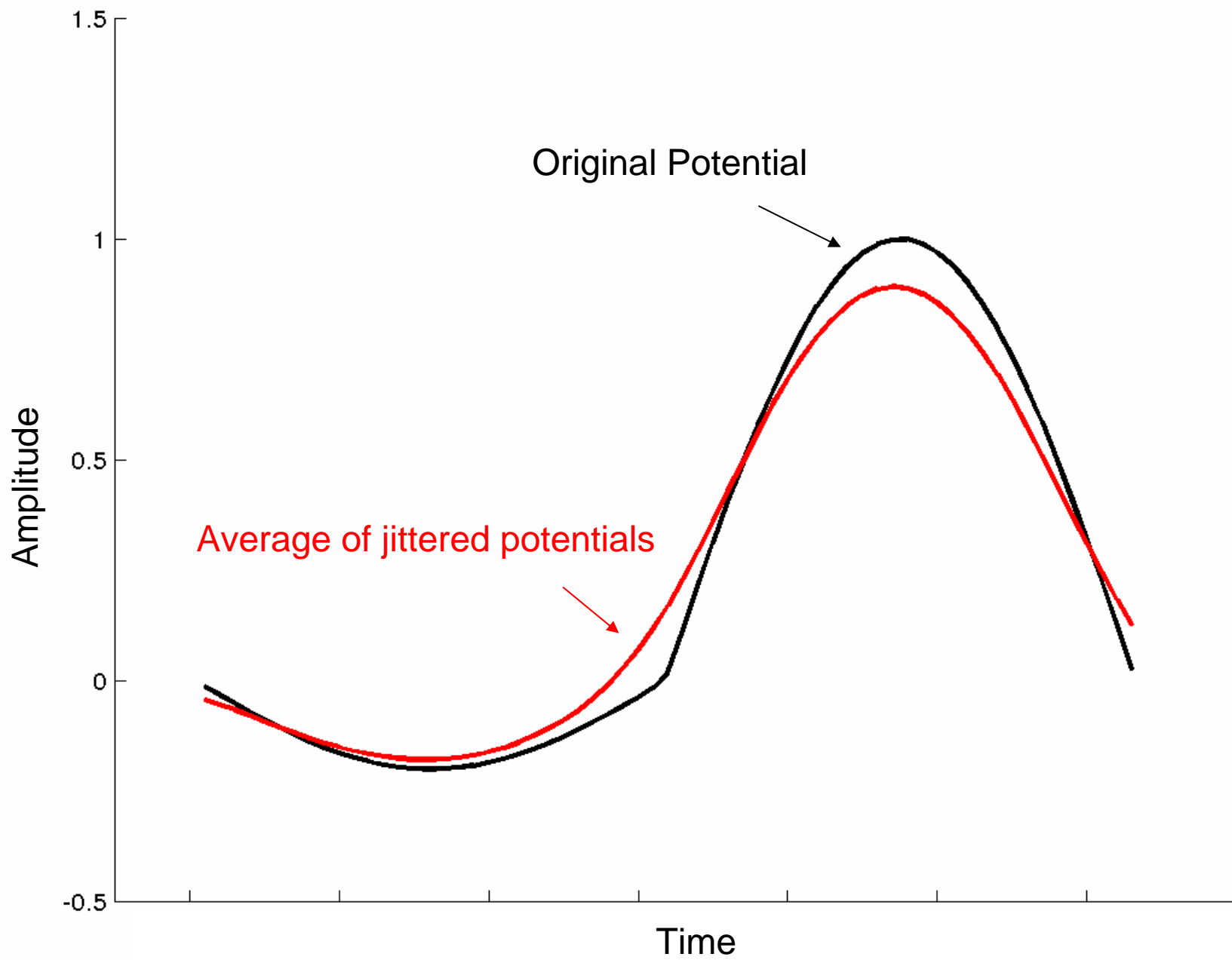
- Typically interpreted as reflecting strength of activity
- But amplitude differences can also arise when violations of assumptions behind averaging occur
- Assume temporal invariance of signal
  - But latency jitter can introduce apparent amplitude differences between two conditions that differ only in the degree of latency variability
- Assume signal identical across trials
  - Possible signal present on some trials but not others
  - Amplitude differences across conditions would then indicate the *probability* of the engagement of a particular process rather than the *degree* of engagement of a particular process

THEORY OF SIGNAL AVERAGING









# Woody Filtering

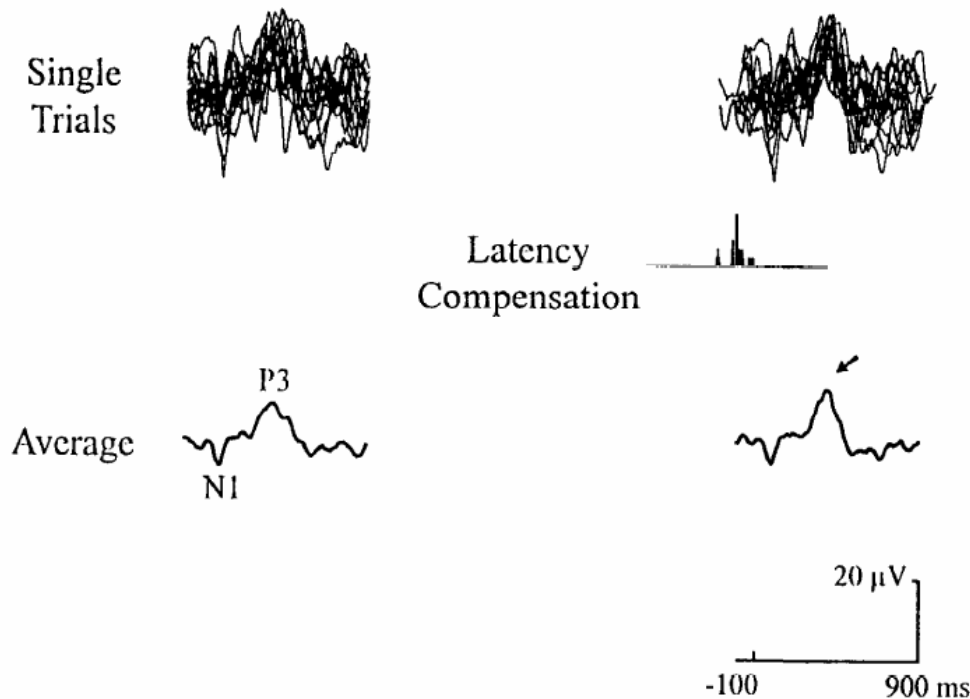
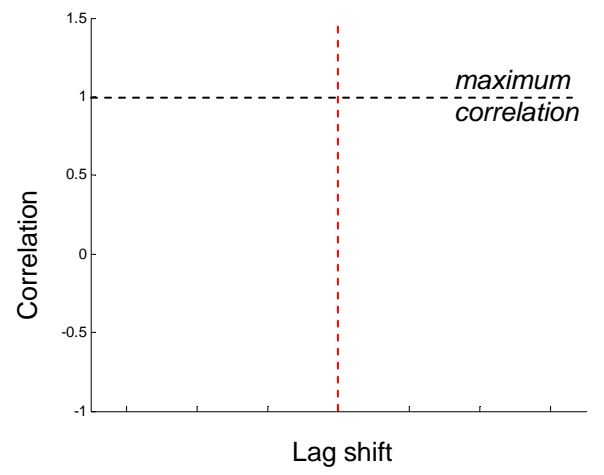
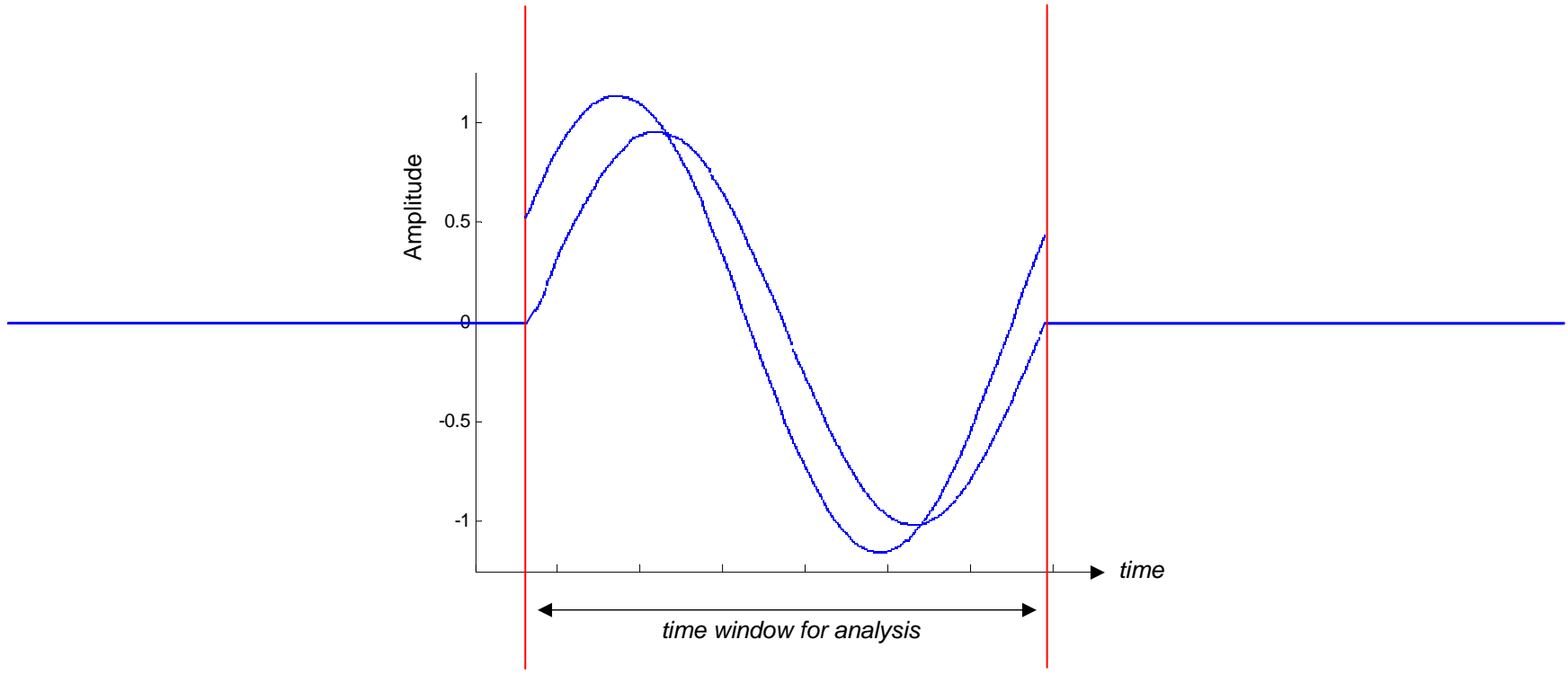


Fig. 11. Woody filtering. The tracings in the upper left of this figure are the 16 single-trial waveforms from Fig. 9. When averaging these waveforms together provides the waveform in the lower left of the figure. In the upper right of the figure the single-trial waveforms have been adjusted in their timing so as to have the greatest correlation with a template waveform. For the initial iteration the template waveform is the average waveform shown in the lower left of the figure. After the single-trial waveforms have been latency-compensated, they are then averaged together to form a new average waveform. This waveform then becomes the template for another cycle of correlations and latency compensations. The latency compensations and the resultant averaged waveform shown on the right of this figure are from the 7th iteration. The latency compensation process is dominated by the P3 wave which is the largest ~~section~~ <sup>wave</sup> in the single-trial waveforms. By aligning the single-trial waveforms around this P3 wave, the final compensated average waveform shows a larger P3 wave (arrow) than the simple average.



# Woody (1967)

1. Calculate a traditional time-locked average (template).
2. Perform cross-correlation between this template and each individual EEG sweep.
3. The shift amount where there's maximum correlation between the EEG sweep and the time-locked average is the jitter estimate.
4. Shift each EEG sweep by its jitter estimate, and re-average the latency-adjusted trials.
5. Repeat the process, now cross-correlating each single trial with the latency-adjusted average.
6. Perform no more than 3 iterations.



# Inferential Limitations

- Null Results
- Scalp Distribution
- Polarity
- Intracerebral Sources
- Amplitude
- Time Course
- Correlation vs. Causation
- Interdomain Mapping



# Time Course

- Is onset of ERP effect onset of divergent processing in the brain?
- Neural activity could differ *before* effect onset, but not be detectable at the scalp
  - Onset latency best construed as upper bound on divergence
- Adequate interpretation of time course of ERP effects requires understanding of functional significance of differences in e.g. peak latency, rise time, and duration of effect

# Correlation vs. Causation

- Experimental modulation of ERPs via cognitive manipulations reveal correlations between neural activity and cognitive processes
- Does not necessarily imply the brain activity measured is:
  - *essential* for cognitive processes of interest
    - Incidentally associated processes
  - *direct* manifestation of those processes
    - Downstream processes
- Need to interfere w/relevant neural activity and see whether it impacts cognitive function
  - Lesions, TMS, drug studies

# Interdomain Mapping: The Mind-Body Problem

- Logic of ERPs typically assumes 1-to-1 mapping between brain states and cognitive states
- Differential brain activity less meaningful if the same cognitive process could be achieved via multiple different neural instantiations
- Differential brain activity doesn't always reveal distinct cognitive processes
  - Early hemispheric differences in visual processing
  - How big of difference is a meaningful difference? (2 adjacent neurons?)

# Exploiting ERP Components

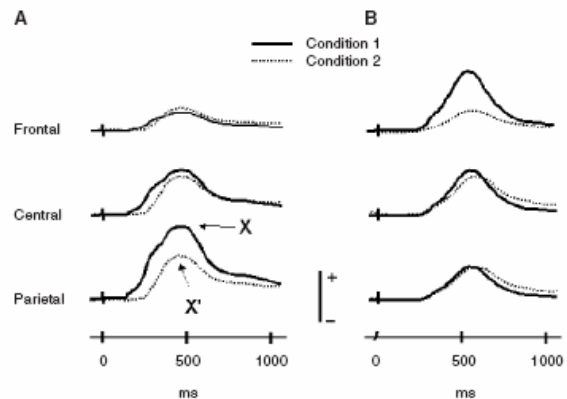


Figure 1.1  
Hypothetical ERP waveforms elicited at three electrode sites in two experimental conditions in two experimental situations (A and B). The differences between the waveforms allow a number of functional interpretations. See text for details.

- Assume positivity at X (relative to X') is known ERP component associated w/a specific cognitive process  $P$
- Inference about the time course of  $P$  in conditions 1 and 2
  - Onset
  - Peak latency
  - Rise time
  - Duration
- Inferences about the degree of engagement of  $P$  in conditions 1 and 2
  - Amplitude
- Rely on well-designed experiments
  - Motivate initial connection between amplitude modulations and engagement of  $P$
  - Motivate initial connection between latency modulations and engagement of  $P$
  - Interpret observed modulations in terms of  $P$

# Case Studies: Mental Chronometry

- In 1960s and 1970s timing of cognitive tasks probed entirely by reaction time tasks
- But RTs conflate several stages of processing
  - Perceptual Processing
  - Identification and Categorization
  - Response Generation
- Use P300 as more specific index?
  - Kutas, McCarthy & Donchin (1977) study

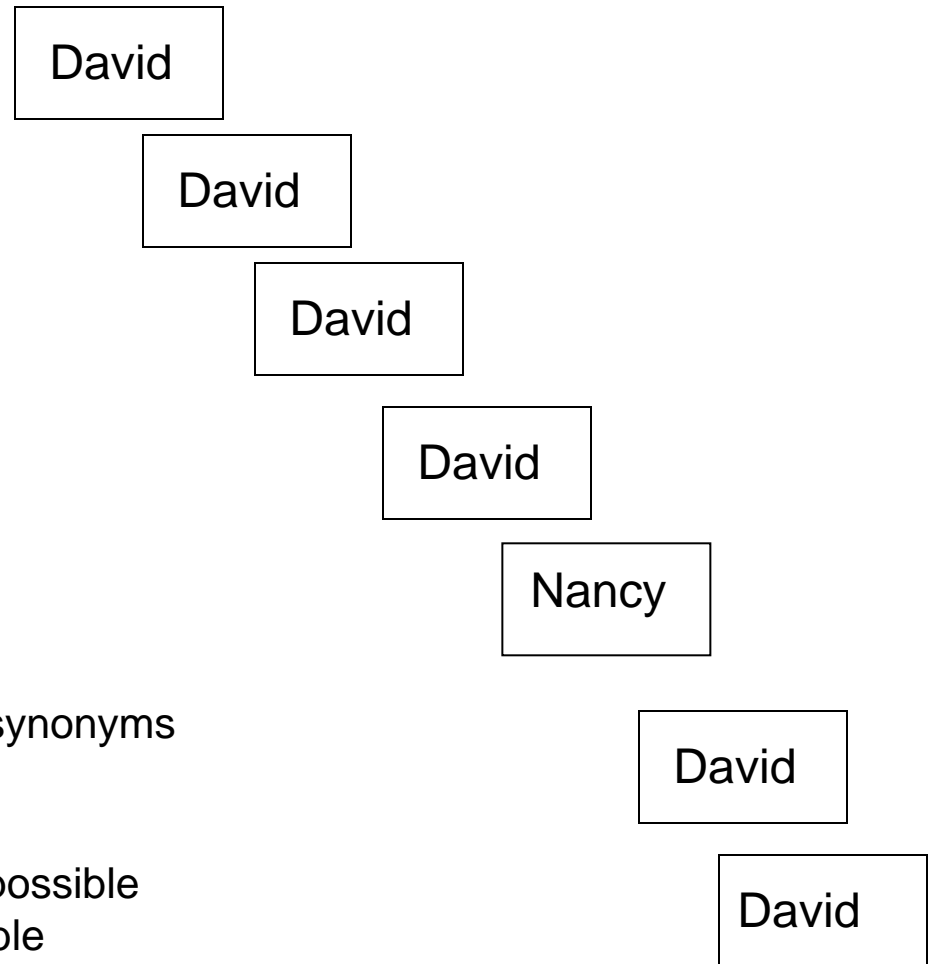


# P300 peak latency: Stimulus Evaluation vs. Response Selection

- If P300 indexes Stimulus Evaluation
  - Peak latency modulated by experimental manipulations that affect stimulus evaluation
- If P300 indexes Response Selection
  - Peak latency modulated by experimental manipulations that affect response selection
- Is P300 latency more correlated with the time it takes people to
  - **evaluate the stimulus**
  - generate the response
- When RT variance is determined by stimulus evaluation demands, P300 latency and RTs should be highly correlated
- When RT variance is determined by response selection demands, P300 latency and RTs should be less correlated

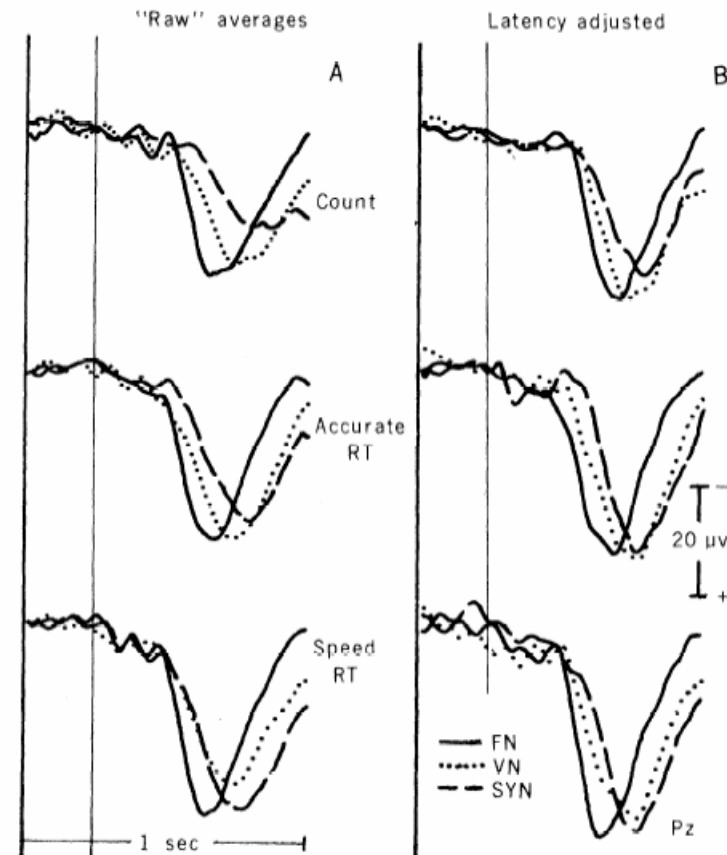
# Experimental Paradigm

- Oddball Paradigm
  - Standard (Probable Stimulus)
  - Target (Rare Stimulus)
  - Task: identify target in some way
- Fixed Names
  - Standard (80%): David
  - Target (20%): Nancy
- Variable Names
  - Standard (80%): Male Names
  - Target (20%): Female Names
- Synonyms
  - Standard (80%): words
  - Target (20%): word “prod” and its synonyms
- Tasks
  - Count Targets
  - Press Button – be as *accurate* as possible
  - Press Button – be as *fast* as possible

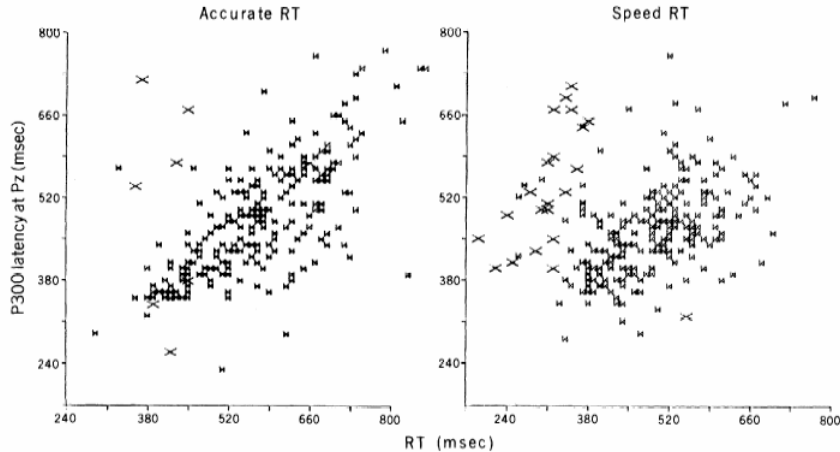


# Results

- Raw Averages (Latencies)
  - Count & Accurate:  $FN < VN < SYN$
  - Speed:  $FN < VN = SYN$
- Latency Adjustment
  - Allows for more valid comparison of amplitudes
  - Also allows for evaluation of P3 latency on individual trials
  - (see next slide)
- Amplitudes
  - Differ before Correction
  - Not after Correction
  - Amplitude differences artifact of latency jitter



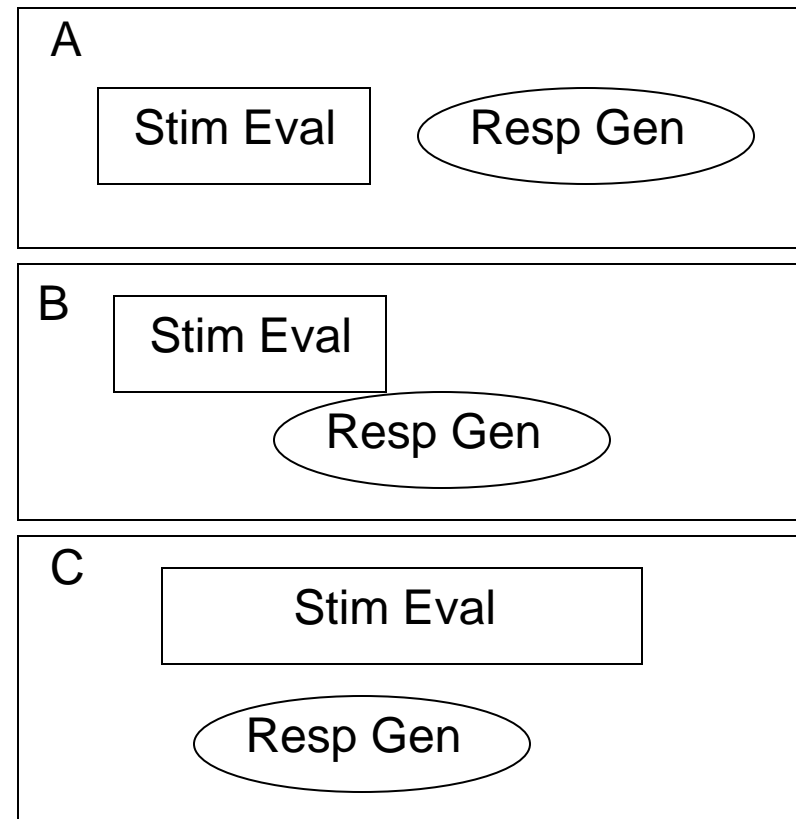
# P3 latencies & RT



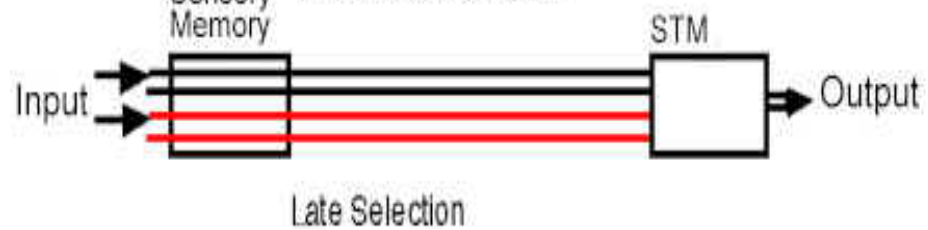
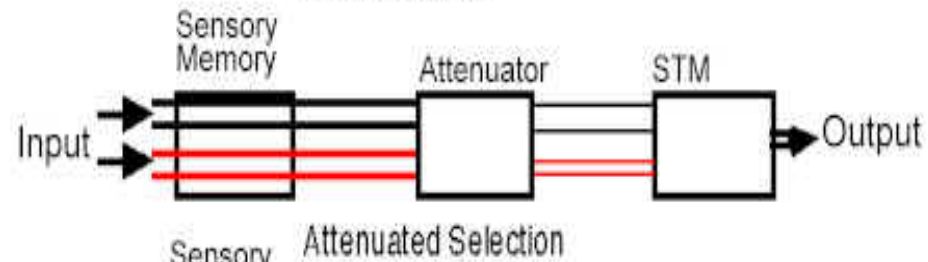
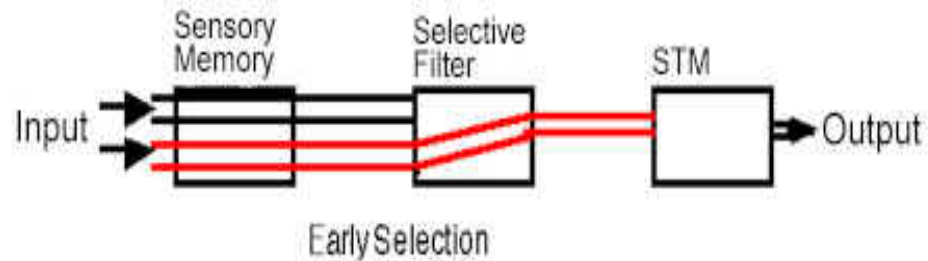
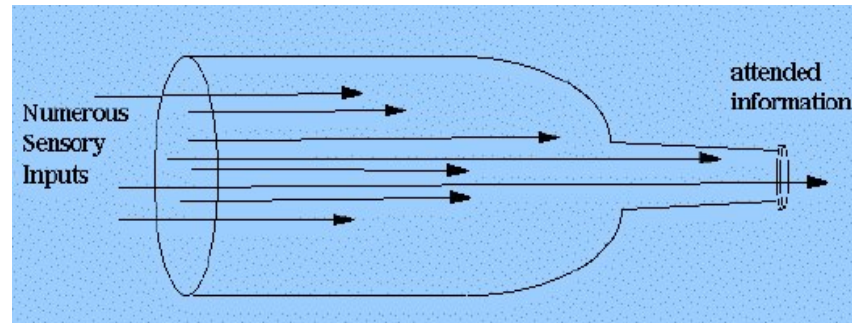
- Correlation
  - Accuracy Condition:  $r=.61$
  - Speeded Condition:  $r=.26$
- Inaccurate responses
  - Marked w/X's
  - More in Speeded
  - Correlation goes up when they are removed
- Relative timing
  - Accurate trials P3 peak *earlier* than RT
  - Inaccurate trials P3 peaks *later* than RT

# Proposed Interpretation

- P300 indexes stimulus evaluation
- RT indexes response generation
- Accuracy Instructions
  - Stimulus Evaluation then Response Generation
  - Correlation between processes indexed by correlation between P300 and RT
- Speed Instructions
  - Response Generation begins before Stimulus Evaluation has been completed
  - Dissociation of processes indexed by lower correlation between P300 and RT
  - Inaccurate responses result when Response Generation proceeds without adequate input from Stimulus Evaluation



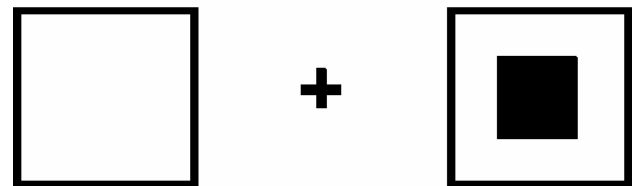
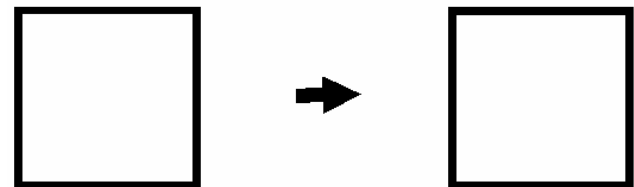
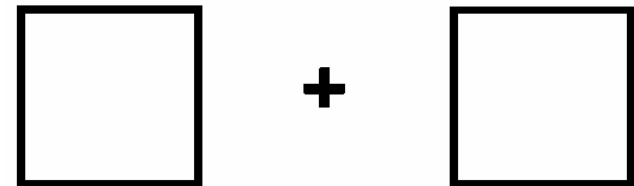
# Case Studies: Attention



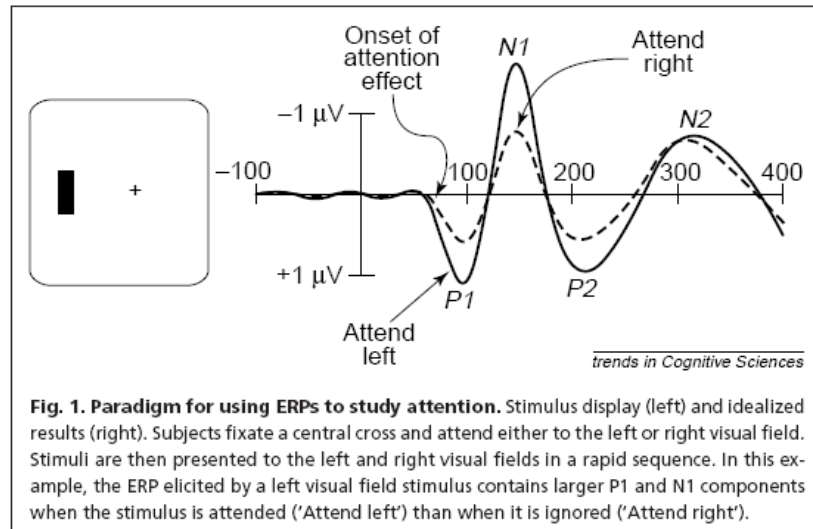
# Cuing Paradigm

- Cue tells subject which direction to attend
- Target appears either in cued or un-cued box
  - More often in cued
- Subject presses button as soon as target appears
- Compare RTs & ERPs
  - Right Side Square:
    - Attended
    - Unattended
  - Left Side Square:
    - Attended
    - Unattended

Stimulus Sequence from an Endogenous Cuing Experiment



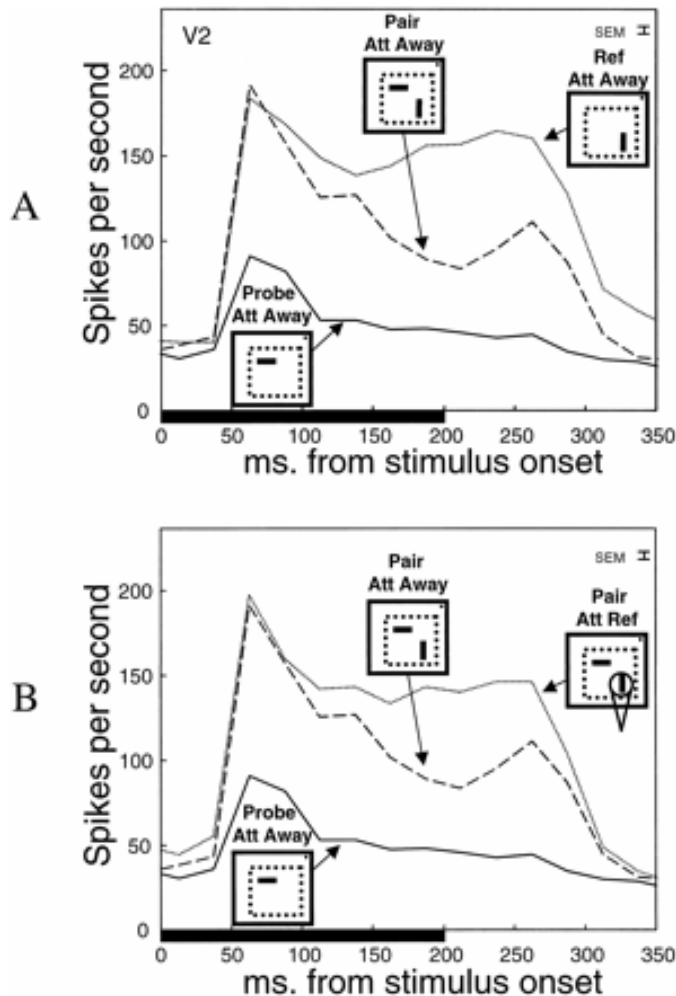
# Timing Inferences



- Without knowledge
  - Attention effects begin at least by 60 ms after the onset of the stimulus
  - Attention effects have ended by 300 ms after the onset of the stimulus
- With prior knowledge
  - P1 and N1 reflect visual processing of the stimulus
  - Attention modulates early sensory processing of stimuli
  - At least in this experimental paradigm



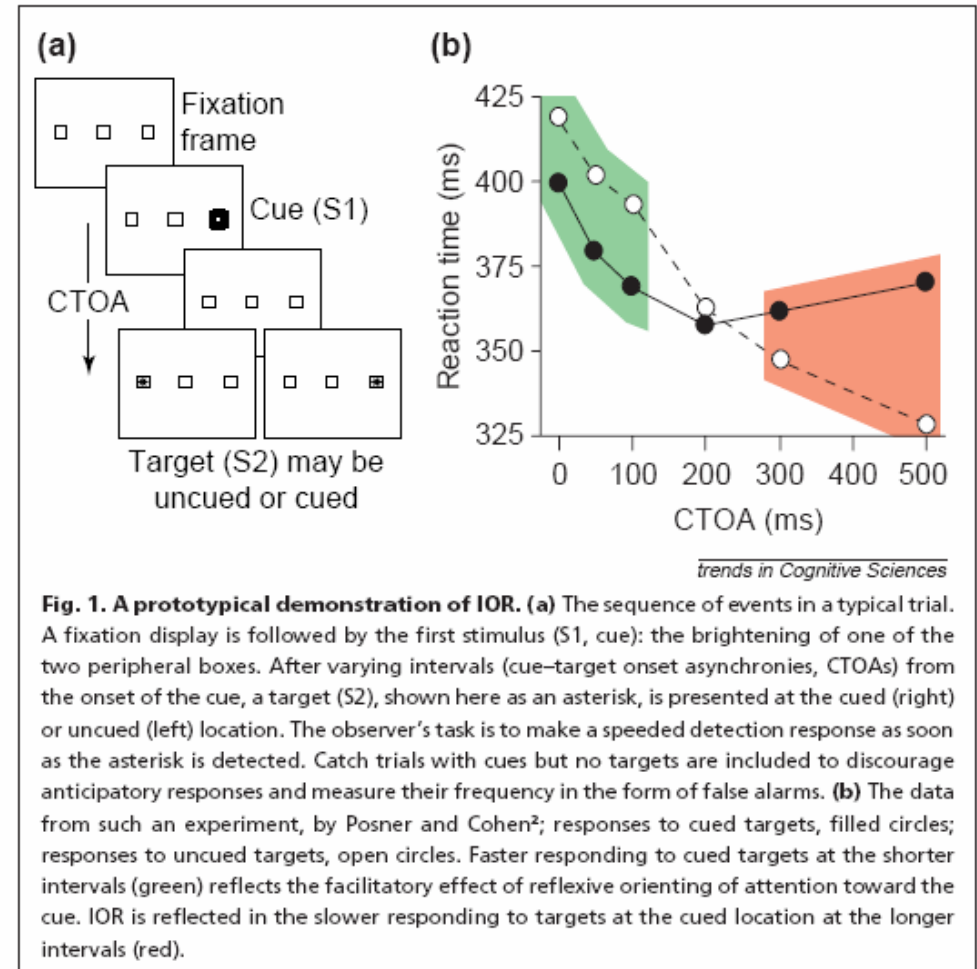
# Reynolds et al.



- Monkey single cell recording in V2
- Ref is stimulus this cell is tuned to
- A: shows activity suppression in presence of another stimulus it's NOT tuned to
- B: greater response to pair stimulus when monkey attends to that region of space than when region is unattended
- Increased spiking rate could be manifested (indirectly) by amplitude enhancements at scalp recording sites

# Inhibition of Return

- Exogenous Cueing
  - Participants faster at cued location even when the cue is not predictive
  - Attention moves automatically
- Inhibition of Return
  - Red region in graph →
- Are effects due to changes in motor thresholds or changes in sensory responsiveness?



# ERP Study

HOPFINGER AND MANGUN

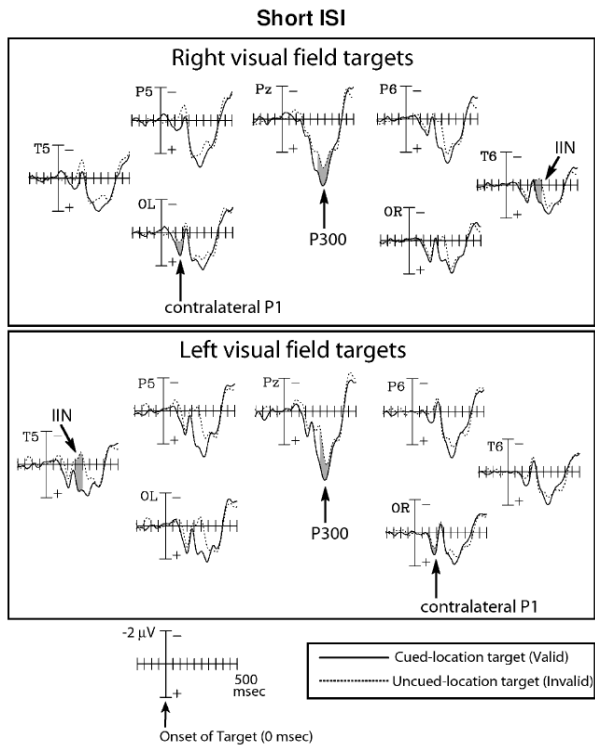


Figure 2. Event-related potentials to right visual field target stimuli (top) and left visual field target stimuli (bottom) at the short cue-to-target interstimulus intervals (ISIs). Electrodes OL and OR are located midway between T5 and O1 and midway between T6 and O2, respectively, of the International 10-20 system of electrode placement (Jasper, 1958). Electrodes P5 and P6 are located between T5 and P3 and between T6 and P4, respectively. Shaded gray areas highlight the latency ranges over which statistics were computed for the contralateral P1 (100–150 msec), the P300 (250–350 msec), and the ipsilateral invalid negativity (IIN; 200–250 msec). At the short cue-to-target ISIs, cued-location targets (solid lines) elicited significantly enhanced P1 and P300 components, relative to uncued-location targets (dashed lines). Uncued-location (invalid) targets elicited a significantly negative going wave, ipsilateral to the target location (the IIN).

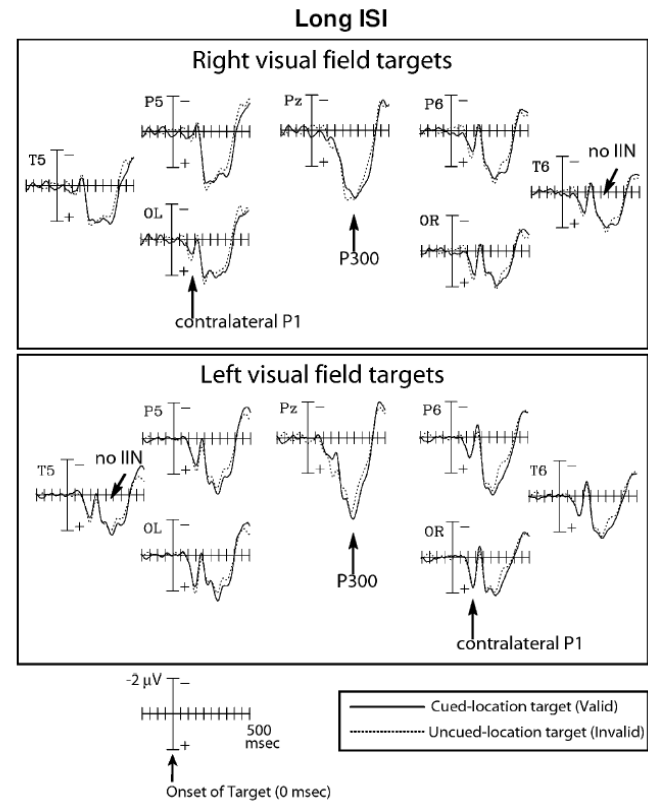


Figure 4. Event-related potentials to right visual field target stimuli (top) and left visual field target stimuli (bottom) at the long cue-to-target ISIs. Scalp electrodes are the same as in Figure 2. There was not a significant difference in the contralateral P1 component, although uncued-location targets show a somewhat stronger level of activity than cued-location targets (solid lines) on the grand-average waveforms (statistics for the P1 were computed over the latency range of 100–150 msec). There also was no statistical difference between cued- and uncued-location targets for the latency range of 250–350 msec, corresponding to the peak of the P300. Finally, the ipsilateral invalid negativity (IIN) observed in the short-ISI data was not observed in the long-ISI data.

# Questions...

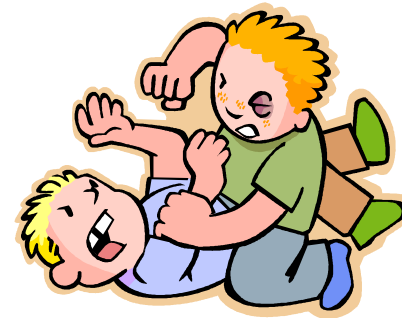
- In short ISIs, why is P1 effect evident over LH channel with RVF and RH channel in LVF?
- What might be going on with the IIN since it shows the reverse pattern?
- Could you explain the null results in the Long ISI as due to power limitations?

# Hopfinger & Mangun

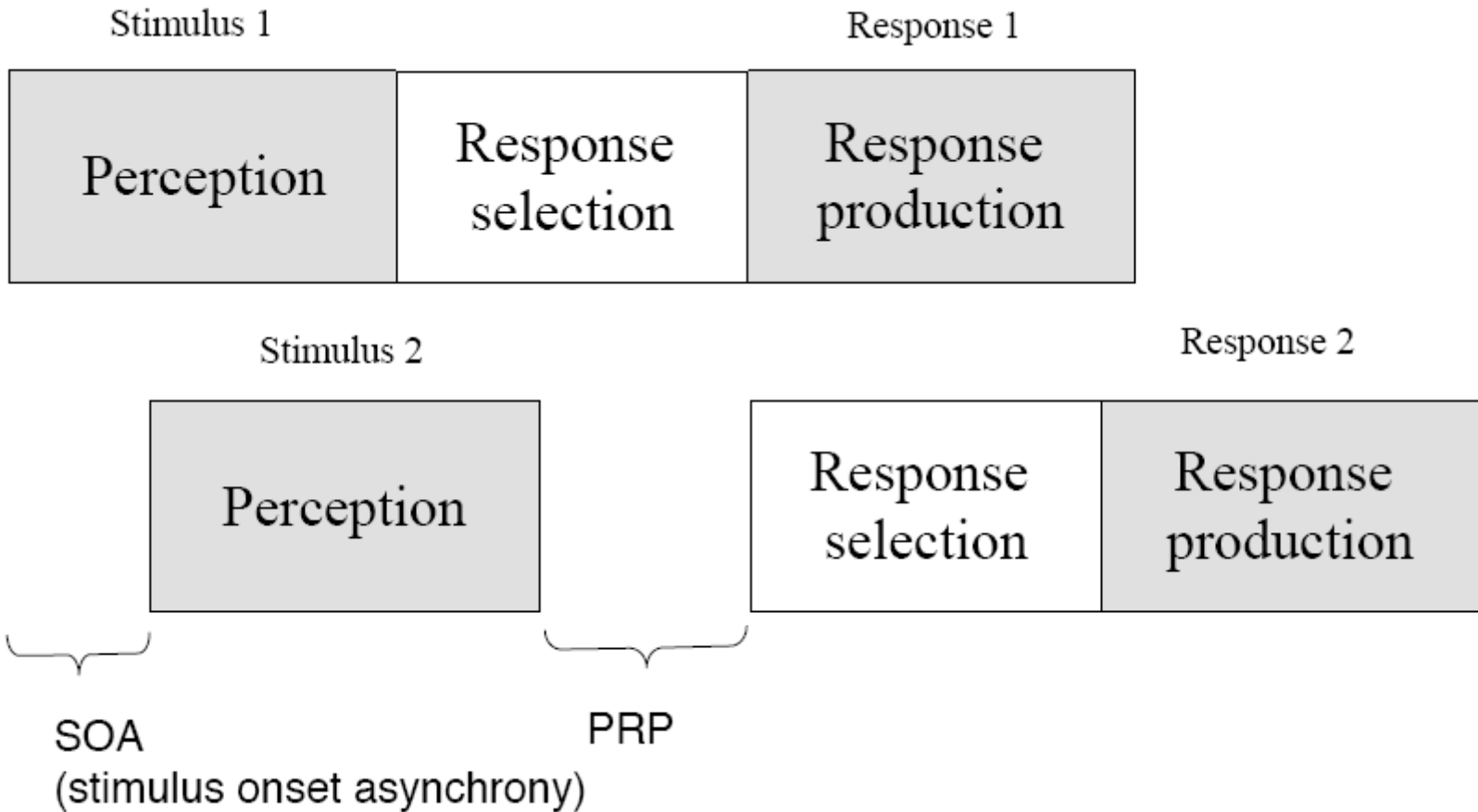
- P1 & P3
  - Larger for valid trials at short ISIs (facilitation trials)
  - Not larger for valid trials at long ISIs (IOR)
  - P1: enhanced perceptual processing
  - P3: greater significance of stimulus
- IIN (Invalid Ipsilateral Negativity)
  - Present at short ISIs (facilitation trials)
    - Reflects disengagement of attention from cued location
  - Absent at long ISIs (where IOR occurs)
    - No need to disengage from cued location, since attention wasn't AT cued location
- Excitatory effect at short ISIs and inhibitory effect at long ISIs both involved modulations of sensory processing

# Case Study: Late Bottlenecks

- Some argue about how early attention can act
- Others argue about whether attentional bottlenecks occur later in the processing stream
  - Pashler
- Central processing capacity is limiting factor in dual task performance



# Psychological Refractory Period



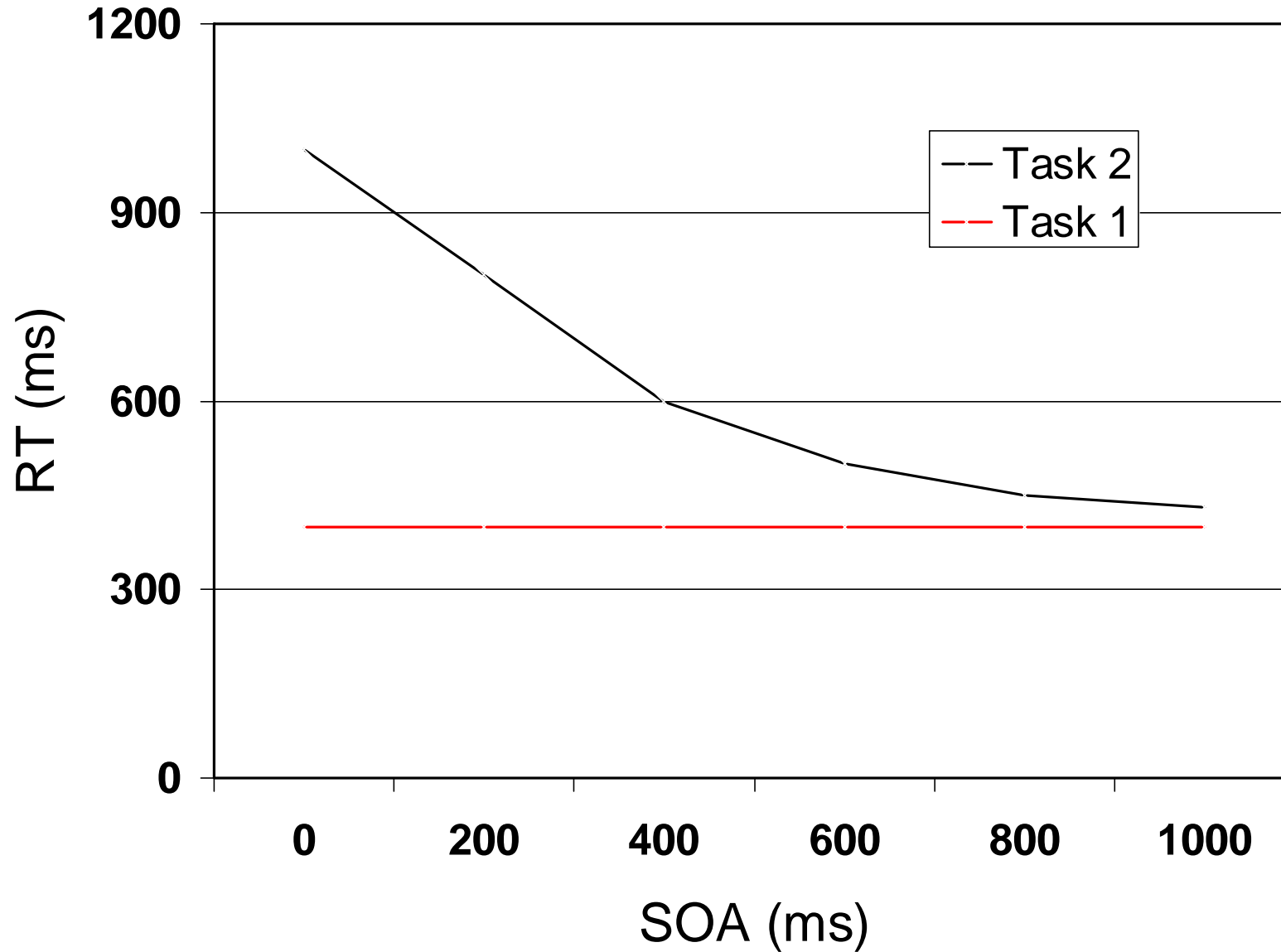
# Terminology

- Response Time of Task 1 = RT1
- Response Time of Task 2 = RT2
- Early (Pre-central), Central & Late (Post-central) processing for each task:
  - Task 1 includes A1, B1 & C1
  - Task 2 includes A2, B2 & C2





# Typical PRP Findings



# Where's the bottleneck?

- Pashler argues that interference in the PRP paradigm is due to limitations on *central* processing capacity rather than peripheral processing capacity
  - Central: response selection
  - Peripheral: perception
- RT data suggests interference occurs
  - Do they tell us unambiguously which stage the interference arises?
- Are there any other ways to address this issue?

**BREAKING A BOTTLENECK !**

*Texaco Scientists found way to Break Isobutane Bottleneck to speed Production of 100-octane Aviation Gasoline*

Millions upon millions of gallons of fine 100-octane gasoline are required to keep America's vast air armadas flying.

One of the difficulties in producing this vast quantity of gasoline was this:

It takes a gallon of isobutane to produce four gallons of aviation gasoline. And until recently isobutane had to be made by a slower, time-consuming process.

That bottleneck was broken.

Texaco Research has developed a new but

already vitally important "liquid catalyst" process for converting plentiful butane into precious isobutane. A process that can operate continuously, without periodic shutdowns. It requires less plant equipment than any previous process.

After the war is won, this typical development of Texaco Research will put more lightning getaway, smoother pick-up, unprecedented power into your new car! And more miles per gallon!

Coming... a finer  FIRE-CHIEF gasoline and a finer  Sky Chief gasoline because of Texaco's work in this war

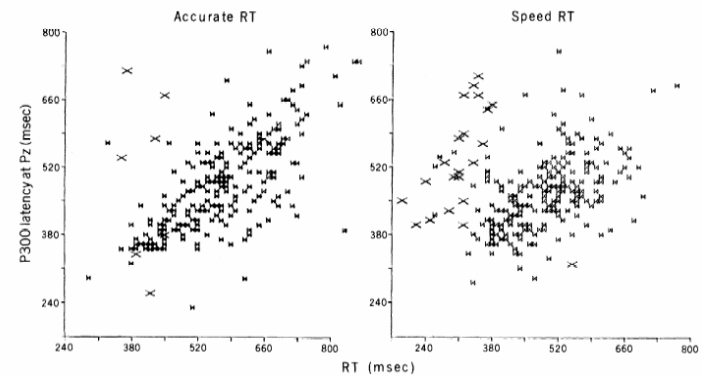


# ERPs!



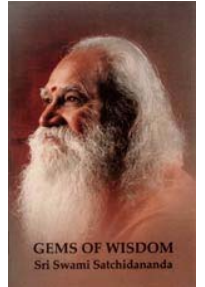
# Recall

- P300 latency is sensitive to stimulus evaluation rather than response preparation



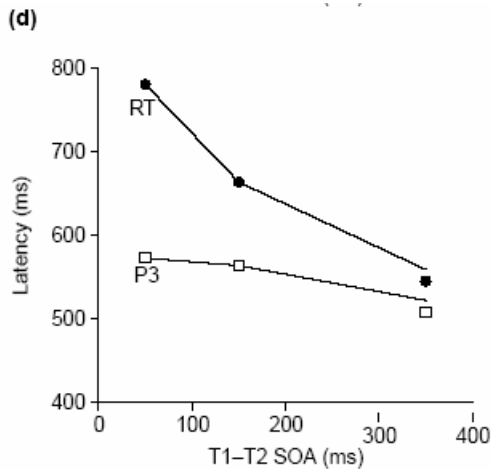
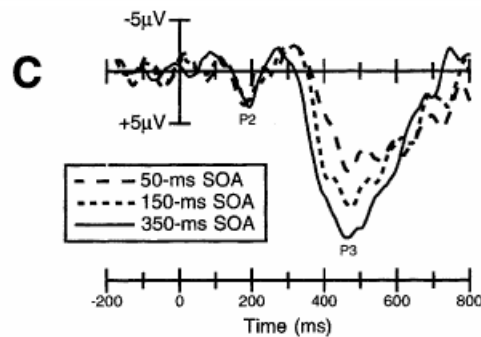
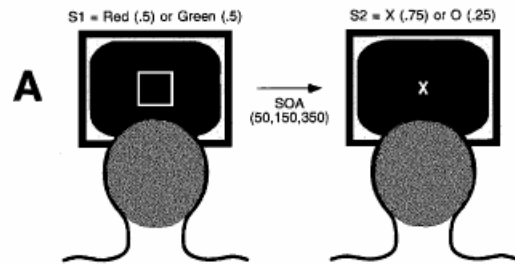
Kutas, McCarthy & Donchin (1977)

# So...



- Why not use P300 latency as index of stimulus evaluation in PRP paradigm?
  - Delayed P300 would suggest bottleneck occurs *at or before* stage of stimulus evaluation
  - No P300 latency shift would point to bottleneck in later stages of processing

# Luck (1998)



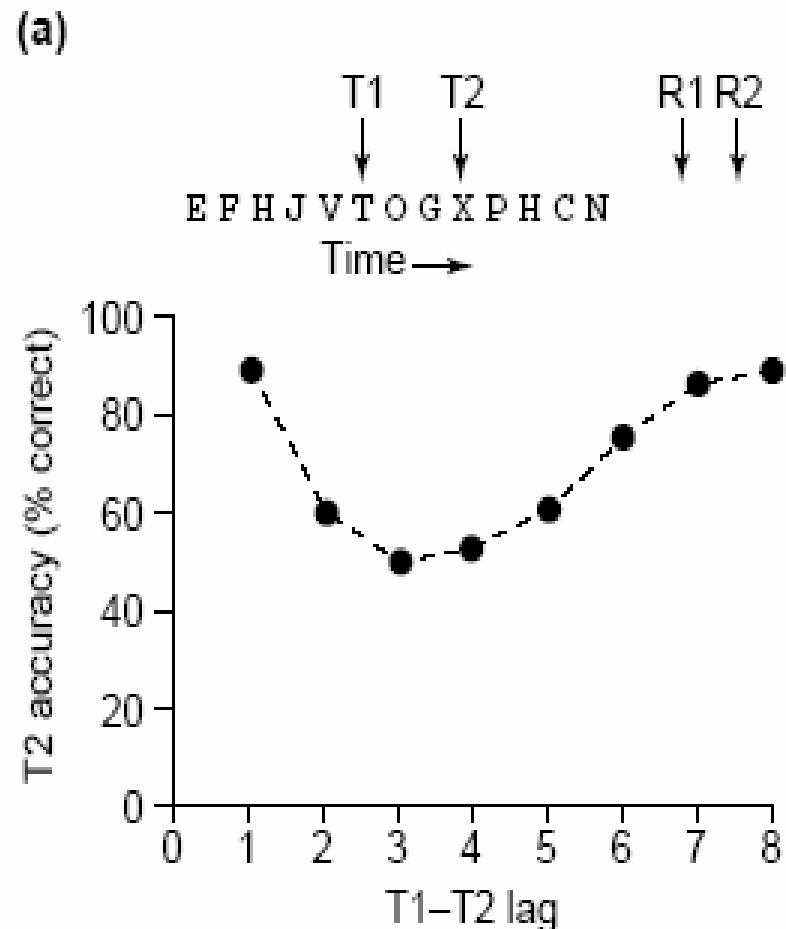
- Dual Task
  - T1: Red vs. Green Square
  - T2: X vs. O
- Findings
  - RT2 affected by SOA
  - P300 amplitude affected by SOA
  - P300 latency not affected by SOA
- Which stage is the bottleneck?
- Are there any ambiguities?

# Attentional Blink Paradigm

- Two tasks, e.g.
  - If you see a vowel, say it out loud
  - If you see a number, press one key if it's odd another if it's even
    - Or even just remember it...
- Stream of characters presented very rapidly (RSVP)
  - Push the limit on people's discrimination abilities
  - Stream composed mostly of nontargets
- What do you suppose happens?
- Further argument for “cognitive bottleneck”

# Attentional Blink Phenomenon

- 10 letters per minute
  - Mostly black, some white
- Dual task
  - T1: Say white letters out loud
  - T2: Is X present/absent?
- U-shaped accuracy curve
  - Good performance lag 1
  - Poor performance lags 2-5 (attentional blink)
  - Good performance lags 6-8
- Unless stimuli entered in working memory, they will be overwritten (due to rapid presentation)
- AB arises because T1 diverts attention needed to update working memory for T2
- How to test whether AB affects the updating of working memory?

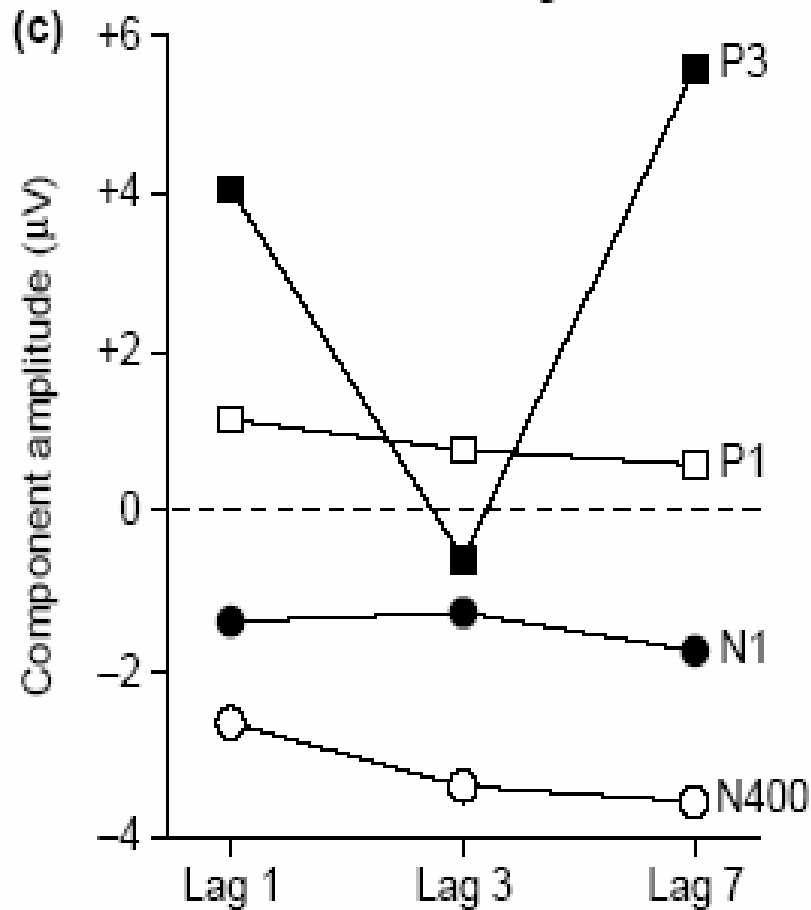




# ERPs!

- Which component?

# Luck et al. (2000)



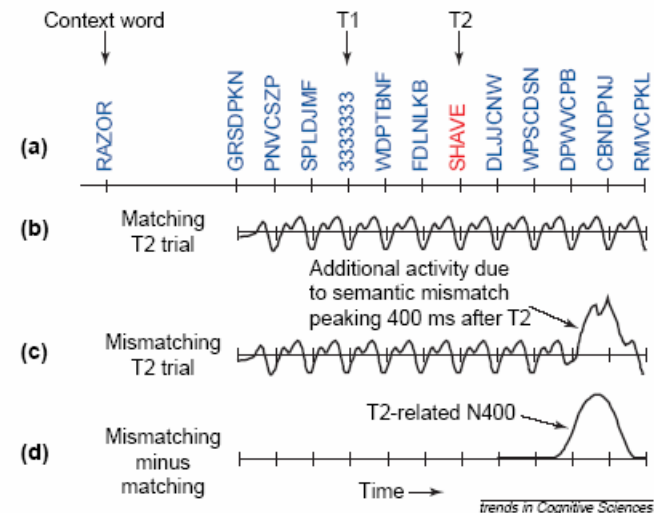
- Which ERP components modulated during AB?
- Not N1 or P1
  - What might this suggest?
  - Any reason for skepticism?
- P3 eliminated!
  - What's the implication for explanations of AB?

# Luck et al. (1996)

- Items that appear during AB are processed visually
- Are they processed to the level of meaning?
- To test
  - Use paradigm to elicit AB
  - Adapt to look at whether ERP component sensitive to semantic analysis is modulated during the AB
    - N400

Stimulus type	Time (ms)	Related trial	Unrelated trial
Context word	1,000	RAZOR	WHEEL
Blank	1,000		
Distractor	83	PNVCSZP	KDSWPVZ
Distractor	83	GRSDPKN	VNMC PKL
Distractor	83	BVCPLMS	FDPMCNV
Distractor	83	DSPWTFR	VPMTDZM
Distractor	83	RLDJH GK	HJDLGFP
Distractor	83	SPLDJMF	DFPLJKH
First target	83	3333333	4444444
Distractor	83	WDPTBNF	GHJDMVT
Distractor	83	SCDPVBF	HDVCBNM
Probe	83		
Distractor	83	FDLNLKB	NMCPVPHJ
Distractor	83	DLJJC NW	DCVPBJM
Distractor	83	WPSCDSN	PCNBVLK
Distractor	83	DPWVCPB	NPMTV DK
Distractor	83	CBNDPNJ	BRTFPMF
Distractor	83	RTPMVBC	JLSDCDK
Distractor	83	TWSCLMN	LKSDVCP
Distractor	83	LJVBCMH	DKKHNV P
Distractor	83	RMVCPKL	WKLDMZP
Distractor	83	DPNMNVZ	CPNHVGB
Blank	1,000		
Response cue	2,000	?	?
Blank	2,000		

#### Box 4. Isolating overlapping ERP waveforms



**Fig. 1. Overlapping ERP components during presentation of a rapid stream of stimuli.** (a) The stimuli on a typical trial, beginning with a 1 s presentation of a context word followed by a stream of stimuli presented at a rate of 10 per second (all stimuli were presented in normal upright orientation at fixation). The targets were a number (T1) followed by a word (T2). At the end of each trial, subjects reported whether T1 was odd or even and whether T2 was semantically related or semantically unrelated to the context word. (b) The overlapping ERP components for a trial in which the T2 word matches the semantic context for that trial. (c) The activity for a semantic mismatch trial, which is equivalent to the matching trials plus the addition of mismatch-related ERP activity following T2. (d) The result of subtracting the matching trials from the mismatching trials, which isolates mismatch-related activity triggered by T2 (primarily the N400 component).

# Results

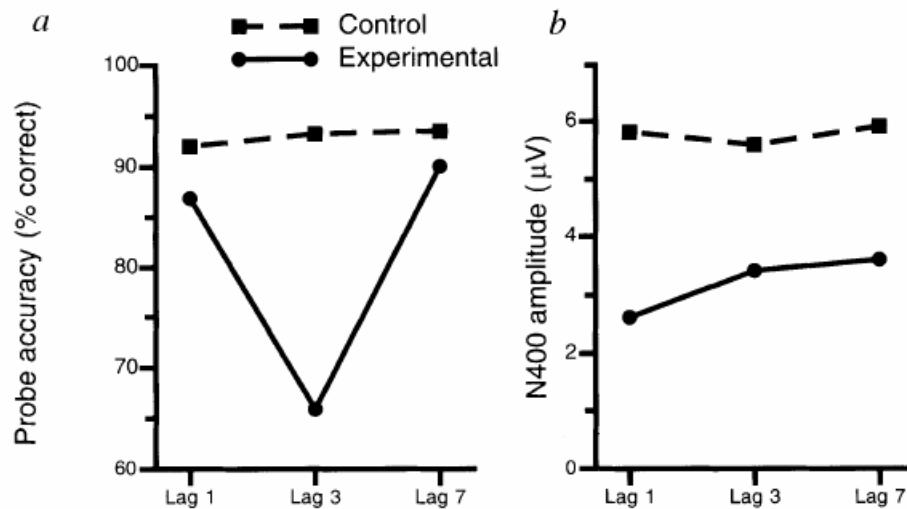


FIG. 2 *a*, Probe-discrimination accuracy as a function of lag (lag of 1-, 3- or 7-strings) for the experimental and control conditions. These values reflect only the trials on which the first target was correctly discriminated (first-target accuracy was 96% correct overall, with no effect of lag). *b*, Mean N400 amplitude as a function of lag for probe words in the experimental and control conditions, measured from the unrelated – related difference waves and averaged across electrode sites. N400 amplitude was computed as the mean amplitude of electrical activity between 300 and 500 ms poststimulus, relative to a 200-ms prestimulus baseline, at the F3, Fz, F4, C3, Cz, C4, P3, Pz and P4 electrode sites.

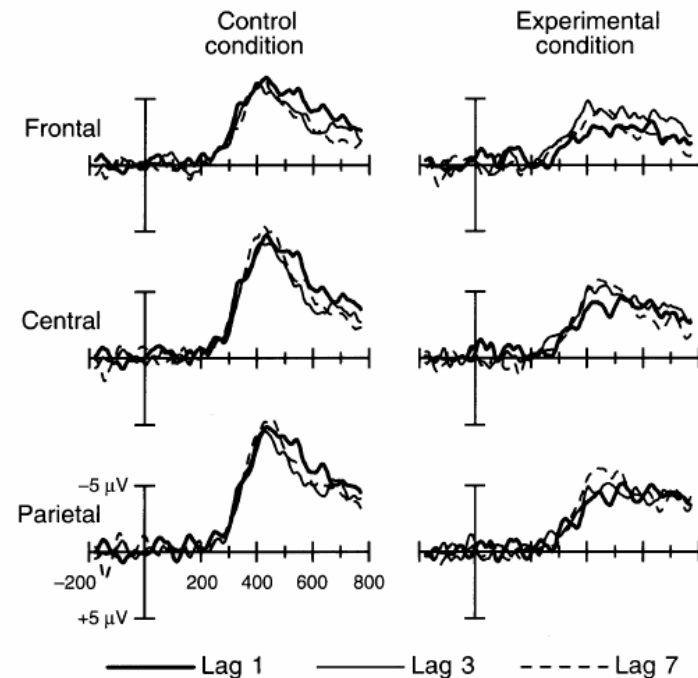


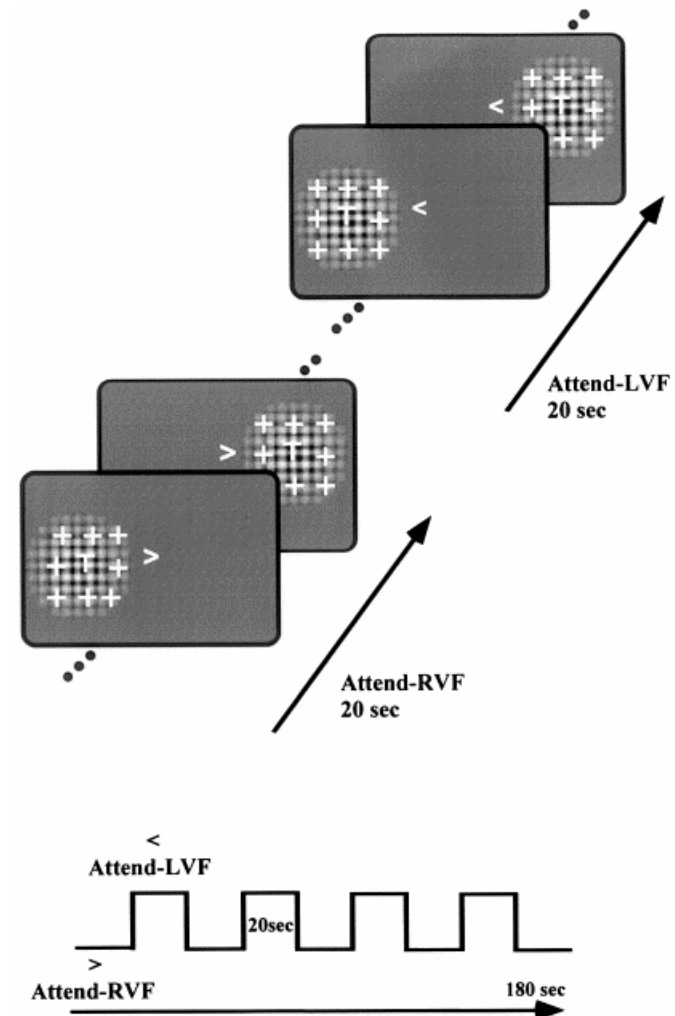
FIG. 3 ERP difference waves at frontal, central and parietal electrode sites along the midline (Fz, Cz and Pz), averaged across the 14 subjects. These waveforms were produced from averages that included only the trials on which the first target was correctly discriminated, but were not sorted according to the accuracy of the response to the probe word. The waveforms were low-pass filtered by convolving them with a gaussian impulse-response function with a standard deviation of 10 ms and a 50% amplitude cutoff of 20 Hz. Time zero represents the onset of the probe word. Note that, by convention, negative is plotted upwards.

# Integrating across studies...

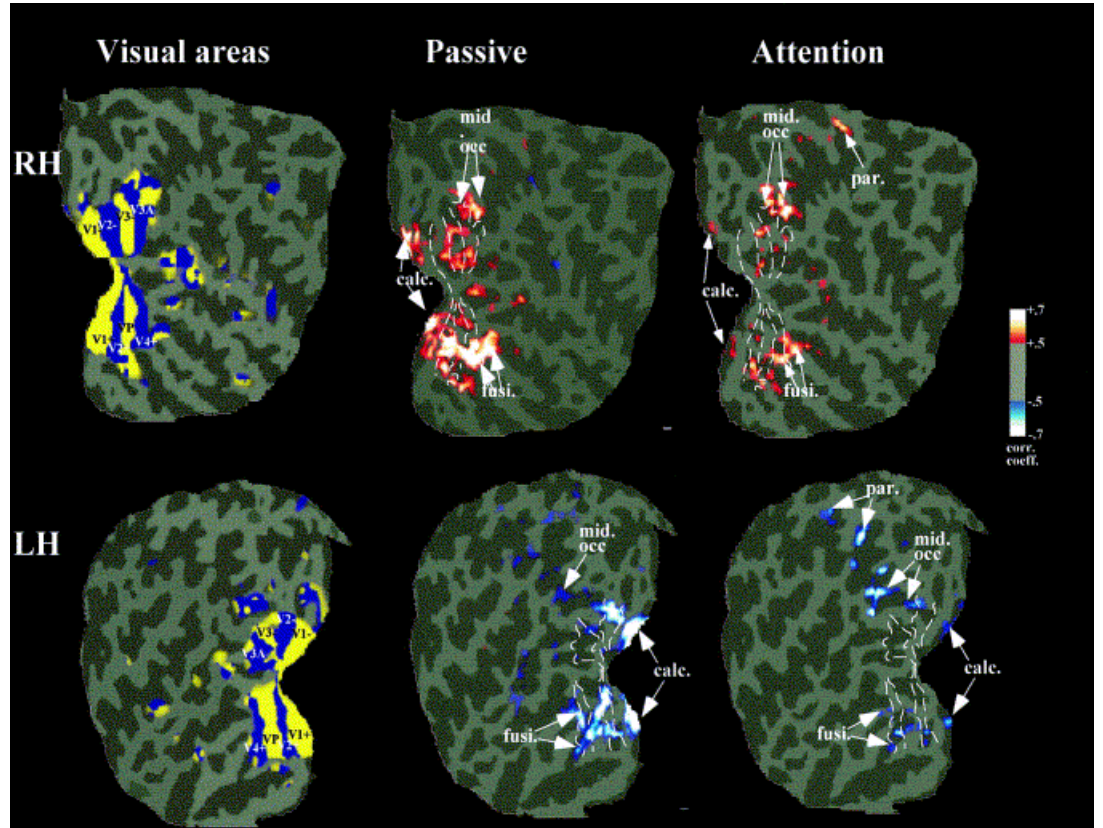
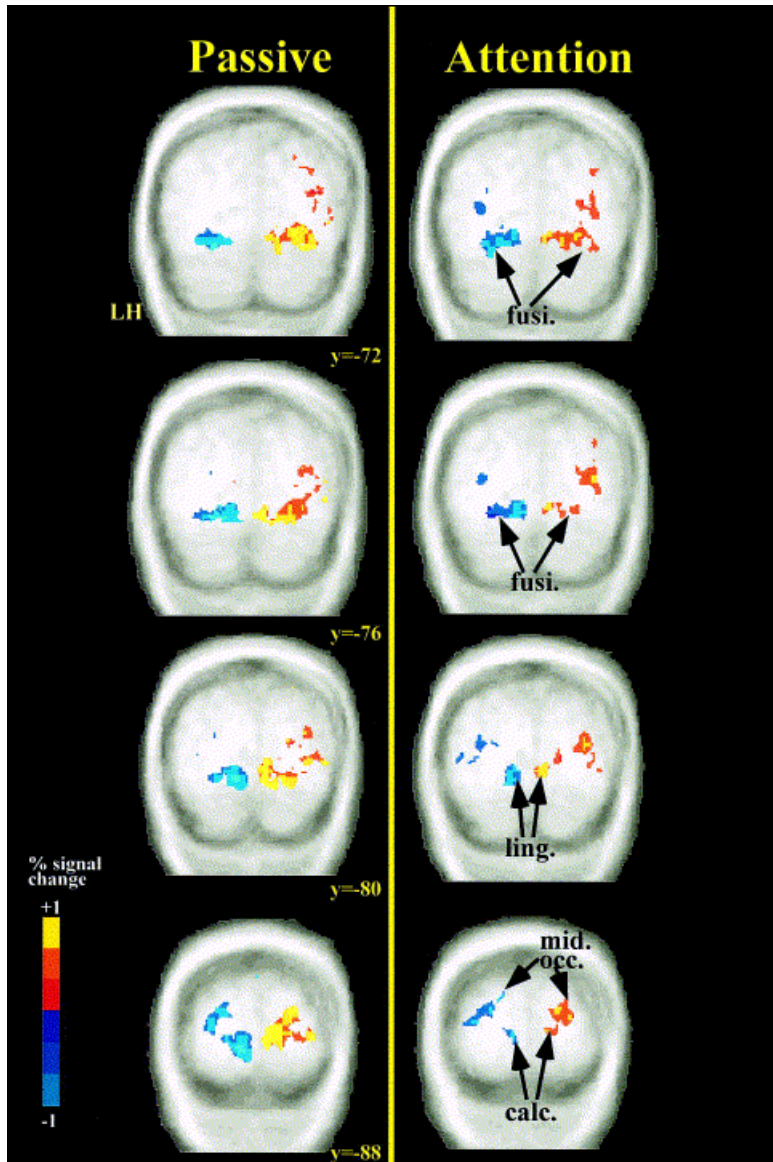
- Attention can have an early effect and impact perceptual processing
  - Cuing paradigms
  - IOR paradigm
  - P1, N1, P3
- Attentional constraints relevant at post-perceptual stages such as response selection or memory updating
  - PRP paradigm
    - Not P1
    - P3 amplitude, not P3 latency
  - AB paradigm
    - Not P1, N1, N400
    - P3 eliminated
- How do these results fit together?

# Integrating across methods

- Do same study w/ERP and fMRI
- Task: look for upside down T on attended side
- Alternate between attend left and attend right
- Any problems with this design?



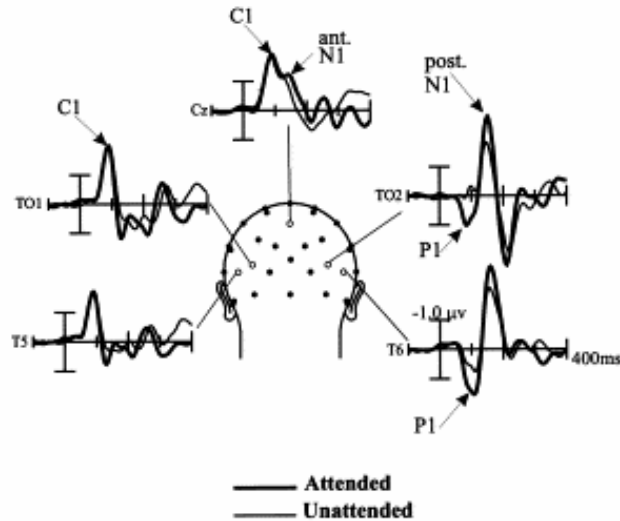
# fMRI Data





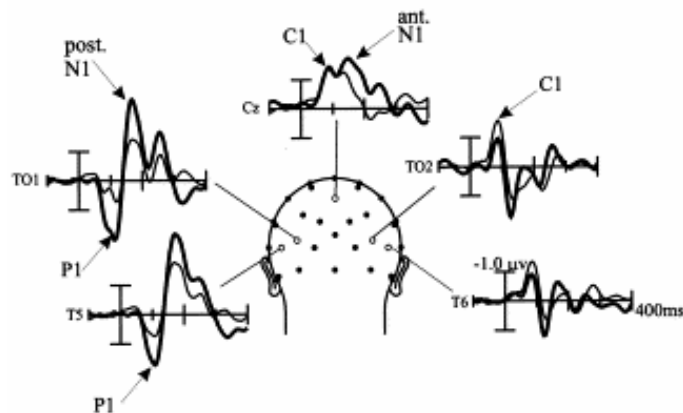
# ERP Data

**LVF Standard Stimuli**



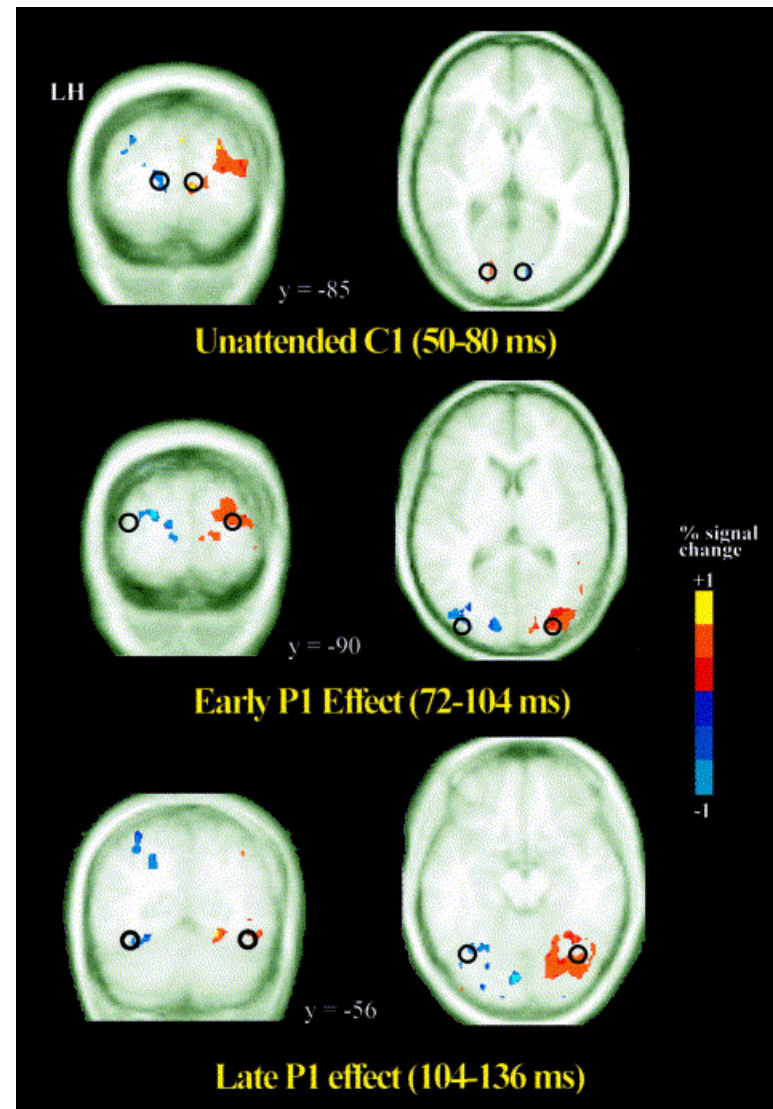
- C1 not attentionally modulated
- P1 larger for attended stimuli over contralateral hemisphere
- Ditto N1

**RVF Standard Stimuli**



# Localizing ERP effects

- C1 in V1 (striate cortex)
- Early P1 near V3 and middle occipital cortex (extra-striate)
- Late P1 in fusiform gyrus



# Putting it together

- fMRI attention effects in V1 suggests attention acts at the earliest stage of visual processing
- However, null effect on C1 ERP component (generated in area V1) argues to the contrary
- Spatial vs. Temporal resolution of techniques
  - V1 activation results from feedback connections from higher-level visual areas
  - V1 attention modulation occurs *after* the initial feedforward activation

Questions?