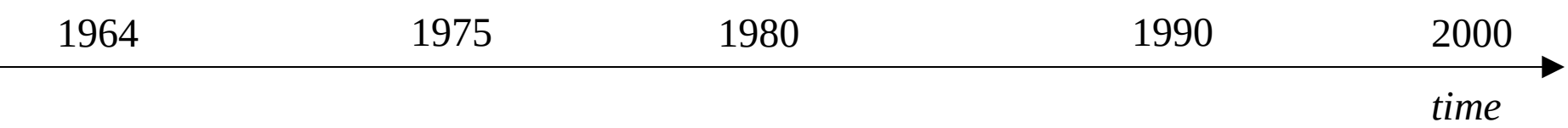
LATE POSITIVITIES ABOUND!!

P300, P3, P3b, target P3, oddball P3,
P-SR, P-CR
late positive component
late positive complex (LPC)
P600 (syntactic positive shift or SPS, semantic P600,
and P600 in memory expts)

P3a, novel P3

Slow Wave (SW), Positive SW (PSW)



CNV, PINV
Grey Walter

O-wave
E-wave
Loveless & Sanford

SPN
MPN
Damen & Brunia

LRP (CMA)
Coles & Gratton; DeJong

BSP, RP
Kornhuber & Deecke
Vaughan et al.

ERN (Ne), Pe
Falkenstein; Gehring

CRN

P300
Chapman & Bragdon
Sutton et al.

Novelty P3
Courchesne et al.

N400
Kutas & Hillyard

P600 /SPS
LAN
Osterhout
Kluender
Neville

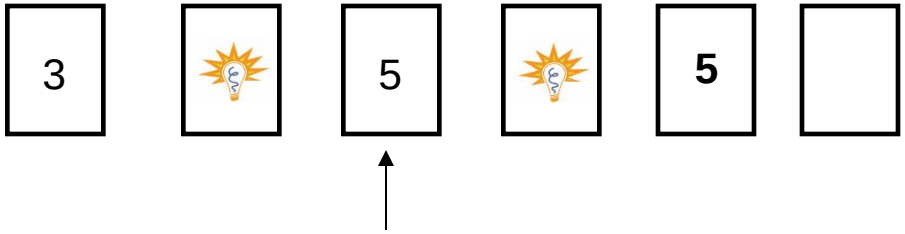
CPS
Steinhauer et al.

N200, P3a, P3b,
SW complex
Squires et al.

N2a, N2b
N2a=MMN
Naatanen

Dm
Paller et al.

Chapman and Bragdon, 1964



Which was larger first or second number or are they equal?

Larger late evoked responses were obtained to number stimuli than to light flashes .. The differences may not be attributed to the stimulus luminance.

Different ERPs to meaningful and non-meaningful stimuli

Some ERP components are not sensitive to sensory manipulations

Sutton et al. 1965

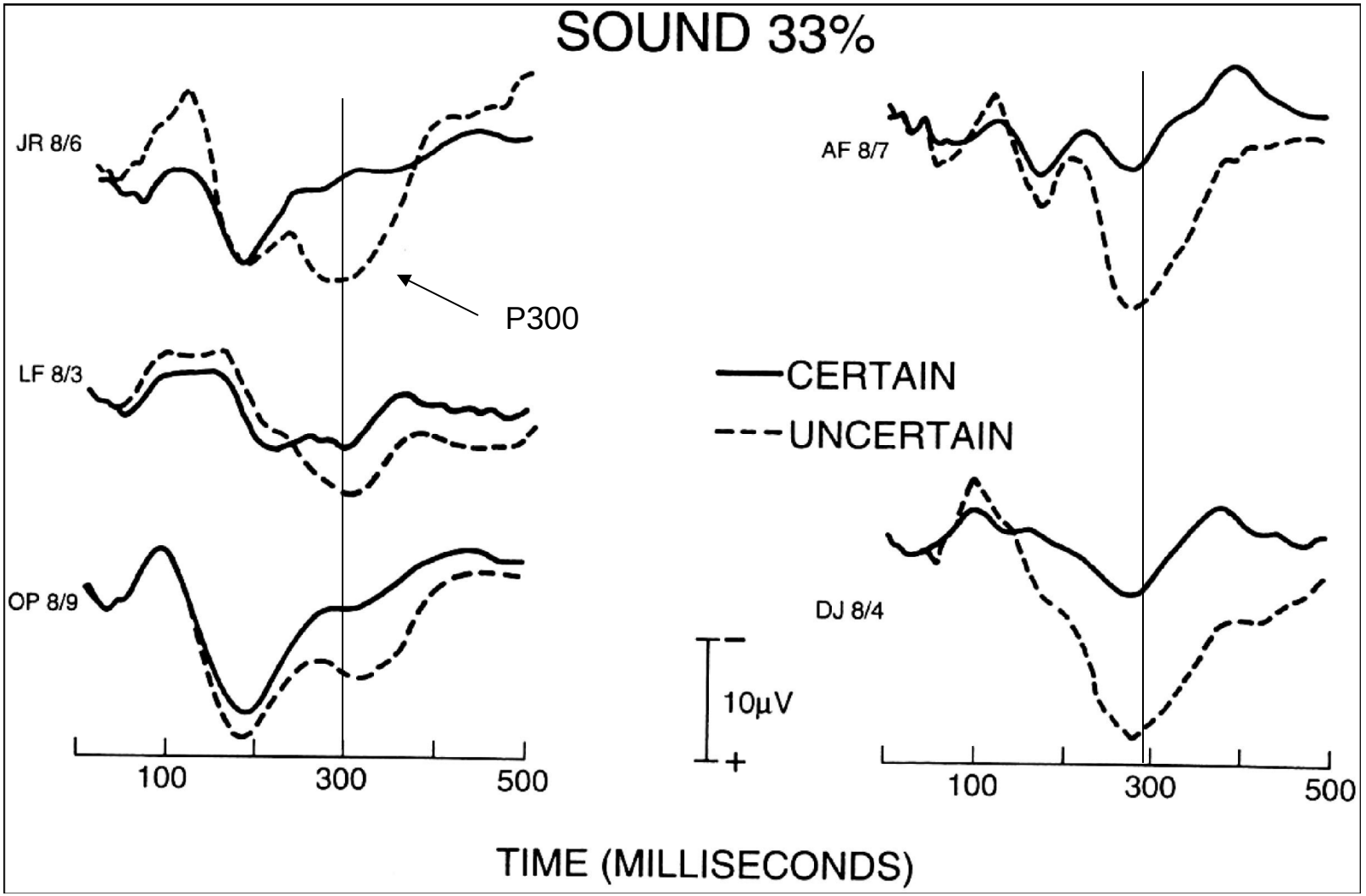
Stimuli: clicks or light flashes

Trial Design: S1(cue) – interval (3-5 s) – S2 (stimulus pairs)

Task: (guess) predict modality (aud or vis) of S2

Predictable: cue was always followed by S2 of certain modality
Unpredictable: S2 modality was uncertain

Compare ERPs when stimulus was certain vs uncertain



Same physical stimulus differing only in certainty; response wasn't simply a function of sensory input but what subjects were doing with it.

Sutton et al. 1965

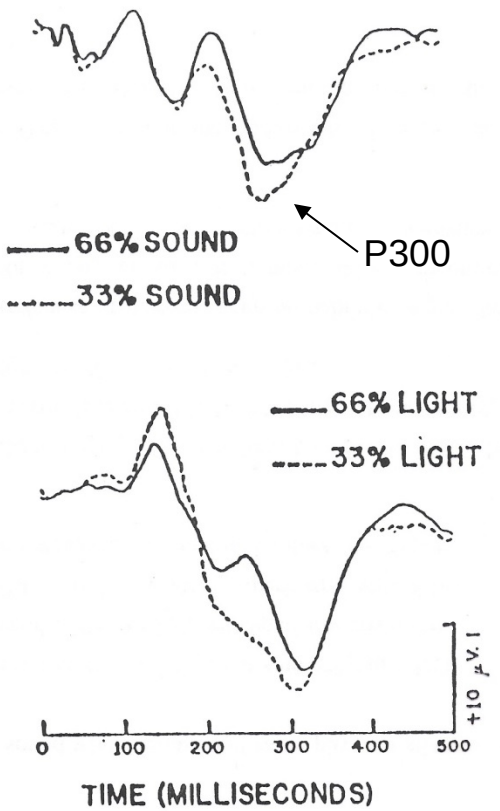


Fig. 2. Average waveforms for different probabilities of sound and light. The 33 percent sound and the 66 percent light had one cueing stimulus while the 66 percent sound and the 33 percent light had a different cueing stimulus.

Cs 179 Sutton et al. 1965 Figure 2

Manipulate degree of uncertainty
-Cue predicted light .33, sound .67
or vice versa

-both elicit P3 but P3 is larger for the less probable event

Effect of correctness

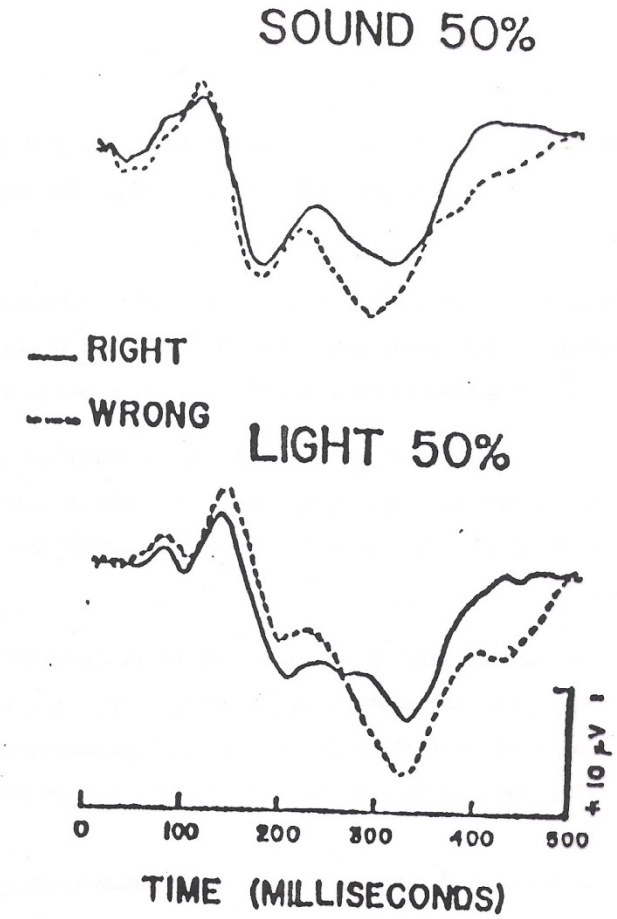


Fig. 3. Average waveforms to uncertain sound and uncertain light stimuli averaged separately as a function of the correctness of the subject's guess.

CS179: Sutton et al. 1965 Figure 3

Hypothesis based on various experiments: P3 might reflect resolution of uncertainty

Uncontrolled factors?

ERP waveform recorded from scalp of human subjects may reflect two kinds of influences. One of these is largely ***exogenous*** and related to the character of the stimulus (objective). The other is largely ***endogenous*** and related to the reaction or attitude of the subject to the stimulus (subjective). *Sutton et al. 1965*

Does P300 really reflect uncertainty resolution?

Sutton, Tueting, Zubin & John 1967

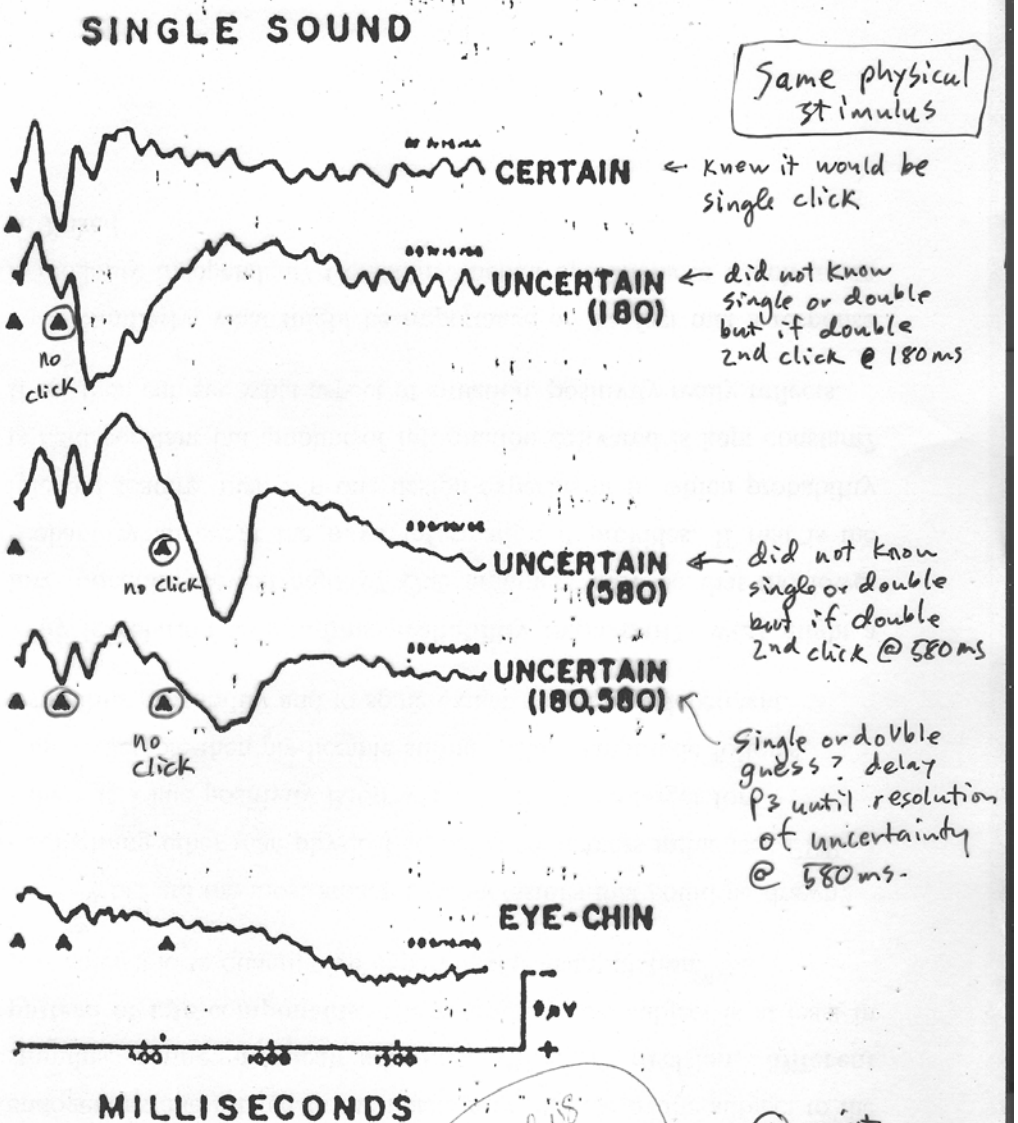
- Manipulated when information is delivered
- Manipulated mode of information delivery

Guess whether stimulus would be single click or double click

Compare ERP to single clicks under conditions where subject either knew how many clicks there would be or not

Independent variables:
Certainty vs uncertainty
Single vs double click
Interval between double clicks, 180 or 580 ms

ERPS to the same physical stimulus -- a single click in all 4 experimental conditions



CS 179 Sutton et al. 1967

Fig. 1. Average response waveforms to single clicks obtained for one subject under several experimental conditions. ▲, Actual delivery of clicks. Ⓐ, Points in time when a second click might have occurred but did not.

There is a late positivity (P300) only when there is uncertainty.

P300 latency determined by the time when uncertainty is resolved.

There is a P300 to a missing stimulus/event (no physical energy)!!!

To show P300 related to information value of stimulus for subject.

Stimuli varied on two dimensions: (number of clicks, intensity)

Loud single
Loud double
Soft single
Soft double

When double click, 2nd click presented at ISI=580 ms

Tasks
(1) Intensity task: Guess loud or soft?
(2) Number of clicks task: Guess single or double?

Predicted Outcomes:	**Guess Intensity**	**Guess Number**
Loud single	at single	at double
Loud double	at single	at double
Soft single	at single	at double
Soft double	at single	at double

Any other outcome, and P3 is not simply related to information value.

— SOFT - LOUD CRITERION
--- SINGLE - DOUBLE CRITERION

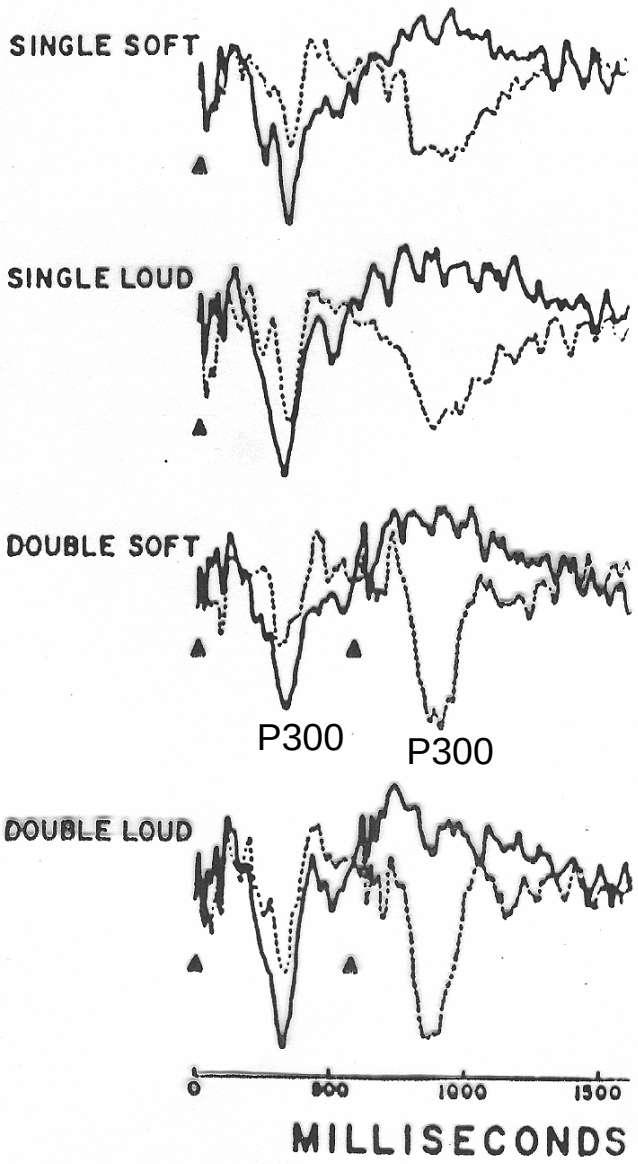


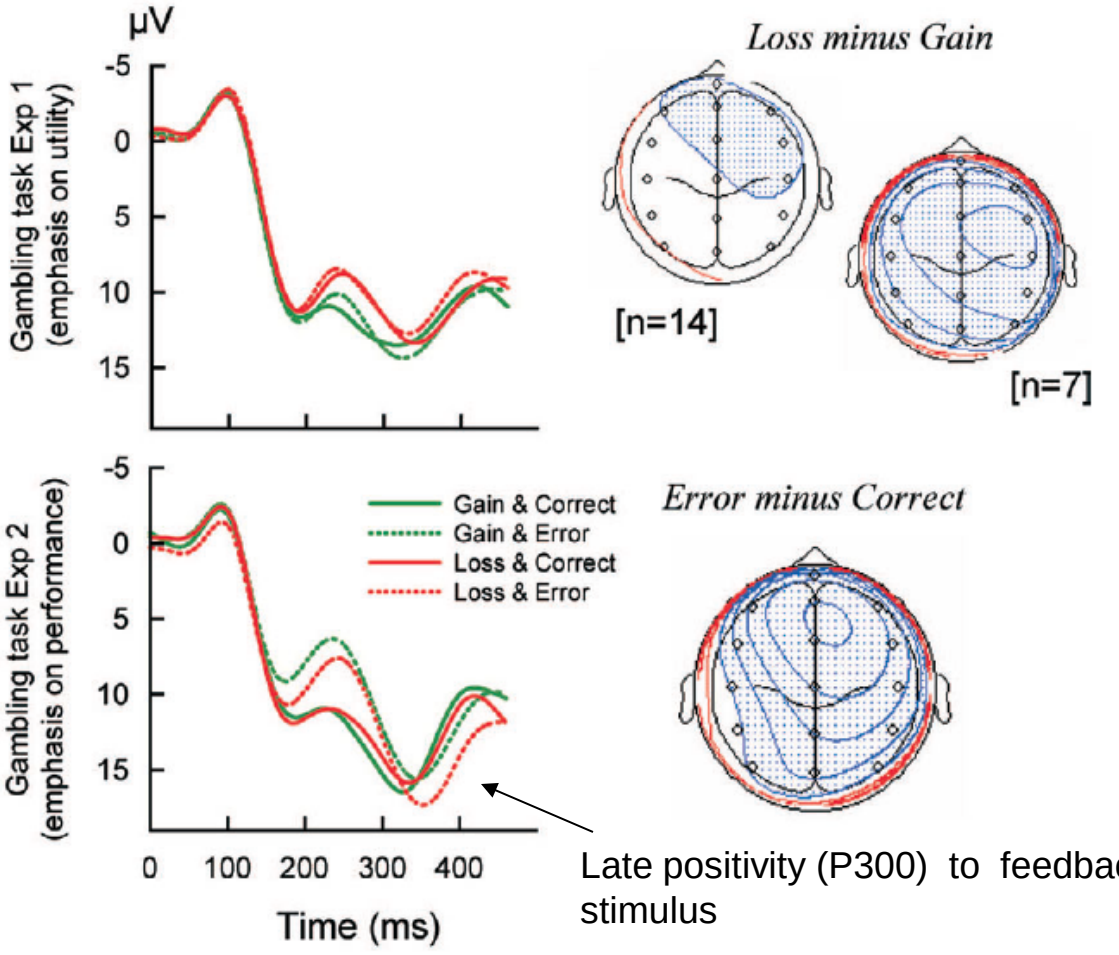
FIG. 25. Information delivery and the P300 comp
or double clicks were presented at soft or loud inte
condition the subjects judged whether the stimulus wa
in a second condition they judged whether it was si

Task: guess
— loud or soft
-- single or double

- Note latency variability
- Smearing
  - area measure

Donchin et al. 1967

P3 in Gambling Task



Late positivity (P300) to feedback stimulus

PARADIGMS FOR ELICITING P3OO COMPONENT

Guess-Feedback paradigm: P300 elicited by stimuli that provide feedback

Oddball paradigm (Bernoulli sequence)

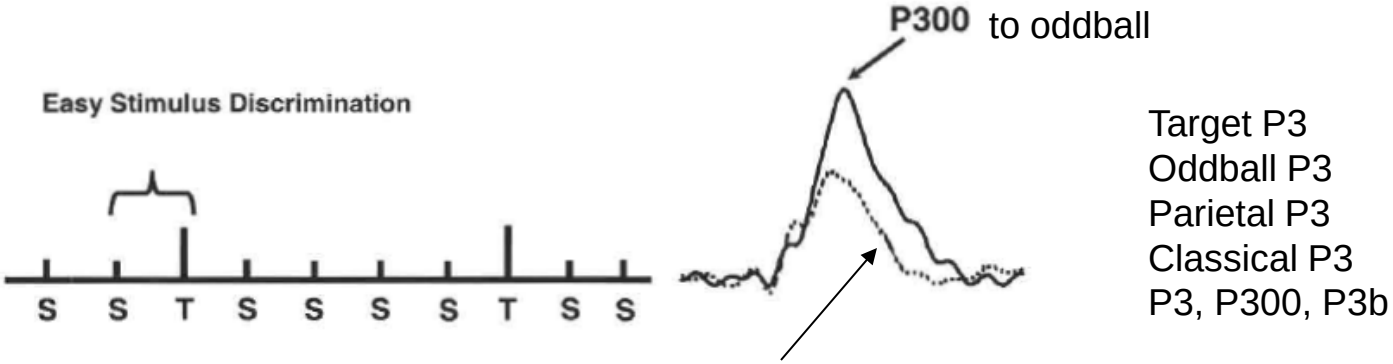
Signal Detection -- signal embedded in noise

Categorization/Matching/Decision Making Tasks

Any experiment requiring decision will elicit a P300 following decision

ODDBALL PARADIGM

S - standard
T - target



(Note: positive up; figure from Polich)

One of two stimuli randomly presented every 1-1.5 sec
Frequent stimulus – standard, background
Infrequent stimulus – target, oddball, deviant

Typical task: mental count of targets or overt response to target (or standard) or to both

Modalities: auditory, visual, somatosensory, olfactory

Note positive up

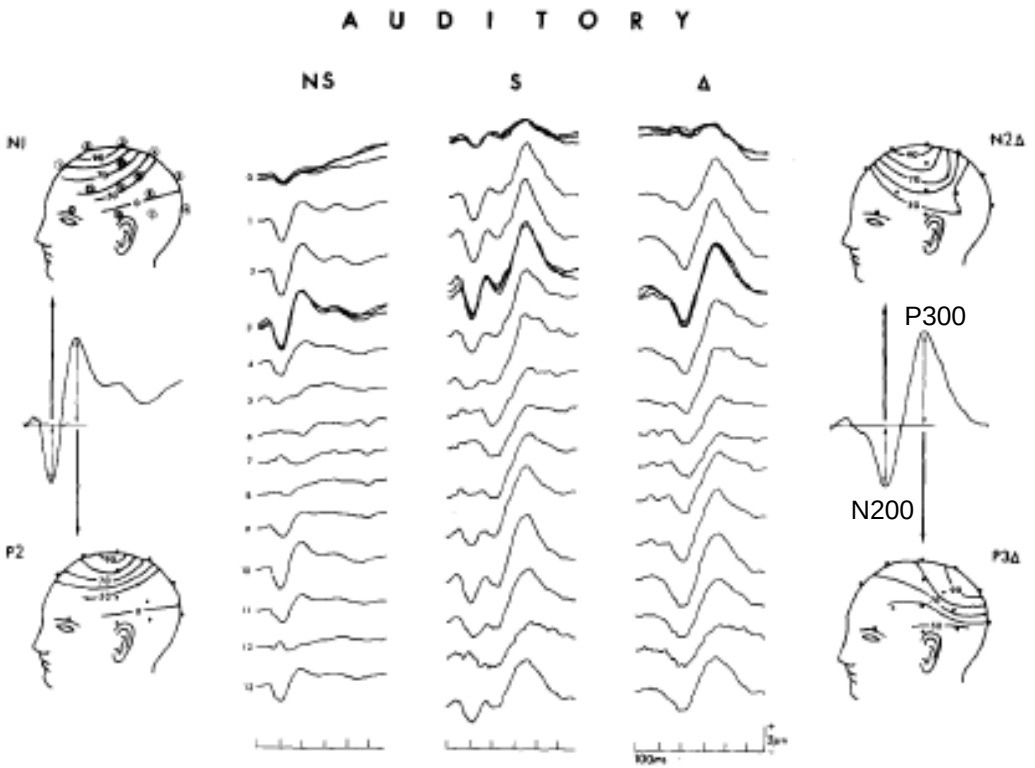


Fig. 1. Mean for eight subjects of the non-signal (NS), signal (S) and difference (Δ) waveforms at each electrode site in the auditory condition. Isopotential topographic distributions are expressed as percentages of maximum response amplitude for the N1 and P2 components of the non-signal response (left) and the negative (N2Δ) and positive (P3Δ) components of the Δ waveform (right). Supraorbital (0) and vertex (electrode 3) traces from the 3 runs are superimposed.

NS – standard
S – target
Delta – target –standard difference (effect)

Simson, Ritter, Vaughan 1977

Note positive up

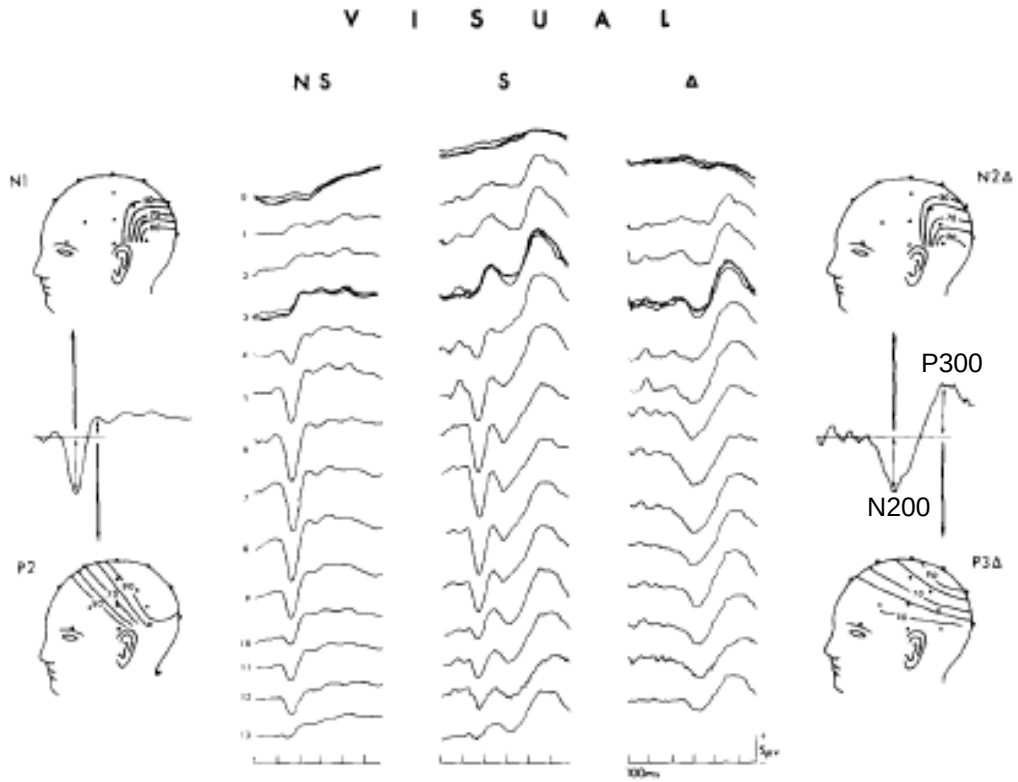


Fig. 2. Mean waveforms and topographic distributions for the visual condition.

NS – standard
S – target
Delta – target –standard difference

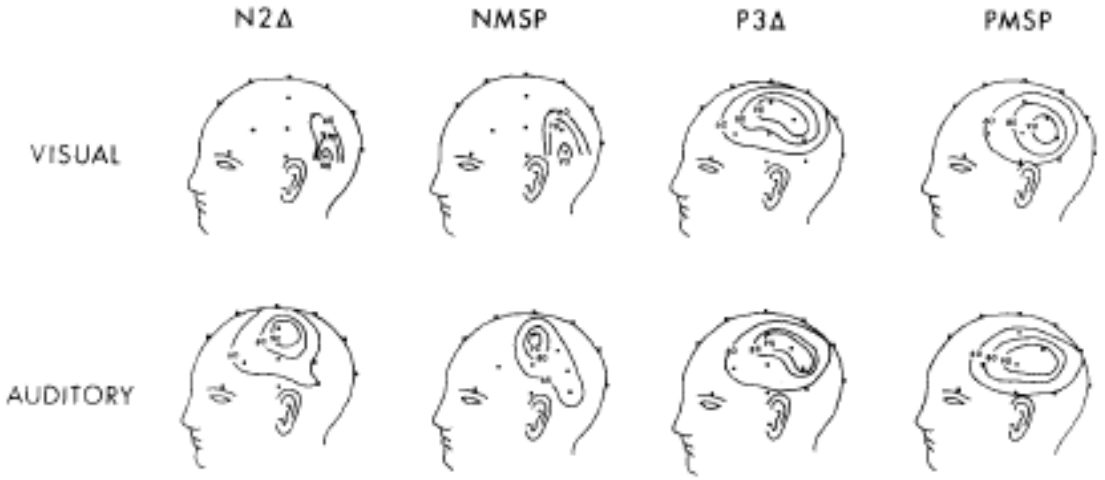


Fig. 3. Uni-hemipheric distributions of the negative (N2Δ, NMSP) and positive (P3Δ, PMSP) components of the different waveforms (Δ) and the missing stimulus potentials (MSPs) in the auditory and visual modalities. These distributions are derived as explained in the text from the data shown in Fig. 1 and 2 of this paper and in Fig. 1 and 2 of Simson et al. (1976).

P3 complex: N2, P3, SW

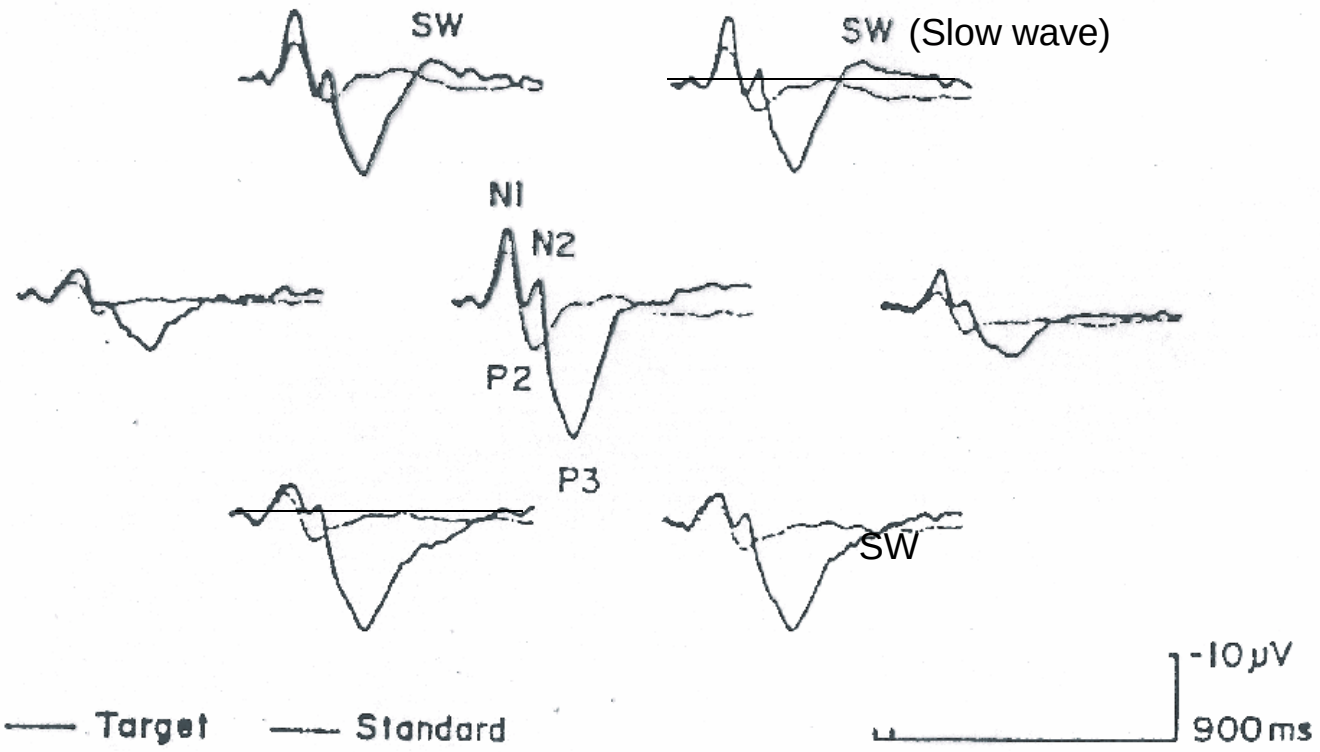


Fig. 8. Event-related potentials recorded during the auditory 'oddball' paradigm. The grand mean waveforms from 12 normal young adults are shown in this figure. On the top line are shown the left and right frontal recordings; on the middle line are shown the left temporal, vertex and right temporal recordings; on the bottom line are shown the left and right parietal recordings. All recordings were made relative to a linked mastoid electrode. Tone bursts having an intensity of 90 dB peak SPL and a duration of 50 msec were presented binaurally through earphones at a rate of 1/1.1 sec. Ninety percent of the stimuli were standard tones of 1000 Hz, and 10% of the stimuli were target tones of 2000 Hz. Subjects were asked to detect and keep a running mental count of the number of targets. In addition to the N1 and P2 components, the ERP to the detected target contained an N2-P3-SW complex of waves. All of these components except for the SW were maximally recorded from the vertex. The SW was recorded

Grand average

Hypotheses for functional significance of SLOW WAVE

Additional processing?

Selection or decision processes

Preparation of response

Evaluation of correctness

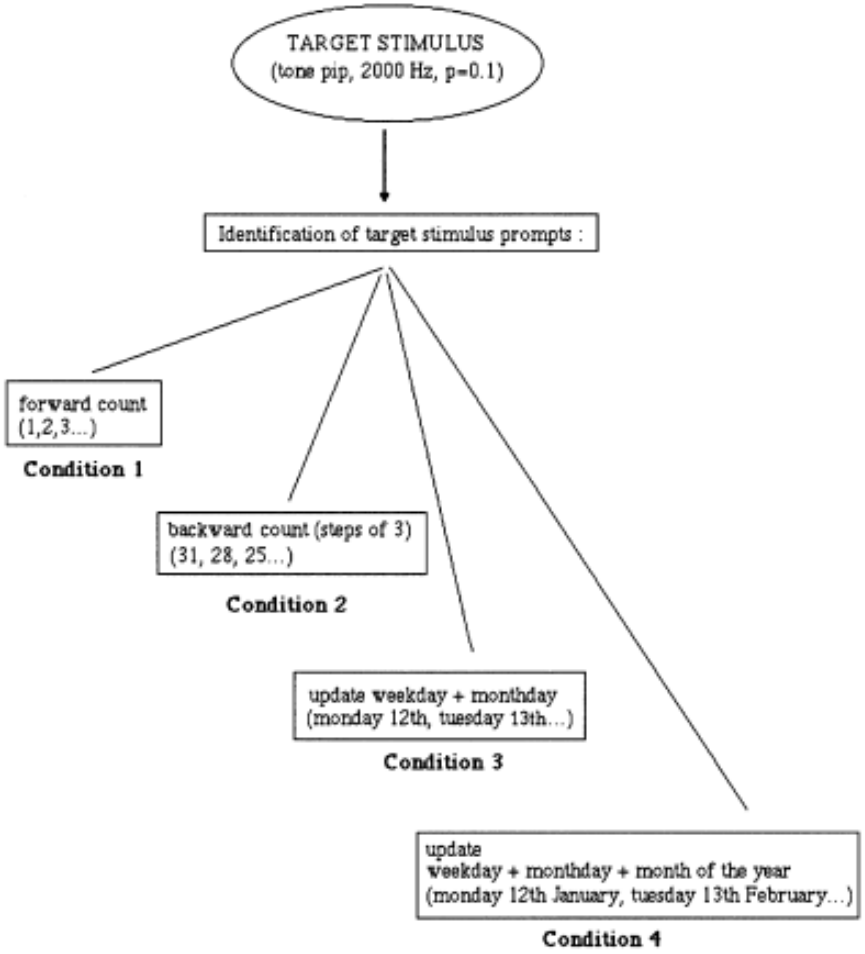


Fig. 1. Graphical outline of the experimental procedure. Detection of target stimuli (top) prompted the subjects to perform a different updating task in each condition. These tasks ranged from a simple forward count (condition 1, left) to a quite complex task needing the simultaneous updating of 3 independent items (condition 4, bottom right).

Garcia-Larrea & Cezanne-Bert, 1998

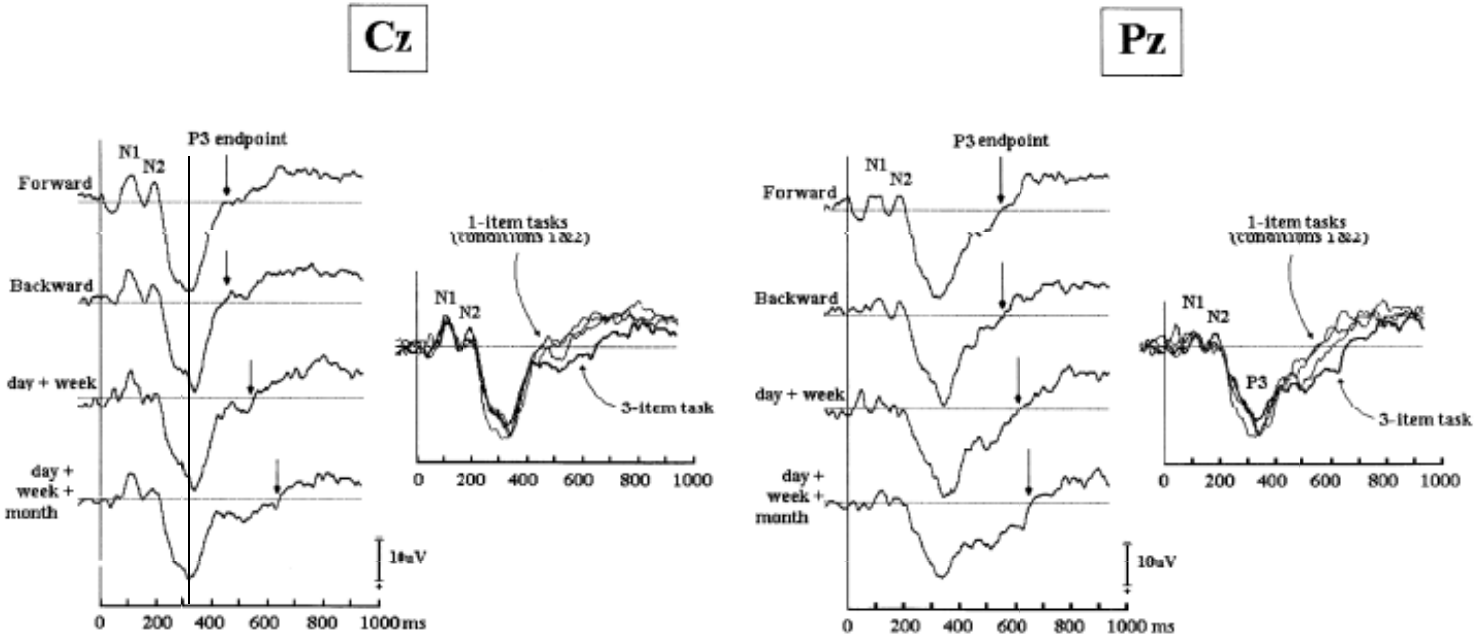


Fig. 2. Grand-averaged ERP traces during each of the 4 conditions. Left and right panels correspond to recordings at Cz and Pz, respectively. For each electrode site, ERPs from the 4 conditions are both stacked (left) and superimposed (right). Vertical arrows mark the 'P3-endpoint' which was used to quantify PSW duration. The 'P3-endpoint' changed little between conditions 1 and 2 (forward and backward counting), but was significantly delayed during the two-item (day + week) and 3-item (day + week + month) updating tasks. On superimpositions the thick traces correspond to the 3-item task: it appears that the reason for the 'P3-endpoint' delay was the development of a positive slow wave between 450 and 600 ms post-stimulus. Average reaction times for conditions 2, 3 and 4 were 784, 1084 and 2636 ms, respectively, after target detection, and therefore exceeded largely the PSW latencies in the same conditions.

Initial P3 peak amplitude indistinguishable across conditions, but duration of positivity varies; positivity lengthens with number of items to be updated – variance in positive slow wave (PSW).

Compare cond 1 vs cond 4

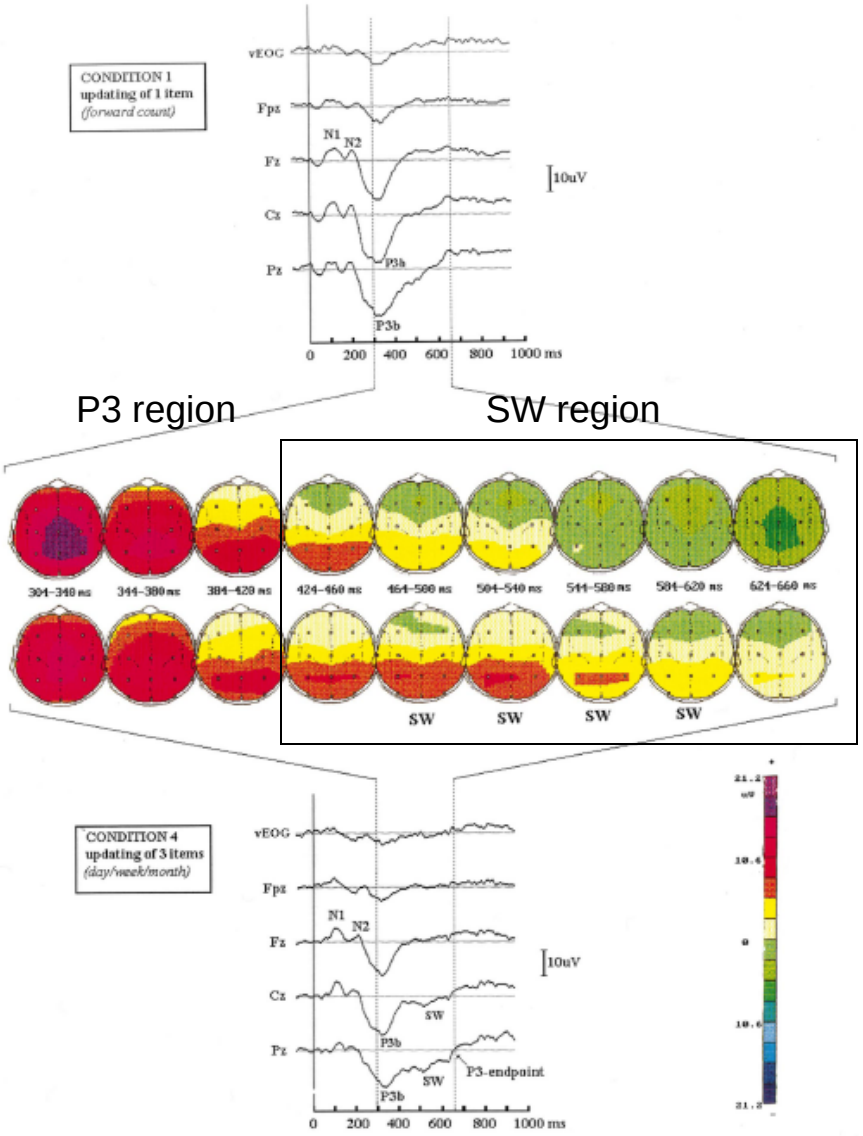


Fig. 4. Traces and maps obtained during conditions 1 (upper) and 4 (lower). Sequential maps correspond to the time window encompassed by the vertical dotted lines. Each map illustrates the average voltage distribution during 36 consecutive milliseconds (9 sampling points). Note that the positive slow wave activity, unapparent in condition 1, was enhanced in condition 4 (maps underscored 'SW') and developed a biparietal distribution until the 'P3-endpoint', at 620 ms approximately.

Difference ERPs: cond 4 minus cond 1

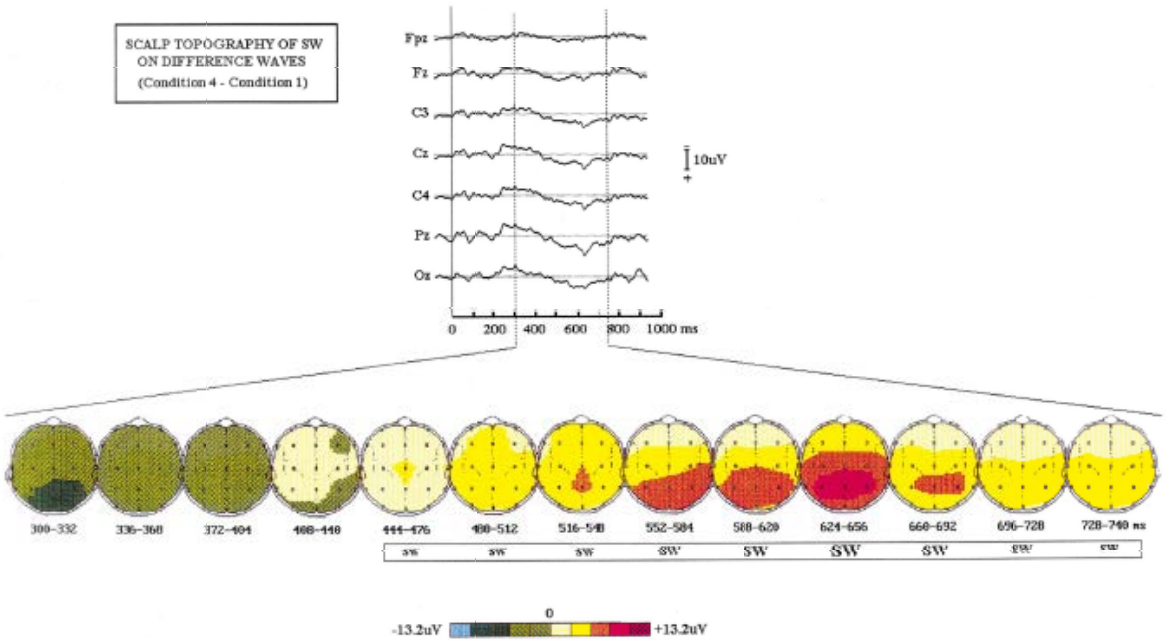


Fig. 5. 'Difference waves' and corresponding maps after subtraction of ERPs in condition 1 from those recorded in condition 4. Relative decrease of P3 amplitude during the 3-item updating task (condition 4) is reflected by a negative trace between 280 and 330 ms, and corresponding green posterior parietal topography on left maps. PSW development in condition 4 is reflected by increased positivity with biparietal distribution, extending from 500 to nearly 800 ms poststimulus.

P3 and Slow Wave (SW) are functionally dissociable

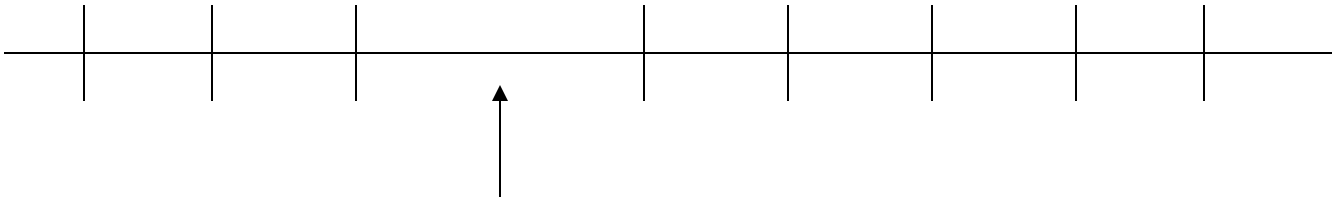
There's still lots to learn about the functional significance of slow waves

Slow waves reflect further processing invoked by increased task demands.

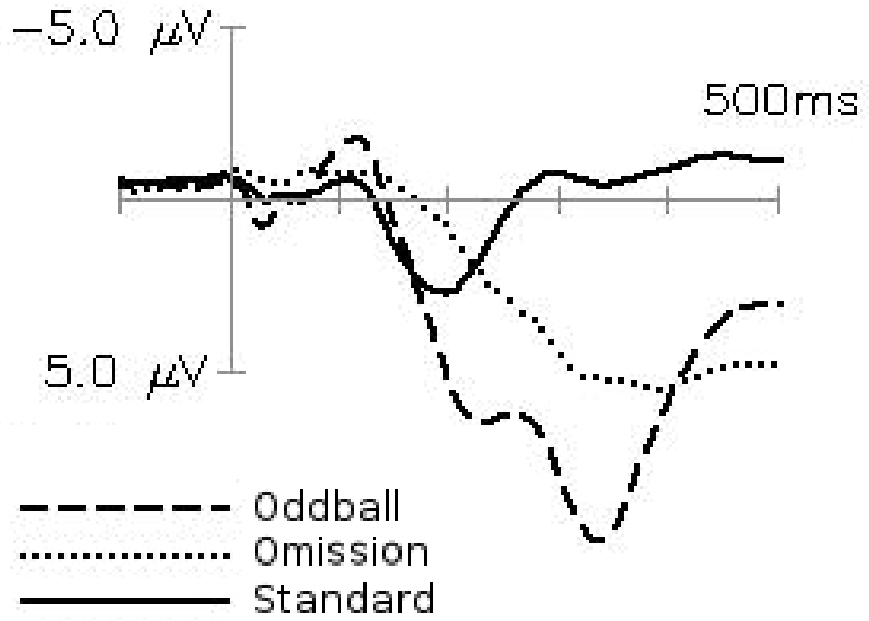
SW distinctions have been made for perceptual and conceptual processes.

There are many more SWs than just frontal negative and posterior positive. e.g., posterior negativities

Memory scanning, mental rotation, mental arithmetic are but a few of the operations that associated with slow wave activity



Omitted/Missing stimulus



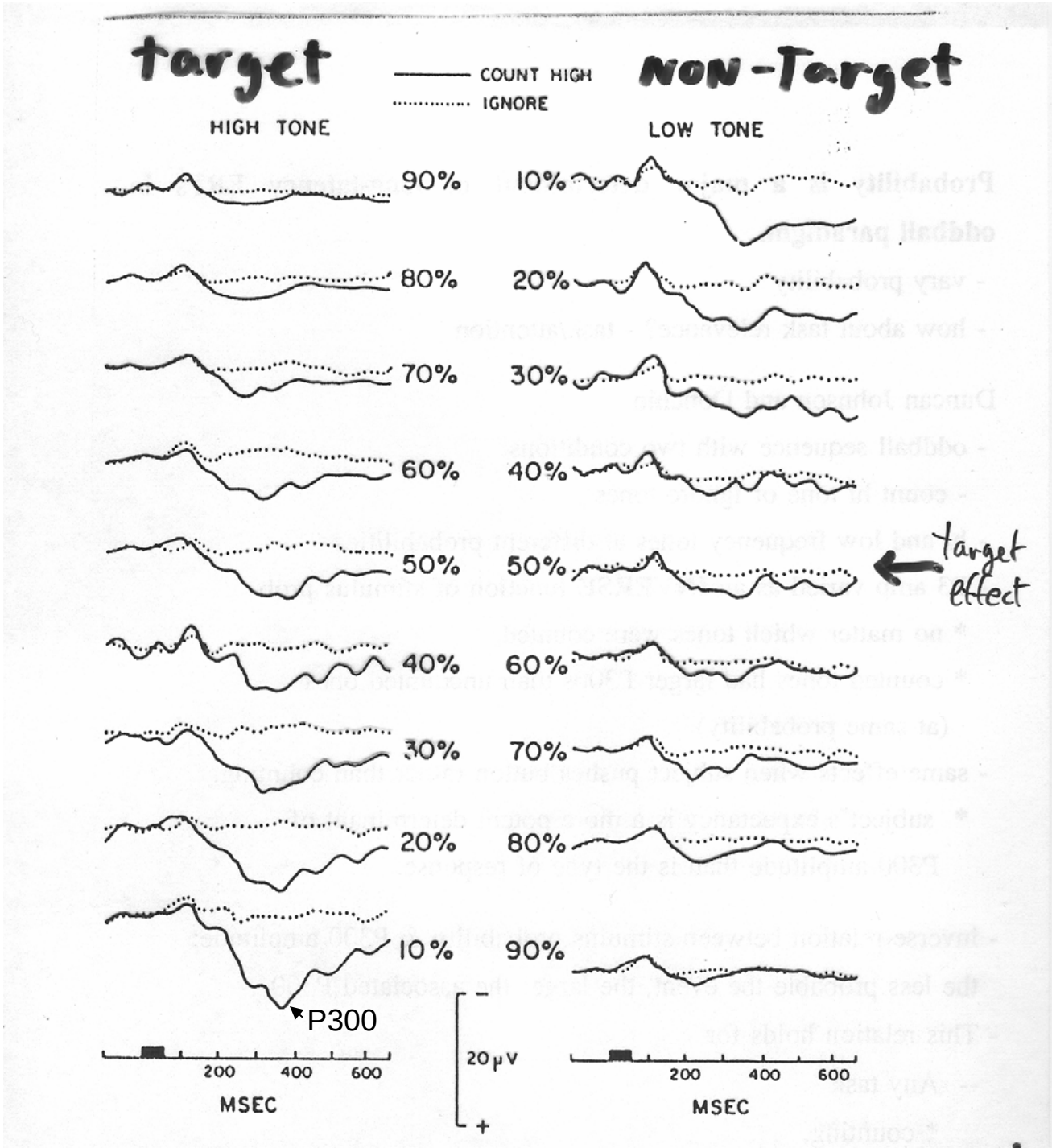
e.g., timing, expectancy, time estimation, rhythm

a priori stimulus probability

Target/non-target (standard)

Vary attn: attend, ignore

P3s in auditory oddball task



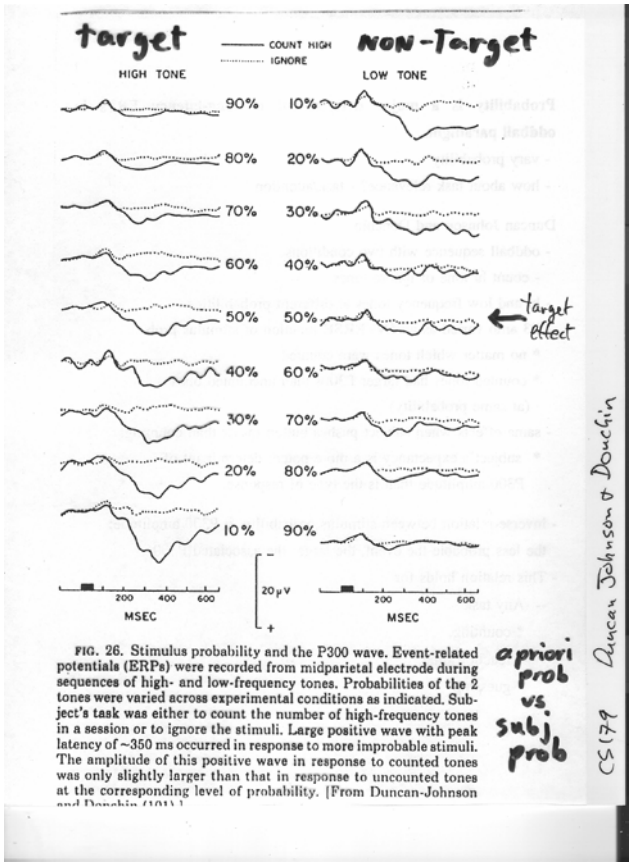


FIG. 26. Stimulus probability and the P300 wave. Event-related potentials (ERPs) were recorded from midparietal electrode during sequences of high- and low-frequency tones. Probabilities of the 2 tones were varied across experimental conditions as indicated. Subject's task was either to count the number of high-frequency tones in a session or to ignore the stimuli. Large positive wave with peak latency of ~350 ms occurred in response to more improbable stimuli. The amplitude of this positive wave in response to counted tones was only slightly larger than that in response to uncounted tones at the corresponding level of probability. [From Duncan-Johnson and Donchin (01).]

1. If stimuli are not task relevant, then there are no P3s and no apparent sensitivity to *a priori* (objective) stimulus probability.

2. If stimuli are task relevant, then the P3 to the target (counted) stimuli is sensitive to objective stimulus probability; the lower the probability, the larger the P3 amplitude.

3. And, if task relevant, even uncounted (non-target) stimuli will show some positivity in P3 range for low probability events.

4. And, even when objective probabilities are equated, the "target" event is associated with a slightly larger P3 than the non-target event.

ust P3

Global probability

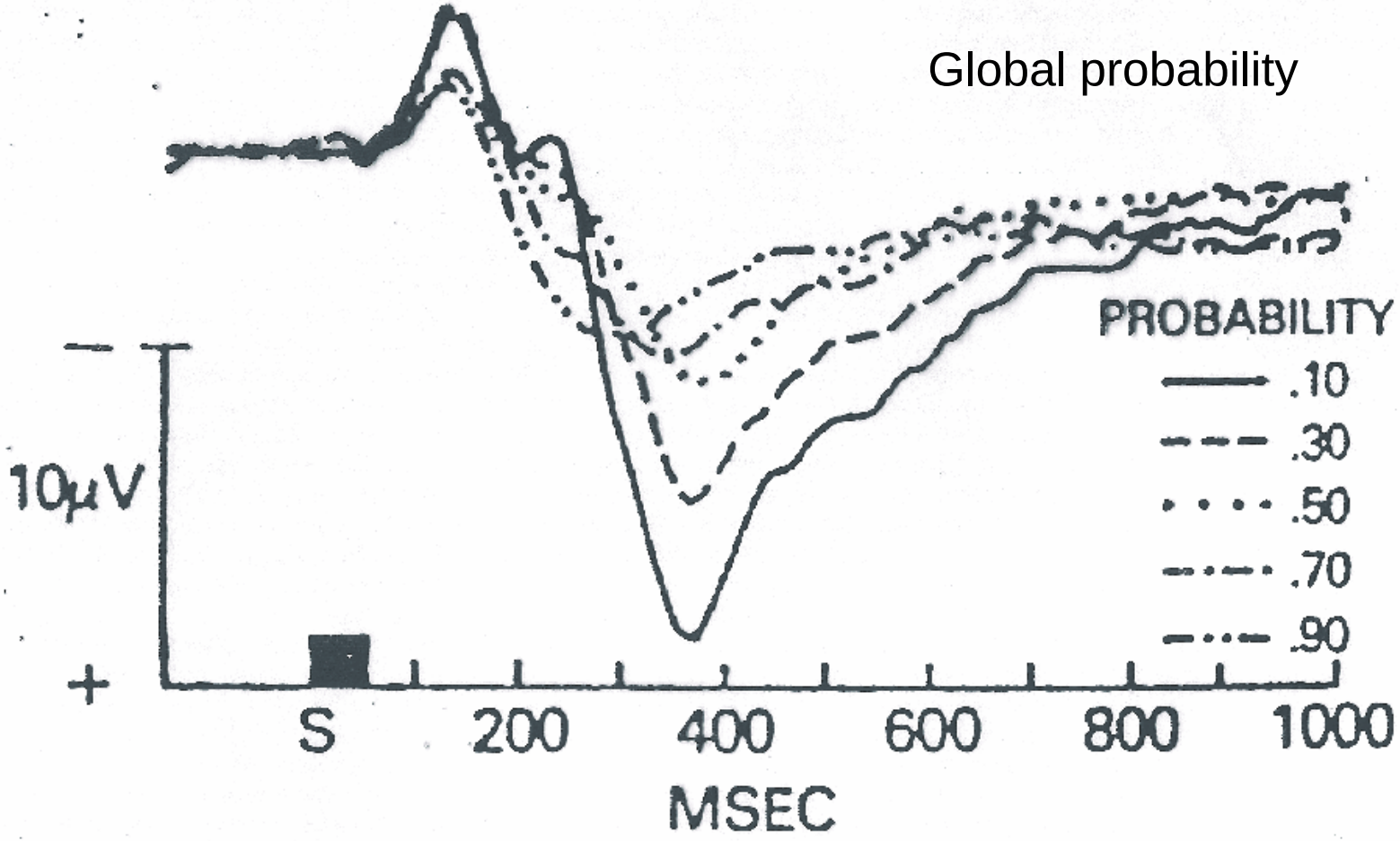


Figure 1. Grand-mean waveforms (N = 7) from P_z for auditory stimuli in an oddball paradigm under RT instructions at five levels of a priori probability. In this and subsequent figures, negative voltages are plotted as upward deflections. Stimulus presentation is indicated by the

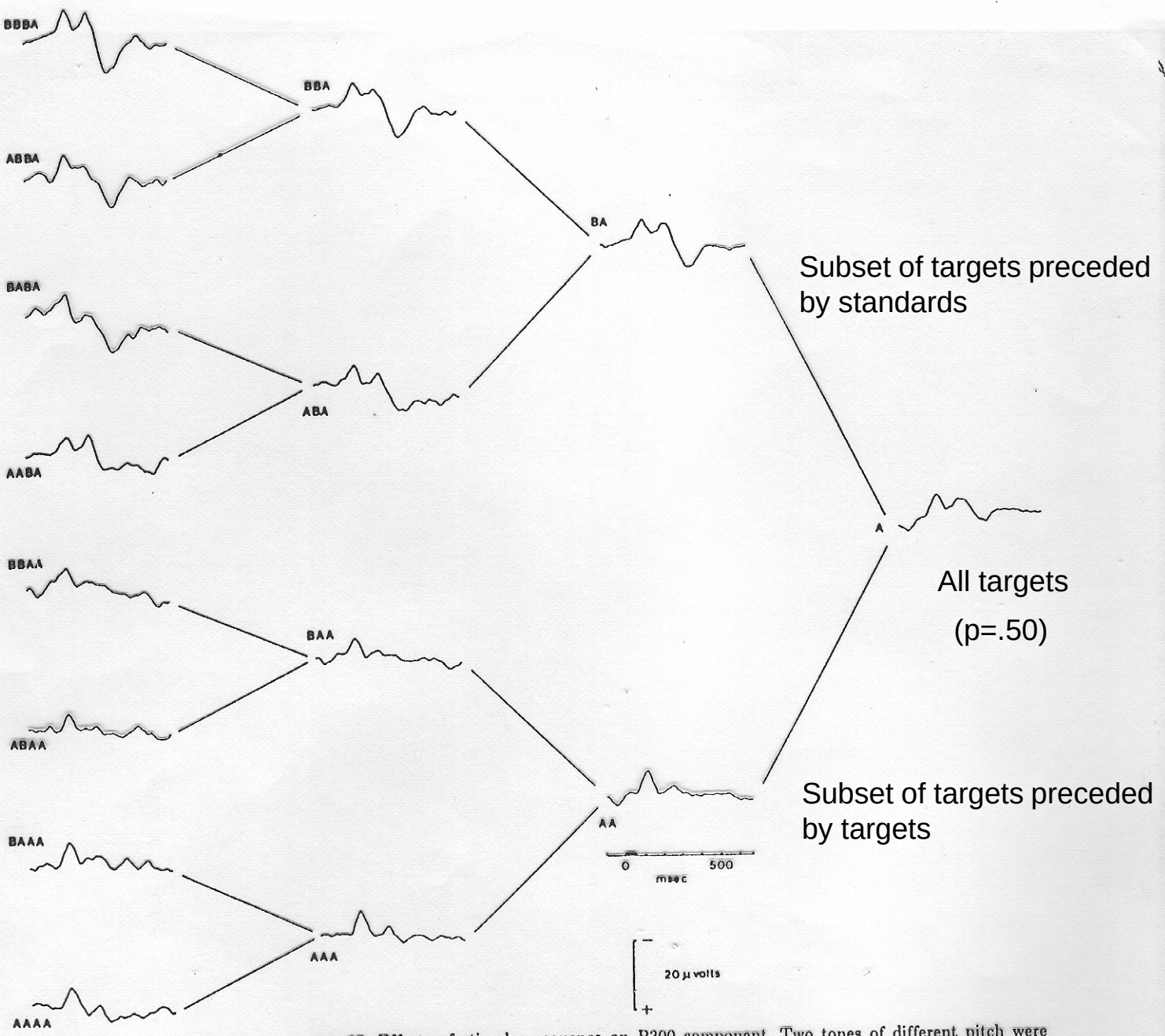
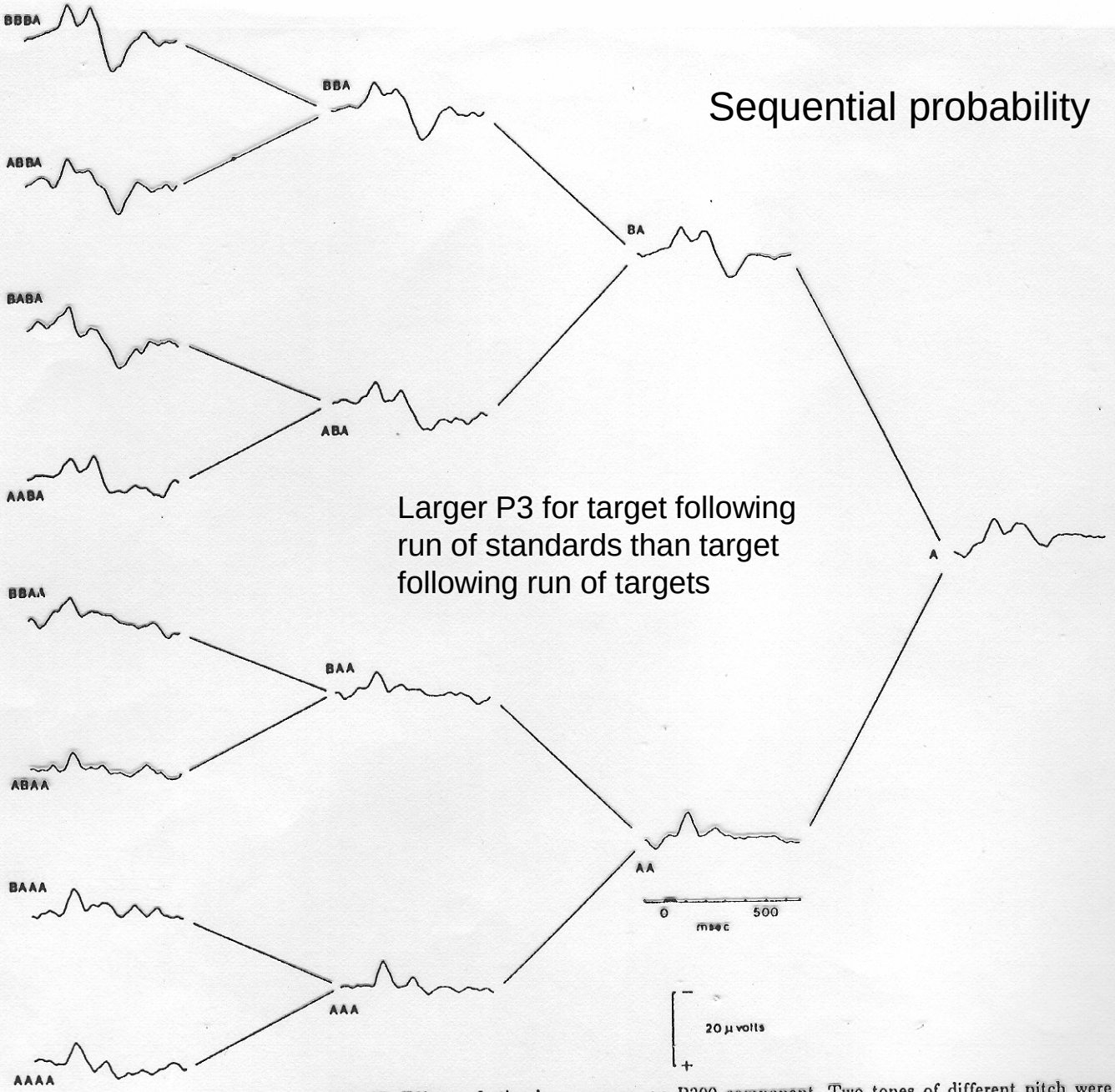


FIG. 27. Effects of stimulus sequence on P300 component. Two tones of different pitch were presented in random sequence with each tone having a probability of 0.5. The event-related potentials (ERPs) to any particular stimulus (A) were averaged according to whether preceding stimuli were of the same frequency (A) or of the other frequency (B). From *left* to *right*: ERPs were averaged according to longer preceding sequences. The P300 wave was larger when the stimulus was preceded by tones



Sequential probability

Larger P3 for target following run of standards than target following run of targets

FIG. 27. Effects of stimulus sequence on P300 component. Two tones of different pitch were presented in random sequence with each tone having a probability of 0.5. The event-related potentials (ERPs) to any particular stimulus (A) were averaged according to whether preceding stimuli were of the same frequency (A) or of the other frequency (B). From *left* to *right*: ERPs were averaged according to longer preceding sequences. The P300 wave was larger when the stimulus was preceded by tones

Even though objective, prior, probability remains constant over a series of trials, the ***subjective probabilities*** *vary from trial to trial, depending on the specific sequence of stimuli preceding each event.*

What about temporal probability and P300?

Keep global probability constant but vary the number of targets per unit time, e.g. 1 target every 250, 750, 3000 ms, etc.

P3 and temporal probability

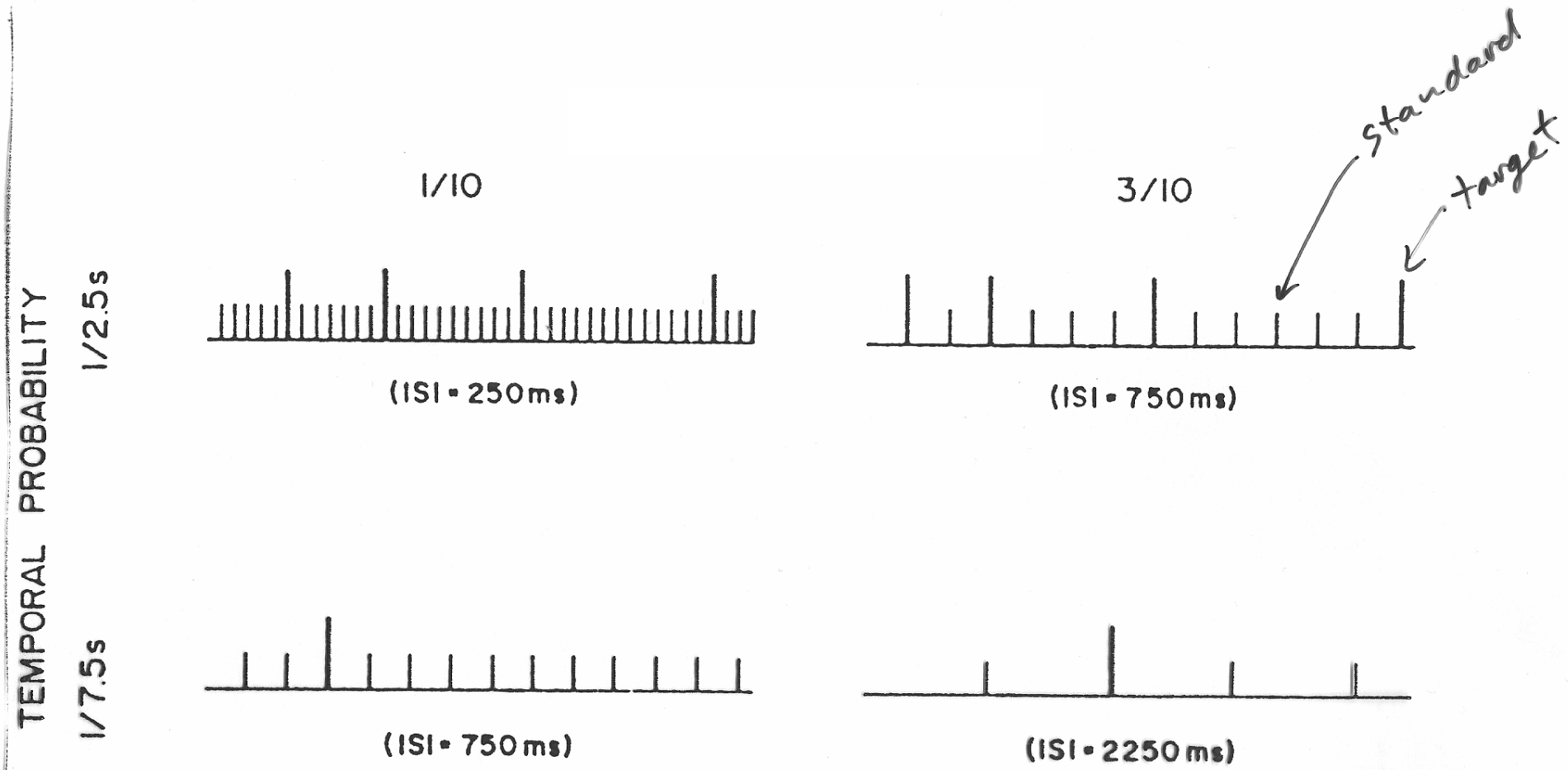


FIGURE 1 Schematic diagram of the four conditions used to dissociate temporal from sequential probability effects in the third experiment. The target stimuli are represented by long markers and the standard stimuli by short.

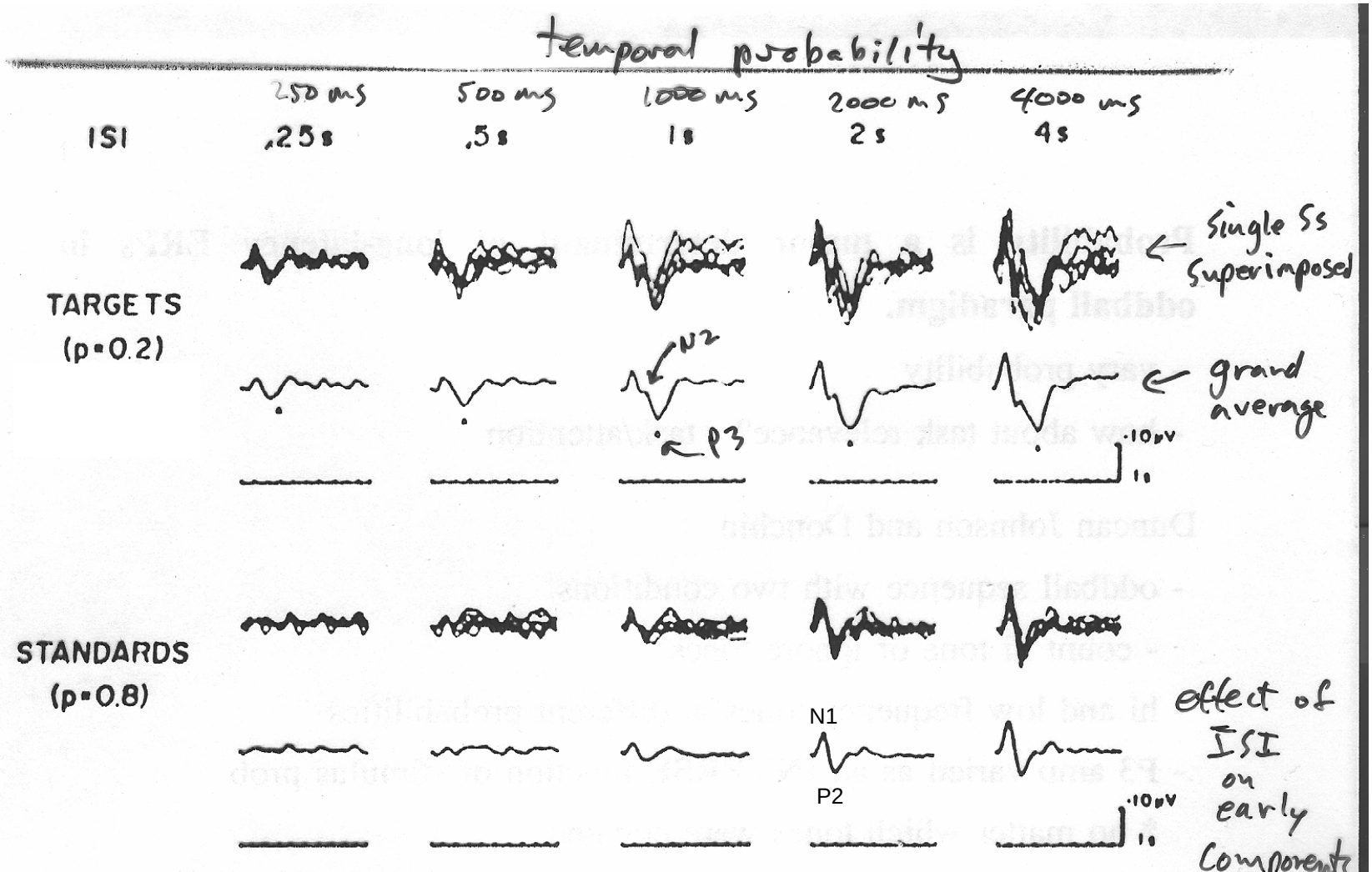


FIGURE 2 The evoked potentials recorded from the vertex in the first experiment. The upper half of the figure shows the superimposed target-evoked potentials from six subjects in all five temporal probability conditions. Below the superimposed waveforms are the corresponding grand averages. On the grand averages the open

Temporal Probability

Keep global probability constant but vary the number of targets per unit time, e.g. 1 target every 250, 750, 3000 ms, etc.

At same a priori stimulus probability (p=.2), targets at longer ISIs elicit larger P3s.

With longer SOAs/ISIs even standards may elicit some P3 activity

Subject probability versus a priori probability

P300 and Stimulus Categorization: Two Plus One is not so Different from One Plus One

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ABSTRACT

Event related brain potentials (ERPs) were recorded from subjects who were instructed to count one of three, equally probable tones presented in a random sequence. In another condition, the subjects had to count one of two stimuli, one of which was presented with a probability of .33. The data support the view that the pattern of variation of P300 amplitude with the sequential structure of the series depends on the category to which events are assigned, rather than on the individual stimuli eliciting the P300. Furthermore, the data support the idea that the amplitude of P300 elicited by task-relevant stimuli is determined by the subjective probability associated with the eliciting event.

DESCRIPTIONS: ERP, P300, Subjective probability, Stimulus categorization.

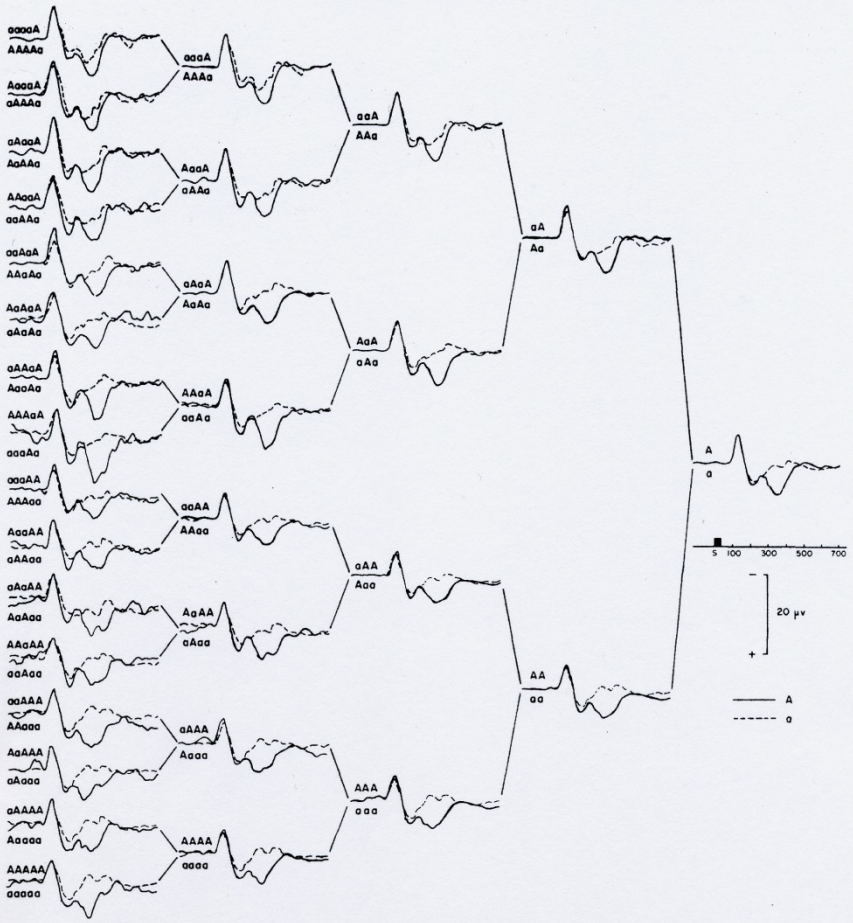


Fig. 2a. Grand-mean (averaged over subjects) vertex ERP waveforms for each sequence in the two-stimulus condition. Solid lines indicate ERPs to counted stimuli, dashed lines indicate uncounted stimuli. Positive voltages are represented as downward deflections in this and all subsequent figures. The stimulus presentation is indicated by the block rectangle on the time scale.

33% oddball target, 67% standards

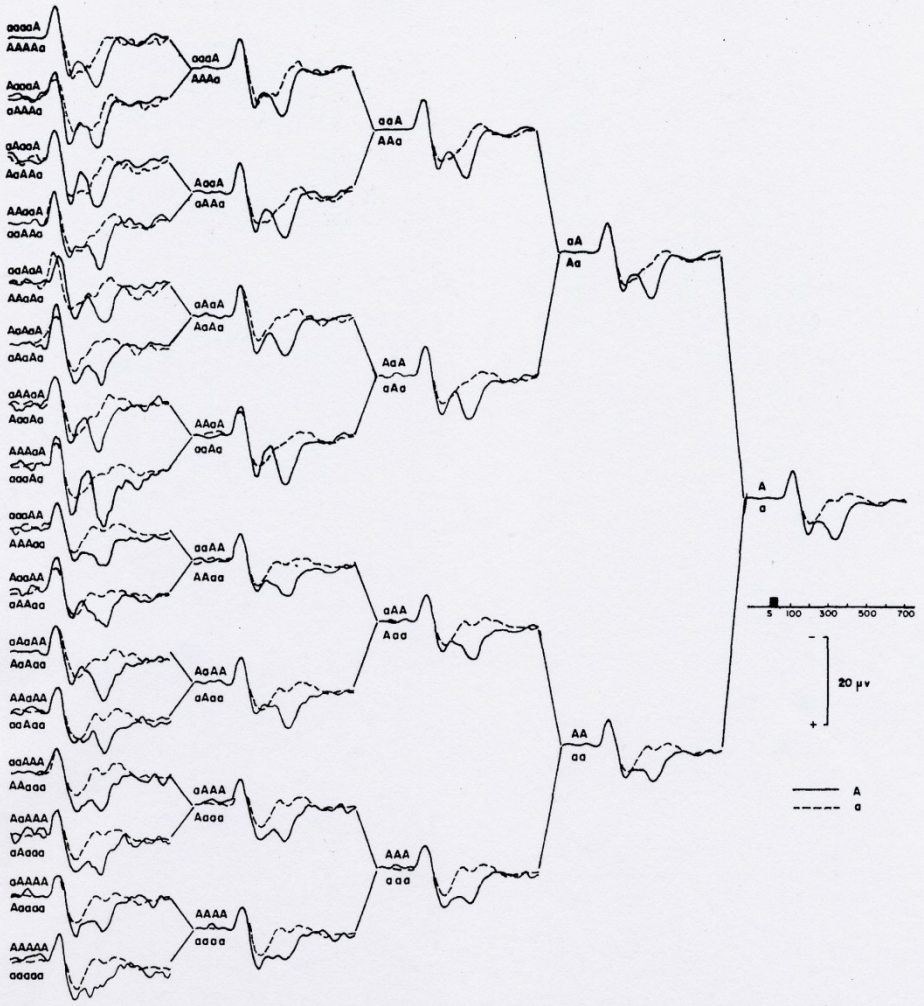
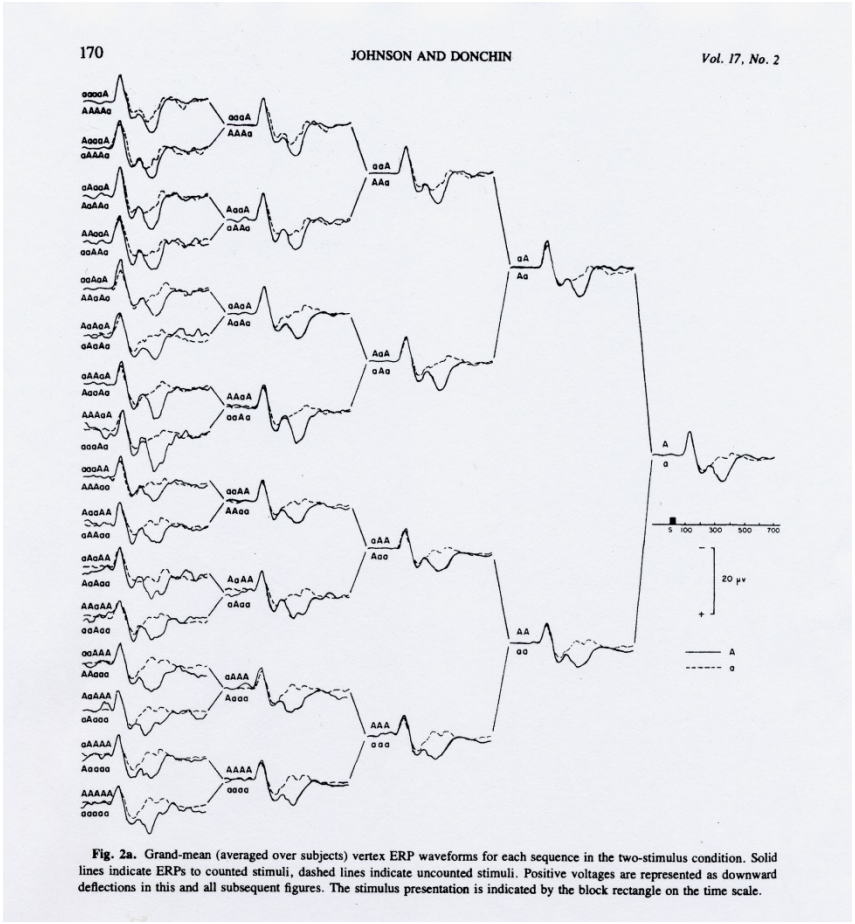


Fig. 3a. Grand-mean vertex waveforms for the three-stimulus condition when the two uncounted stimuli were sequentially coded as a single stimulus. Solid lines indicate ERPs elicited by counted stimuli, dashed lines indicate uncounted stimuli.

33% target, 33% standard A and 33% standard B collapsed



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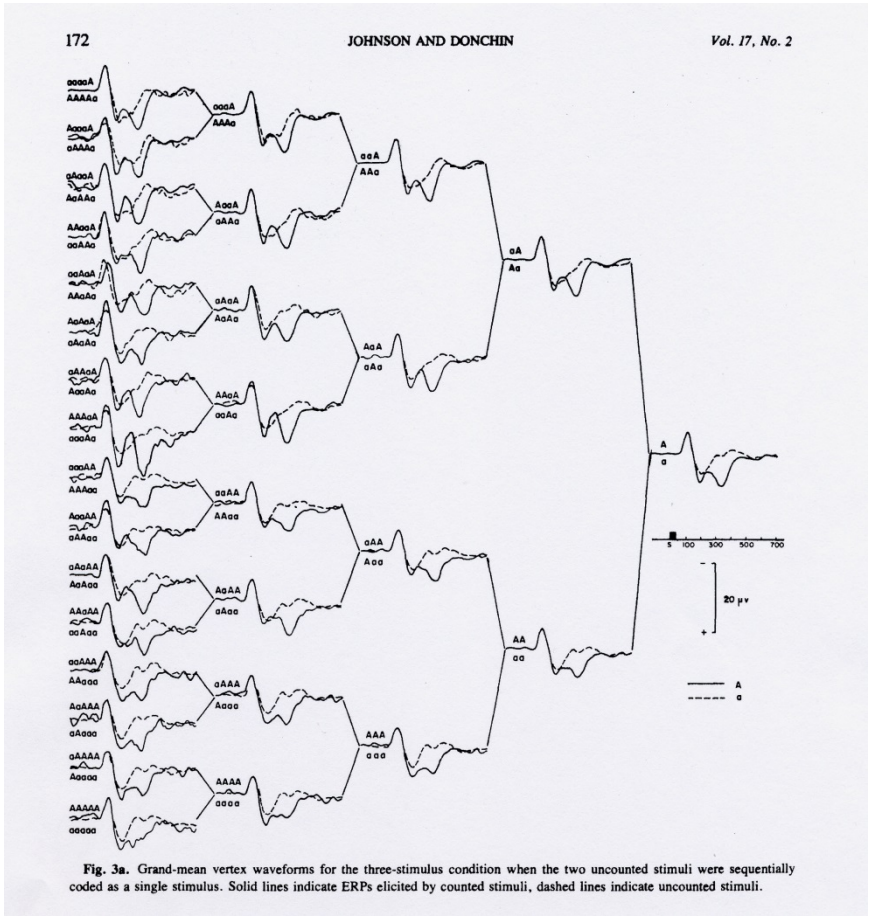

Fig. 3a. Grand-mean vertex waveforms for the three-stimulus condition when the two uncounted stimuli were sequentially coded as a single stimulus. Solid lines indicate ERPs elicited by counted stimuli, dashed lines indicate uncounted stimuli.

Probability of standard = .67

Probability of each standard = .33

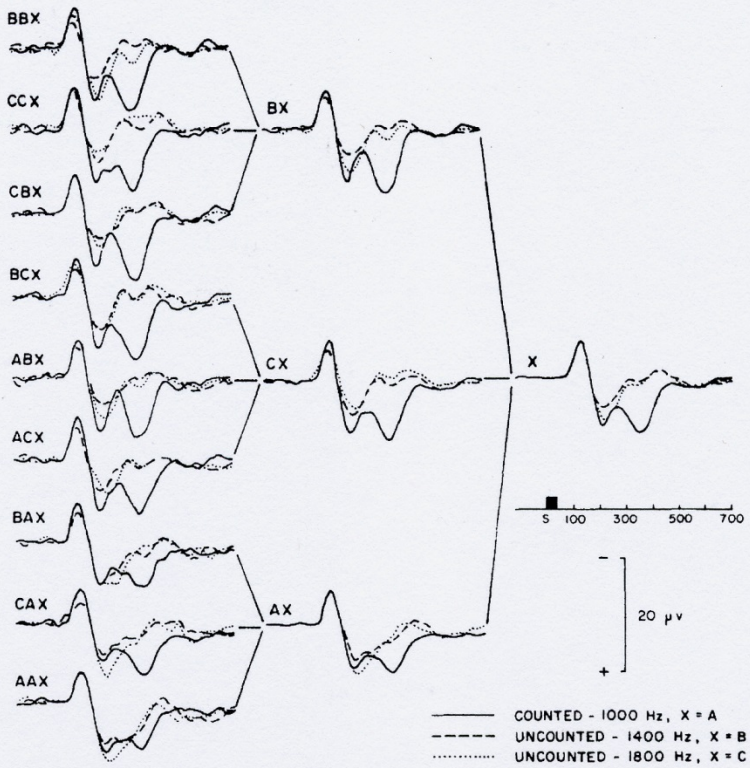

Fig. 4a. Grand-mean vertex ERPs for the three-stimulus condition when all stimuli were coded individually. Solid lines indicate ERPs to counted stimuli (A), dashed lines to uncounted, 1400-Hz stimuli (B), and dotted lines to uncounted, 1800-Hz stimuli. The portrayal of three superimposed ERP averages necessitated the use of the "X" notation in the sequence labels. To determine which averages are superimposed, each stimulus letter (A, B, C) is substituted in turn for "X." For example, in the averages denoted as "BX," the solid line represents the sequential average for the sequence BA; the dashed line represents the sequence BB; and the dotted line represents the sequence BC.

33% target, 33% standard A, 33% standard B

It is not a priori probability per se that matters!

What really matters is *subjective probability* of the target event!

If target or oddball for (mental) counting or responding were T, then in this sequence, it would have larger P3 than any of the individual letters, even though all of them have a lower *a priori* probability of occurrence than it does (p=.25).

a b a g d f m **T** r n l **T** s w **T** h j n **T** **T** y e q p **T** s l z x p

Target = T

Standard = all other letters, each of which alone has lower probability than T