Iowa State University EEG and ERP Workshop

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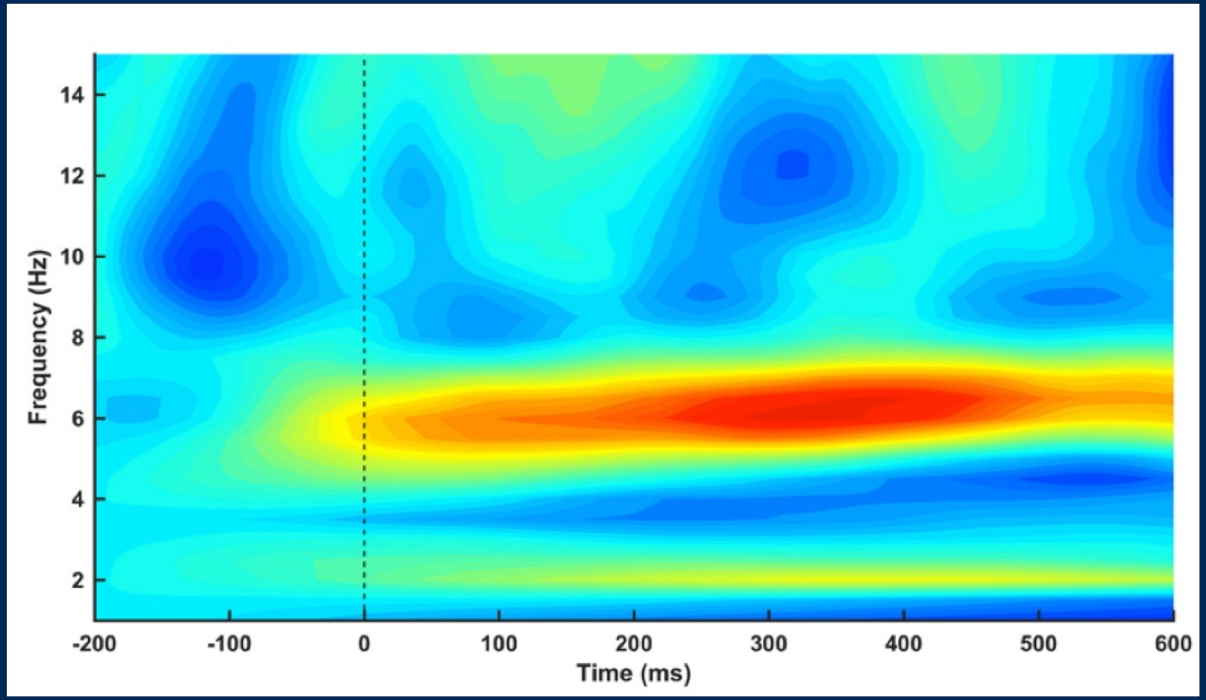


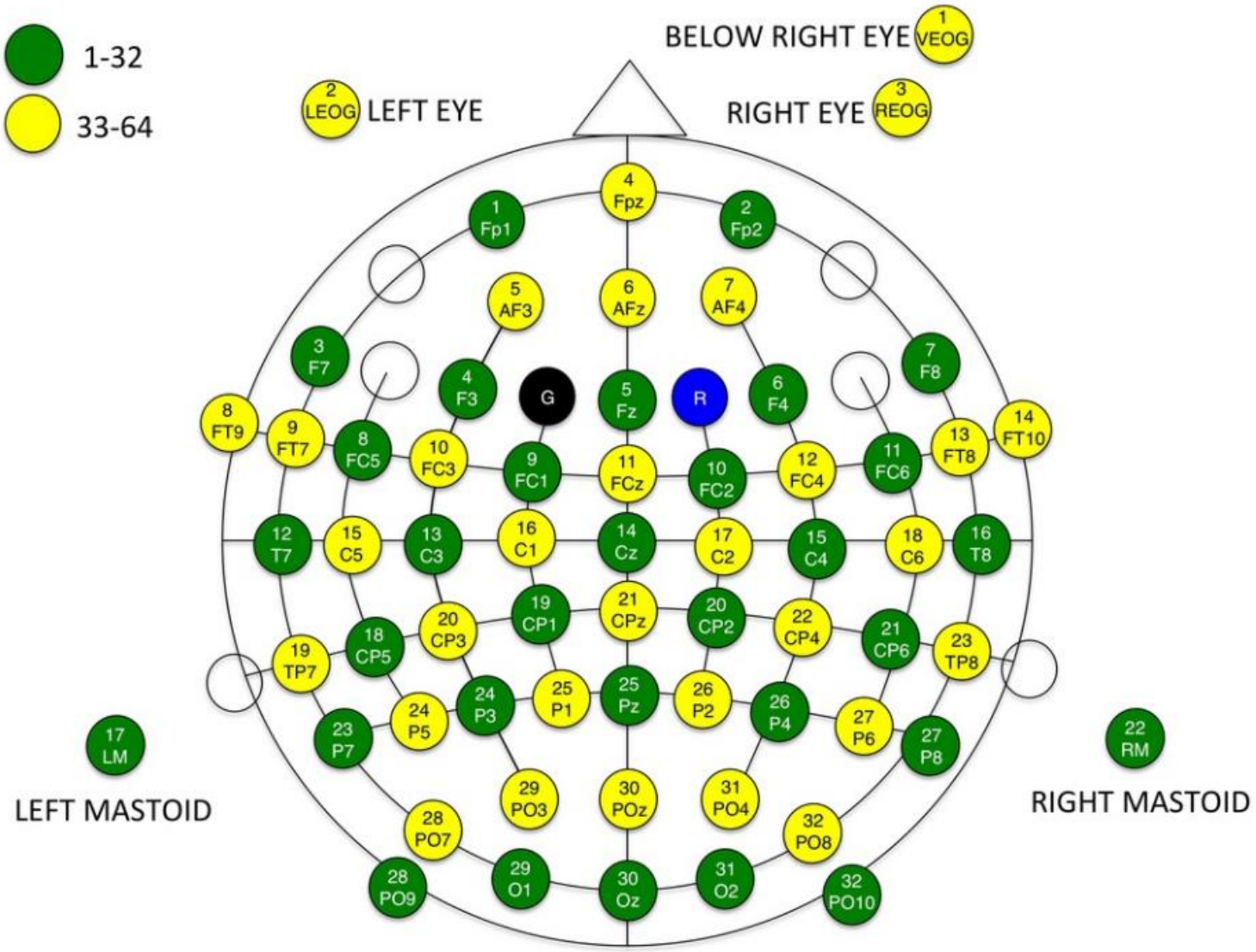
Collecting "Good" Data

"CRAP IN = CRAP OUT"

Collecting "Good" Data

Before the Participant Arrives

- clean electrodes
- dry electrodes
- equipment in place
- 2 RAs present
- experiment / markers tested
- choice of reference channels
- cap layout
- electrical noise


1-32
33-64
BELOW RIGHT EYE
1 VEOG
2 LEOG LEFT EYE
RIGHT EYE 3 REOG
4 Fpz
1 Fp1
2 Fp2
5 AF3
6 AFz
7 AF4
3 F7
7 F8
4 F3
G
5 Fz
R
6 F4
8 FT9
9 FT7
8 FC5
10 FC3
9 FC1
11 FCz
10 FC2
12 FC4
11 FC6
13 FT8
14 FT10
12 T7
15 C5
13 C3
16 C1
14 Cz
17 C2
15 C4
18 C6
16 T8
19 CP1
21 CPz
20 CP2
22 CP4
19 TP7
18 CP5
20 CP3
21 CP6
23 TP8
24 P3
25 P1
25 Pz
26 P2
26 P4
27 P6
24 P5
23 P7
27 P8
17 LM
22 RM
LEFT MASTOID
29 PO3
30 POz
31 PO4
28 PO7
32 PO8
28 PO9
29 O1
30 Oz
31 O2
32 PO10
RIGHT MASTOID

Collecting "Good" Data

Setting Up

- accurate placement of skin electrodes
- proper sized cap
- cap properly in place
    - the side to side rule
    - the pencil trick
- the right amount of gel
    - avoid bridging

Collecting "Good" Data

Setting Up

- cap movement during collection
- cap snugness
- ELECTRODE IMPEDENCES!
- checklists

Collecting "Good" Data

During the Run

- monitor impedances
- monitor waveforms
- rest breaks – make them take them!
- monitor behavior
- motivation!

Collecting "Good" Data

After the Run

- clean the equipment properly
- review what went well / poorly
- RUN SHEETS
- look at the data right away and make notes based on the RUN SHEET
- review data quality immediately

Collecting "Good" Data

Design

- Cog Assess
- Training Standards

Setting up an EEG / ERP Lab

The Space

QUIET

Control and Recording Room

Electromagnetic Shielding

What You Need

EEG System (what kind, how much)

Caps and Electrodes (how many)

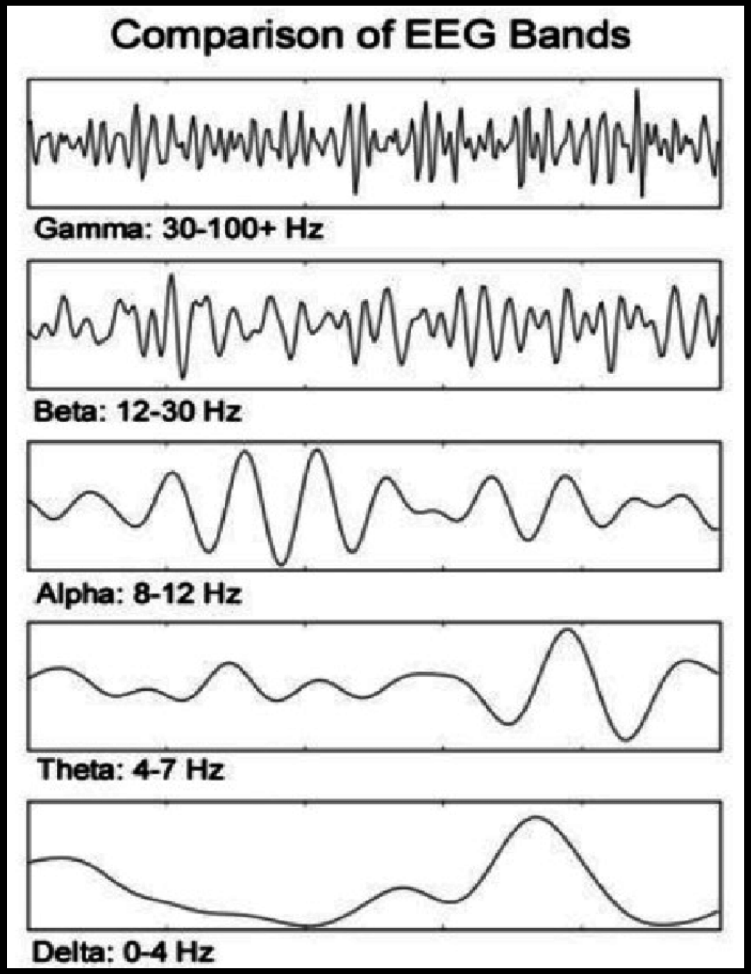
Collection and Analysis Software ($$$)

2 x Computers

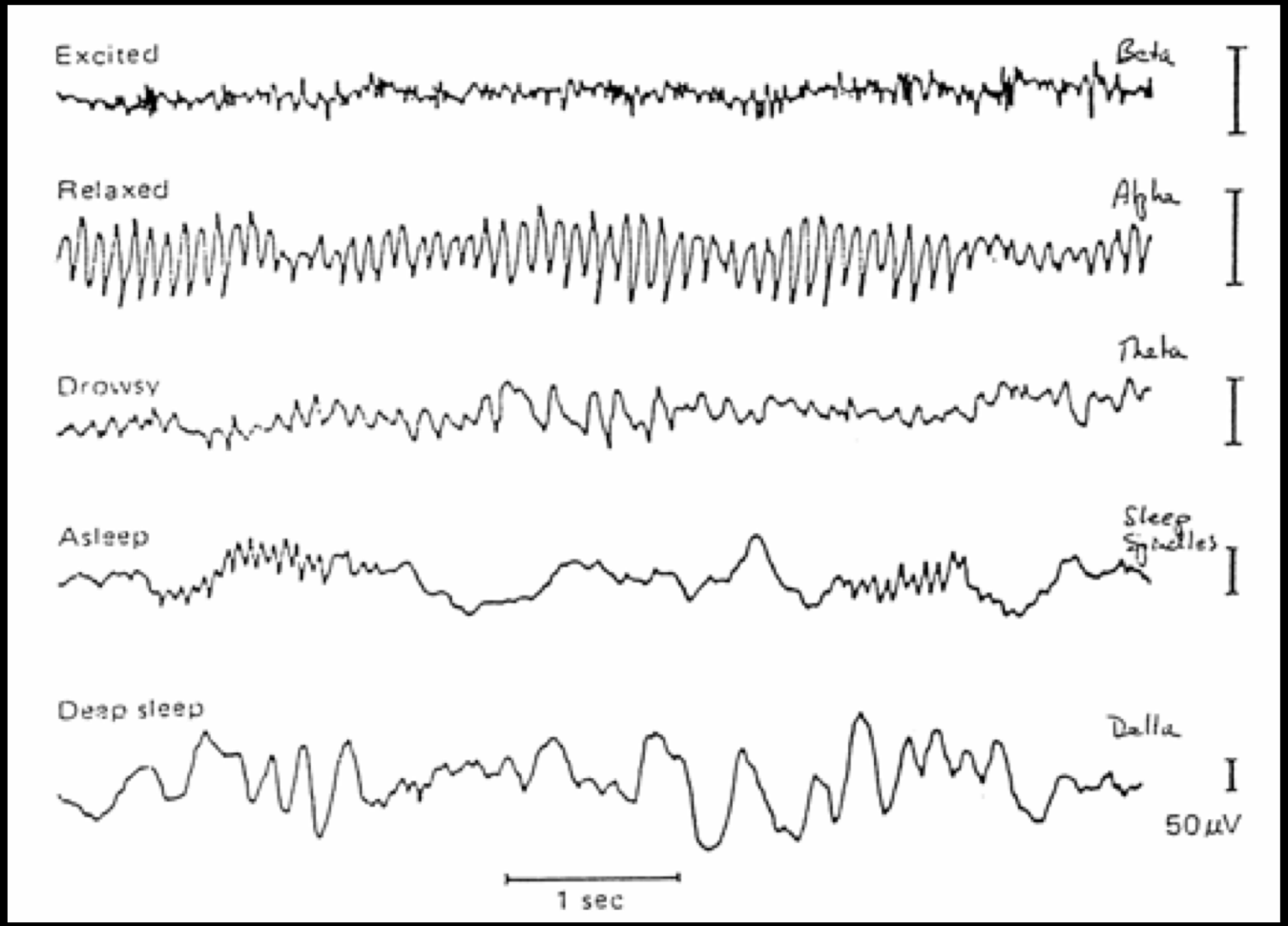
Supplies ($$$, cost per participant = wear and tear)

An Overview of EEG and ERP Components

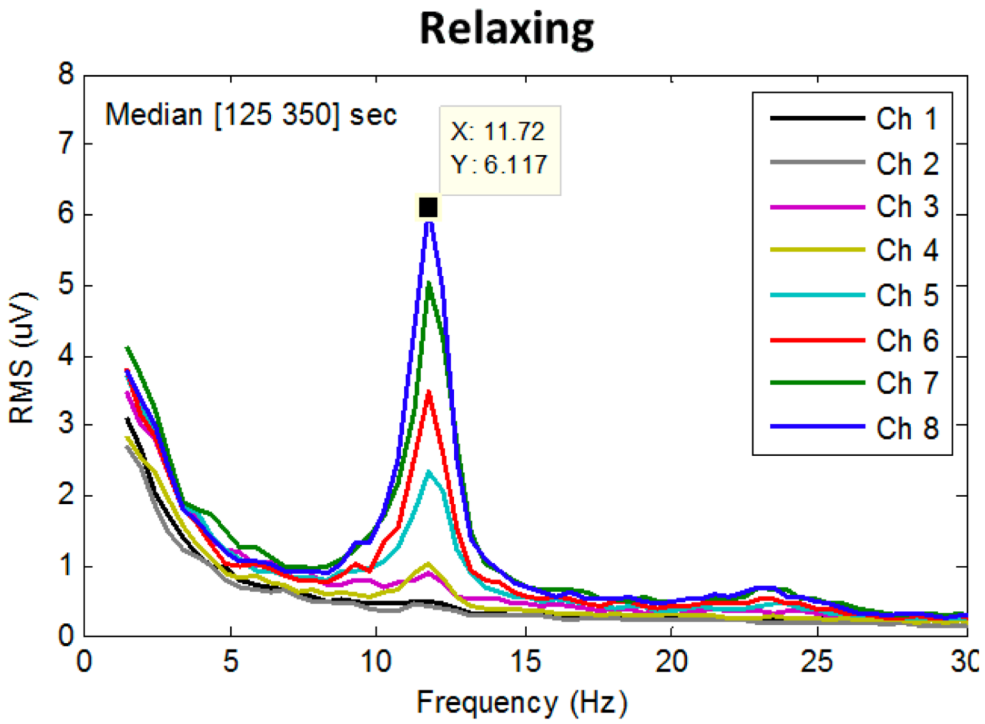
An Overview of EEG Frequency Bands

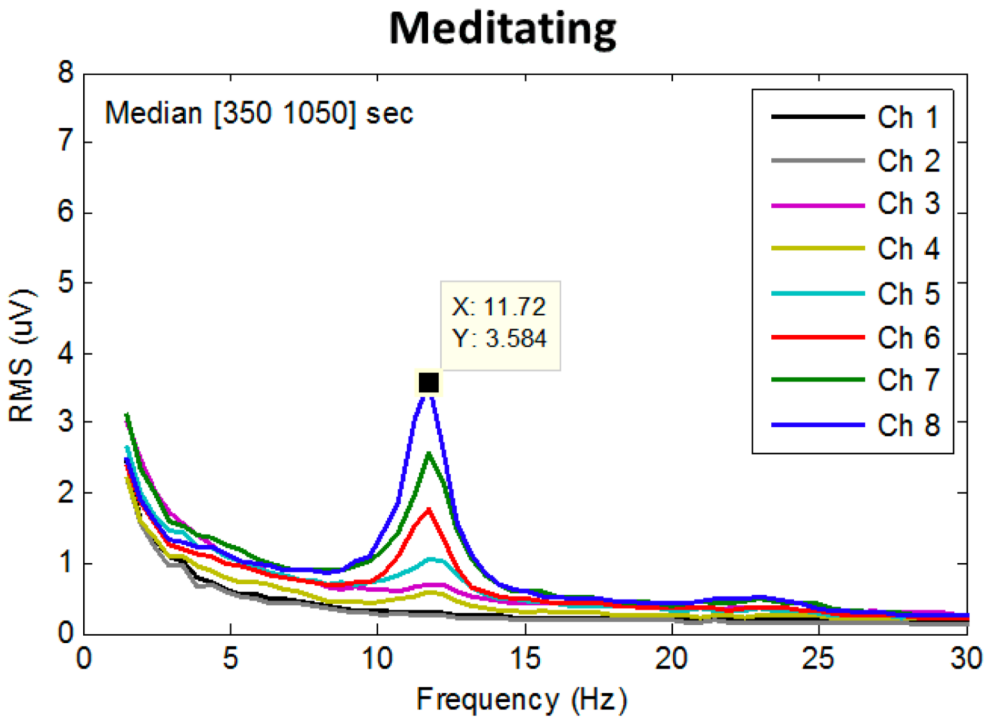

Comparison of EEG Bands
Gamma: 30-100+ Hz
Beta: 12-30 Hz
Alpha: 8-12 Hz
Theta: 4-7 Hz
Delta: 0-4 Hz

Sleep

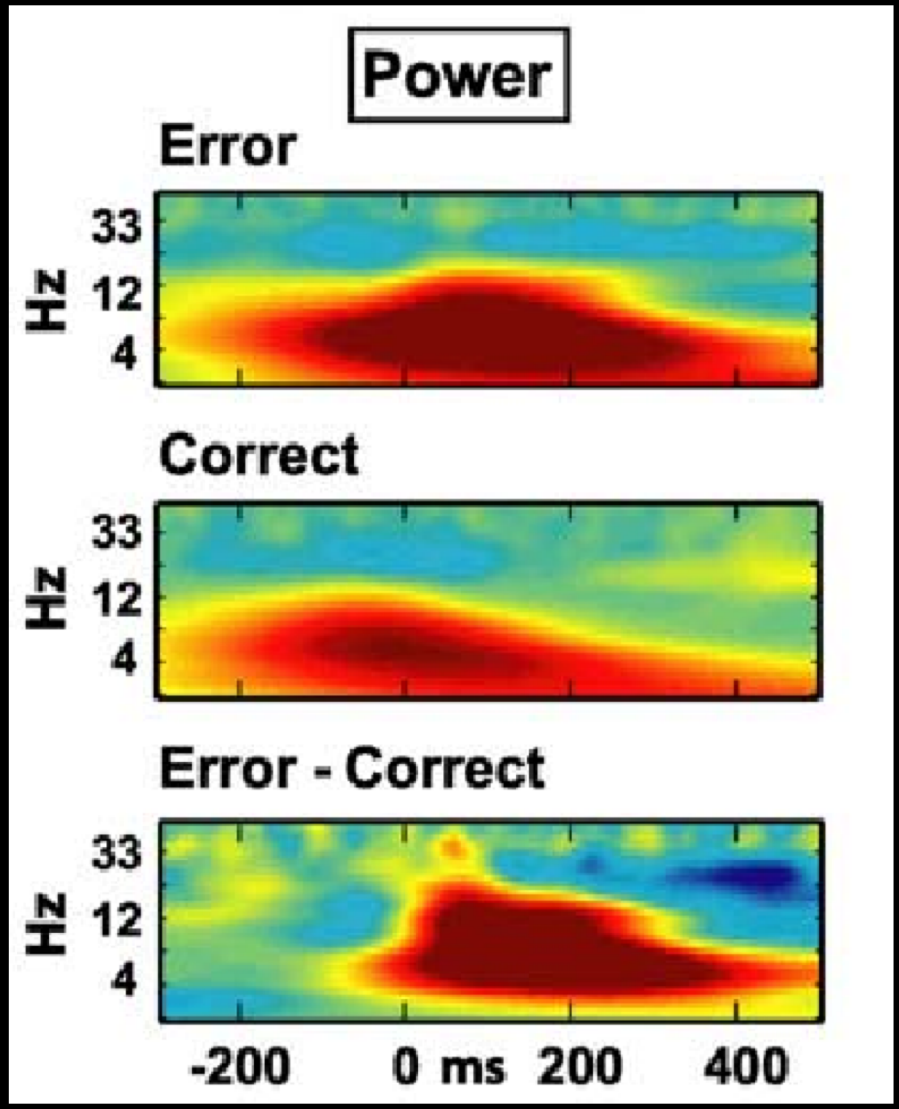

Excited
Beta
Relaxed
Alpha
Drowsy
Theta
Asleep
Sleep Spindles
Deep sleep
Delta
50 μV
1 sec

Meditation

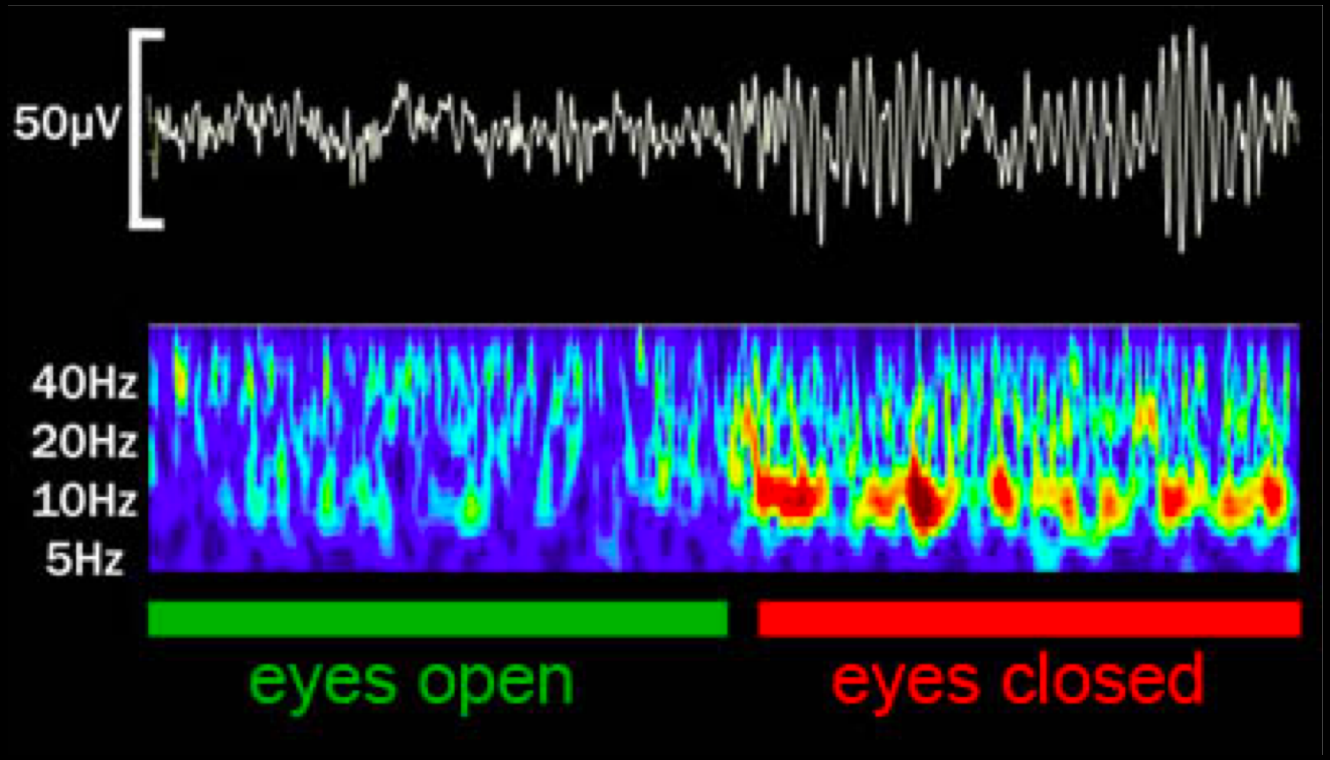

Relaxing
Median [125 350] sec
X: 11.72
Y: 6.117
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 6
Ch 7
Ch 8
RMS (uV)
Frequency (Hz)
0
1
2
3
4
5
6
7
8
0
5
10
15
20
25
30


Meditating
Median [350 1050] sec
X: 11.72
Y: 3.584
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 6
Ch 7
Ch 8
RMS (uV)
Frequency (Hz)
0
1
2
3
4
5
6
7
8
0
5
10
15
20
25
30

Cognitive Control



Attention



	Frontal	Posterior
Delta 0.1 to 3 Hz	Increases Following Sleep Deprivation	Reward (Gain) Reward Magnitude
Theta 4 to 7 Hz	Cognitive Control Reward (Loss)	Memory Retrieval (increases the more an item is remembered)
Alpha 8 to 12 Hz	Left: Approach System Positive Affect / Motivation Right: Avoid System Negative Affect / Motivation	Attention Decrease = Concentration Increase = Relaxation
Beta 13 to 30 Hz	Working Memory Outcome Evaluation	Semantic Memory Processing
Gamma 31 to 100 Hz	Higher Level Consciousness Cortical Synchronization	Correlates with Behavioral Measures

Summary

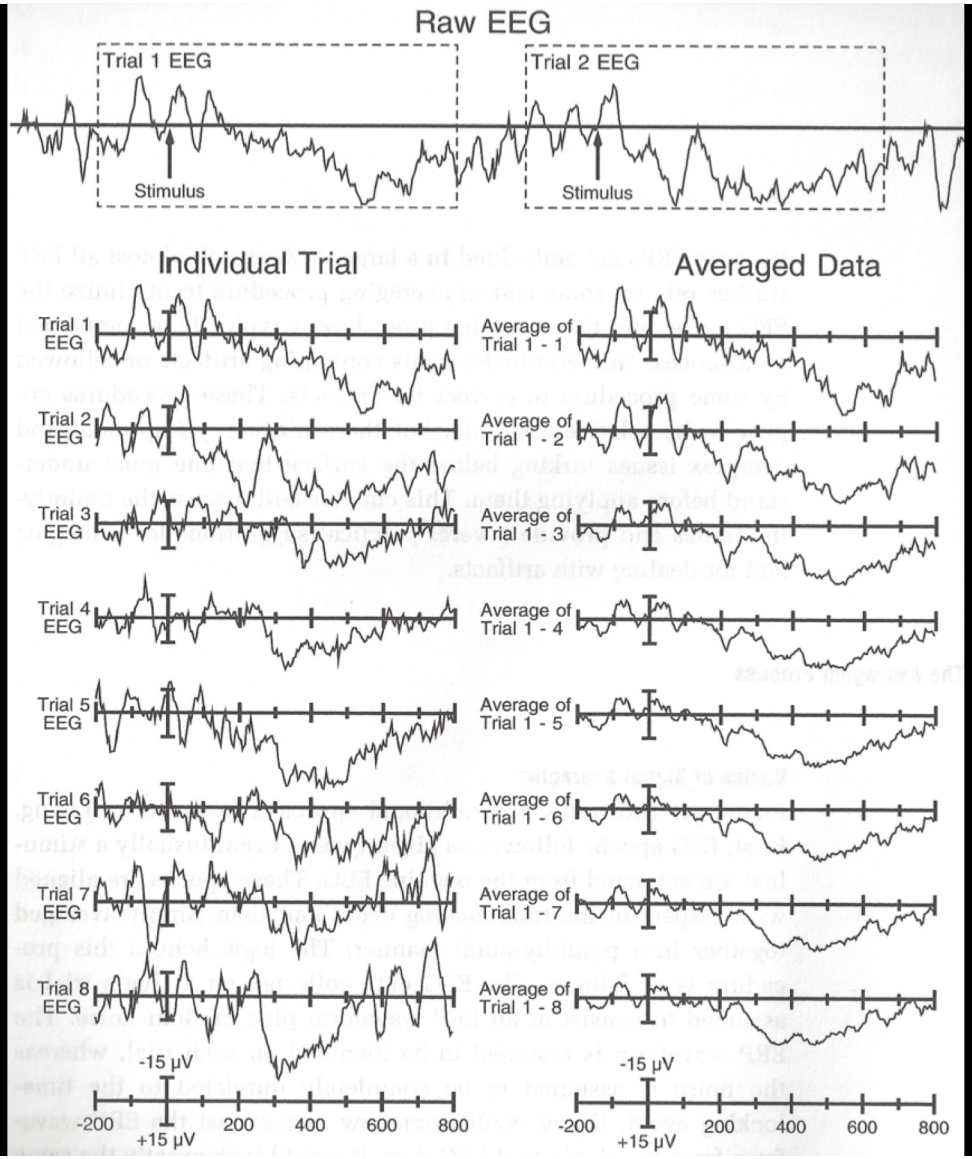
There is a large body on EEG frequency bands.

The research is not conclusive, and is frequently at odds with itself.

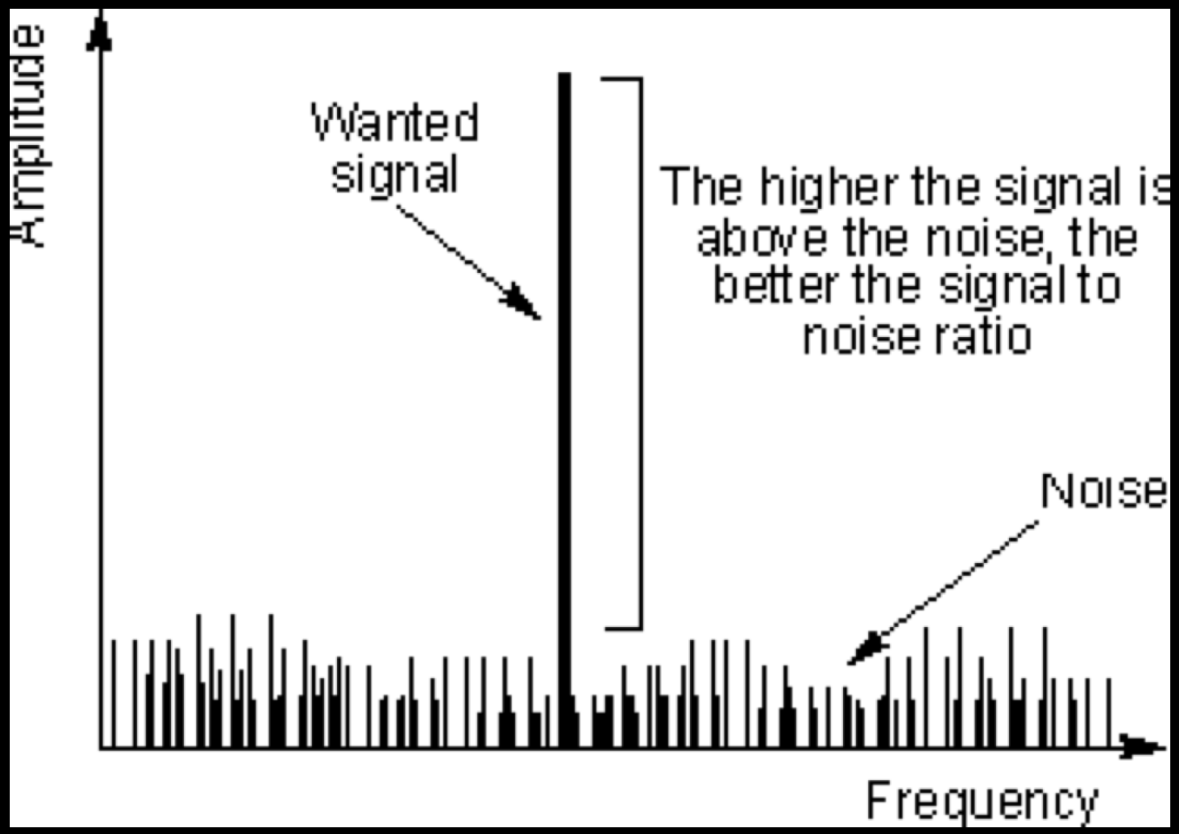
More is known about ERP components.

An Overview of ERP Components

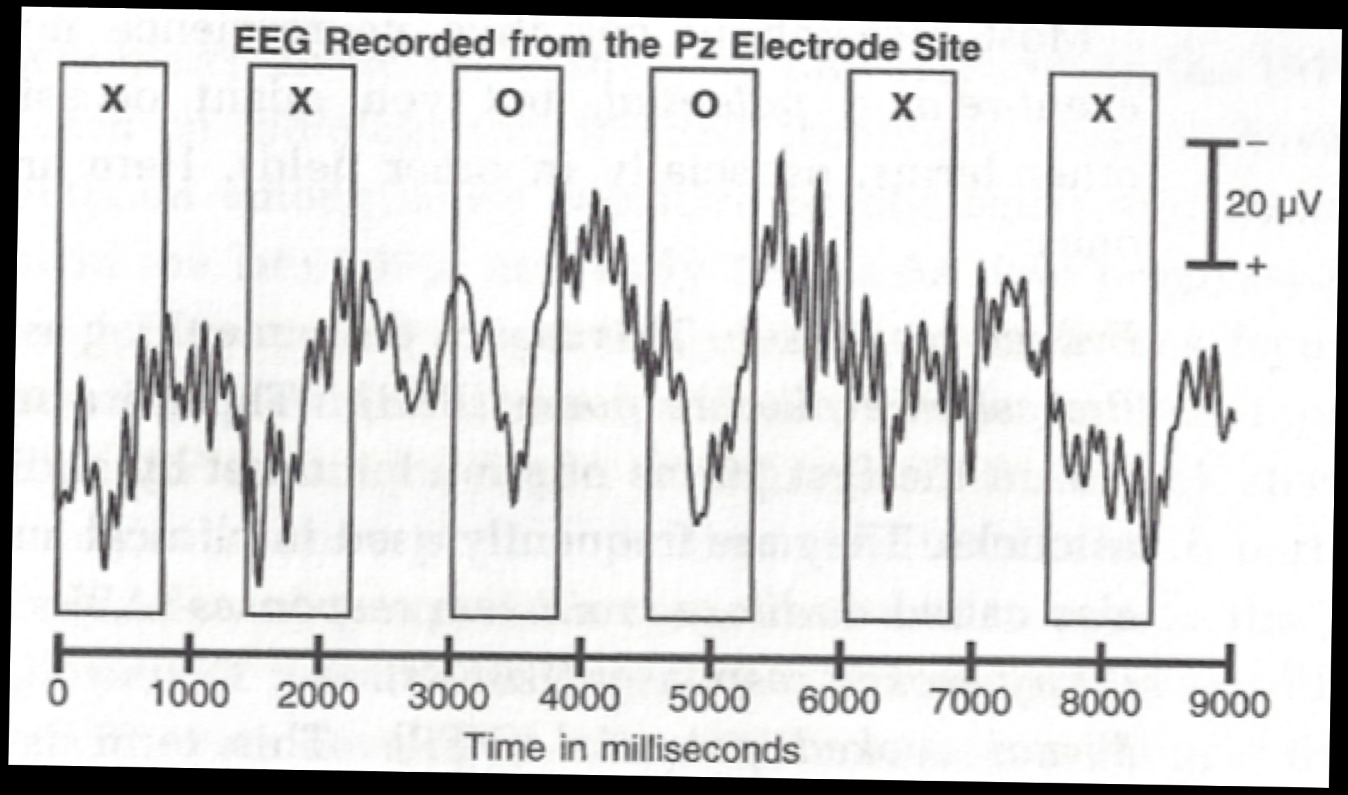
What is an ERP component?

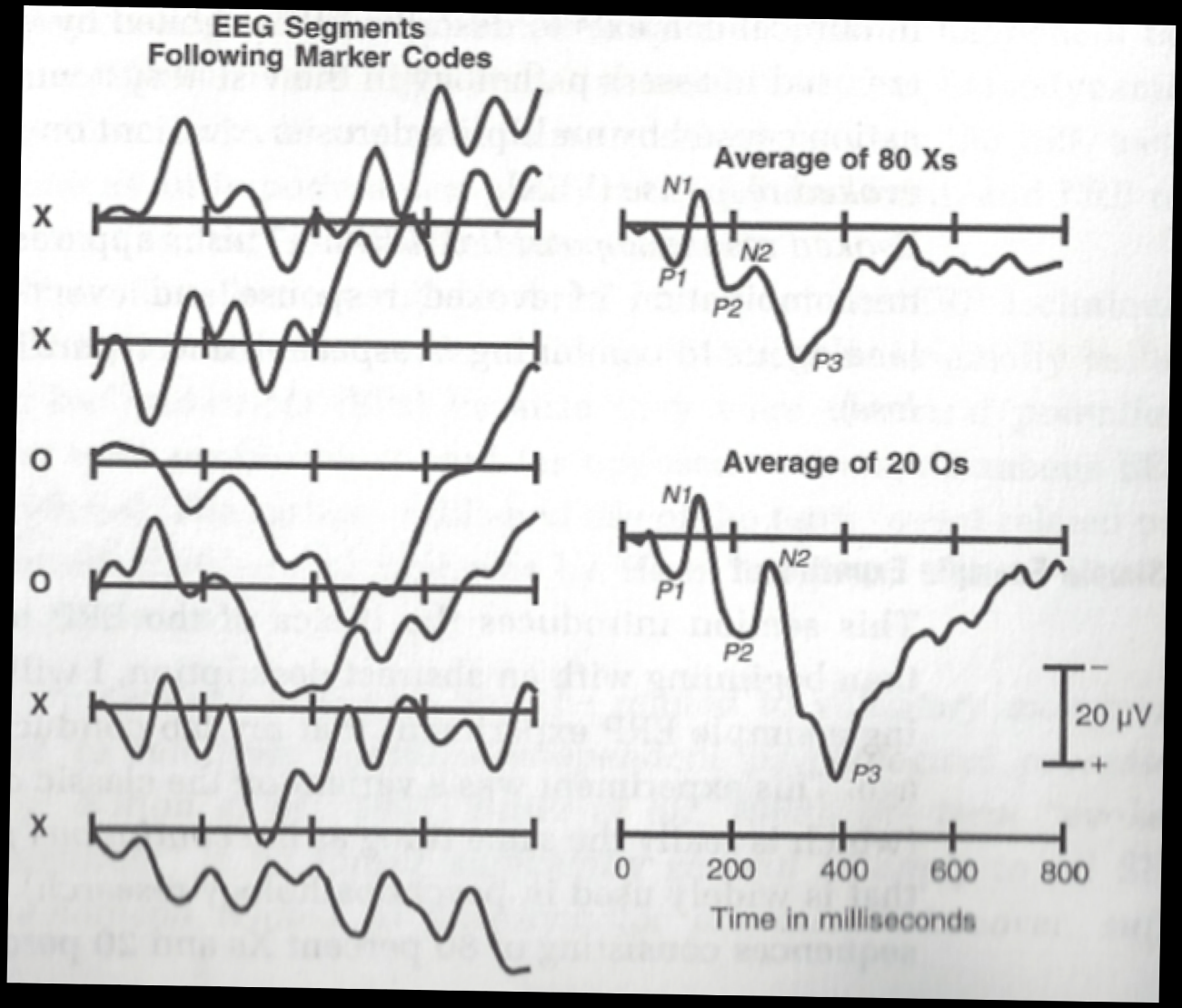

Raw EEG
Trial 1 EEG
Trial 2 EEG
Stimulus
Stimulus
Individual Trial
Averaged Data
Trial 1 EEG
Trial 2 EEG
Trial 3 EEG
Trial 4 EEG
Trial 5 EEG
Trial 6 EEG
Trial 7 EEG
Trial 8 EEG
Average of Trial 1 - 1
Average of Trial 1 - 2
Average of Trial 1 - 3
Average of Trial 1 - 4
Average of Trial 1 - 5
Average of Trial 1 - 6
Average of Trial 1 - 7
Average of Trial 1 - 8
-15 µV
+15 µV
-200
200
400
600
800
-15 µV
+15 µV
-200
200
400
600
800

Signal to Noise Ratio



How do we typical improve SNR in neuroimaging?


EEG Recorded from the Pz Electrode Site
X
X
O
O
X
X
20 μV
−
+
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Time in milliseconds


EEG Segments
Following Marker Codes
X
X
O
O
X
X
Average of 80 Xs
N1
P1
N2
P2
P3
Average of 20 Os
N1
P1
N2
P2
P3
20 μV
−
+
0
200
400
600
800
Time in milliseconds

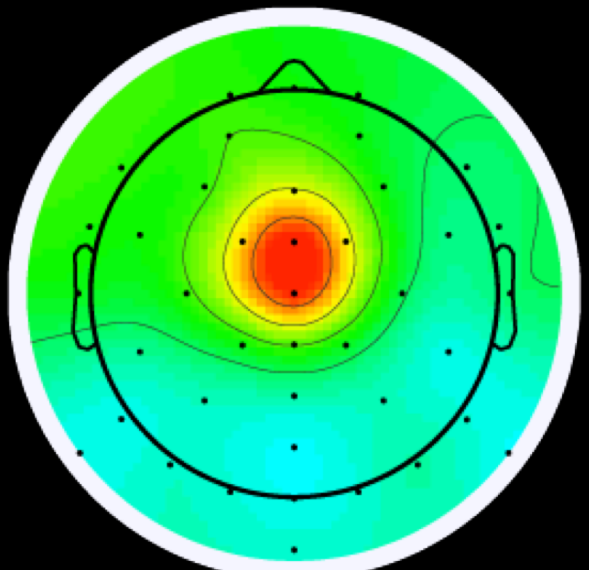
Component Definition

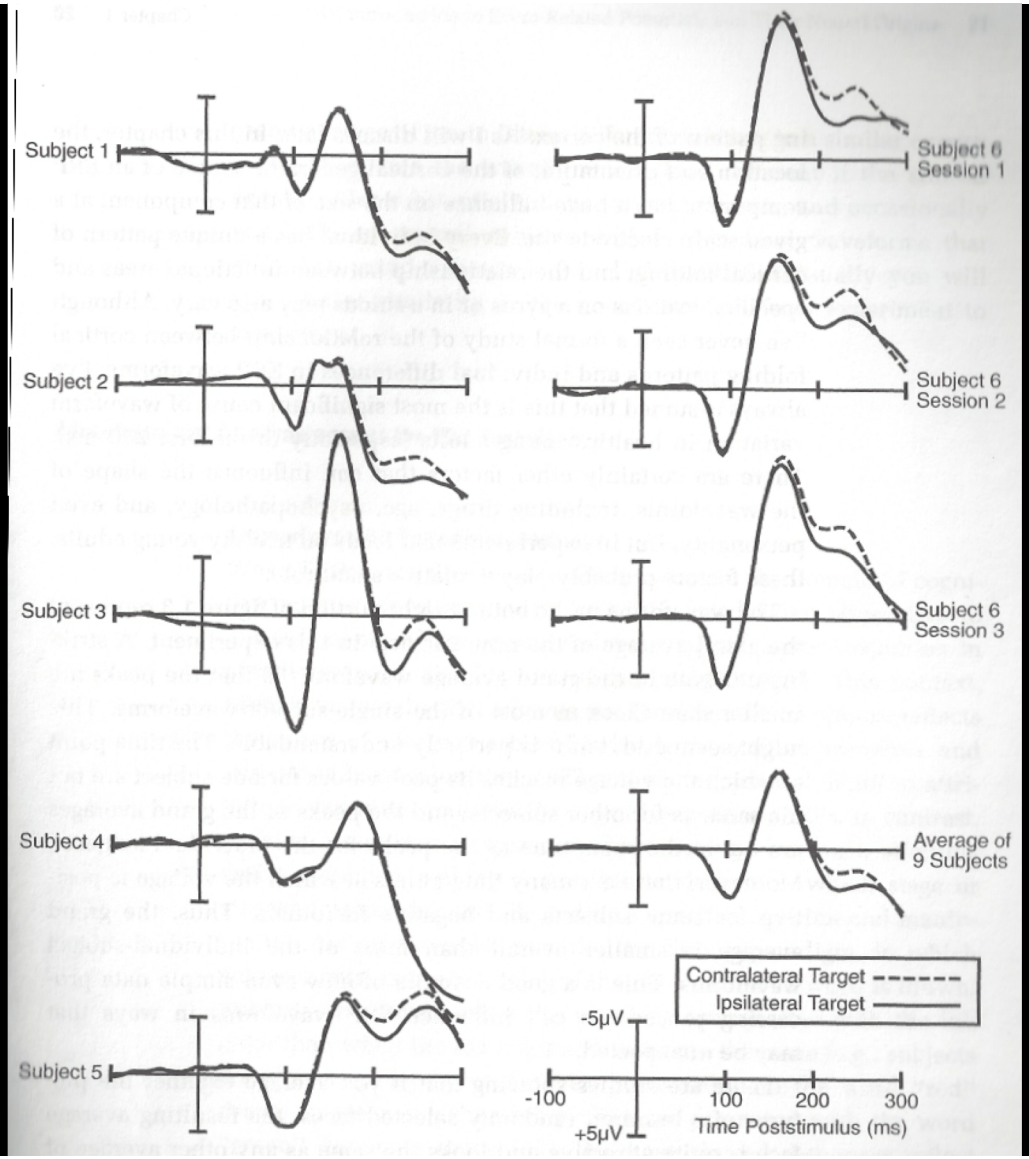
ERP Components have:

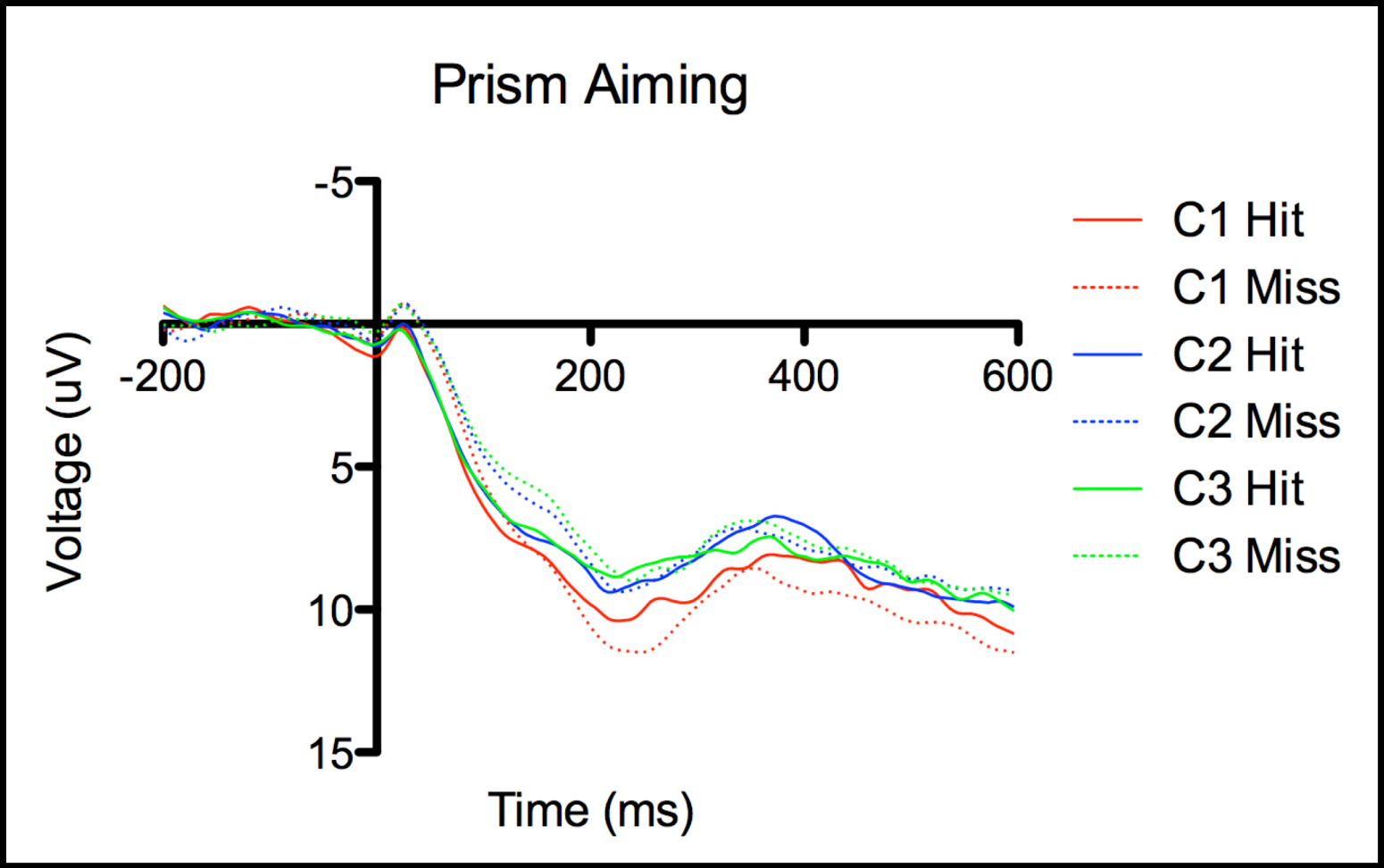
A Polarity (e.g., N200, P300)

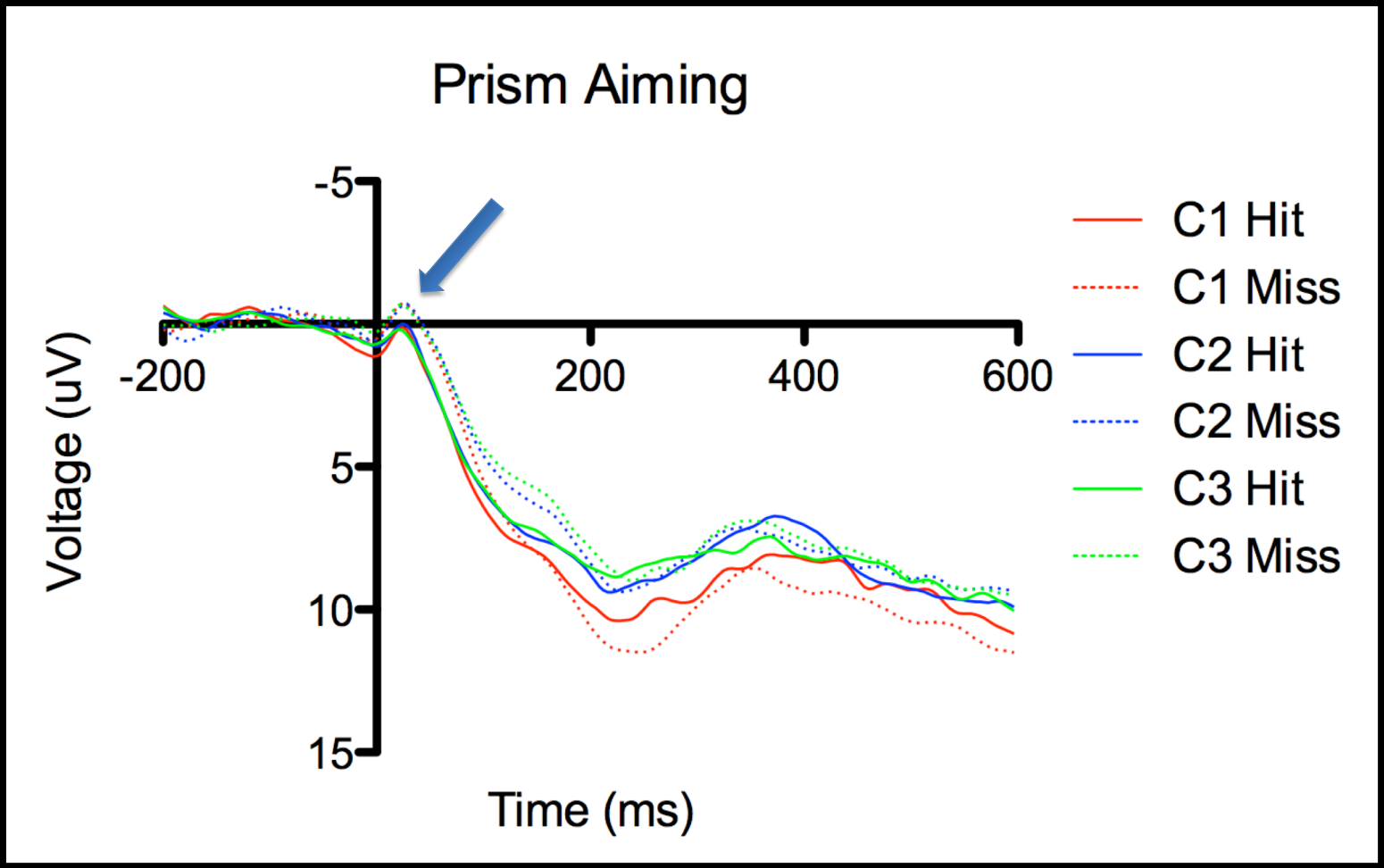
A Timing (e.g., 200 to 300 ms)

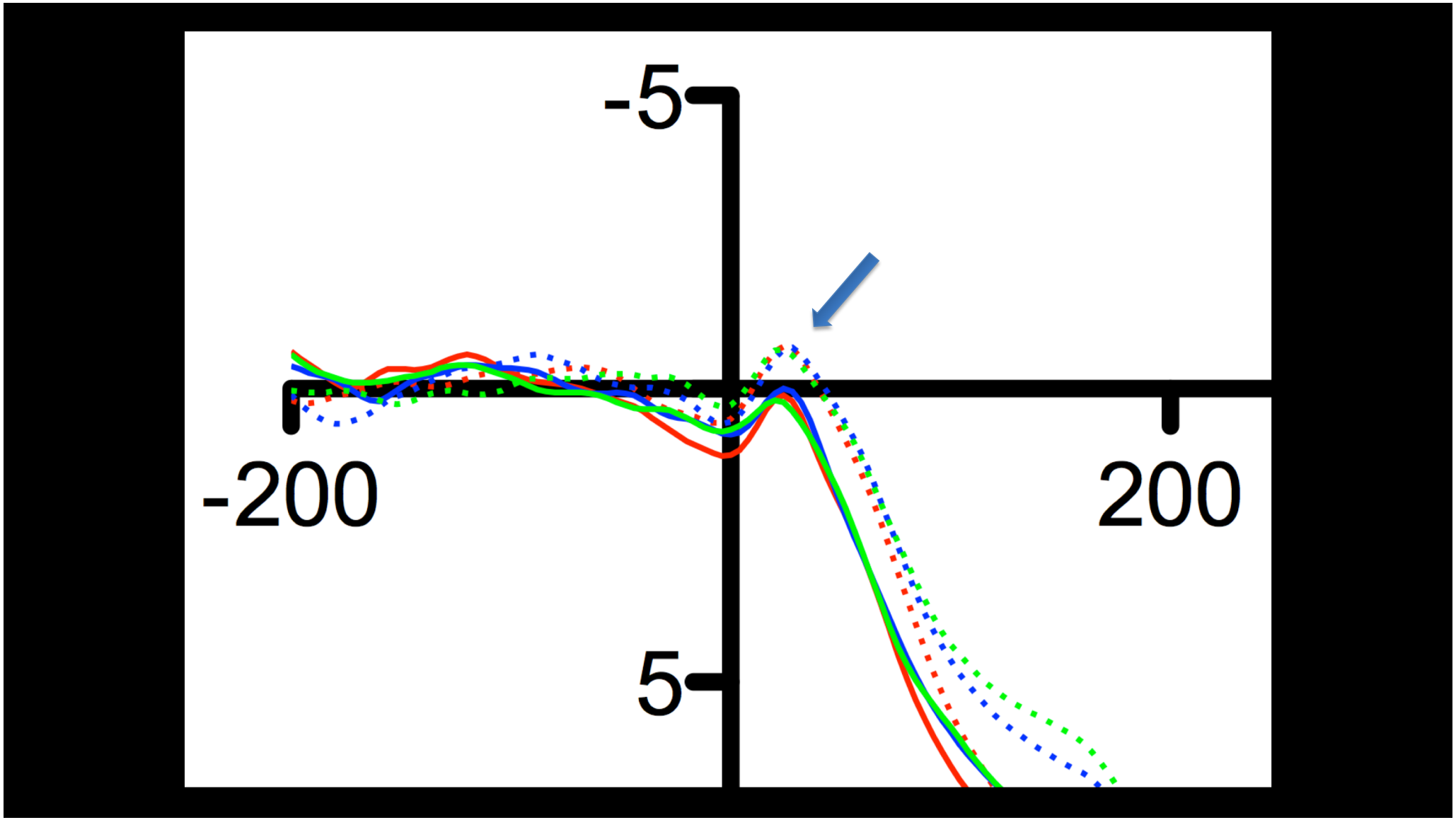
A Scalp Topography

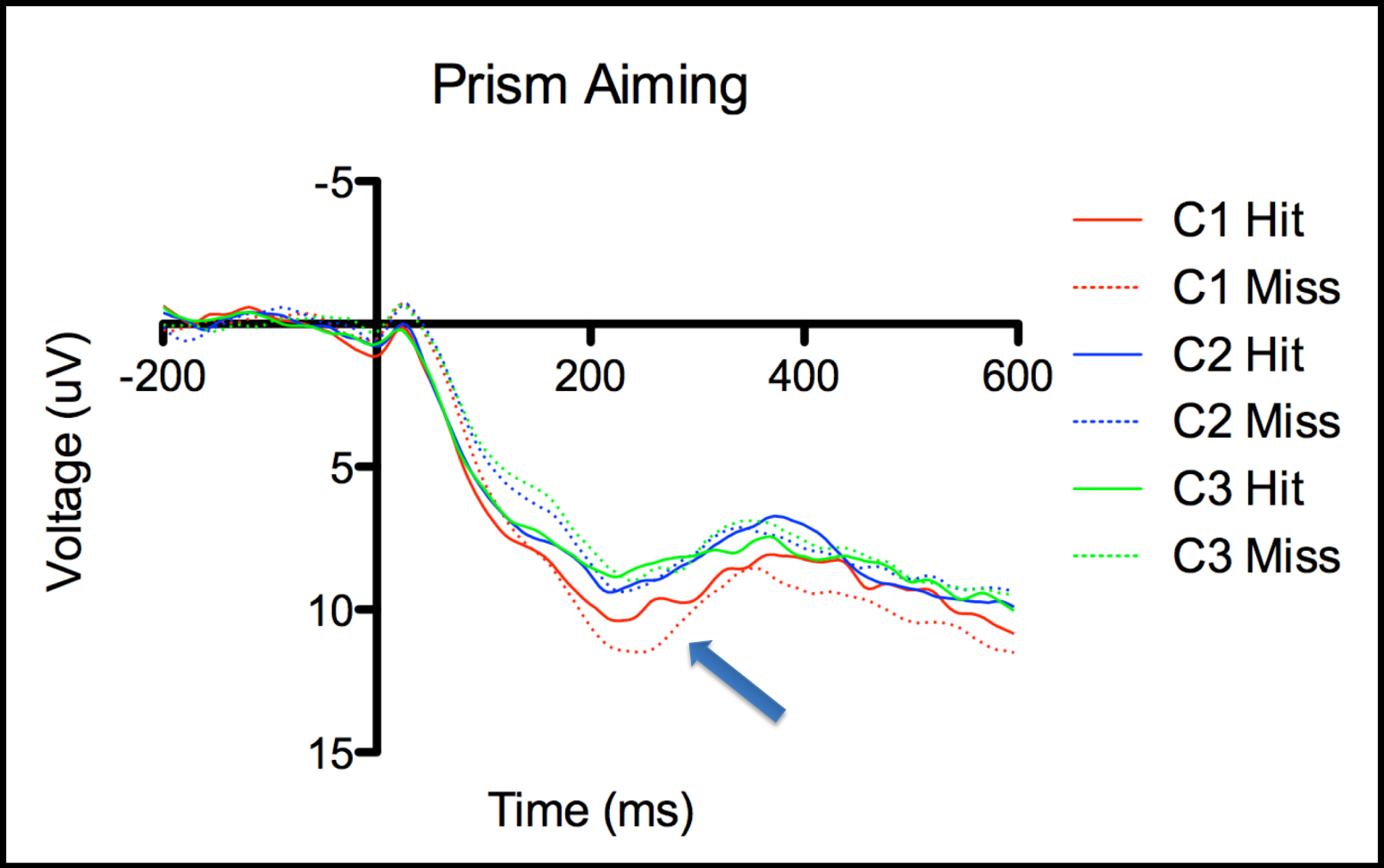


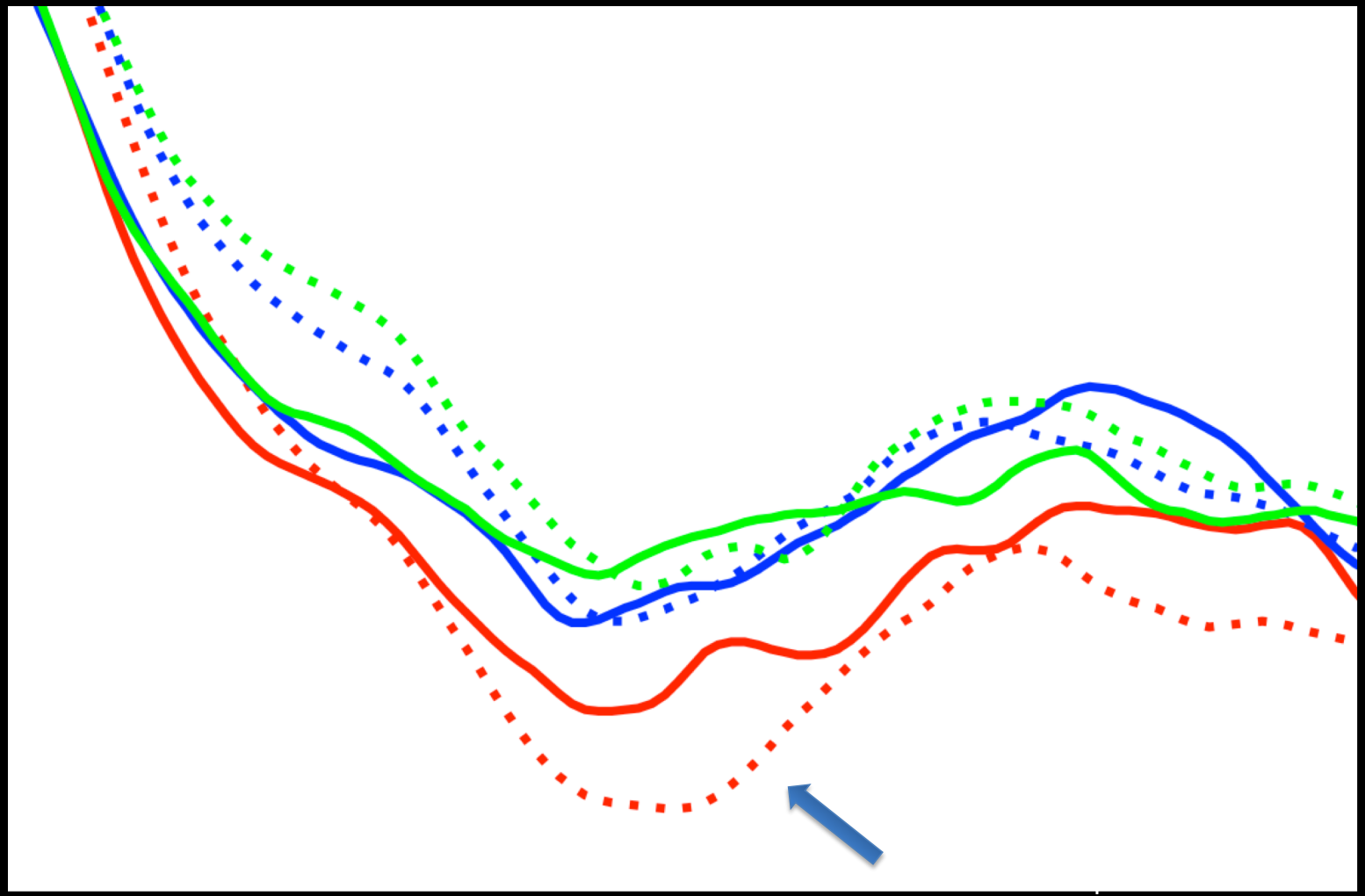

Subject 1
Subject 2
Subject 3
Subject 4
Subject 5
Subject 6 Session 1
Subject 6 Session 2
Subject 6 Session 3
Average of 9 Subjects
Contralateral Target
Ipsilateral Target
-5μV
+5μV
-100
100
200
300
Time Poststimulus (ms)


Prism Aiming
-5
5
10
15
-200
200
400
600
Voltage (uV)
Time (ms)
C1 Hit
C1 Miss
C2 Hit
C2 Miss
C3 Hit
C3 Miss

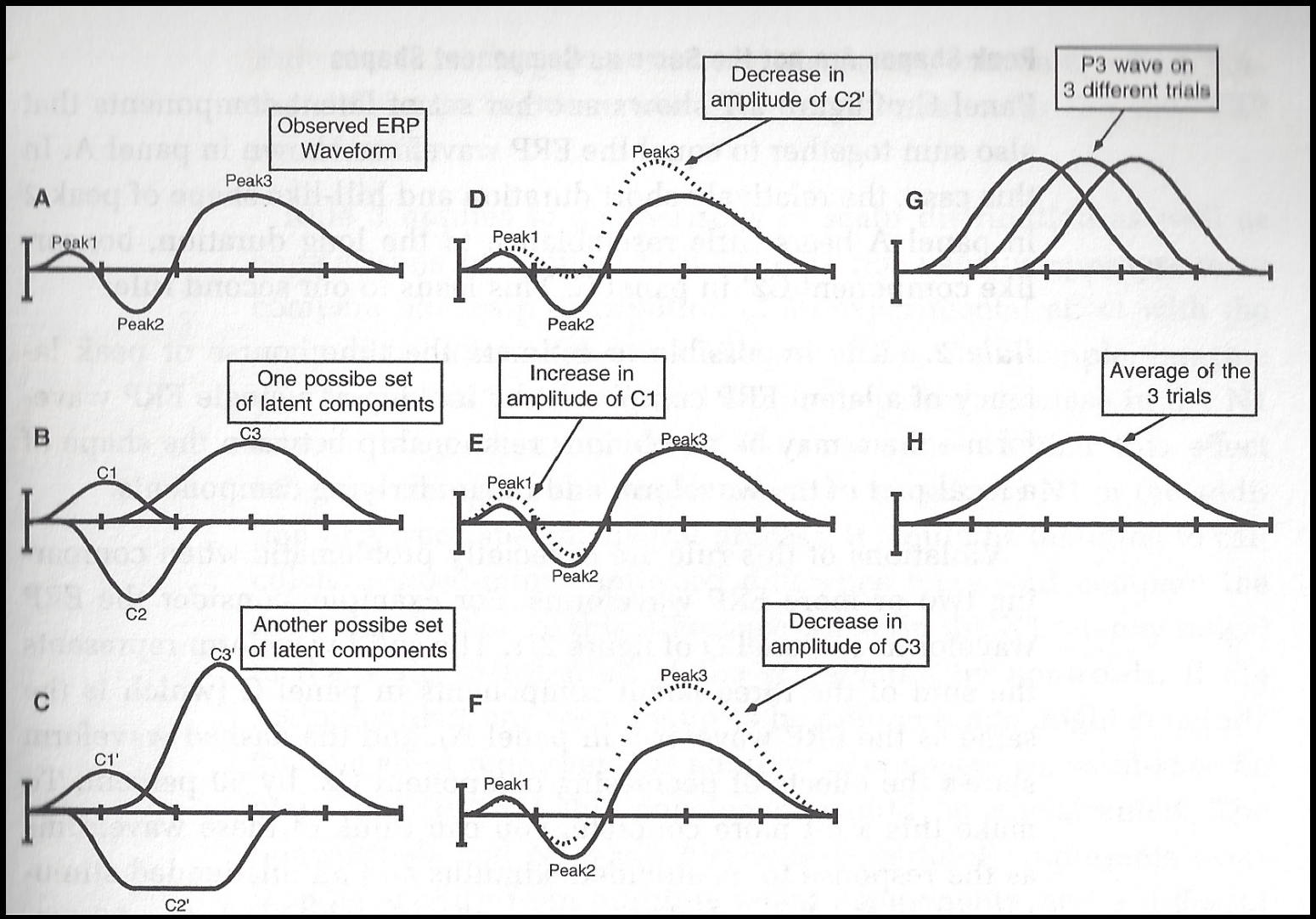

Prism Aiming
-5
5
10
15
-200
200
400
600
Voltage (uV)
Time (ms)
C1 Hit
C1 Miss
C2 Hit
C2 Miss
C3 Hit
C3 Miss

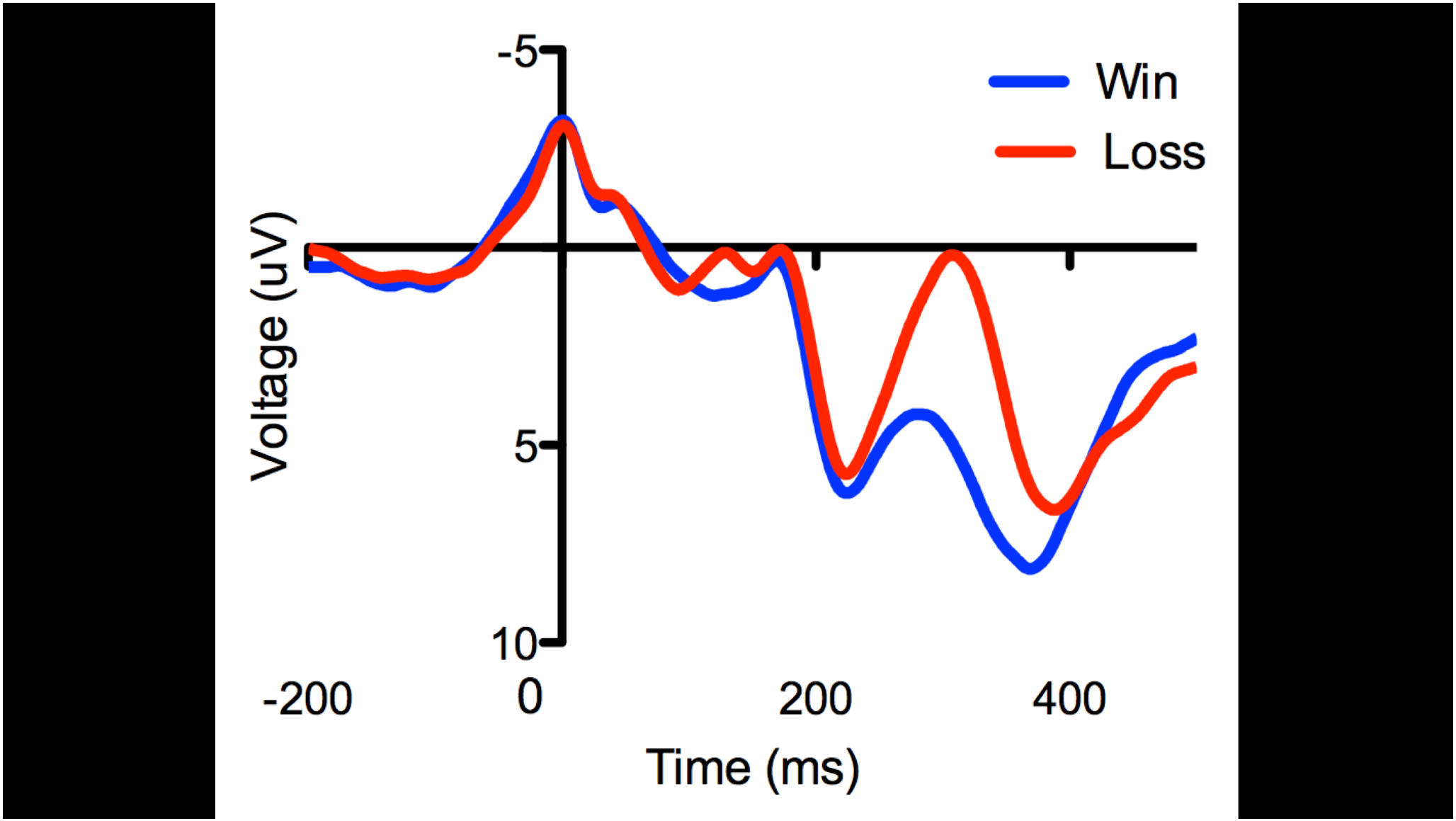

-5
-200
200
5

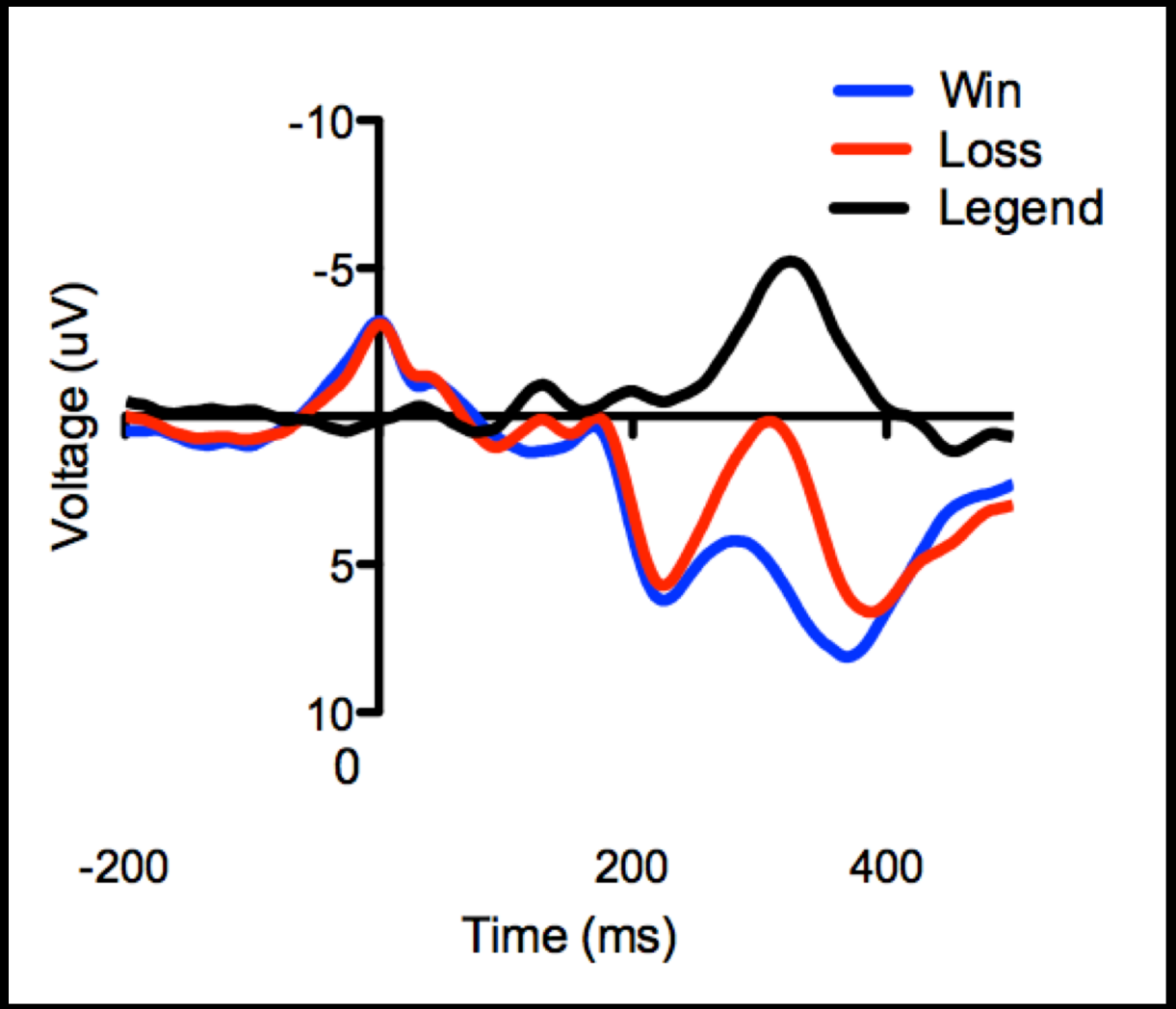

Prism Aiming
-5
5
10
15
-200
200
400
600
Voltage (uV)
Time (ms)
C1 Hit
C1 Miss
C2 Hit
C2 Miss
C3 Hit
C3 Miss

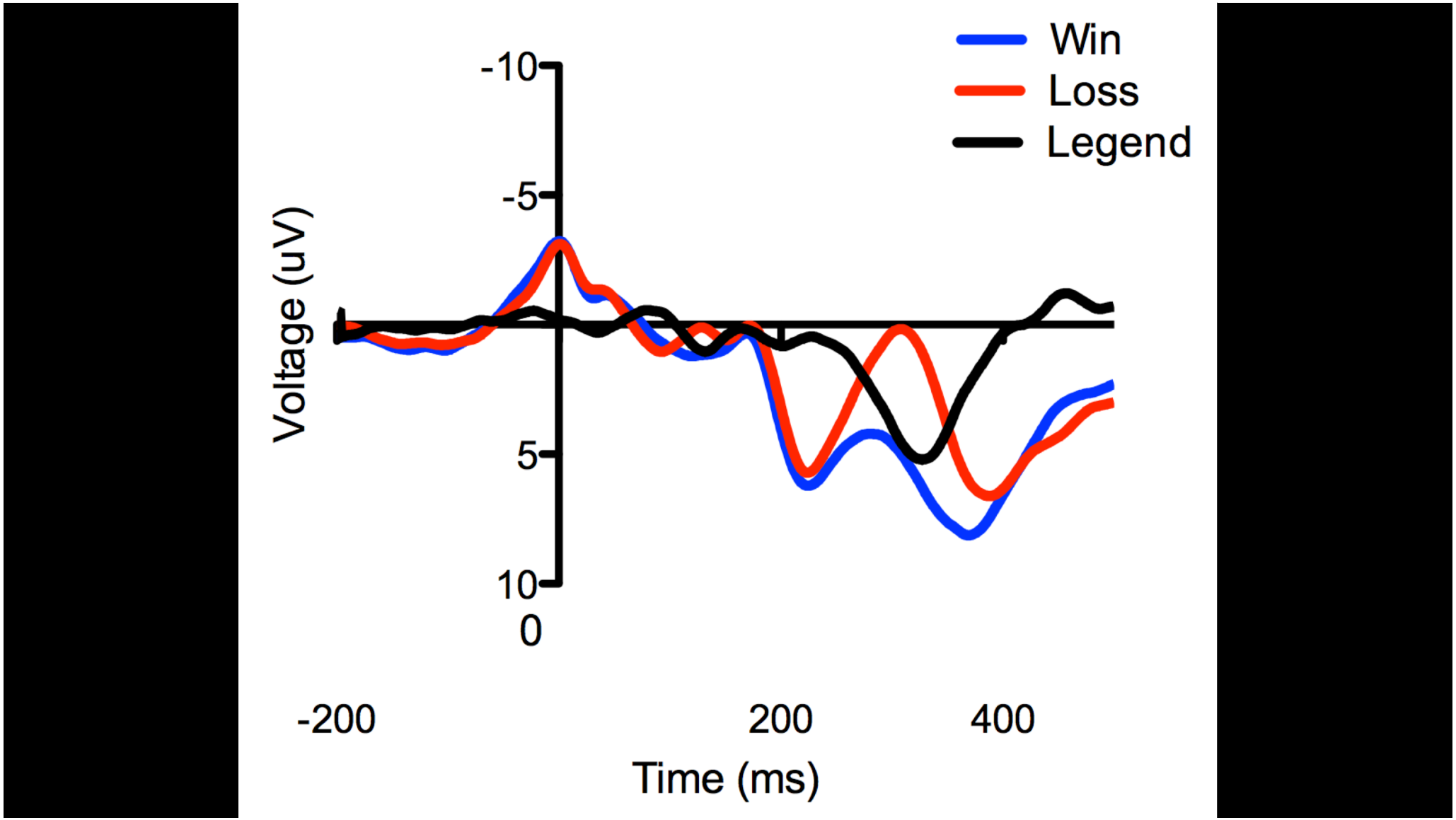


Components on Conditional Waveforms?

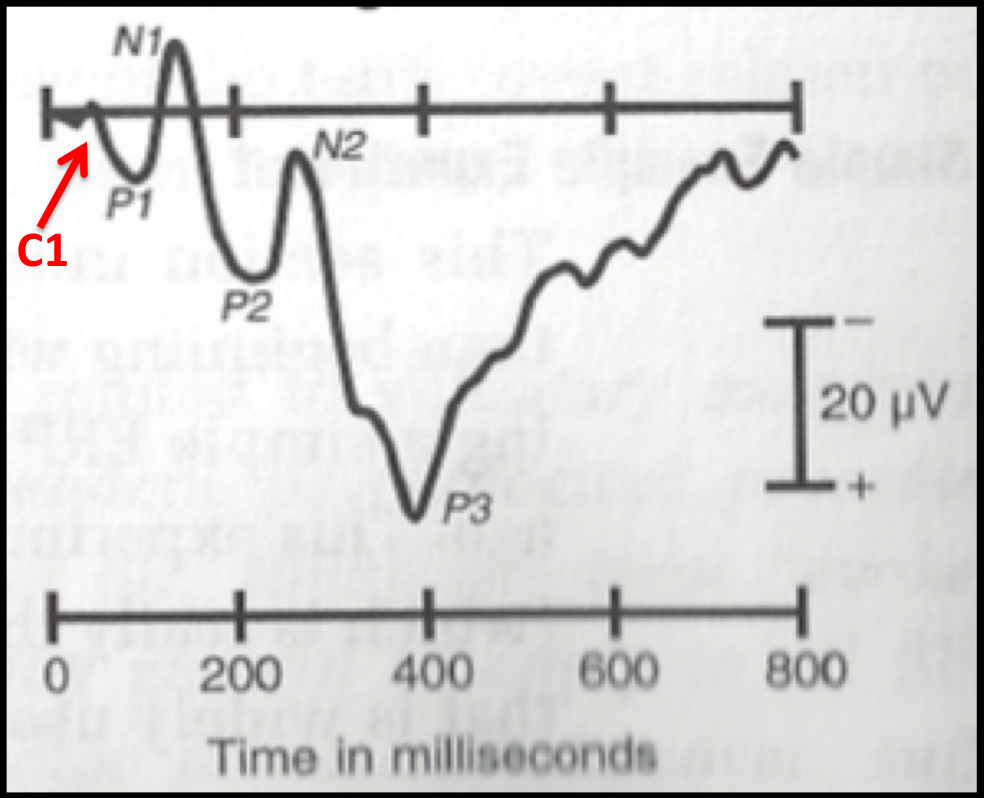

Observed ERP Waveform
A
Peak1
Peak2
Peak3
One possibe set of latent components
B
C1
C2
C3
Another possibe set of latent components
C
C1'
C2'
C3'
Decrease in amplitude of C2'
D
Peak1
Peak2
Peak3
Increase in amplitude of C1
E
Peak1
Peak2
Peak3
Decrease in amplitude of C3
F
Peak1
Peak2
Peak3
P3 wave on 3 different trials
G
Average of the 3 trials
H


-5
5
10
Win
Loss
Voltage (uV)
-200
0
200
400
Time (ms)


Win
Loss
Legend
-10
-5
5
10
0
Voltage (uV)
-200
200
400
Time (ms)


Win
Loss
Legend
-10
-5
5
10
0
Voltage (uV)
-200
200
400
Time (ms)

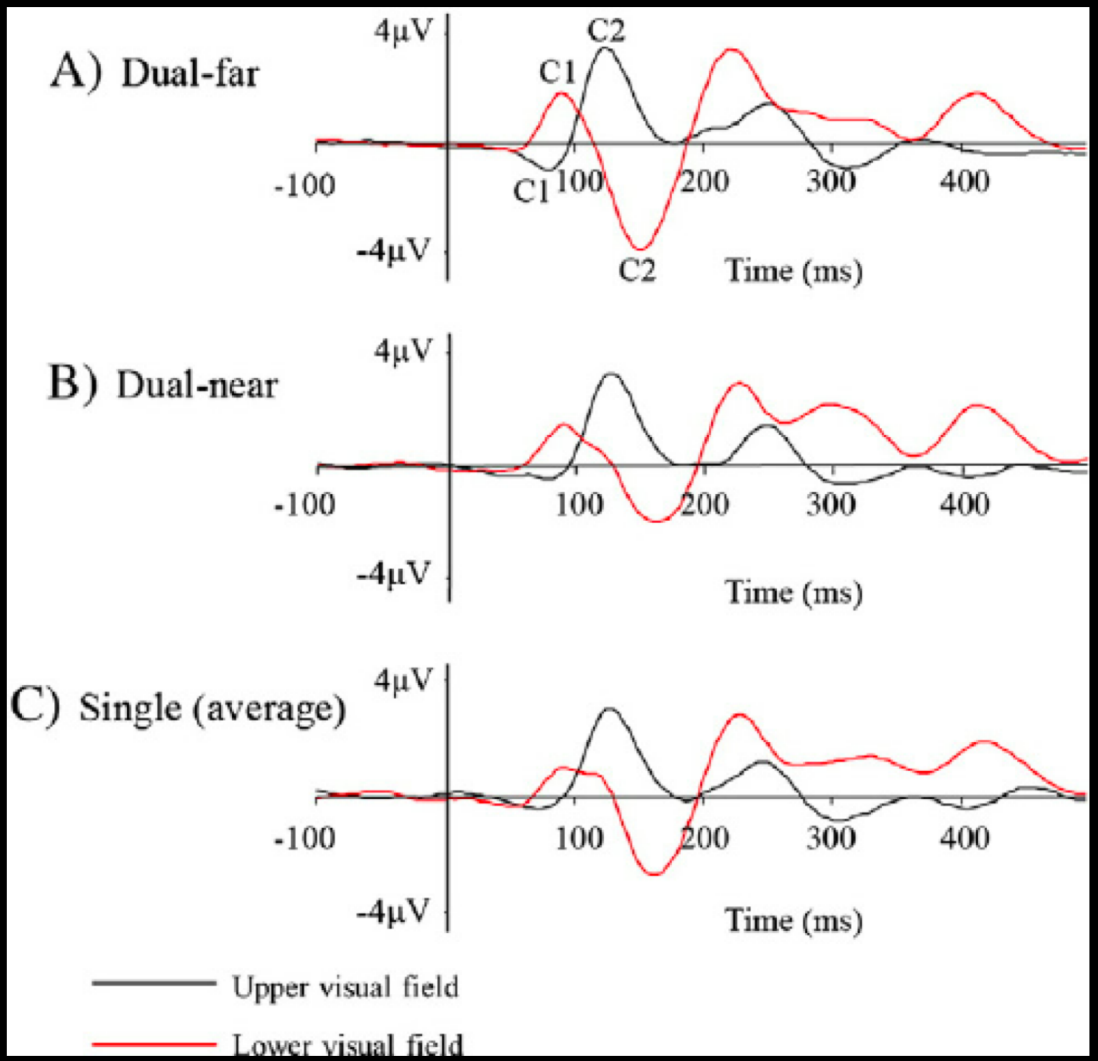
Summary of the "Classic" ERP Components



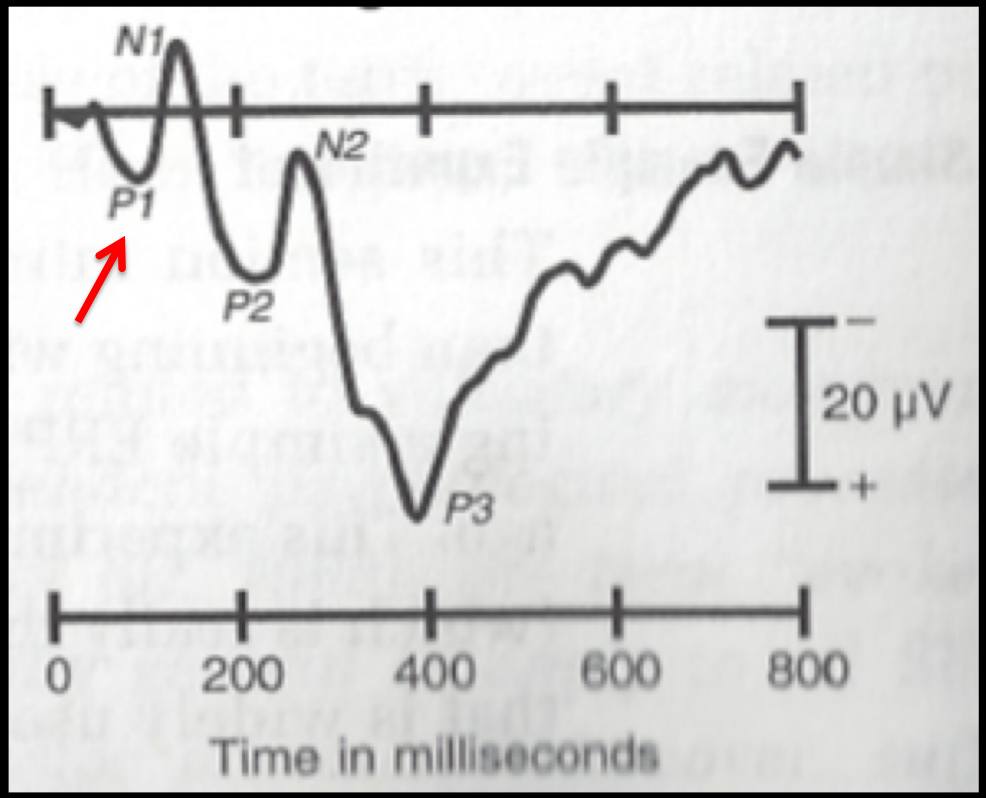
Summary of the "Classic" ERP Components

C1

- Posterior Midline
- Reflects processing in V1
- Polarity varies on stimulus parameters and stimulus location, thus "C"
- Can summate with P1
- Starts 40 to 60 ms post stimulus
- Peaks 80 to 100 ms post stimulus
- Hard to see


A) Dual-far
4μV
C2
C1
-100
C1
100
200
300
400
-4μV
C2
Time (ms)
B) Dual-near
4μV
-100
100
200
300
400
-4μV
Time (ms)
C) Single (average)
4μV
-100
100
200
300
400
-4μV
Time (ms)
Upper visual field
Lower visual field

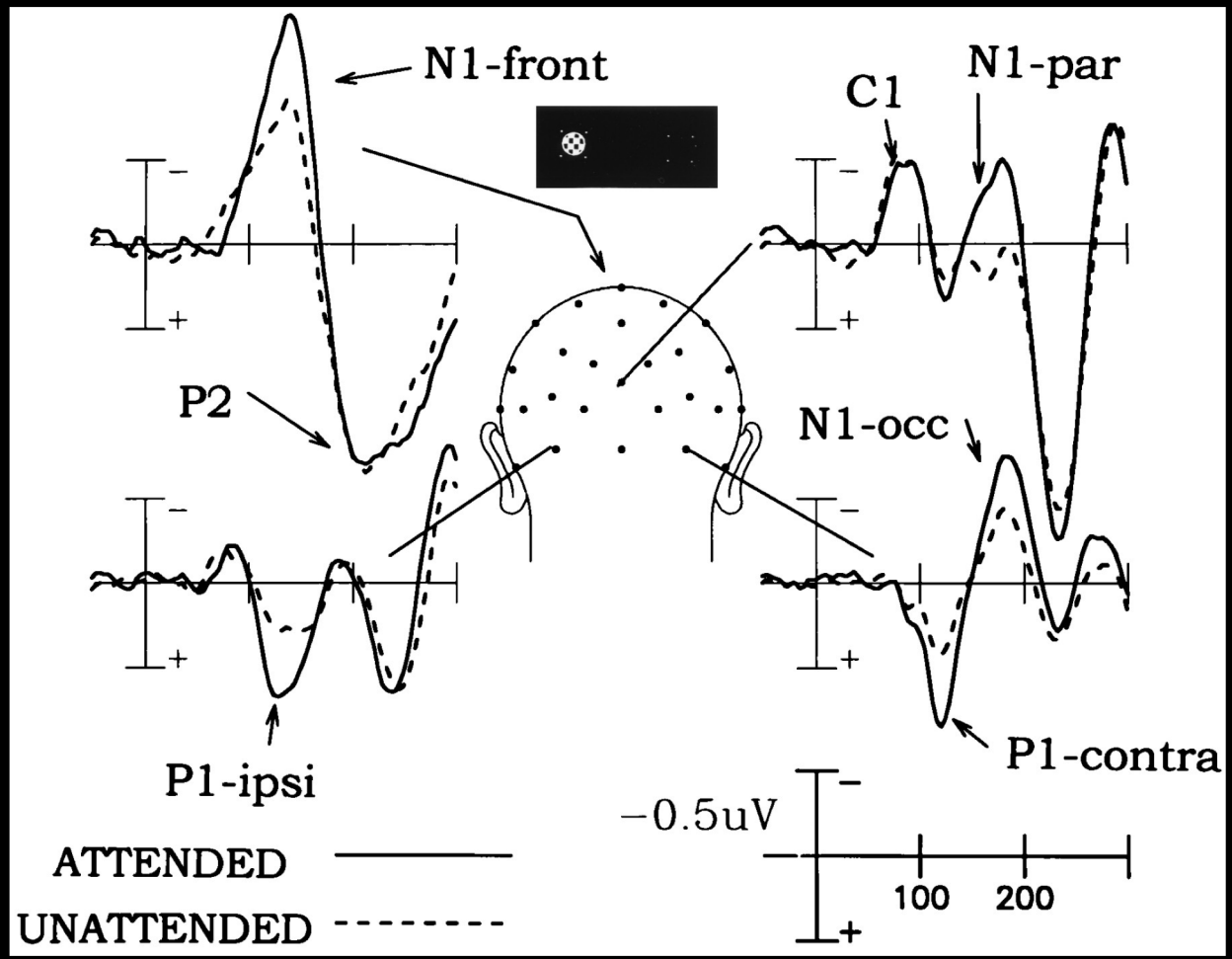
Summary of the "Classic" ERP Components



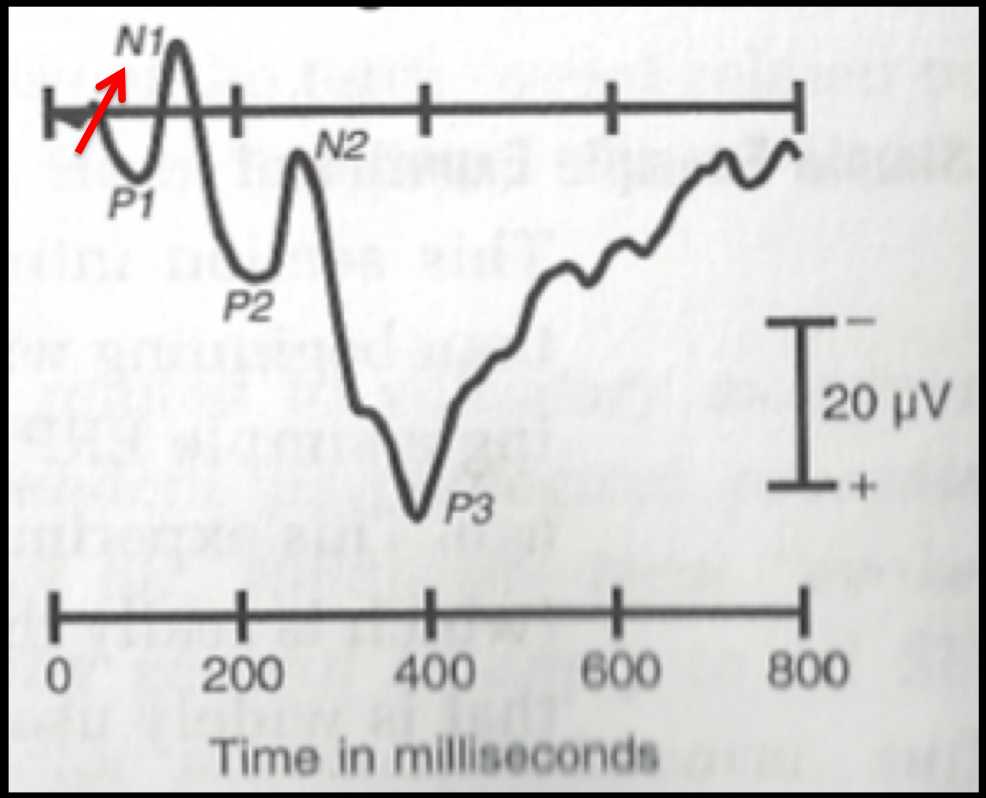
Summary of the "Classic" ERP Components

P1 Lateral Occipital Electrodes

- Early visual areas: V3, V4*
- Starts 60 to 90 ms post stimulus
- Peaks 100 to 130 ms post stimulus
- Sensitive to:
  - Stimulus Parameters
  - Spatial Attention


N1-front
C1
N1-par
P2
N1-occ
P1-ipsi
P1-contra
ATTENDED
UNATTENDED
−0.5uV
100
200
−
+

Summary of the "Classic" ERP Components



Summary of the "Classic" ERP Components

N1 Lateral Occipital Electrodes

Early visual areas: V3, V4*

Follows P1

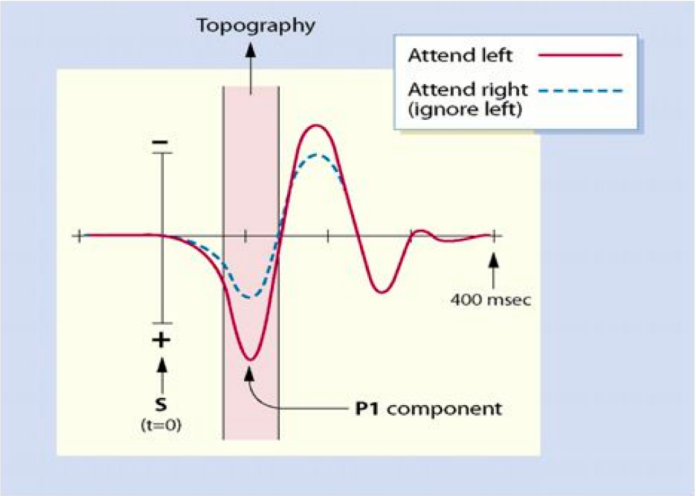
Peaks 100 to 200 ms post stimulus

Has both early and late components

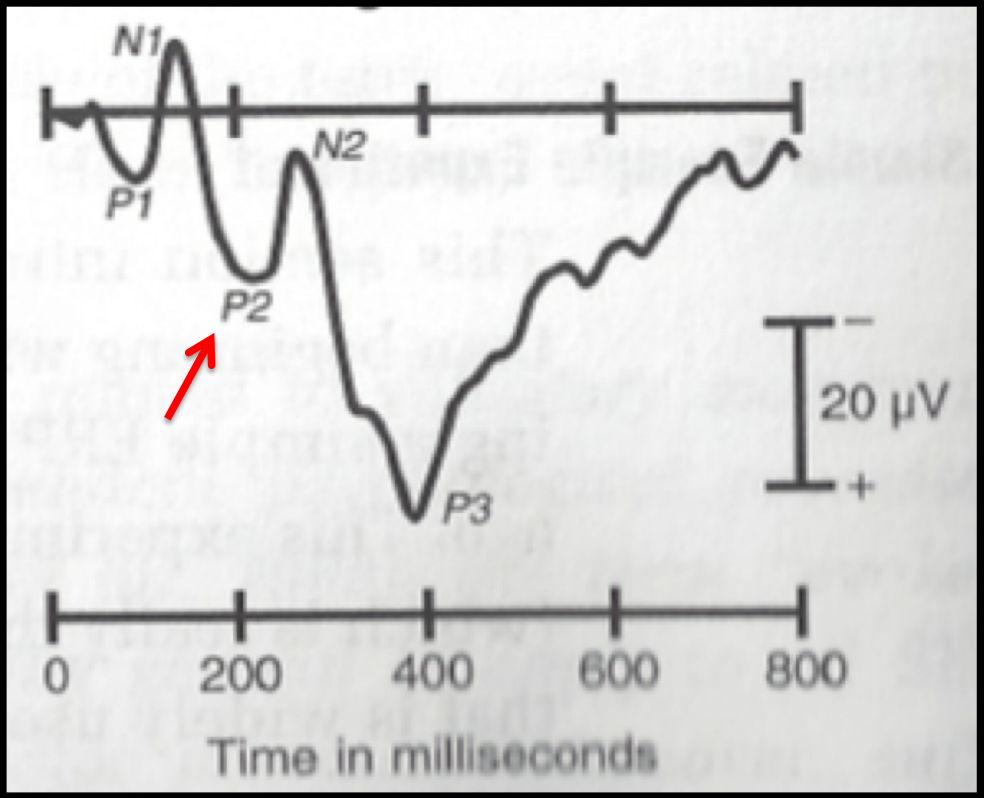
Early N1 spatial attention, later N1 stimulus categorization (N170)

Does Visual Attention Modulate Visual Evoked Potentials?

- Result: several components of the visual ERP are modulated by attention
  - P1 and N1 are larger for attended relative to unattended stimuli



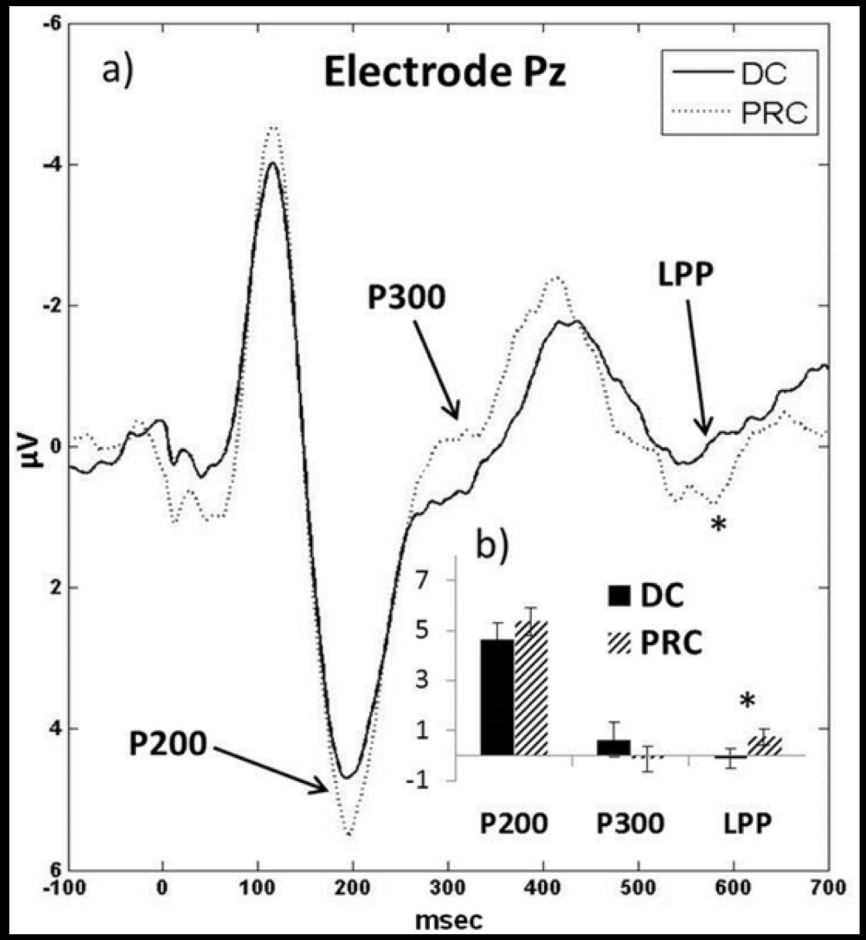
Summary of the "Classic" ERP Components



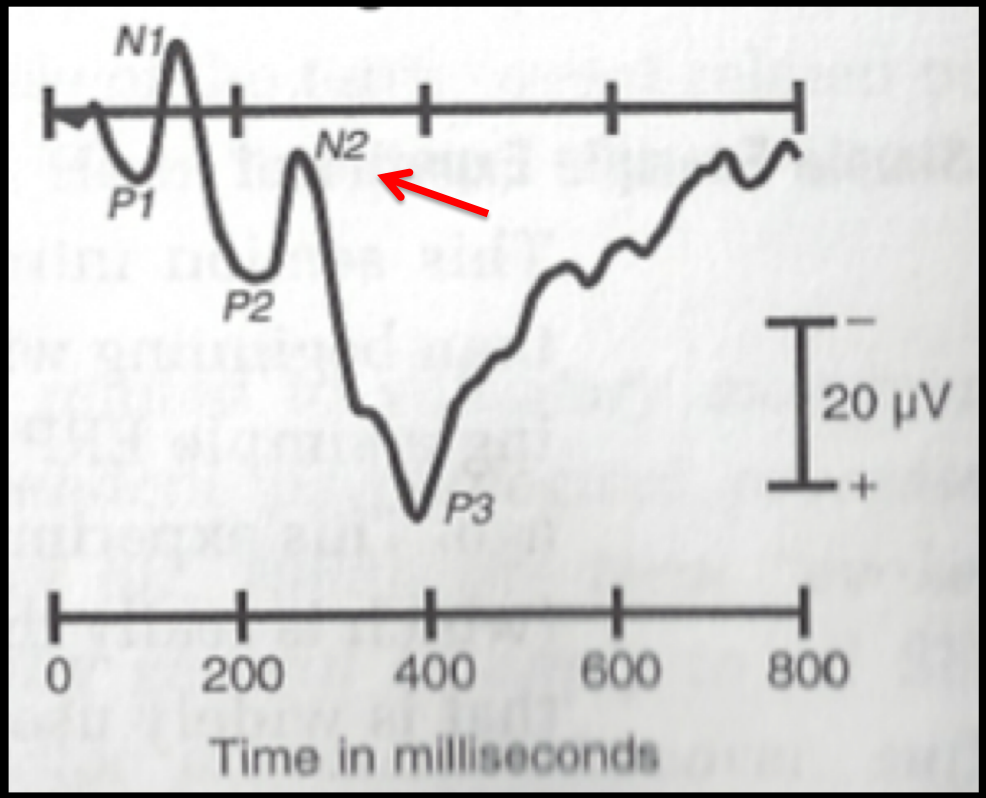
Summary of the "Classic" ERP Components

P2

- Anterior and Posterior Components
- Prior to N2, but sometimes not seen
- Sensitive to a variety of stimulus parameters and task properties
- Not well studied


a)
Electrode Pz
DC
PRC
P300
LPP
P200
μV
msec
b)
DC
PRC
P200
P300
LPP
*
*

Summary of the "Classic" ERP Components



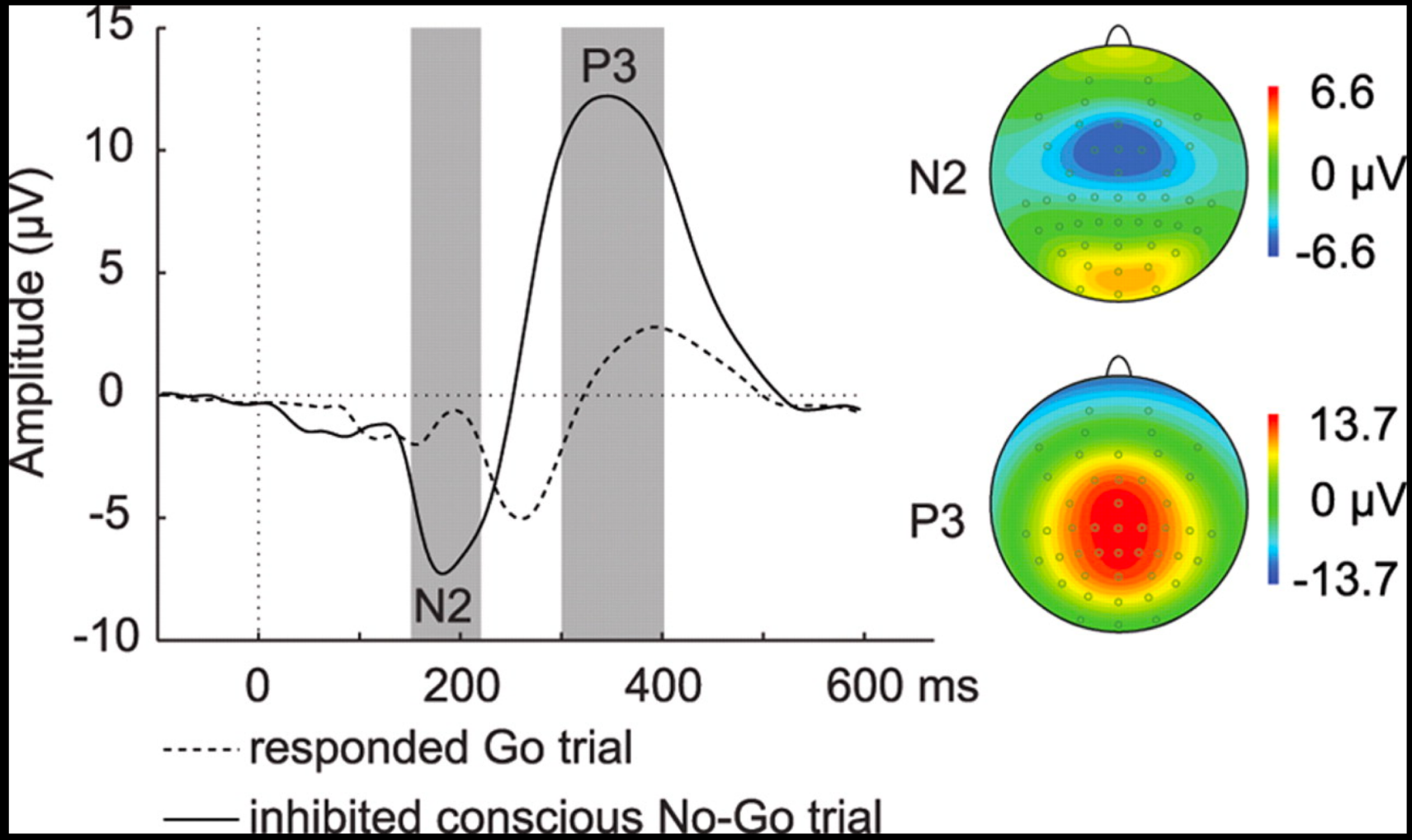
Summary of the "Classic" ERP Components

N2 Anterior and Posterior Components

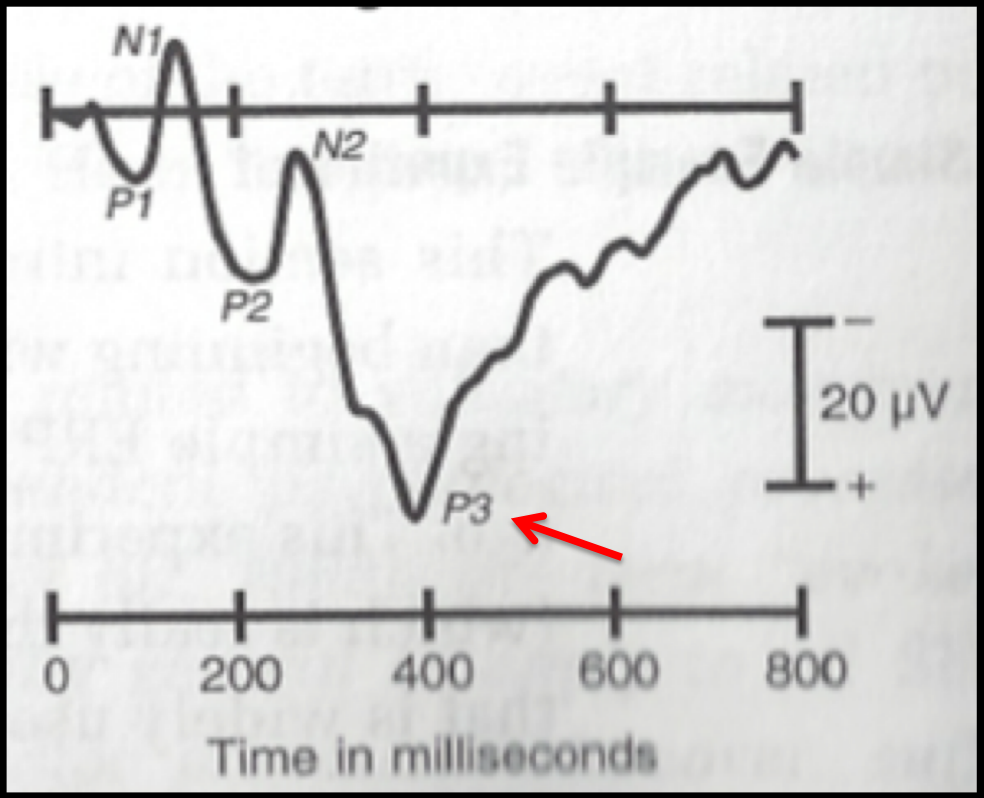
Follows P2, but sometimes not seen

Sensitive to a variety of stimulus parameters and task properties

- stimulus frequency
- reward processing
- N2a "mismatch negativity"
- N2b stimulus deviation
- N2pc attention


15
10
5
0
-5
-10
Amplitude (μV)
P3
N2
0
200
400
600 ms
responded Go trial
inhibited conscious No-Go trial
N2
6.6
0 μV
-6.6
P3
13.7
0 μV
-13.7

Summary of the "Classic" ERP Components

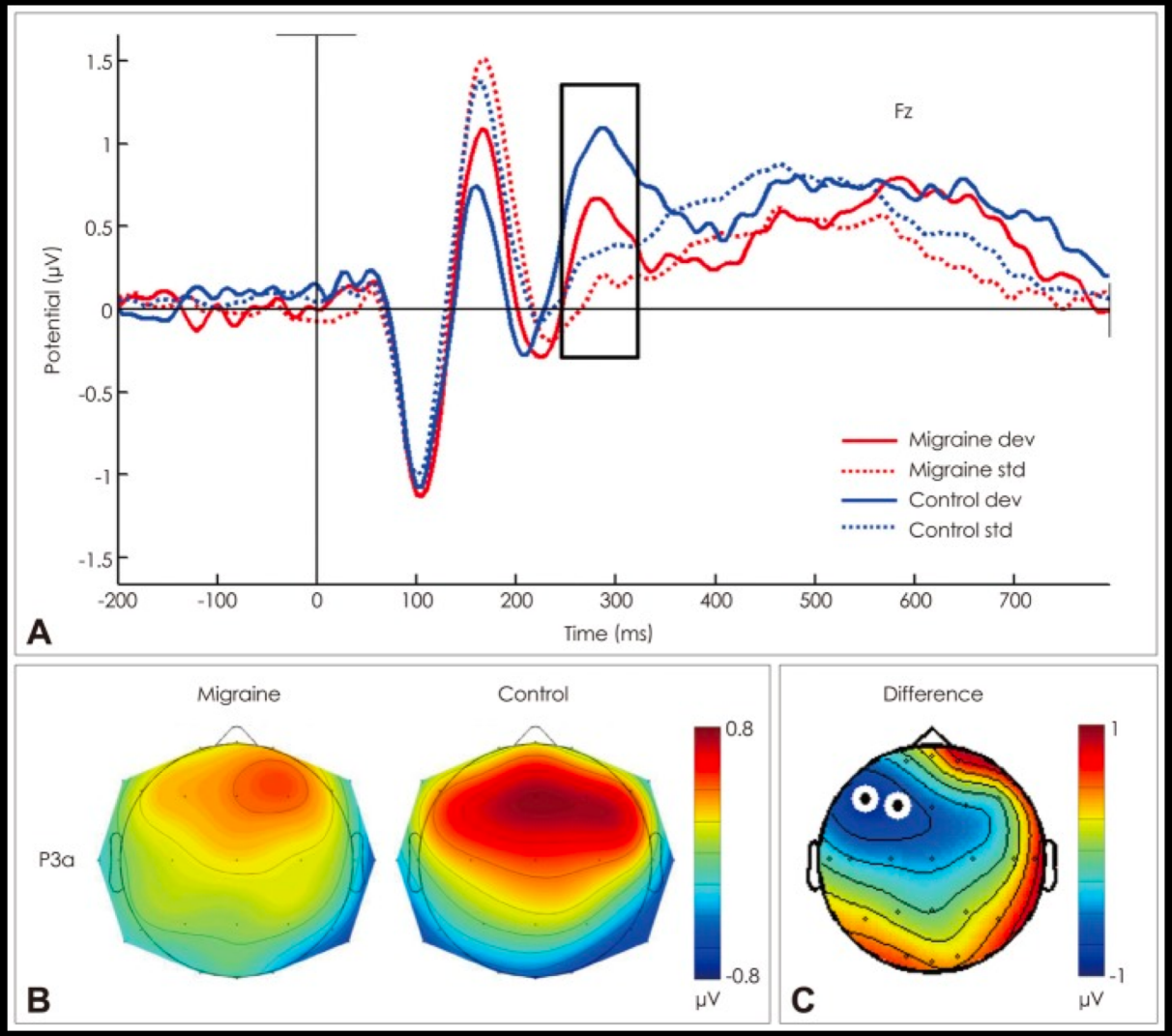


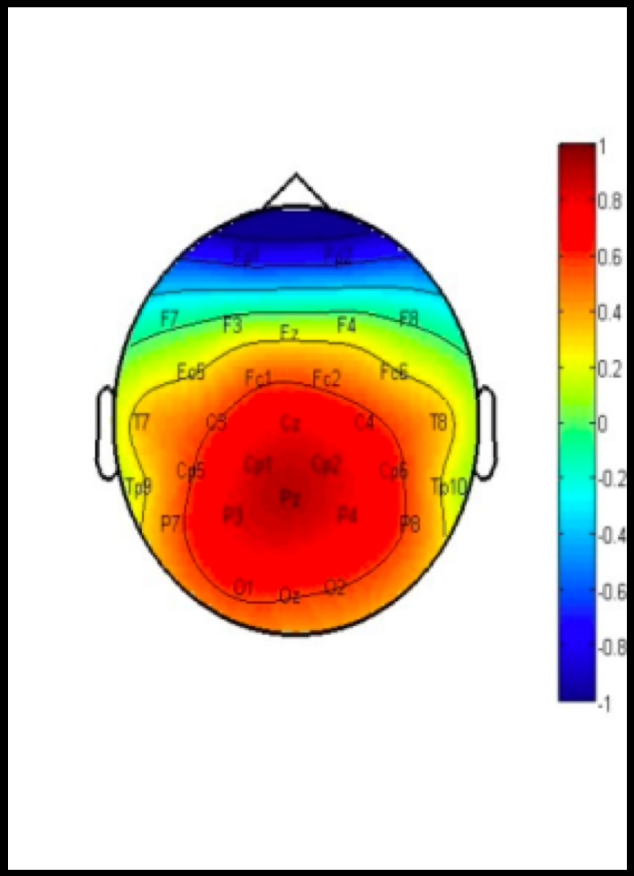
Summary of the "Classic" ERP Components

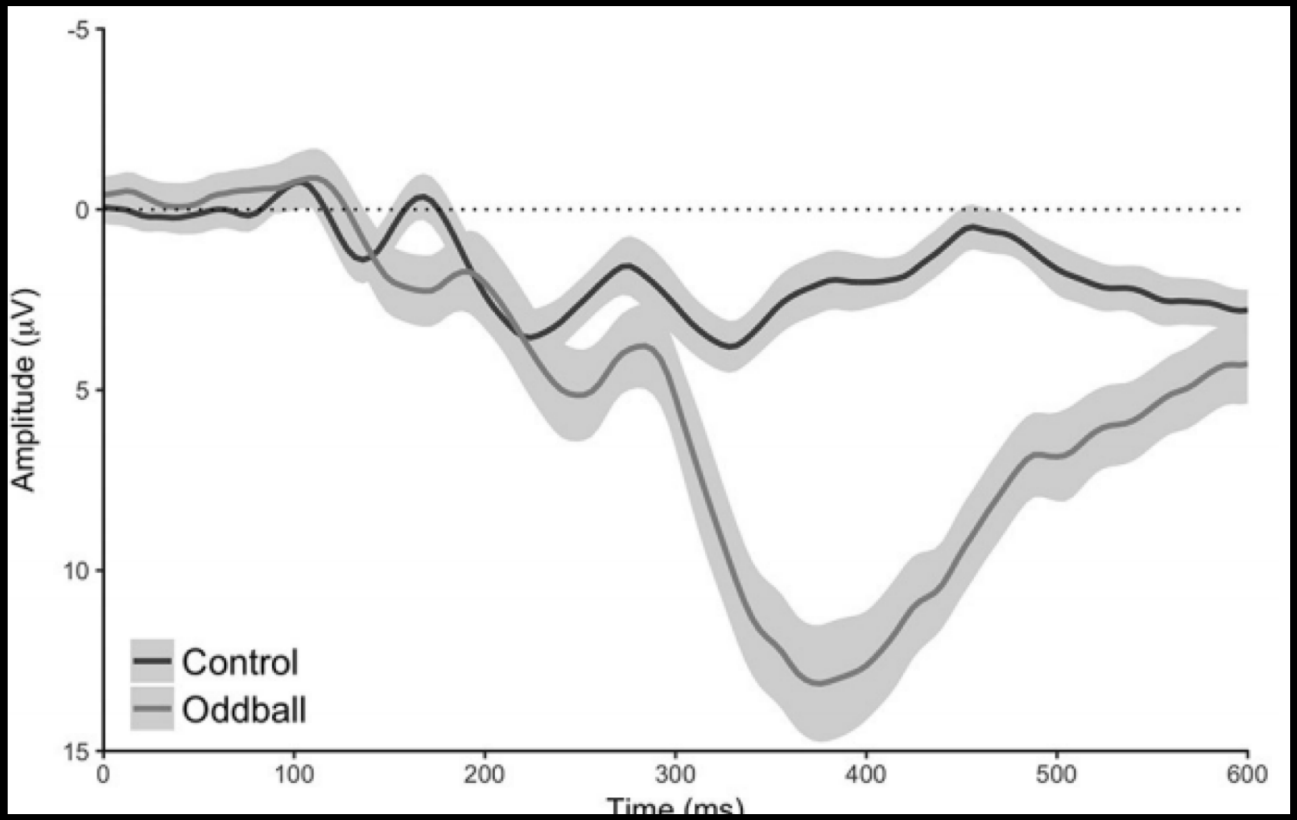
P3 Anterior and Posterior Components

Follows N2, latency can be quite late (600 ms)

- P3A (frontal)
  - novelty
- P3B (posterior)
  - context updating
  - LC-NE
  - "cognitive processing"

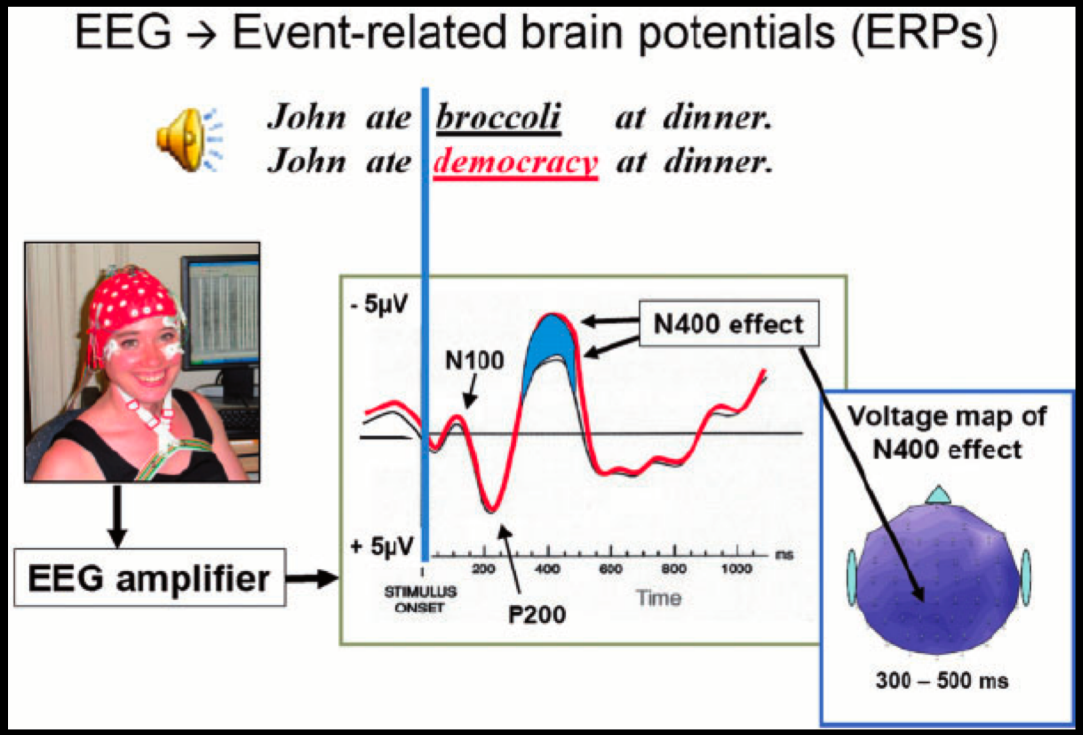

Fz
Potential (μV)
1.5
1
0.5
0
-0.5
-1
-1.5
-200
-100
0
100
200
300
400
500
600
700
Time (ms)
Migraine dev
Migraine std
Control dev
Control std
A
Migraine
Control
P3a
0.8
-0.8
μV
B
Difference
1
-1
μV
C


F7
F3
Fz
F4
F8
Fc5
Fc1
Fc2
Fc6
T7
C3
Cz
C4
T8
Cp5
Cp1
Cp2
Cp6
Tp9
Tp10
P7
P3
Pz
P4
P8
O1
Oz
O2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1


-5
0
5
10
15
Amplitude (μV)
0
100
200
300
400
500
600
Time (ms)
Control
Oddball

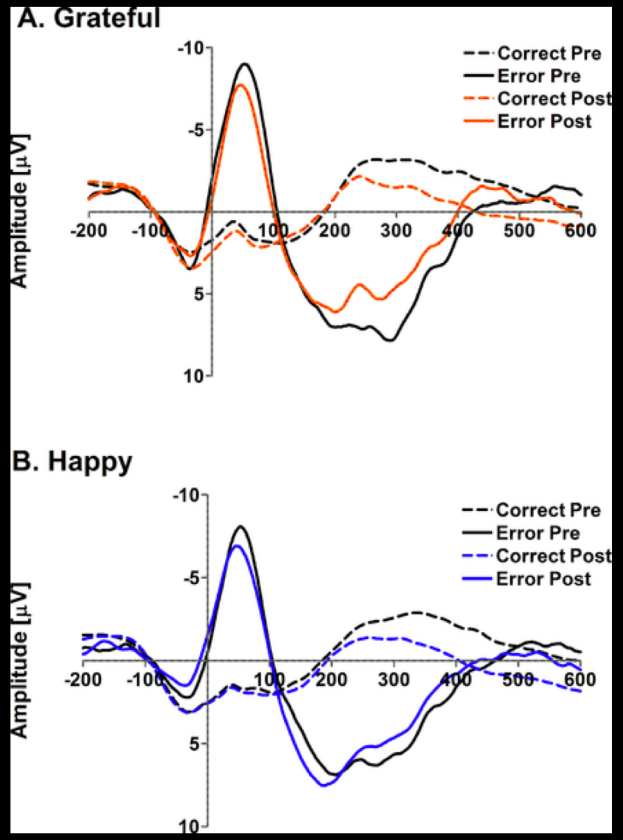
Summary of the "Classic" ERP Components

N4 Semantic violations



Summary of the "Classic" ERP Components

ERN	Response Errors
Pe	Error Positivity



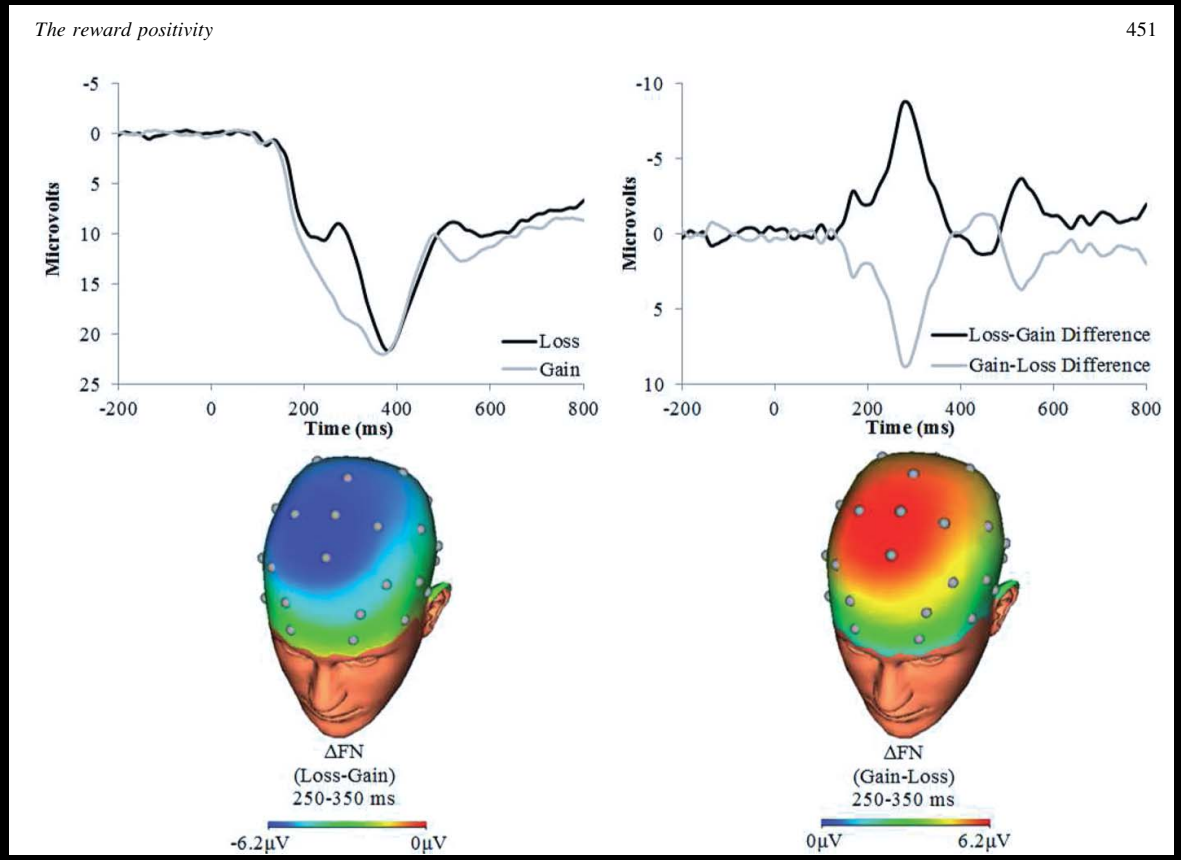
Summary of the "Classic" ERP Components

FRN

- Error Feedback (FN, MFN, fERN)

Reward Positivity

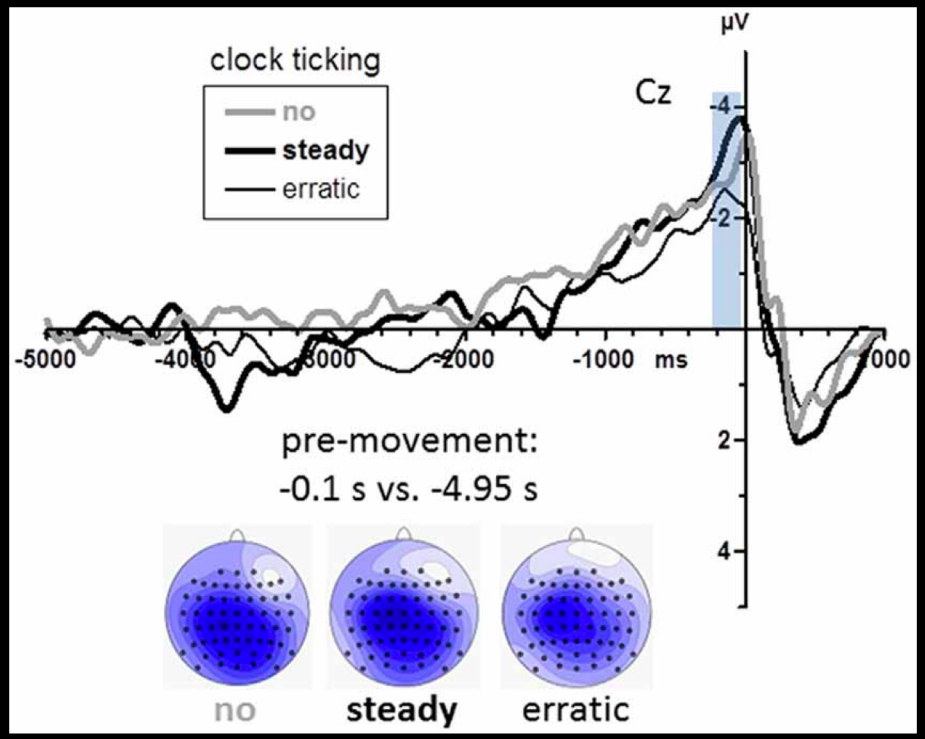
- Mirror inverse of above (RewP)



Summary of the "Classic" ERP Components

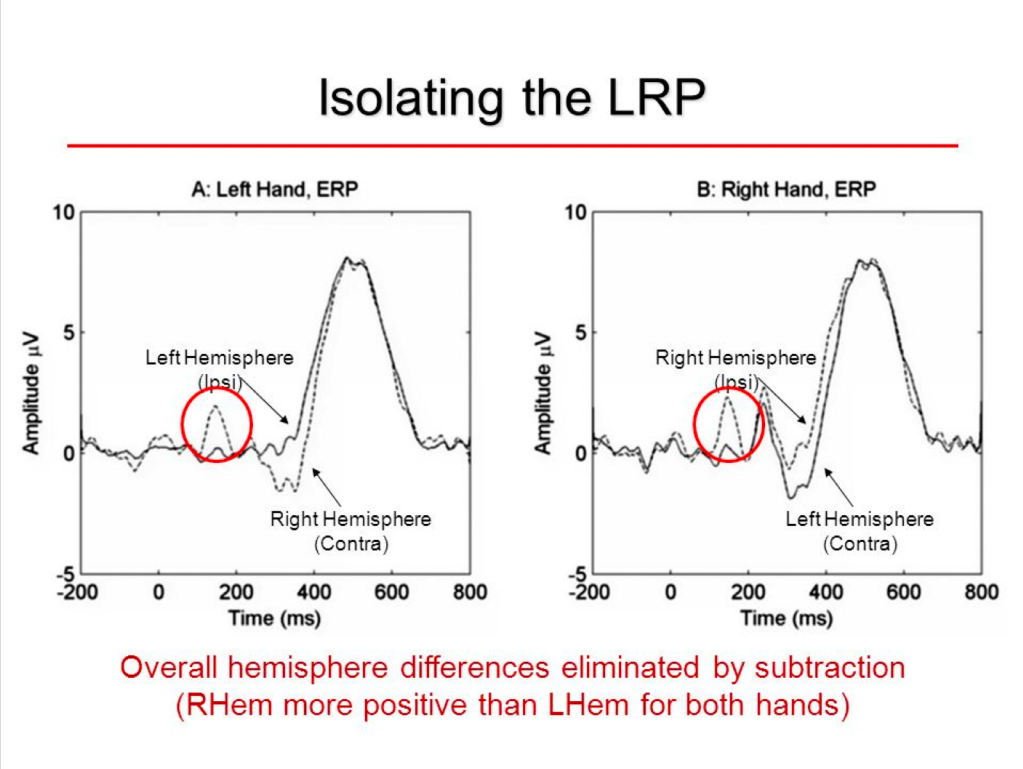
BP

Bereitschaftspotential



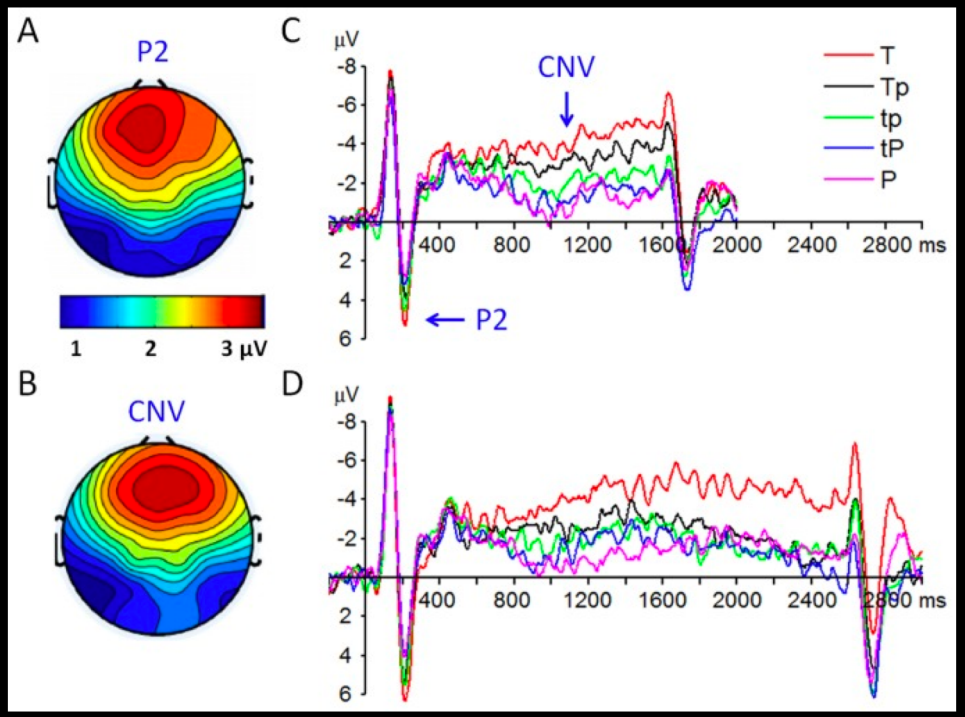
Summary of the "Classic" ERP Components

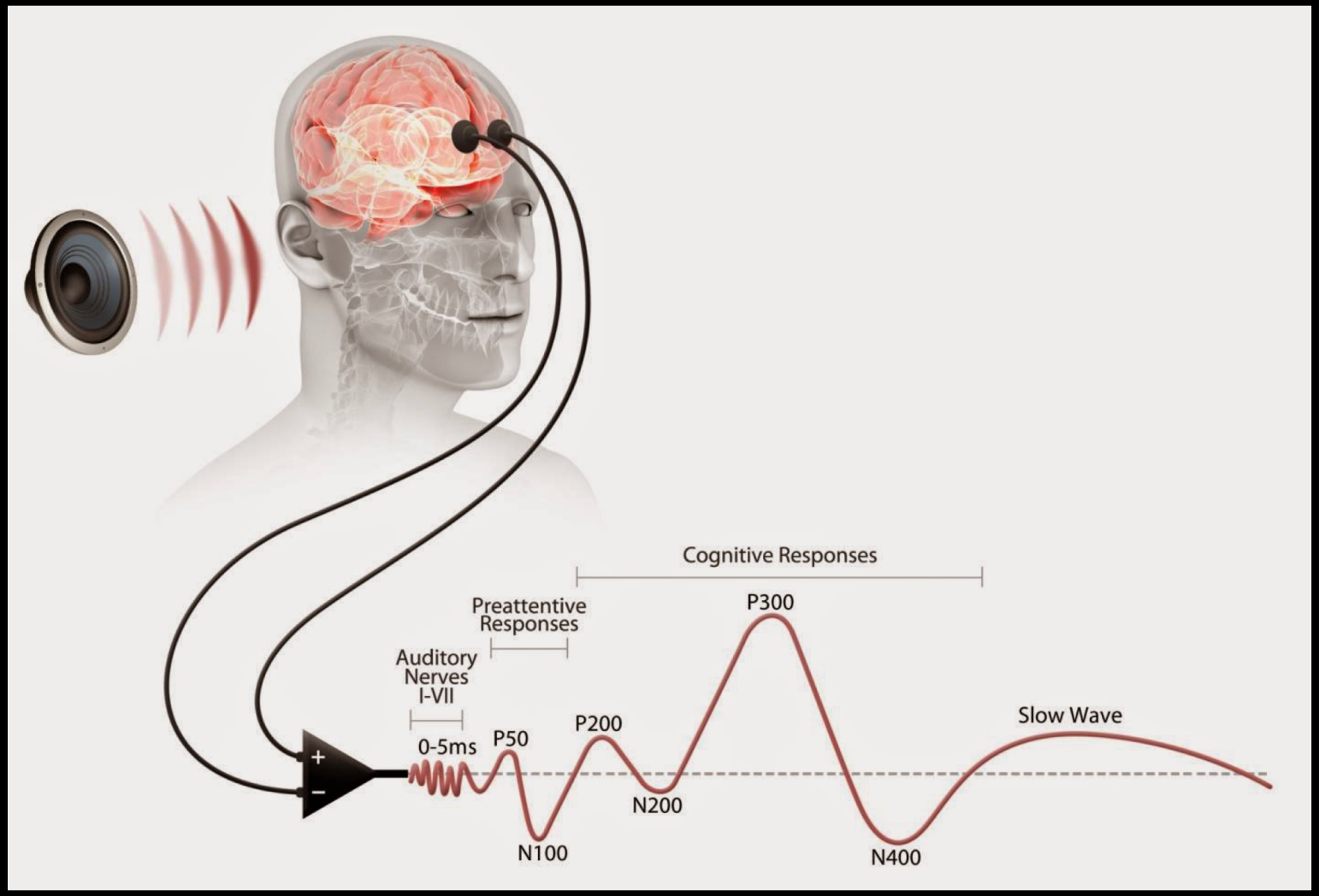
LRP Lateralized Readiness Potential



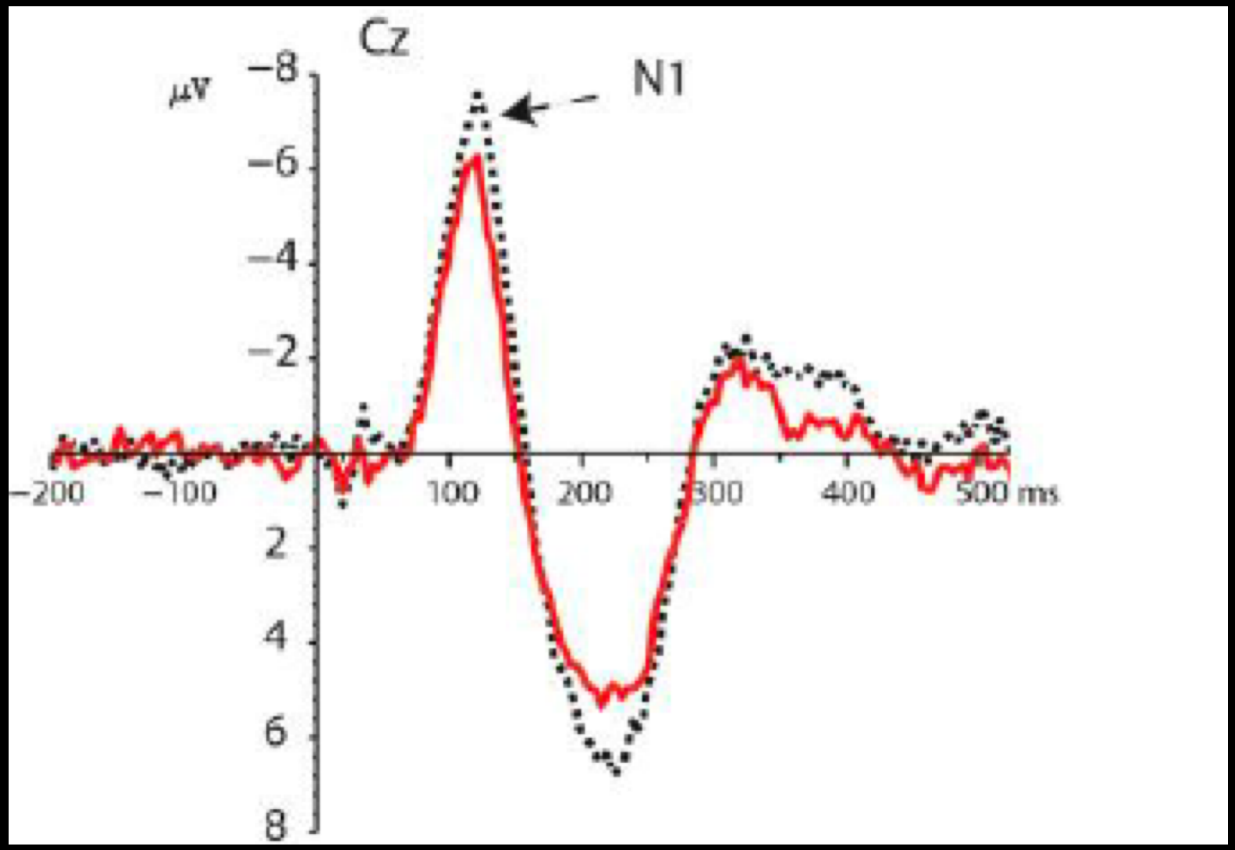
Summary of the "Classic" ERP Components

CNV: Expectancy

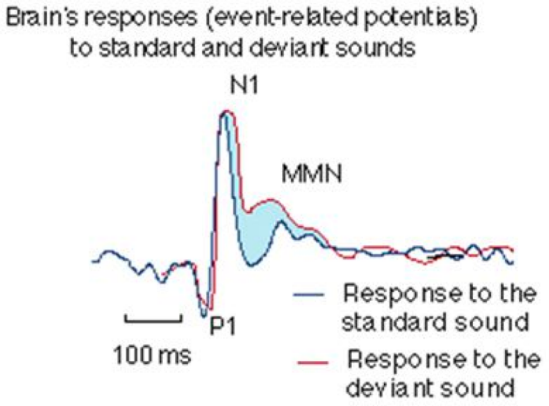


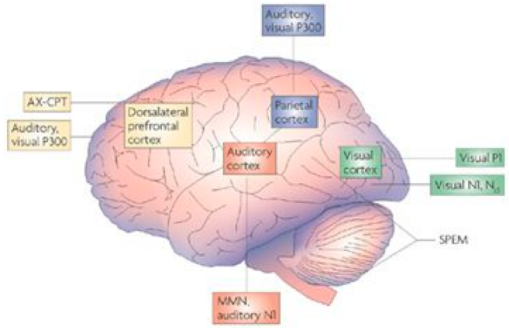

Cognitive Responses
Preattentive Responses
Auditory Nerves I-VII
0-5ms
P50
N100
P200
N200
P300
N400
Slow Wave
+
−

Auditory N100 to Attended Targets



ERP Components –Mismatch Negativity (MMN)





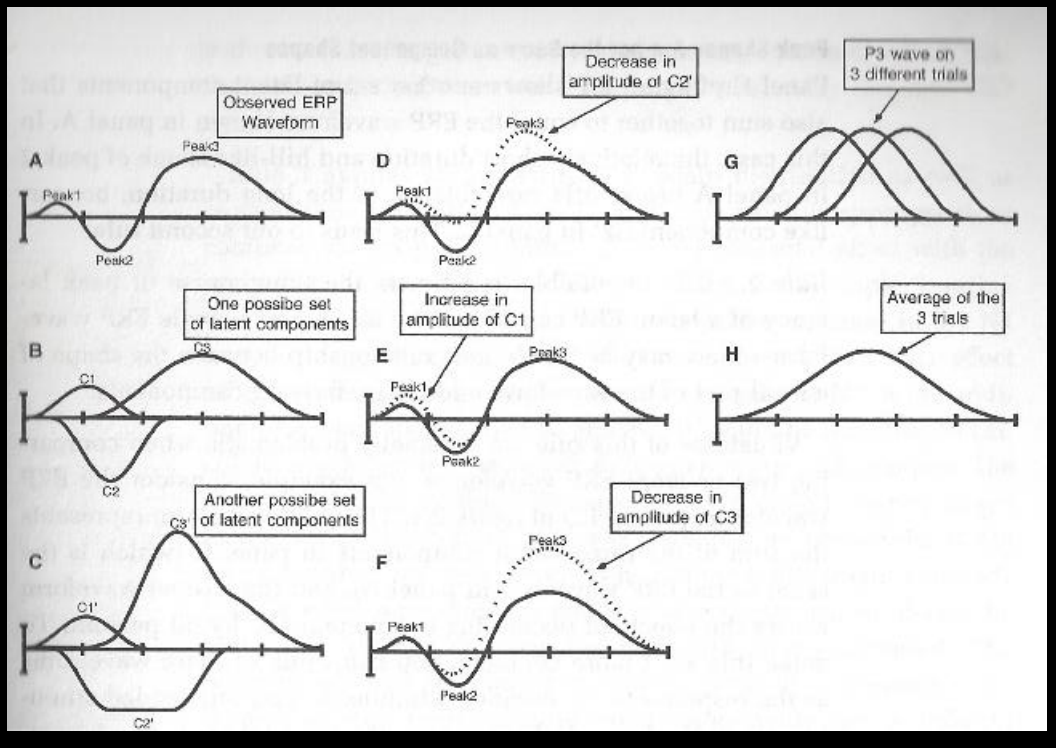
- observed when subjects are exposed to a repetitive train of identical stimuli with occasional mismatching stimuli
- negative-going wave that is largest at central midline scalp sites and typically peaks between 160 and 220 ms.
- Several other components are sensitive to mismatches if they are task-relevant, but the MMN is observed even if subjects are not using the stimulus stream for a task
- thought to reflect a fairly automatic process that compares incoming stimuli to a sensory memory trace of preceding stimuli.

Rules for Experimental Design and ERP Data Collection

(Luck, 2014)

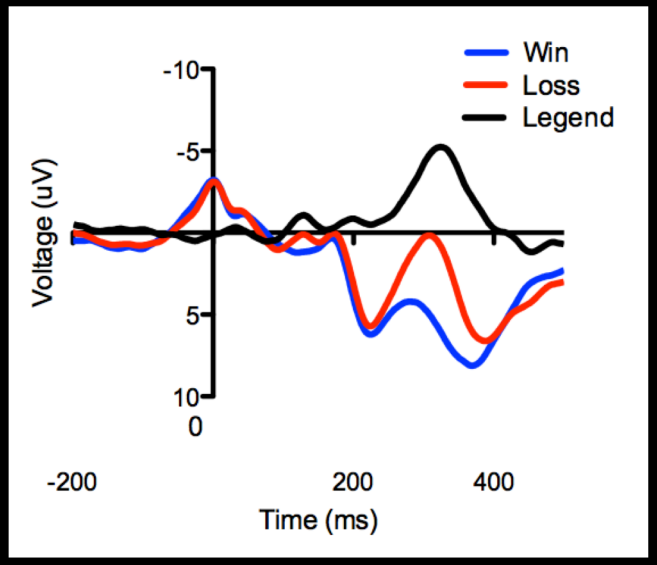
Rule 1

Peaks and components are not the same thing. There is nothing special about the point at which the voltage reaches a local maximum.



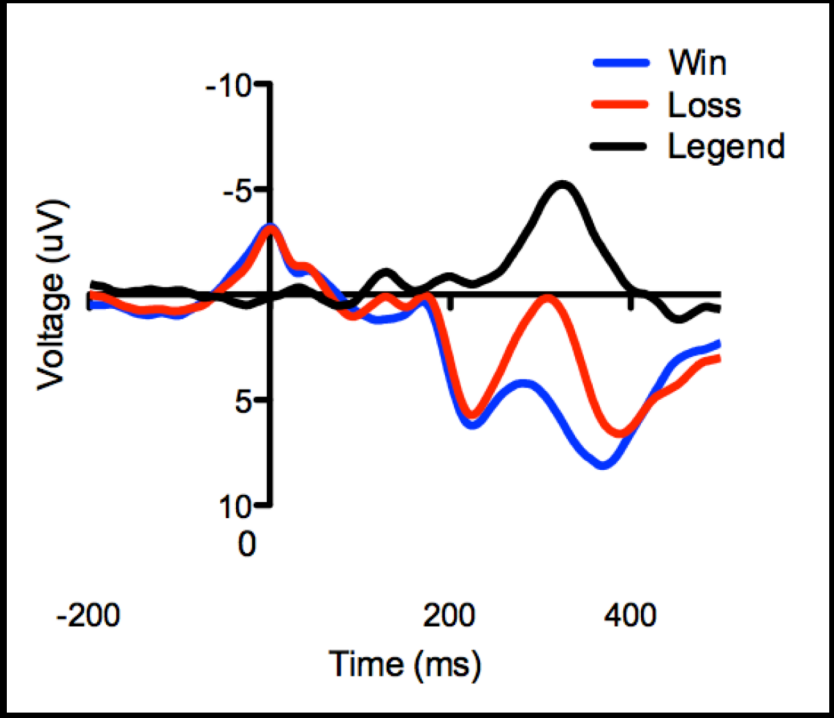
Rule 2

It is impossible to estimate the time course or peak latency of a latent ERP component by looking at a single ERP waveform – there may be no obvious relationship between the shape of a local part of the waveform and the underlying components.



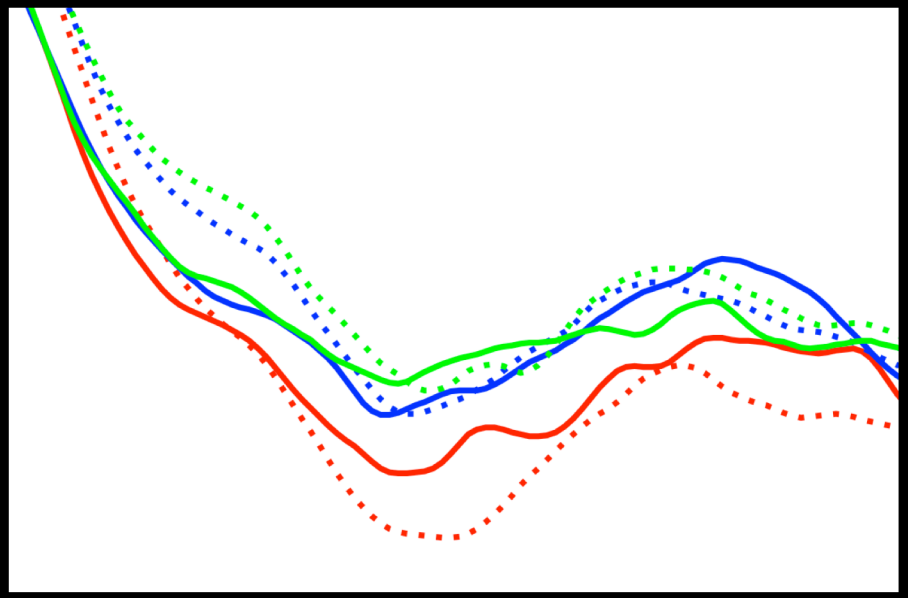
Rule 3

It is dangerous to compare an experimental effect (i.e., the difference between two ERP waveforms) with the raw ERP waveforms.



Rule 4

Differences in peak amplitude do not necessarily correspond with differences in component size, and differences in peak latency do not necessarily correspond with changes in component timing.



Rule 5

Never assume that an averaged ERP waveform accurately represents the individual waveforms that were averaged together. In particular, the onset and offset times in the averaged waveforms will represent the earliest onsets and latest offsets from the individual trials or individual subjects that contribute to the grand average.

Rule 6

Whenever possible, avoid physical stimulus confounds by using the same physical stimuli across different pychological conditions.

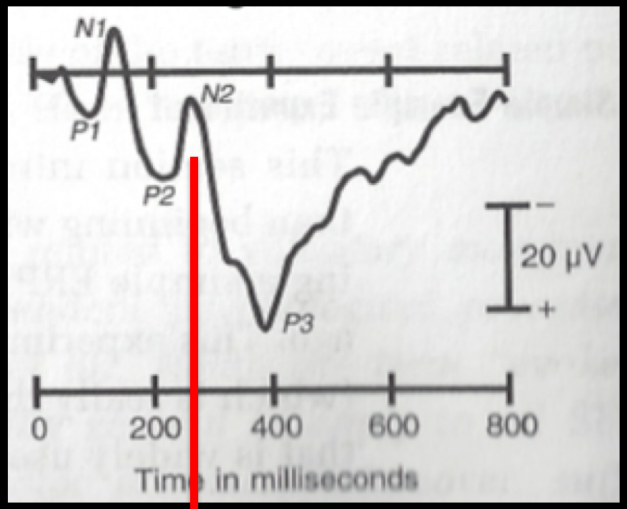
IV = Gender

Rule 7

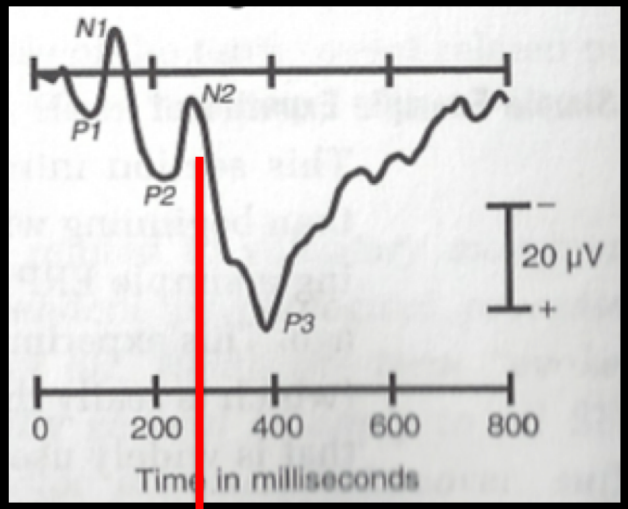
When physical stimulus confounds cannot be avoided, conduct experiments to assess their plausibility.

Rule 8

Be cautious when comparing averaged ERPs that are based on different numbers of trials.



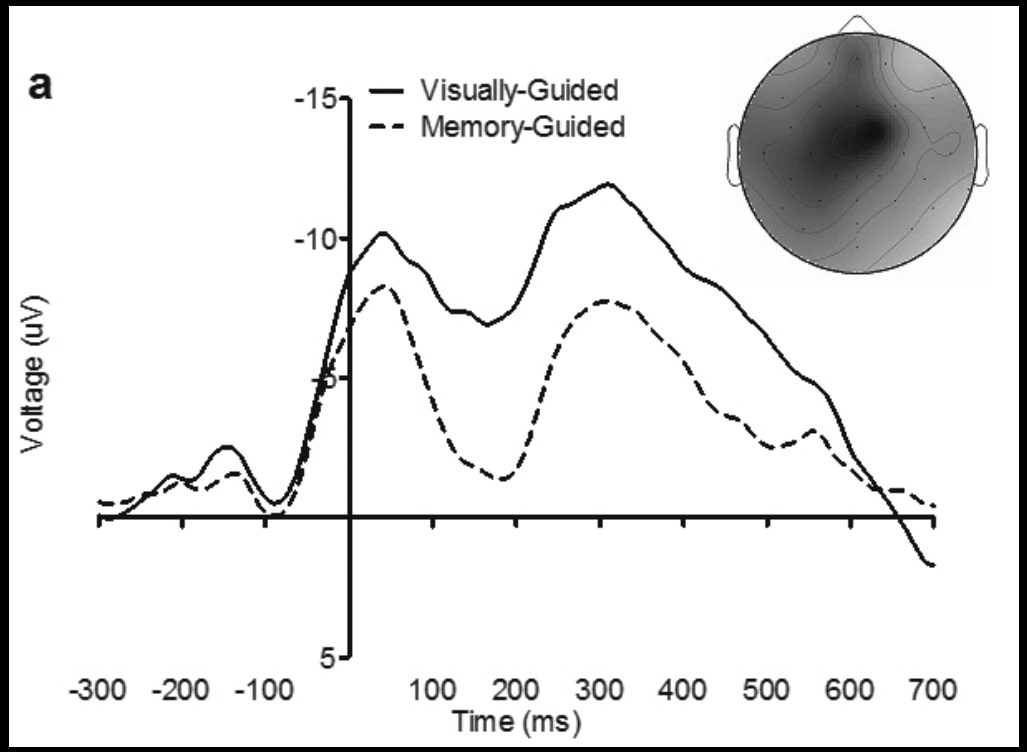
Reward



Stimulus Frequency

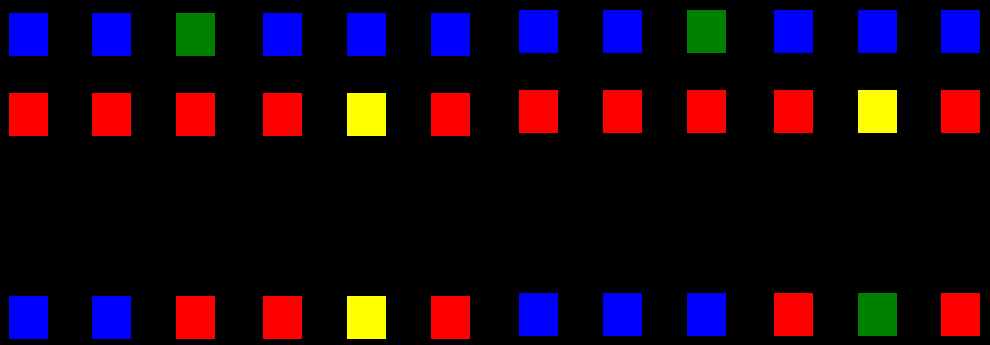
Rule 9

Be cautious when the presence or timing of motor responses differs between conditions.



Rule 10

Whenever possible, experimental conditions should be varied within trial blocks rather than between trial blocks.



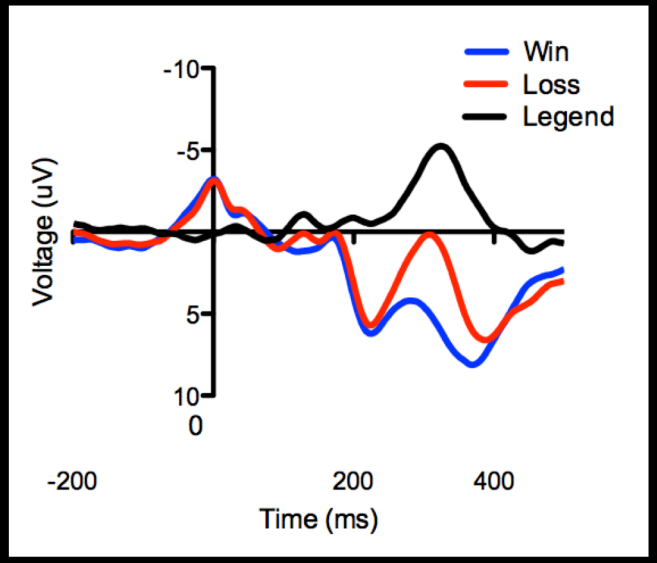
Rule 11

Make sure that any given stimulus only conveys a single piece of information if possible.

X

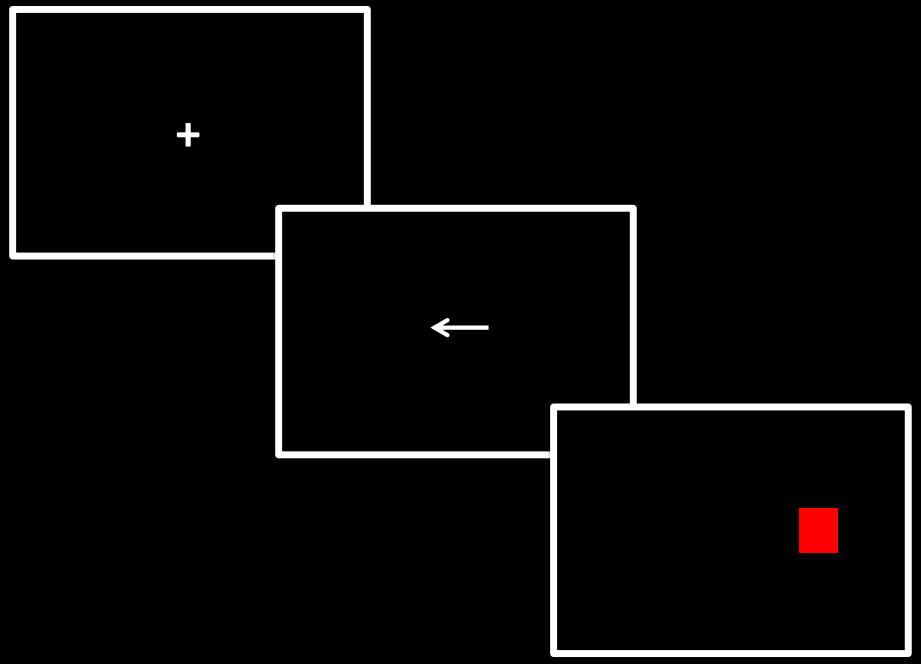
Design Strategies

1. Focus on a Specific Components



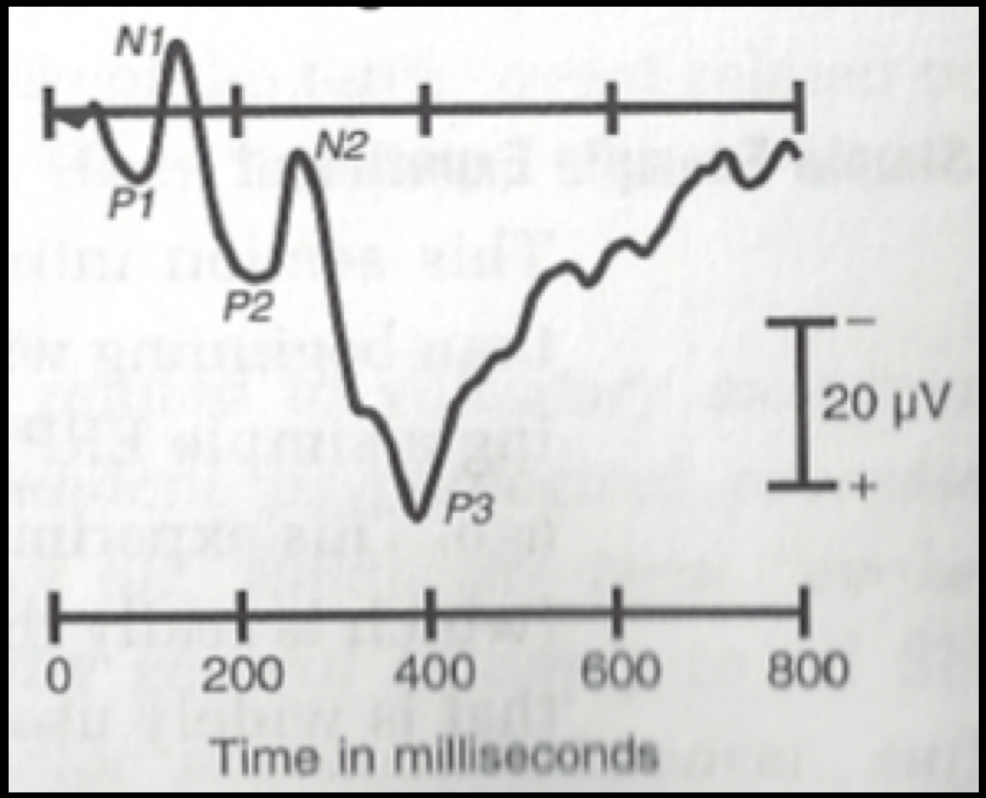
Design Strategies

2. Use Well Studied Experimental Manipulations



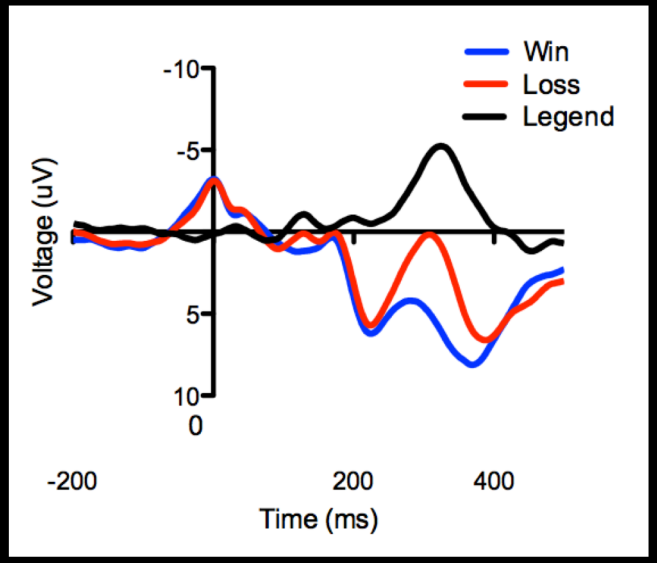
Design Strategies

3. Focus on Large Components



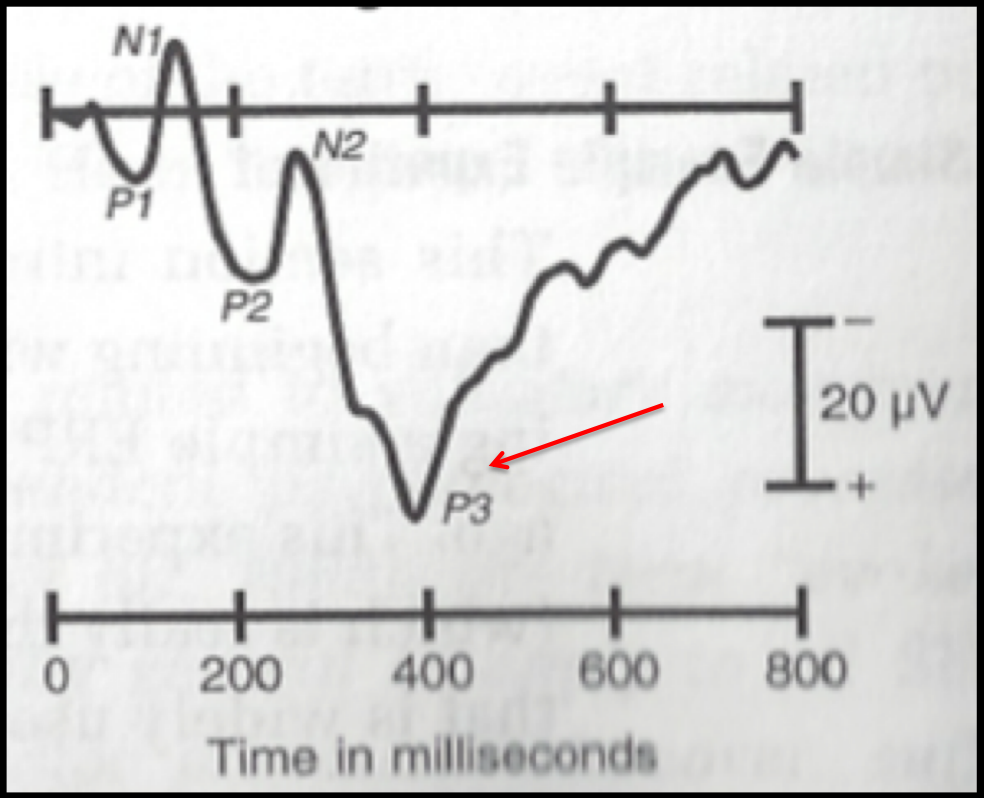
Design Strategies

4. Isolate Components with Difference Waves



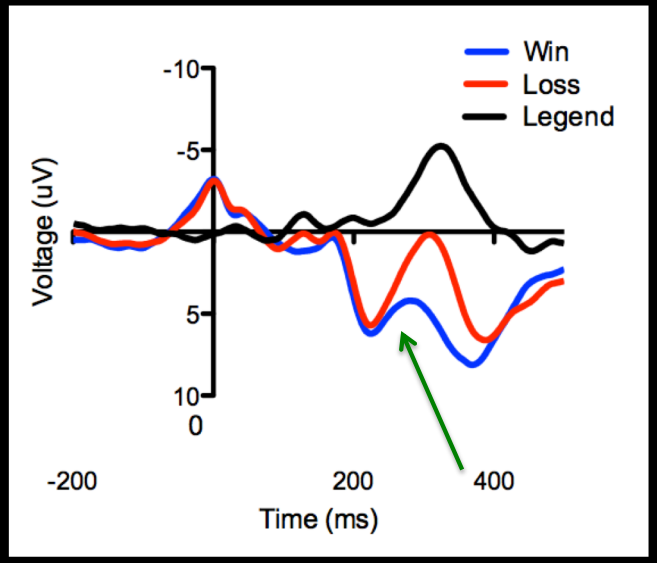
Design Strategies

5. Focus on Components that are Easily Isolated



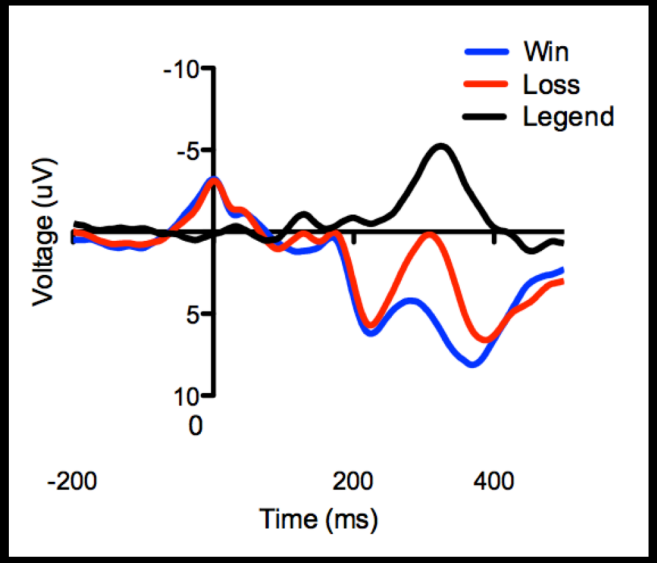
Design Strategies

6. Component Independent Experimental Designs



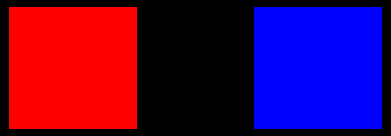
Design Strategies

7. Hijack Useful Components from Other Domains

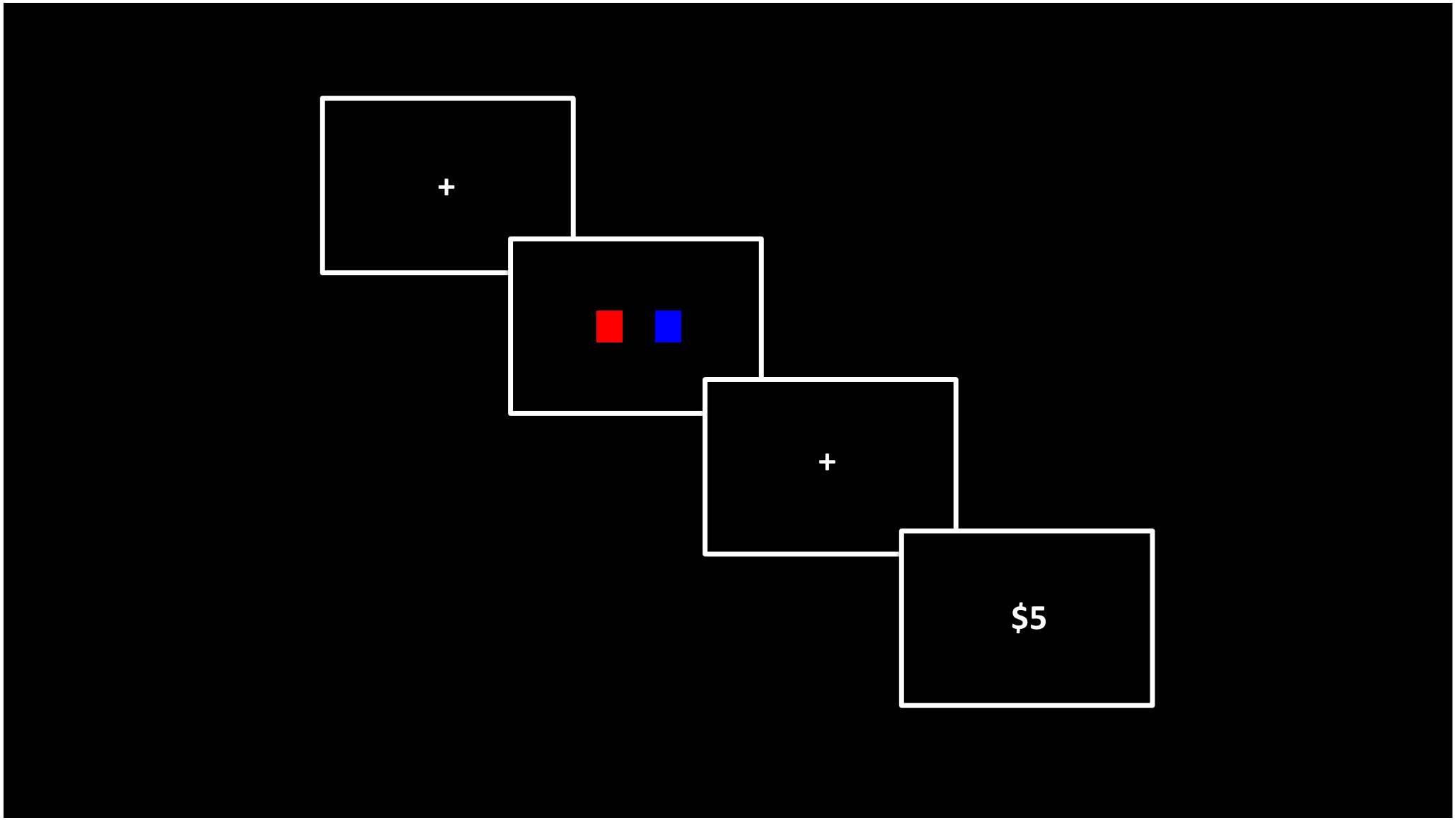


2c. A Typical ERP Experiment

Krigolson et al., 2013



We wanted to run the two arm bandit, but make it learnable. Why? We wanted to see if cues would acquire values with learning. But, there are a lot of problems with this. Consider the original design idea…


+
+
$5

Some other problem situations…

The "Tanaka" Principle

"You cannot ERP every behavioral experiment"

You want to have participants read text, what is the problem?

You want to use a video clip as a stimulus, what is the problem?

You want to study voluntary movements that are self-paced, what is the problem?

You want to look at the ERP response to a stimulus, but want to use a subsequent response to separate the stimuli into different bins…

Activity (Time Permitting)

Design an EEG / ERP Study