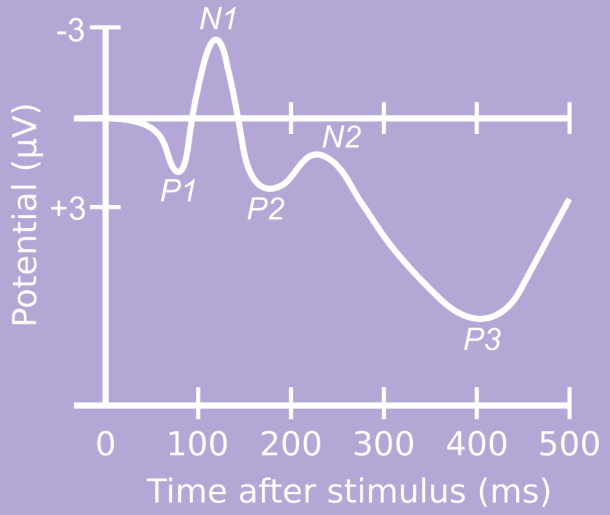
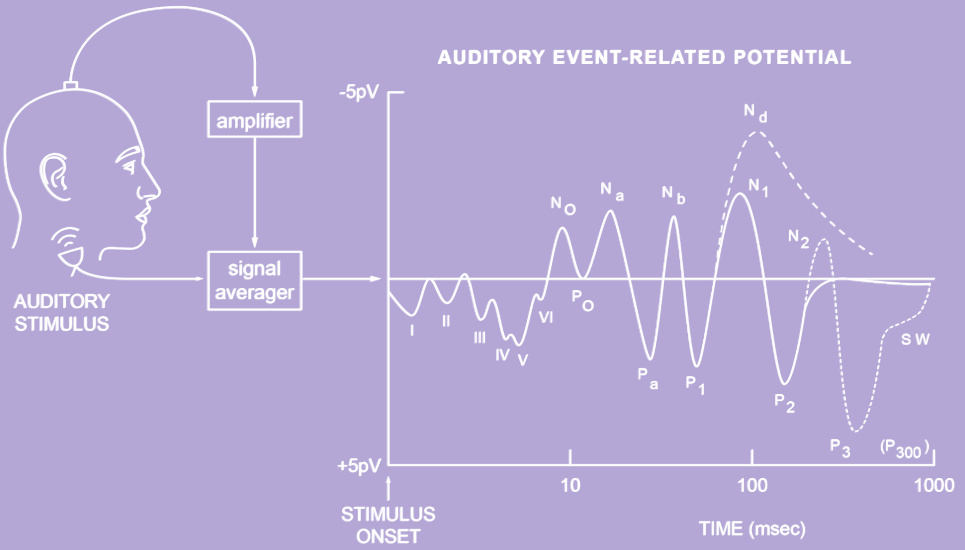
WEEK 6

Event-Related Potentials



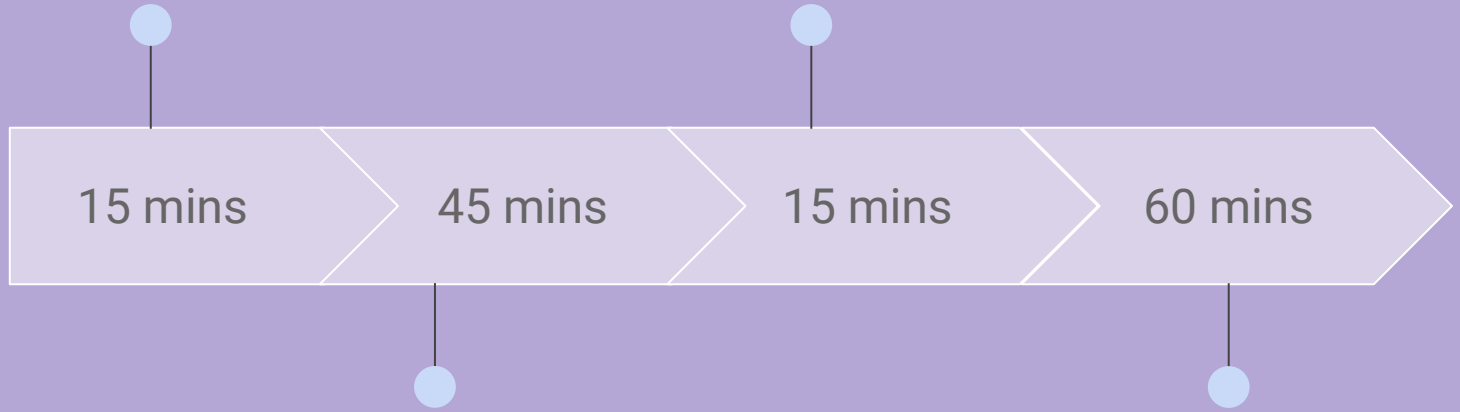


Objectives

- Understand what an **event-related potential (ERP)** is, when to expect it, and how to observe it
- Gain familiarity with some of the most commonly studied ERPs
- Consider how machine learning could be applied to understand ERPs
- Begin to contemplate the real-world applications of interpreting ERPs

Defining ERPs and examining ERP categories

Introducing a real-world application of ERP analysis



Introducing commonly studied ERP waveforms

N170 or P300 Experiment Exercise

What is an Event-Related Potential (ERP)?

- A very small (in μV) and brief (in ms) voltage change measured by EEG
- Time bound to a sensory, motor, or cognitive event
- Represents a large number of cortical pyramidal neurons firing in synchrony while processing information

Parameters:
latency (ms) and amplitude (μV)

Naming Convention:
P = positive deflection
N = negative deflection

Categories of ERPs

Sensory/Exogenous

- Exogenous = developed from **external** factors
- **Early** waves (components peaking within first ~100 ms after stimulus)
- Depend largely on **physical parameters of stimulus** (independent of cognitive processing)
- **Independent of subject's consciousness level**

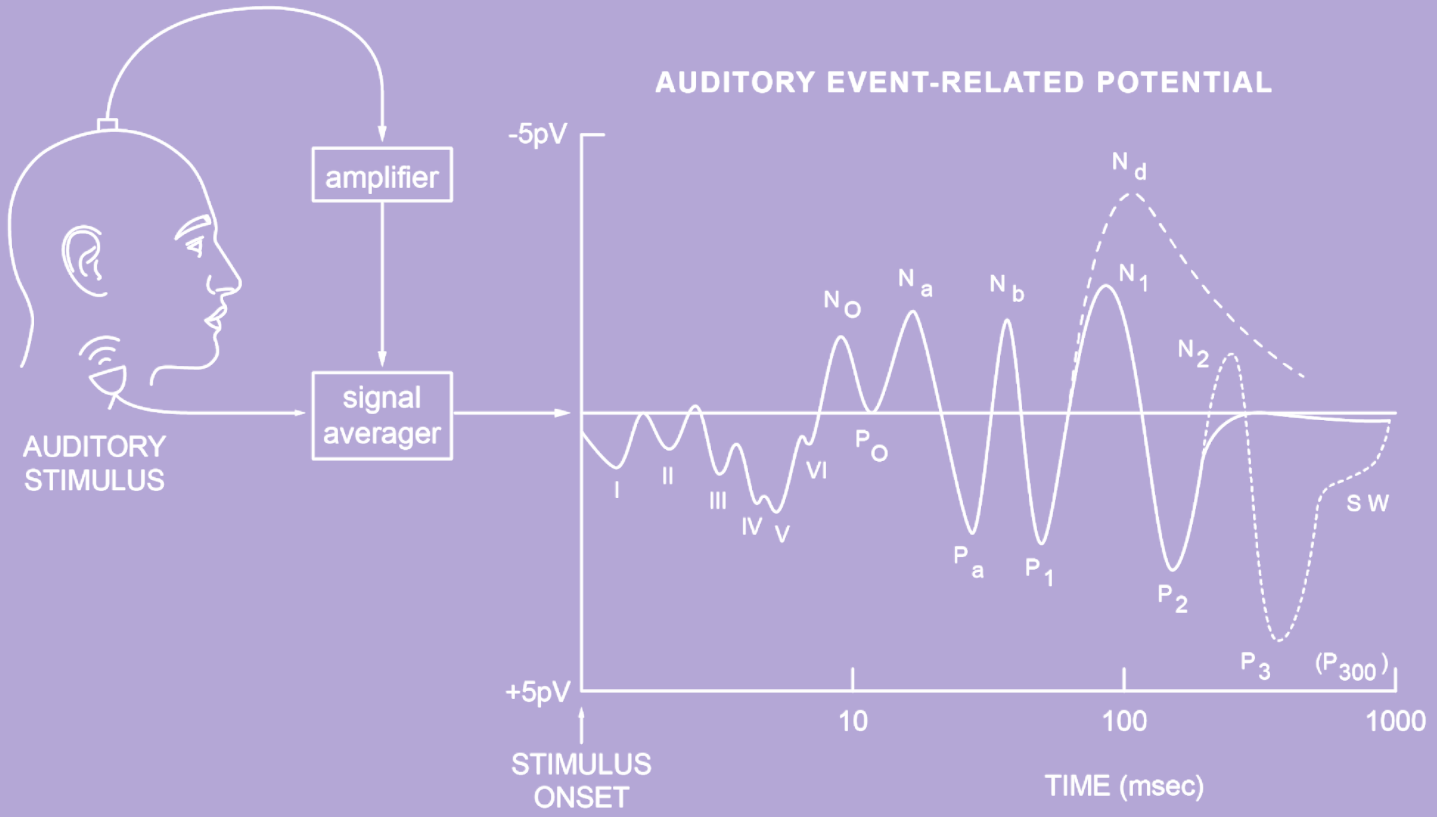
Example: seeing a face

Cognitive/Endogenous

- Endogenous = developed from **internal** factors
- **Later** waves
- Reflect the **manner in which the subject evaluates the stimulus** (independent of stimulus' physical features)
- Can be evoked in the absence of a stimulus
- **Affected by attention level**, relevance to task, and resources required for stimulus processing

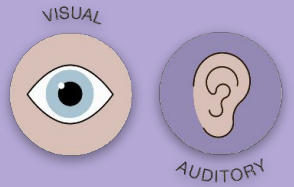
Example: performing mental calculations

Classic ERP Waveforms



P50 Wave

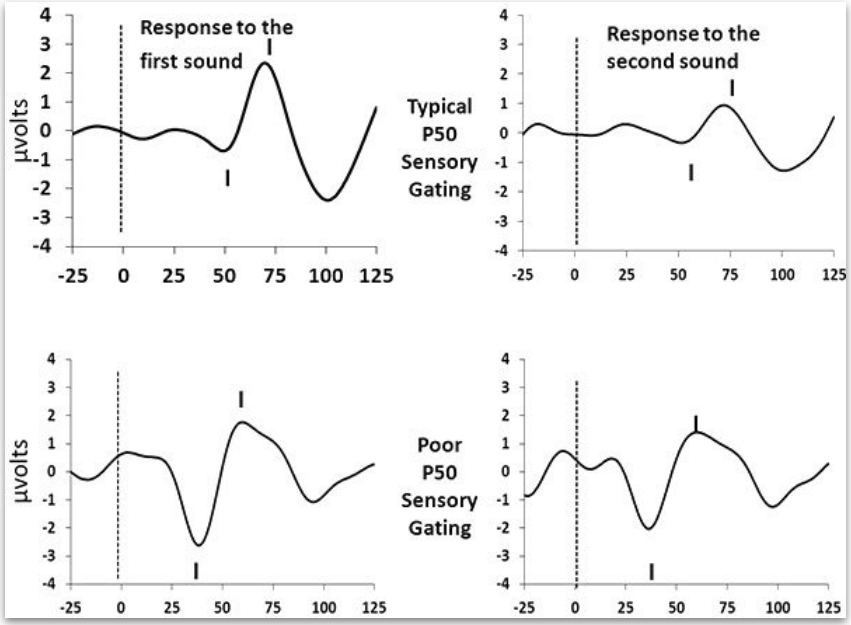
Stimulus Types:



Sensory Gating

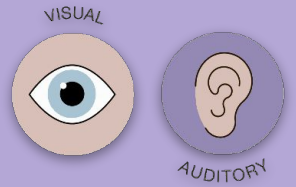
- **Latency:** 40-75 ms
- **Location**: center (Cz)
- **Stimulus:** paired-click or steady-state paradigm
- **Usage:** assess ability to selectively attend to salient stimuli while ignoring redundant/repetitive/trivial stimuli

Note: amplitude is the absolute difference between the P50 peak and the preceding negative trough



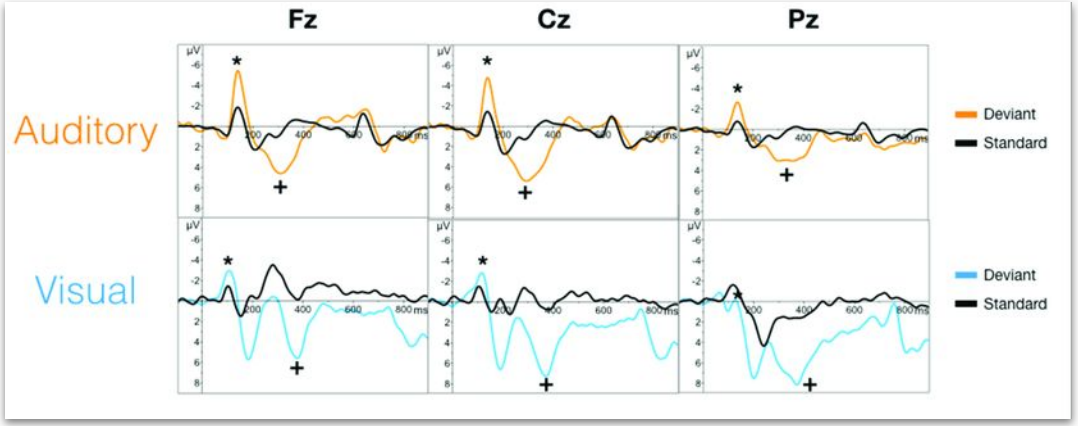
N100/N1 Wave

Stimulus Types:



Matching

- **Stimulus:** oddball paradigm
- **Usage:** to assess visual/auditory discrimination
- **Subcomponents**:
  - **Auditory → Latency**: ~75-150 ms
  - **Visual → Latency:** ~100-200 ms
    - **Note**: component at lateral occipital cortex larger for discrimination tasks than detection tasks

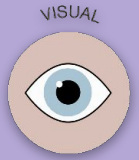


Note: affected by attention (↑ attention → ↑ amplitude), arousal, interstimulus interval, stimulus intensity; may reflect the addition of an endogenous component

N170 Wave

MUSE-detectable

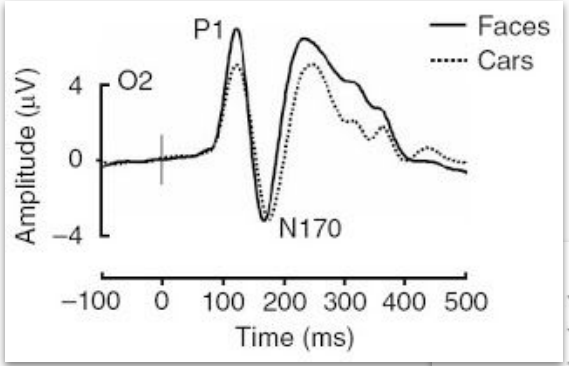
Stimulus Type:

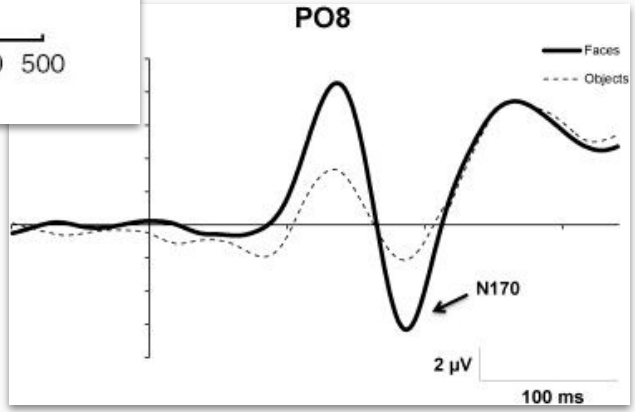


Face Recognition (?)

- **Latency:** 90-200 ms
- **Location**: right hemisphere
- **Stimulus:** faces, familiar objects or words
- **Usage:** to assess expert recognition

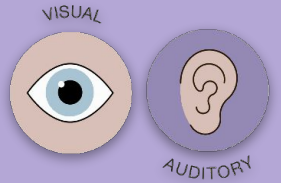
Note: later and/or larger for inverted faces than for upright faces (also for inverted familiar non-face stimuli)





P200/P2 Wave

Stimulus Type:



Matching/Sensation-Seeking (?)

- **Latency:** 100-250 ms
- **Stimulus:** oddball paradigm
- **Usage:** assess individual's sensation-seeking behaviour or ability to compare between predicted and actually perceived states of world

Note: not well-understood; exogenous, but modulated both by stimulus characteristics and by cognitive and task demands

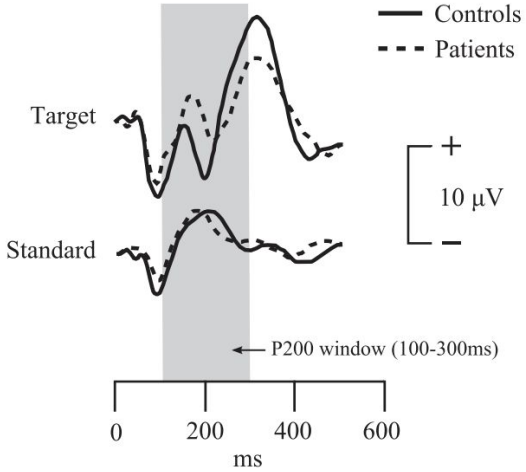
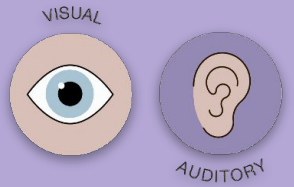


Fig. 1. Typical ERP to an auditory oddball task at the Cz electrode. The P200 component is present in both target and standard stimuli and corresponds to the first positive deflection after the first negative deflection (i.e., the N100 component). Adapted from Biological Psychiatry, Vol. 40, by S. B. Stefánsson and T. J. Jónsdóttir, "Auditory event-related potentials, auditory digit span, and clinical symptoms in chronic schizophrenic men on neuroleptic medication", pp. 19–27, Copyright (1996), with permission from Elsevier.

N200/N2 Wave

✓ MUSE-detectable

Stimulus Type:

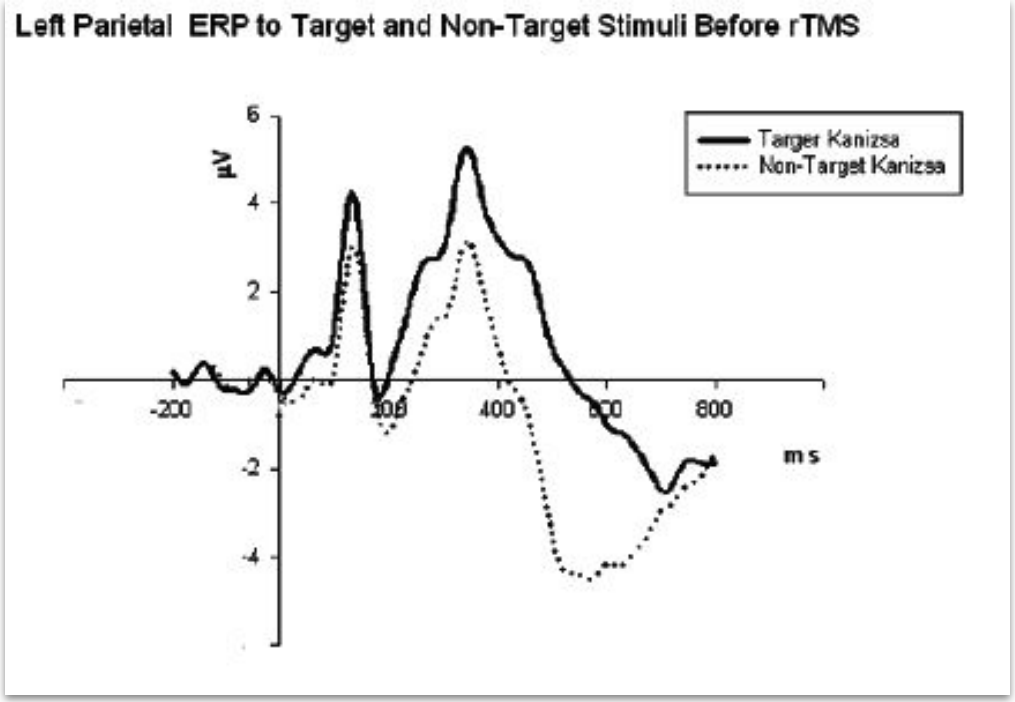


Basic N2 (Temporal)

- **Latency:** ~225-250 ms
- **Location:** bilateral, anterior
- **Stimulus:** repetitive, non-target stimulus (only if subjects looking for deviant targets of some sort)
- **Usage:** to assess ability to match/compare stimuli

Note: larger amplitude when other stimuli (*deviants*) occasionally interrupt repetitive stimulus train

Subcomponents: N2a, N2b



Basic N2 Subcomponents

Stimulus Types:

If deviant is *task-irrelevant*...

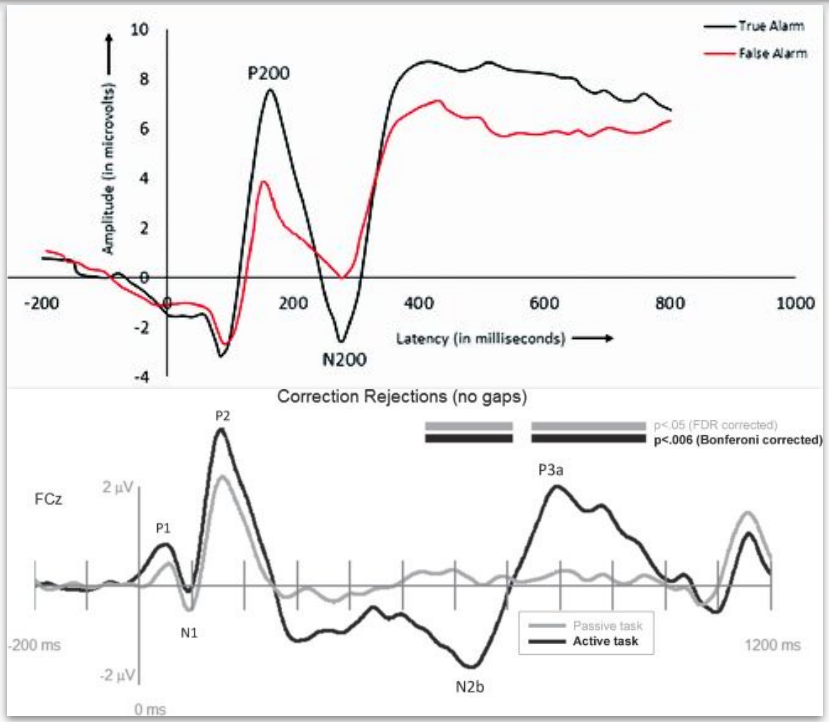
N2a: Mismatch Negativity (MMN)

- **Latency:** 160-220 ms
- **Usage:** to assess automatic process that compares incoming stimuli to a sensory memory trace of preceding stimuli

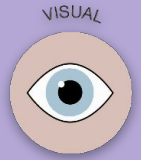
If deviant is *task-relevant*...

N2b: Stimulus Categorization

- **Latency:** somewhat delayed
- **Usage:** to assess stimulus categorization process
- **Note:** larger for less frequent targets
- **Location:** auditory → central; visual → posterior



More on the N200/N2 Wave

Stimulus Type: 

N2 for Visuospatial Deviance

Stimulus: simultaneous array that contains several identical items plus one deviant item

Subcomponents: N2, N2b, N2pc

N2

- **Stimulus:** target/non-target deviant
- **Location:** bilateral, anterior
- **Note:** not as automatic as MMN since only present when subjects looking for deviant targets of some sort

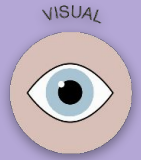
N2b

- **Latency:** after N2
- **Stimulus:** target (or target-resembling) deviant
- **Location:** bilateral, posterior
- **Note:** probability-sensitive

N2pc

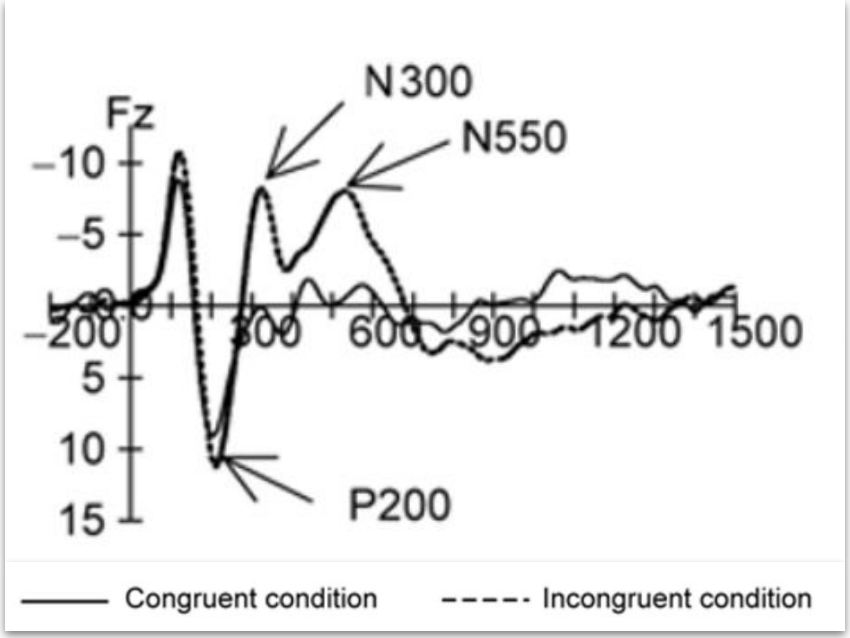
- **Latency:** after N2
- **Stimulus:** target (or target-resembling) deviant
- **Location:** contralateral to target, posterior
- **Note:** probability-insensitive, reflects focusing of spatial attention onto target location (and possibly suppression of surrounding nontarget items)

N300/N3 Wave

Stimulus Type: 

Semantic Congruity & Expectancy

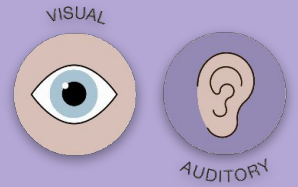
- **Latency:** ~300 ms
- **Location:** frontal
- **Stimulus:** word + picture pairing
- **Usage:** matching of visual input to stored semantic knowledge
- **Note:** size of effect indexes ease with which a picture is matched to a word (incongruent → greater amplitude)



P300/P3 Wave

✓ MUSE-detectable

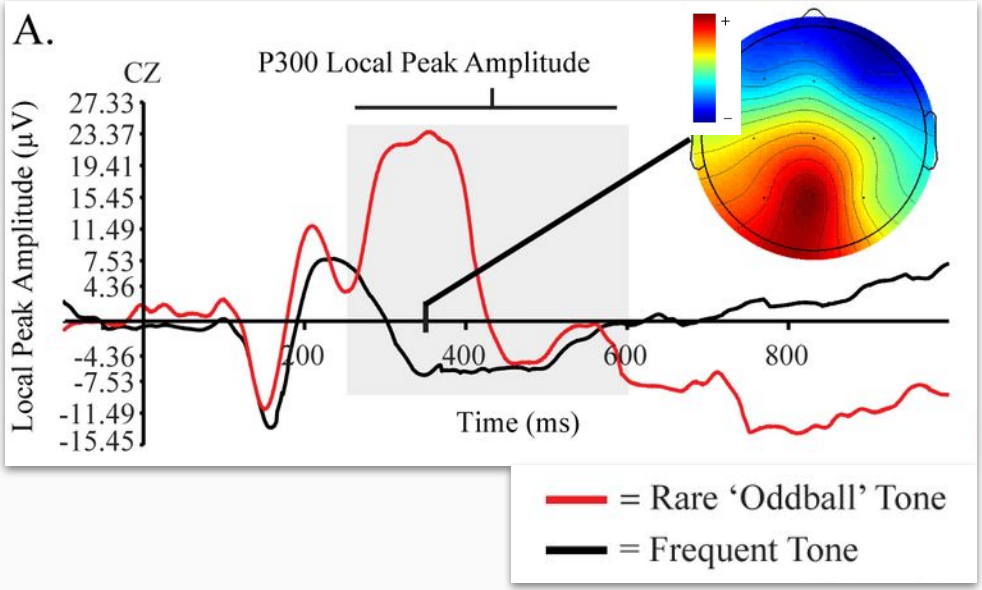
Stimulus Type:



Stimulus Classification

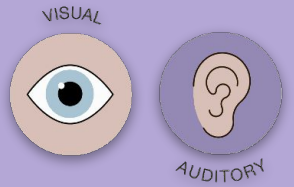
- **Latency:** 250-400 ms
- **Stimulus:** oddball paradigm
- **Usage:** assess quality and speed of stimulus classification

Note: latency is usually interpreted as the speed of stimulus classification resulting from discrimination of one event from another; greater amplitude represents greater attention



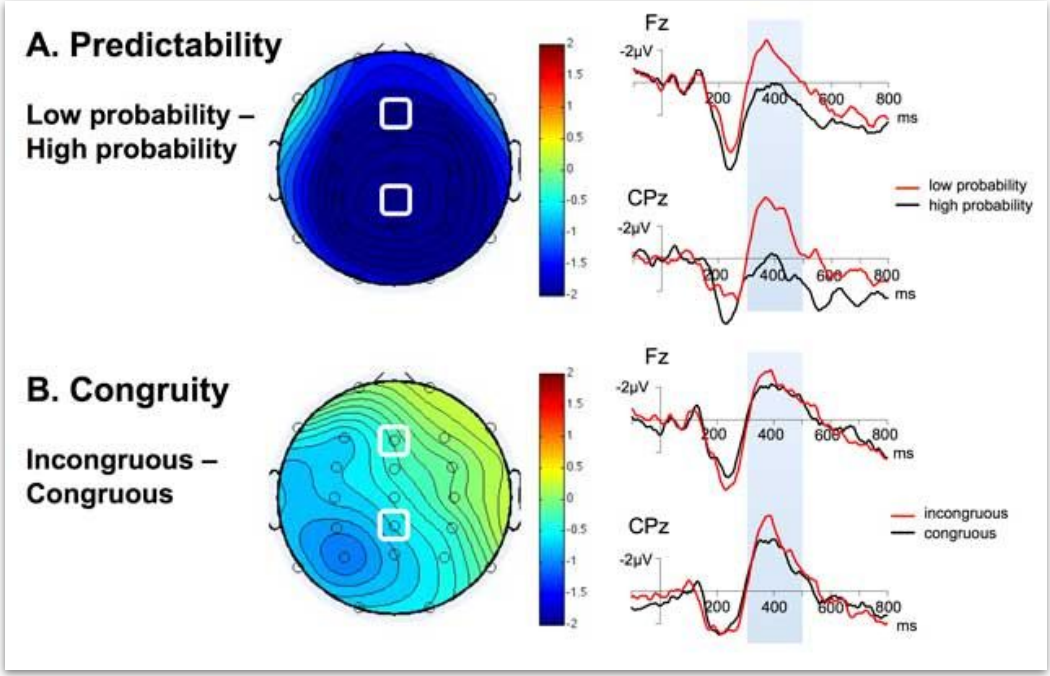
N400/N4 Wave

Stimulus Type:



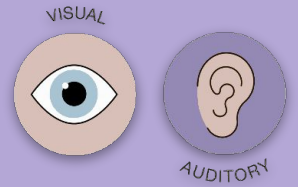
Semantic Processing

- **Latency:** ~400 ms
- **Location:** central
- **Stimulus:** violations of semantic expectancy
- **Note:** amplitude varies inversely with word's relationship to semantic context (less related → larger amplitude); if semantically unrelated, no N300 (only N400)



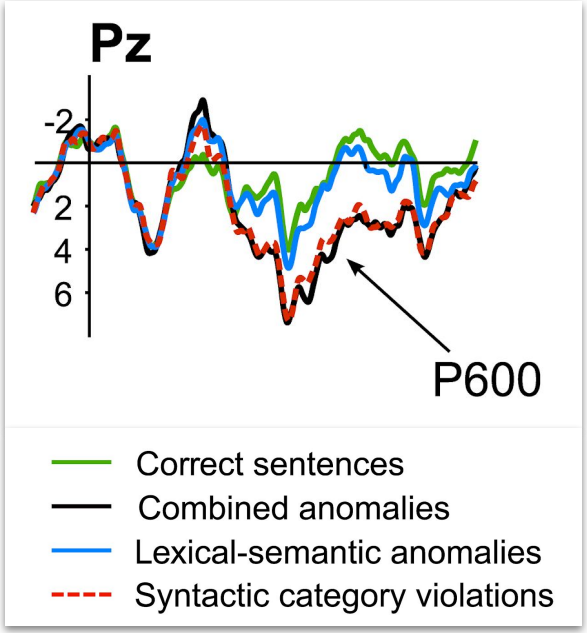
P600/P6 Wave

Stimulus Type:



Language Processing

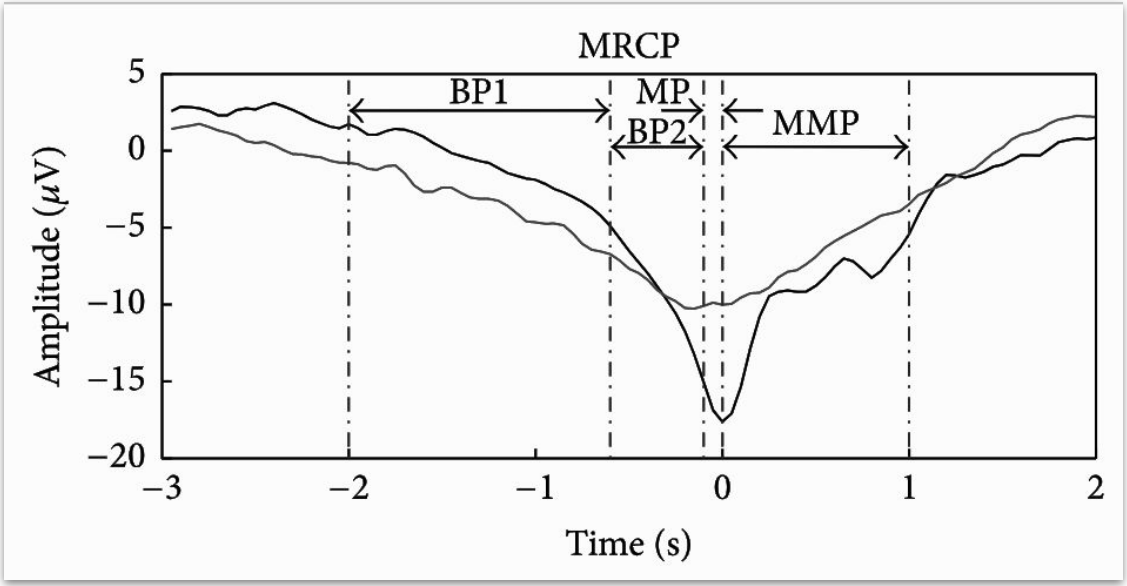
- **Stimulus:** violations of syntactic expectancy; syntactically complex or temporarily-ambiguous sentences
- **Early (Latency: ~500-750 ms)**
  - **Location:** midline
  - **Reflects:** reactivation of contextual information in order to process syntactic integration
- **Late (Latency: ~750-1000+ ms)**
  - **Location:** parieto-occipital
  - **Reflects:** general sentence reanalysis and repair; controlled processes related to decision-making and categorization
  - **Note:** highly modulated by the presence or absence of a task and by experimental design



Movement-Related Cortical Potentials

Stimulus Type: 

- **Latency:** close before/after movement
- **Stimulus:** movement or movement-like activity
- **Usage:** detect voluntary movement
- **Note:** 4 components:
  - Bereitschafts potential
  - Reafferent potential
  - Pre-motion positivity
  - Motor potential

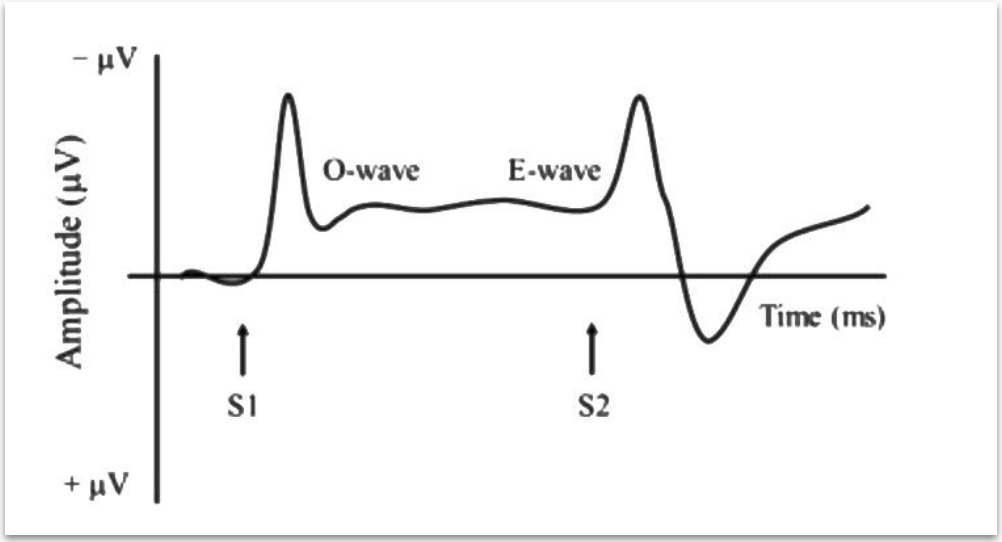


Contingent Negative Variation

Stimulus Type:

Arousal/Attention

- **Latency:** “early” (arousal processes) or “late” (attention to task)
- **Location:** premotor cortex
- **Stimulus:** standard reaction time or chronometric paradigm
- **Usage:** expectation of a stimulus and motor preparation for a response



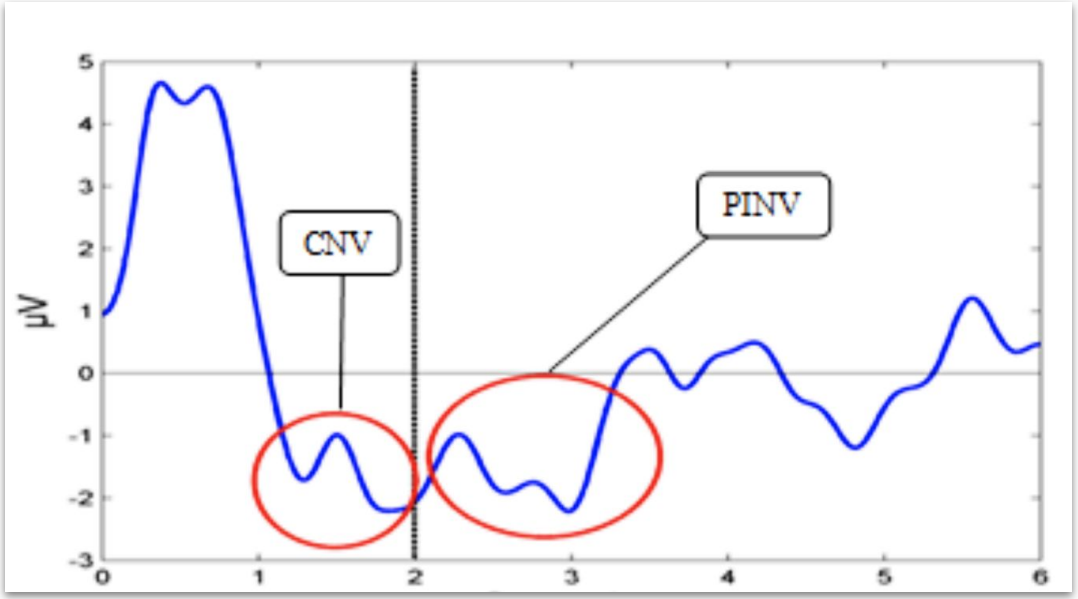
Note: negative deflection only observed if subject expects to do motor task upon relevant signal (i.e. not observed when stimulus is presented in the absence of task)

Post-Imperative Negative Variation

Stimulus Type:

Sustained Cognitive Activity

- **Latency:** continuation of CNV
- **Stimulus:** imperative signal (S2) seen in CNV (standard reaction time or chronometric paradigm)
- **Usage:** marker for sustained cognitive activity
    - Represented by the continued negative deflection even after the presentation of S2



Real-World Application:

Predicting Test Anxiety

Classification of test-anxious individuals using Event-Related Potentials (ERPs): The effectiveness of machine learning algorithms

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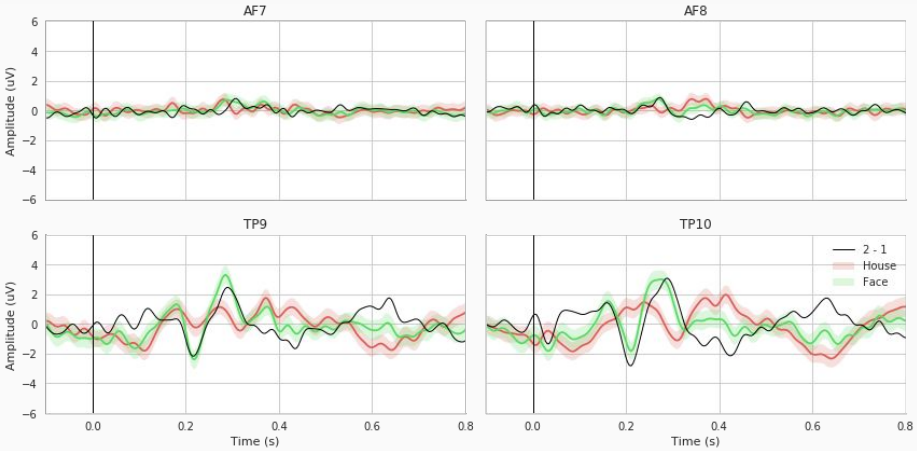
- **Problem:** level of test anxiety commonly assessed by surveys—results may be affected by participants' attitudes
- **Solution:** using emotional stroop paradigm to elicit P1, P2, N2, P3 and LPP, can predict high or low test anxiety with >80% accuracy using the convolutional neural network (CNN) machine learning algorithm (similar accuracy in other algorithms as well)

Exercise:

Pre-Process & Analyze N170 or P300



N170

P300