ERP Components

What is an ERP Component?
Peaks ≠ Components

Peaks are things that we observe in our scalp recordings, whereas components occur in the brain and can’t be directly observed from scalp electrodes. The observed peaks are the result of the underlying brain components, but the relationship can be complex.
With a few rare exceptions, ERPs are generated by cortical pyramidal cells during neurotransmission. To be visible on the scalp, a large number of neurons must be active at the same time.
The extracellular electric fields produced during neurotransmission sum across the neurons in an area, forming an equivalent current dipole that points perpendicular to the active cortical surface.

This will give us a negativity in our scalp EEG electrodes on one side of the dipole and a positivity on the other side.

http://www.psych.nmsu.edu/~jkroger/lab/EEG_Introduction.html

DeFelipe (2022)
The sequence of positive and negative peaks at a given scalp electrode reflects the sum of many of these components, each of which has its own time course.

The components overlap in time. It’s difficult to tell when a single component actually begins and ends by looking at the ERP waveform.
Source Waveforms

C1

C2

C3
Each internal component is represented by an arrow, showing the location and direction of the dipole for that component.

Each component also has a source waveform, which is the change in voltage over time in that brain area in response to a given event.
Voltages simply sum together in a conductor. As a result, the voltage recorded at each electrode will be a weighted sum of the underlying source waveforms.
You have a different weight for each combination of component and electrode site.

Note: These are arbitrary weights and may not match the actual weights for this combination of components and electrodes.
The contribution of a given source to a given electrode site at a given time is simply the amplitude of the source waveform at that time multiplied by the weight between that component and the electrode site.

Note: These are arbitrary weights and may not match the actual weights for this combination of components and electrodes.
Timing of peaks often differs from timing of components.

The first component peaks at 100 ms, whereas the first peak in the scalp waveform is at 50 ms.

It looks like the second peak goes from about 90 to 180 ms, but the underlying component actually goes from about 50 to 225 ms.
Observed waveform at scalp electrode

Underlying brain components

225 ms

Di Russo et al. (2002)
There are usually way more components than there are obvious peaks. There are at least 10 distinct components active between 50 and 150 ms in the sensory response to a visual stimulus.

Di Russo et al. (2002)
ERP Components

Naming Conventions
P for positive-going
N for negative-going

Number: Ordinal position in waveform (if <= 5)
Latency in milliseconds (if > 5)
Every component will be positive on one side of the head and negative on the other (although we might not have electrodes positioned to see both sides of the dipole)
C1 can be either positive or negative depending on whether the stimulus is presented above or below the point of fixation.

This is because primary visual cortex is folded up in the calcarine fissure, and the upper and lower visual fields project to opposite sides of the fissure.
Visual N1 $\neq$ Auditory N1

Visual P3 = Auditory P3
ERP
Components
Sensory Components
The sequence of voltages over time reflects the sequence of processes that are triggered by a stimulus.
The visual P1 and N1 waves reflect the combination of many different brain areas, most of which are in higher-level areas of visual cortex.
The C1, P1, and N1 waves are highly sensitive to the physical properties of the stimulus, such as brightness.
The N1 wave—often called N170—is bigger for faces than for most other classes of stimuli.

Experience also plays a role: For example, words elicit a large N1 in experienced readers.
The P1 and N1 are larger for attended-location stimuli than for ignored-location stimuli. However, these effects are typically observed only for spatial attention, and only when attention has shifted prior to stimulus onset.

Attend Left or Attend Right in different trial blocks

Luck & Kappenman (2012, Oxford Handbook of ERP Components)
Response to Auditory Click

- Auditory brainstem responses (ABRs)
  - Cochlea, cochlear nerve, brainstem nuclei
  - Used for neonatal hearing evaluation

The auditory brainstem responses are the one common exception to the rule that ERPs are ordinarily generated by cortical pyramidal cells.

They’re used to diagnose hearing impairments in clinical audiology and to screen for hearing problems in newborns.

Pratt (2012, Oxford Handbook of ERP Components)
Response to Auditory Click

- Midlatency responses (MLRs)
  - Medial geniculate nucleus and primary auditory cortex

Pratt (2012, Oxford Handbook of ERP Components)
Auditory “long-latency” sensory responses

- Multiple cortical areas

Pratt (2012, Oxford Handbook of ERP Components)
Mismatch Negativity (MMN)

One tone every 500 ms
80% 1000 Hz / 20% 1500 Hz

Deviant tones elicit a larger negative response than standards around 200 ms that is called the mismatch negativity or MMN.

The MMN doesn’t require the subject to perform a task.
The MMN well suited for use in infants, where it has been used to study the development of phoneme discrimination.
The MMN can be used to predict which coma patients will recover.
ERP Components
Attention

This video was made possible by NIH grant R25MH080794 and is shared under the terms of a Creative Commons license (CC BY-SA 4.0)
N2pc
(pc: posterior contralateral)
Covert Attention: Shift of mental processing resources
Overt Attention: Shift of eye position
N2pc
(pc: posterior contralateral)
N2pc
(pc: posterior contralateral)

N2pc is a negative-going voltage deflection over posterior electrode sites contralateral to the object being attended.
Task
Attend to red in some blocks and green in other blocks.
Press a button to indicate whether gap on attended-color item is on top or bottom.

The stimulus locations are randomized from trial to trial, so when the display appears, the subject has to search for the target.

We’re studying covert attention, so we have subjects keep their eyes locked on the central fixation point and use their peripheral vision.
Once the stimuli appear, it takes about 200 ms for attention to shift to the target. Then we see the N2pc as a negative-going wave over the contralateral hemisphere.
The threat image elicited a robust N2pc: the voltage was more negative contralateral to the threat than ipsilateral to the threat.

Kappenman et al. (2014, Frontiers in Psychology)
Contralateral Delay Activity (CDA)

Subjects are asked to remember the colors of the circles and ignore the rectangles.

They only have to remember the colors for 900 ms, and then they see a test array. They then indicate whether the colors of any of the circles have changed.

Task: Remember the colors of the circles

Leonard et al. (2013, Cerebral Cortex)
Contralateral Delay Activity (CDA)

Task: Remember the colors of the circles

You initially see an N2pc as attention is shifted to the circles.

This is followed by the CDA: a sustained voltage over the hemisphere contralateral to the objects being maintained in memory.

Leonard et al. (2013, Cerebral Cortex)
Luck, S. J., & Kappenman, E. S. (2012). ERP Components and Selective Attention (pp. 295–327).


Perez, V. B., & Vogel, E. K. (2012). What ERPs can tell us about working memory (pp. 361–372).
Decoding the Contents of Working Memory

Decoding the Contents of Working Memory

16 combinations of 4 identities and 4 expressions. Subjects simply had to remember the most recent face. Their memory was tested after a random 12% of faces.

Bae (in preparation)
One set of support vector machines was trained to classify the identity of the face independently of the expression.

Another set of support vector machines was trained to classify the expression independently of the identity.
Decoding accuracy was well above chance for both identity and expression.
This video was made possible by NIH grant R25MH080794 and is shared under the terms of a Creative Commons license (CC BY-SA 4.0)

ERP Components Language
I take my coffee with cream and _____.

Semantically incongruous words elicit a large N400 wave peaking around 400 ms after the onset of the word.

N400

“I placed my keys on the kitchen floor” (medium N400)
“I placed my keys on the kitchen table” (small N400)

“Tree” -> “Nurse” (large N400)
“Doctor” -> “Nurse” (small N400)

"Life is what happens when you're busy making other plans." -John Lennon

The size of the N400 for a given word reflects the extent to which that word can be predicted from the preceding context.

"Life is what happens when you're busy make other plans."

P600 instead of N400 for syntactic violations
ERP Components
Categorization & Emotion

This video was made possible by NIH grant R25MH080794 and is shared under the terms of a Creative Commons license (CC BY-SA 4.0)
You can get this P3 effect for virtually any kind of stimuli, as long as the task requires the subject to classify the stimuli into a frequent category and a rare category. It’s the task-defined categories that matter, not the probabilities of the physical stimuli per se.
Press button 1 for B (oddball)      Press button 2 for A, C, D, E (standard)

Probability of oddball category = 20%
Probability of standard category = 80%

Block 1: Target = B, Standards = \{A, C, D, E\}
Block 2: Target = E, Standards = \{A, B, C, D\}
Block 3: Target = A, Standards = \{B, C, D, E\}
Block 4: Target = D, Standards = \{A, B, C, E\}
Block 5: Target = C, Standards = \{A, B, D, E\}

https://erpinfo.org/erp-core
The Late Positive Potential (LPP)

The LPP primarily reflects arousal and not valence.