Leun J. Otten: Why ERPs?

- Allows to identify *when* cognitive functions operate
  - *dynamics* of cognitive functions
- Cheap and easy method to *fractionate* cognitive functions
- In combination with other modalities, allows to identify functional brain *networks*
How to Interpret ERPs?

ERP Effect

- Known?
  - Yes: Use as marker of process associated with the effect
  - No: Scalp distribution: Which process Time course: When process is active Amplitude: How active process is
Inferences: ERP Effect Unknown

ERPs:
1. differ between conditions
   → Cognitive processes differ between conditions
2. differ between conditions at time $x$
   → Cognitive processes differ by time $x$
3. differ in distribution across the scalp
   → Cognitive processes differ qualitatively.

From Otten & Rugg (in press).
Inferences: ERP Effect Known

ERPs: Differ with respect to certain ‘component’ $X$
→ Cognitive process associated with component engaged to different degree or at different time

From Otten & Rugg (in press).
ERP ‘Components’

- Components usually labelled by polarity and time/order of occurrence; sometimes given functional name

- Definitions:
  
  *Theoretical*: Signature on scalp of activity from specific neuroanatomical source(s), associated with specific functional process

  *Operational*: Part of the waveform with a circumscribed scalp distribution (alluding to the underlying neural configuration) and a circumscribed relationship to experimental variables (alluding to the cognitive function served by the activity of this configuration).

- Issues: Functional significance seldom completely understood, difficult to identify and/or dissociate components
Some Common Components

- ABR, P1, N1, P2 (early perceptual processing)
- P50, N1d, N2a, N2b, N2pc (attention and discrimination)
- P300/P3b/LPW, P3a, novelty P3 (context updating)
- LRP (motor processing)
- ERN (error processing)
- Left parietal, mid-frontal, right frontal effects (memory)
- N400, P600/SPS, LAN, N270, PMN (language)
- BP, CNV, NSW, PSW (preparatory processes)
- And many many more…
1. ERPs contain not one, but many, effects
   • ERPs represent neural activity that is aggregated across time and space
   • Need to decompose waveforms.
Things to Keep in Mind (2 of 8)

2. Null result usually means little

- Experiment may not have had enough statistical power
- Waveforms may not have been quantified or analyzed in the optimal way
- ERPs sample only a subset of total brain activity: activity only visible on the scalp when elements of a neuronal population activate or de-activate synchronously, and when their geometric configuration is such that their activity summates.

Processes and neural activity not necessarily equal across conditions!
3. Meaning of scalp distribution differences unclear

- Different scalp distributions suggest different patterns of neural activity across conditions or time.
- But, nature of difference unknown. Difference may be due to anatomically distinct generators, or different relative contributions (in terms either of their strengths or time courses) of different components of a common set of generators.
4. Polarity has no particular significance

- Polarity defines an ERP effect
- However, polarity determined by location of reference electrode, baseline against which the effect is compared, and location and orientation of intracerebral sources
- Polarity also varies because of neurophysiological reasons, e.g. whether input is inhibitory or excitatory and whether input is received via synapses distal or proximal to the cell bodies.
5. Scalp field ≠ intracerebral sources

- No transparent relationship between an electrical field observed on the scalp and the brain regions giving rise to that field.
- Need formal source localization methods.
6. Amplitude ≠ strength of process

- Amplitude differences can occur in the absence of a change in the strength of the underlying neural activity.
- Signal averaging assumes across-trial invariance. Amplitude differences can arise when:
  - Signals differ in time of occurrence across trials (‘latency jitter’) and the degree of variability differs between conditions.
  - Conditions have different proportions of trials carrying effects of constant amplitude. In that case, amplitude differences carry information about probability that process is engaged.
7. Time course is relative

- The onset of an effect does not necessarily reflect the actual point in time when the brain first distinguishes the conditions, but presents an upper bound.
- Depending on the question of interest, time course may be characterized by various parameters including onset, latency to peak, rise time, and/or duration.
8. Correlation vs causation

- All inferences from neuroimaging data are correlational
- Neural activity may not be necessary for a process, but may reflect processes downstream or incidental to it
- To study causation, must interfere with neural activity and study consequences
- Brain lesions, pharmacological manipulations, TMS.