III. TIME DOMAIN ANALYSIS

EEG-TRAINING

OUTLINE

1. Goal
2. Terminology
3. How to time analyze
    1. Averaging
    2. Baseline comparison
4. Caveats to avoid
5. Application: the P300 speller

1) GOAL

- Time-domain analysis is performed when we want to link observable events (stimulus or behavior) to cortical activity
- In particular, the assumption is that **time-locked** and **phase-locked** to the event of reference

2) TERMINOLOGY

- **Time-locked:** neural activity is time-locked to an event when its onset happens systematically at a pre-defined distance from the event
- **Phase-locked:** neural activity is phase-locked to an event when it starts systematically at the same phase
- **ERP:** *Event-Related Potentials* are time- and phase-locked events that manifest in the form of a change in potential as a consequence of an external event
- For an extensive list of different ERPs, refer to *Sur S, Sinha VK. 2009*

3) HOW TO: AVERAGING

- We have explained several times that EEG data is noisy, even after pre-processing
- Making peaks of potential appear at the single trial level is not obvious, but since we want to answer the question of whether a systematic effect occurs or not, **averaging** is the solution
- Average all trials **per channel and per condition** and then display the obtained times series

3) HOW TO: BASELINE

- Place yourself in the case where you compare the ERP for two types of events:
  - Then, you can simply compare the ERP for each event, substract the two and see how the ERPs differ
- What if you compare the activity « with event » to the activity « without event »?
  - Compare to the neural activity when no event is occuring: **baseline activity**
  - Taken before the event, over a few hundred ms (200 to 500ms usually)
- In fact, even in the first case you can benefit from baseline substracting
  - You allow to create a zero by assuming that no relevant activity is present in the baseline

3) HOW TO: BASELINE

- There are different forms of baseline normalizations that you can apply (see Cohen, Mike X. *Analyzing neural time series data: theory and practice*. Issues in clinical and cognitive neuropsychology. Cambridge, Massachusetts: The MIT Press, 2014., chp. 18)
- One that is easy and many times enough is baseline substraction:
  - Average the signal in the baseline period (per electrode and per epoch)
  - Withdraw this average from each electrode and each epoch

4) CAVEATS TO AVOID

- « I don't see specific peaks, it means that the brain does not respond to the event! »
  - **No,** it can mean that the data is not well aligned (there are shifts during the acquisition)
  - It can also mean that the event-related activity is not time-locked
  - It can also mean that the event-related activity is not phase-locked
  - In any case: look at other analyses methods (see next lecture!) before ditching your hypothesis or the data
- « I see great peaks in some places, it means the brain reacts really well »
  - Any interpretation has to be cautious. Depending on your baseline normalization method, you may want to see how the baseline looks beforehand

5) APPLICATION: THE P300 SPELLER

- P300 (*Sutton et al. (1965)*): conscious detection of stimulus
- Used in oddball paradigms: show a series of stimuli but only a small subset (up to 25%) is relevant
- Lin et al. (2018) (and others before them) use this to make a speller (useful for completely locked-in patients who cannot communicate otherwise)
- Their principle: show 3 letters at a time, screen changing rapidly. A P300 component will appear if the target letter is on the screen (no P300 otherwise). Each letter is repeated 3 times, allowing for decoding of the target letter by combining the sequences where a P300 appeared

CONCLUSION

- ERP analysis is simple and can provide interesting insight in linking neural activity to external stimuli or behavior
- It is however not suited for all kinds of activity, and only a very small subset of activity can be extracted
- Complementary analyses can be performed, in particular in the frequency domain, which we will cover in parts in the next lecture

REFERENCES

- Lin, Z., Zhang, C., Zeng, Y. *et al.* A novel P300 BCI speller based on the Triple RSVP paradigm. *Sci Rep* **8,** 3350 (2018). https://doi.org/10.1038/s41598-018-21717-y
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