2021 MEG Training: M/EEG Experimental Design

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Bo-Cheng Kuo

Department of Psychology

National Taiwan University

bckuo@ntu.edu.tw

1. A basic plan for an M/EEG study
   (1) Research question (novelty? Importance?)
   - How information processing is implemented in the brain
   - Technology: Why MEG or EEG?

   (2) Hypothesis (define mental process to examine)
   - Neural hypothesis: postsynaptic potentials
   - Psychological hypothesis: how a given manipulation (independent variables) should change measurements (dependent variables)

   (3) Experiment (design task to manipulate that process):
   - Task-positive or task-negative?
   - Independent variables and dependent variables
   - Between-subject or within-subject (or repeated measure)
   - Tasks (Sufficient number of trials per each cell/condition)?
     (a) Large effect: 30-60
     (b) Medium effect: 150-200
     (c) Small effect: 400-800
     (d) Double with children or patients
   - Trial structure and events codes
   - Designs: event-related, block and resting.
     (A) Event-related design: events are mixed (or jittered) with relatively shorter intervals (relative to fMRI design)
     (B) Block design: frequency-tag or SSVEP (steady-state visually evoked potential)
     (C) Resting state

   (4) Data acquisition (measure M/EEG and behavioural data)
   - Operating status of the system and set-up (check trigger and timing)
   - Preparation of the participant (HPI, EOG, and ECG)
   - General acquisition setup
     (a) Eye movements and blinks
     (b) ECG (or EKG)
     (c) Head movements
     (d) Anatomical MRI (if source localisation is part of planned analysis)

(5) Analyses, statistics and inferences (according to the design, extracting signals based on the stimulus event of interest)
- Sensor-based data analysis:
  (a) Event-related potential or magnetic field (ERP or ERMF)
  (b) Spectral analysis: evoked/induced oscillation (power and phase)
- Source-based data analysis:
  (a) Source localisation for ERP/ERMFs
  (b) Source localisation for oscillations
  (c) Functional and effective connectivity analyses

2. Experimental design considerations
(1) What should we control?
- Stimulus properties
- Stimulus timing
- Inter-stimulus or -trial interval (randomisation)
- Whenever possible (if event-related), conditions/tasks/stimuli should be varied within blocks rather than between blocks
- Instructions
- Responses
- Noises (internal and external)
  (a) Trial-by-trial variations
  (b) Artifacts (eyes-closed alpha, eye blinks and movements, muscle activity, skin potentials, etc.)
  (c) Environmental noise

(2) Combined techniques: MEG+fMRI, MEG+EEG

3. Other considerations
(1) Participants: metal-free, large numbers (as many as possible), sleepy, training.
(2) Amplifier and filter settings.
(3) Experimental time: about 60 minutes (given whole session is about 1.5-2 hours).
(4) Multiple runs with short breaks (recording limitation approximately 10 mins for a run).
(5) Always look at the M/EEG recording throughout the experiment.
(6) Keep participants happy. Talk to them during break.
(7) Do a proper analysis for the first participant's data before running anyone else. Check event codes.

4. Design strategies
(1) Keep the experiment as simple as possible
(2) Probably need additional experiments
(3) Focus on specific (or large) effects (e.g. ERP/ERMF or frequency band)

(4) Use well-studied experimental manipulations
(5) Large trial numbers, few conditions
(6) Avoid confounds
(7) Decide in advance the key experimental comparisons of interest

Recommendations for reading:

1. MEG: An introduction to methods, Oxford University Press, 2010
2. Luck, S. J. (2014). An introduction to the event-related potential technique. Cambridge, MA: MIT Press.
3. Gross et al. (2013). Good practice for conducting and reporting MEG research. NeuroImage, 65, 349-363.
4. Lopes da Silva (2013). EEG and MEG: Relevance to Neuroscience. Neuron, 80, 1112-1128.
5. Pernet et al. (2020). Issues and recommendations from the OHBM COBIDAS MEEG committee for reproducible EEG and MEG research. Nature Neuroscience, 23, 1473-1483.