BASICS OF SINGLE-DIPOLE AND DISTRIBUTED-SOURCE IMAGING

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OVERVIEW

• Forward solution and inverse problem
• Dipole fitting
• Distributed-source imaging methods
  • Nonadaptive
  • Adaptive
• Limitations & considerations
“Source-space imaging approaches...define sets of weights per electrode such that the weighted sum of all electrodes is an estimate of activity emanating from some physical location in the brain”
24.1 - THE FORWARD SOLUTION

• What is the scalp topography given a particular signal generated in the brain?

• With or without M/EEG data

• Factors
  • Head model: perfect sphere or anatomically measured
  • Electrode positions: standard montage or measured

• Role of dipolar signal
  • X-, y-, z-axes
24.2 - THE INVERSE PROBLEM

- Given scalp EEG topography, what are the most likely location(s), [dipolar] orientation(s), and magnitude(s) of brain source(s)?

- Theoretically, no single solution

- Practically, methods for estimating best solution require several assumptions/parameters
LET’S BESA!
24.3 – DIPOLE FITTING

- Single point or small # of points that explain maximal amount of topographical variance
- Typically done on one time-point or window average
- **Pro**: helpful for data reduction (thoughts?)
- **Con**: assume that single dipole is the only source of brain activity
24.4 – NONADAPTIVE DISTRIBUTED-SOURCE IMAGING METHODS

• Many dipoles with fixed locations and orientations, so only estimate magnitude(s)
  • Define set of electrode weights for each source location

• Pro:
  • Fast
  • Apply to single time point
  • Produce cool-looking maps like fMRI

• Con:
  • Statistical considerations/complications

• Example: (s)LORETA
RESEARCH EXAMPLE
PRIOR STUDIES ON THETA & SLEEPINESS

- Finelli et al. (2000), Neuroscience
- Tinguely et al. (2000), NeuroImage
THETA & SLEEP HOMEOSTASIS

Spectral power

Correlation w/ sleep SWA

Plante, Goldstein et al. (2013), J Affect Disord
Do individuals who report having higher sleep disturbance show greater frontal source-estimated waking theta activity compared to those with lower sleep disturbance?
**PRESENT STUDY – “GEEG” DATASET**

- **Participants**
  - **N=313 total** (N=143 with history of MDD, N=163 without Hx of MDD, N=7 with unique Hx of dysthymia)
  - Excluded if Axis I diagnosis other than MDD or dysthymia
  - Age: 19.2 ± 2.0 (range: 17-34)

- **Design**
  - 4 sessions across 2 weeks; 2 recordings per session = 8 total EEG recordings
  - Eyes-closed, 4-minutes per recording
  - 64-channel EEG w/ semi-automatic artifact rejection followed by sLORETA source modeling procedures
  - BDI-II at each session (4 times total)

- **Measures for analysis**
  - Sleep item on BDI-II
  - Average source modeled EEG in theta range (4-8Hz)
BDI-II SLEEP ITEM & SUBGROUP STRATIFICATION

- Sleep disturbance score calculated as average of 4 sessions
- **HIGH sleep disturbance (N=50):** at least 1.5 average score
- **LOW sleep disturbance (N=263):** less than 1.5
- **Insomnia (N=34):** at least 1.5 for “b” responses
- **Hypersomnia (N=16):** at least 1.5 for “a” responses

16. Changes in Sleeping Pattern

0  I have not experienced any change in my sleeping pattern.

1a  I sleep somewhat more than usual.
1b  I sleep somewhat less than usual.

2a  I sleep a lot more than usual.
2b  I sleep a lot less than usual.

3a  I sleep most of the day.
3b  I wake up 1–2 hours early and can’t get back to sleep.
INDIVIDUALS WITH HIGHER SLEEP DISTURBANCE SHOW GREATER FRONTAL THETA

Goldstein et al., in preparation
EFFECTS ARE MORE ROBUST WITHIN THE GROUP WITH A HISTORY OF DEPRESSION

Blue: HIGH sleep-disturbance < LOW

Red: HIGH sleep-disturbance > LOW

Goldstein et al., in preparation
• Compute weights using info about scalp electrode location AND data from those electrodes

• Methods:
  • Covariance of interelectrode activity (similar to PCA)
  • Cross-spectral density
  • Use data from entire window, but then can apply weights to single time points

• Pro: weights are adapted to data

• Con: parameters to be set and consequences for source estimation

• Example: beamforming
• Great idea, although high accuracy is rare
  • Spatial precision is currently 5-10 mm\(^3\) at best

• Some research questions may allow more precision and confidence
  • Example: visual processing paradigms

• EEG vs. MEG source estimations
  • EEG can be as good as, or better than MEG for source estimation due to broader dipole sensitivity
  • However, info for parameter setting (e.g. tissue conductivity) is often better for MEG data