Where it's at: Estimating sources of frontal EEG alpha asymmetry

Ezra E Smith[1], James F Cavanagh[2], and John JB Allen[1]

[1]University of Arizona; [2]University of New Mexico

Summary

Alpha activity in the dlPFC, insula, pre- and post-central gyri, and medial PFC, contributes to surface alpha asymmetry and depression risk.

Background

Frontal EEG alpha asymmetry is related to emotional styles and risk for depression. However, only a handful of PET and fMRI studies have investigated asymmetry across the frontal lobes, and the regions which give rise to frontal EEG alpha asymmetry and depression risk are not well understood.

Method

Participants

- MDD+ participants (N=143) met criteria for a lifetime history of major depressive disorder but no other Axis I disorder besides dysthymia.
- MDD- participants (N=163) never met criteria for major depression or any other Axis-I disorder.

Procedure

Surface data

- 64-channel EEG was recorded 8 times – four days, two sessions each day. Results here include all 8 sessions of eyes-closed resting data (4 minutes per recording session).
- Artifacts were identified visually and with custom MATLAB-based scripts.
- EEG data were transformed to a Current-Source Density (CSD) montage.
- For each session, the average power in the alpha band (8-12Hz) was log-transformed, and homologous electrodes were subtracted from one another to compute an asymmetry score (e.g., Ln[F8] – Ln[F7])

Source estimate (Standardized Low-Resolution Electromagnetic Tomography, sLORETA)

- sLORETA estimated the three-dimensional power (6239 voxels) for the alpha band (8-12Hz) for each session.
- sLORETA estimates were normalized by dividing power at a voxel by the power across all voxels (sum of all voxels = 1)
- Source asymmetry was computed by averaging the alpha power across voxels corresponding to each Brodmann area, then subtracting homologous (right-left) areas.

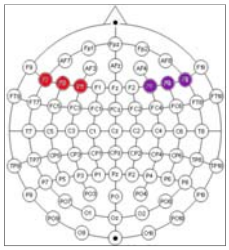
Analyses

- Surface and source asymmetry correlations are based on a participants' grand-averaged data across 8 sessions.
- Spearman rank correlations were used to find Brodmann areas that contributed substantial variance to surface asymmetry ($r \geq .3$, uncorrected $p<.0000001$) .
- Mixed-linear models (MLM) were used to assess the effects of depression on source estimates of asymmetry. MLMs were only computed for Brodmann areas related to surface asymmetry $r \geq .3$. MLMs for depression were conducted on the full dataset: each participants' session was entered as a within-subjects factor.

N=306
8 EEG sessions
143 MDD+
163 MDD-

(1) Collect and process data

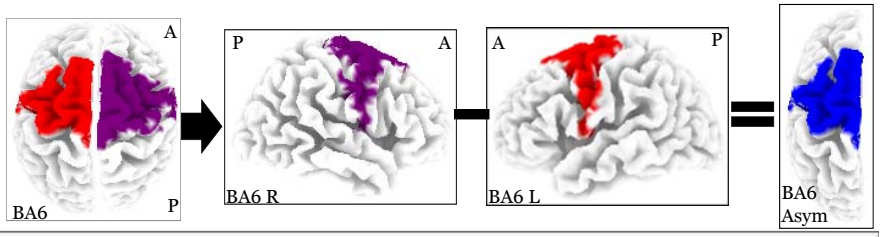
(2) Calculate surface asymmetry
Right sites – Left sites



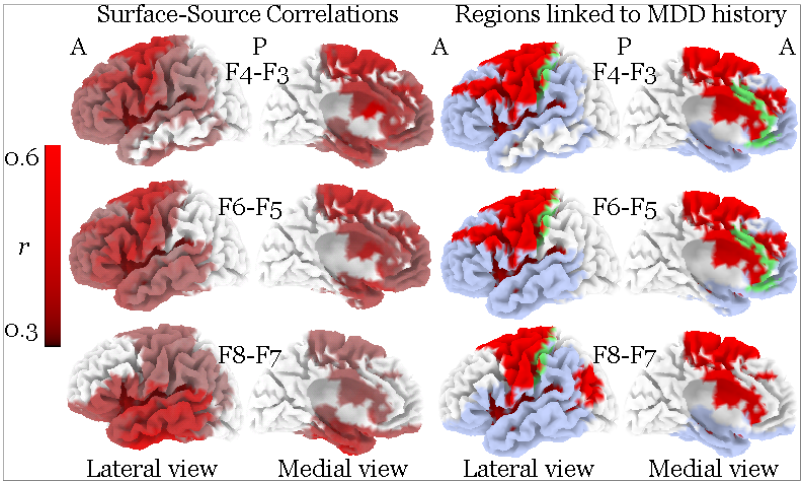
(3) sLORETA source estimates

$$K = \begin{pmatrix} k_{1,1} & k_{1,2} & \dots & k_{1,N_V} \\ k_{2,1} & k_{2,2} & \dots & k_{2,N_V} \\ \dots & \dots & \dots & \dots \\ k_{N_E,1} & k_{N_E,2} & \dots & k_{N_E,N_V} \end{pmatrix}$$

(4) Calculate source asymmetry by subtracting R-L Brodmann's



Results and Discussion



Left panel: Correlations between surface asymmetry and source asymmetry estimates for 3 different pairs of electrode sites (all correlations $r \geq .3$).

Right panel: Blue indicates regions that contributed substantial variance to surface asymmetry ($rs \geq .3$). Less left-than-right activity in MDD+ participants is shown in green ($p \leq .05$) and red areas ($p \leq .01$). Less left-than-right activity is inferred from more left-than-right alpha power.

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Contact: ezrasmith@email.arizona.edu

- **Brain regions related to surface asymmetry and to less left-than-right activity in MDD+**
  - **Postcentral gyrus (BA 1,2,3)**
  - **Precentral gyrus (BA 4)**
  - **Premotor cortex (BA 6)**
  - **Dorsolateral PFC (BA 9)**
  - **Insula (BA 13)**
  - **Rostral cingulate (BA 24,33)**
  - **Dorsal cingulate (BA 32)**
  - **Angular gyrus (BA 39)**
- **Less relative left dlPFC activity in MDD+**
  Less relative left dlPFC activity may indicate reduced approach-oriented cognitive control strategies in MDD+ participants.
- **Insula contributes substantially to surface asymmetry (*rs*>.6)**
  Insula activity has not been previously linked to frontal EEG alpha asymmetry, although it has been linked to depression and anxiety in resting-state fMRI reports.
- **Altered processing of autonomic input in MDD+**
  The left insula receives predominantly parasympathetic afferents, whereas the right insula receives mostly sympathetic afferents. Less relative left insula activity in MDD+ participants may indicate a relative insensitivity to parasympathetic afferents in MDD. This is consistent with our recent work finding decreased BOLD-RSA coupling in the left anterior insula in MDD, and that this BOLD-RSA coupling increases with successful antidepressant treatment.
- **Tonic sensory-motor activity may reveal vulnerability for (or consequence of) low approach motivation and MDD risk**
  Less relative left activity in the medial PFC in strongly right-handed MDD+ participants may indicate diminished action-monitoring perhaps related to behavioral approach. Similarly, activity in the pre- and post-central gyri in a strongly right-handed sample could reflect a reduction in approach motivation in MDD+ participants.