Patterns of State and Trait Regional Brain Activity in Depression Support the Capability Model of EEG Asymmetry

Jennifer L. Stewart[1] , James A. Coan[2], Andrew W. Bismark[1], David N. Towers[3], & John J.B. Allen[1]

[1.] University of Arizona; [2.] University of Virginia; [3.] University of Illinois at Urbana-Champaign

Abstract

Resting frontal electroencephalographic (EEG) asymmetry is a promising marker of risk for major depressive disorder (MDD) and propensities to engage in less approach- than withdrawal-motivated behaviors across situations.

The capability model of individual differences in EEG asymmetry (Coan, Allen, & McKnight, 2006) suggests, however, that brain activity during emotional challenge will provide a stronger index of the capacity for depressed individuals to engage in approach and withdrawal responses when emotion regulation may be needed.

Frontal EEG asymmetry during rest and emotional challenge of approach (anger, happiness) and withdrawal (fear, sadness) was assessed on 4 occasions in 203 individuals age 18-34 (31% male) with (*n* = 93) and without (*n* = 110) a diagnosis of lifetime MDD (MDD+ and MDD-).

Although results for men were not entirely consistent, findings for women were very clear: MDD+ women exhibited greater relative right frontal activity (lower right frontal alpha power) than MDD- women across conditions.

Importantly, EEG asymmetry during the emotional challenge task was a more powerful indicator of lifetime MDD status than resting asymmetry in women, evidence in support of the capability model.

Additionally, MDD+ women displayed lower bilateral alpha power during the emotional challenge conditions than MDD- women, indicating that different mechanisms may underlie patterns of state and trait asymmetry as a function of lifetime MDD status in women.

Introduction

Dispositional Model of EEG Asymmetry:

Frontal EEG asymmetry at rest is thought to reflect individual differences in dispositional style, or a general tendency to engage in approach or withdrawal motivation or behaviors.

For example, less left than right resting frontal EEG activity (e.g., Allen et al., 2004b) may reflect reduced approach motivation and sensitivity to reward that may tap a diathesis toward the development of depression (Davidson et al., 2002). However, this relationship is typically of a small to medium effect size, and with methodological differences across laboratories influencing results (e.g., Allen et al., 2004a; Davidson, 1998; Hagemann 2004).

Capability Model of EEG Asymmetry:

Individual differences in depression should be more powerful during approach and withdrawal emotional challenges than at rest, potentially powerful enough to reduce the influence of methodological differences across labs (Coan et al., 2006).

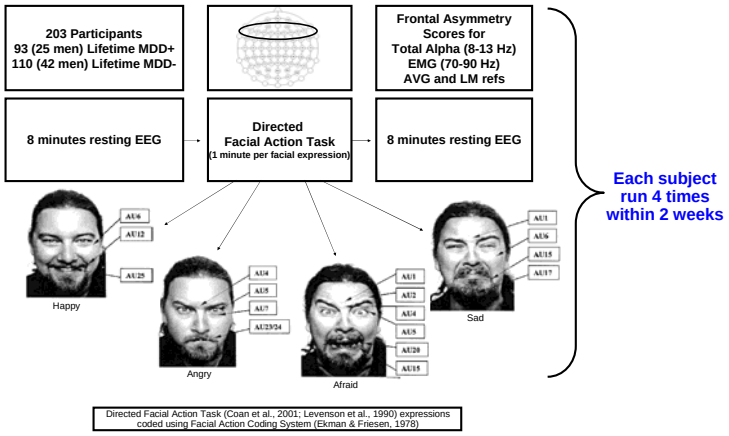
Hypotheses

1) MDD+ participants will display lower relative left frontal activity than MDD- participants across approach, withdrawal, and rest conditions.

2) EEG asymmetry during approach and withdrawal conditions, however, will demonstrate larger differences between MDD+ and MDD- groups than EEG asymmetry at rest, consistent with the capability model of individual differences.

3) EMG activity (70-90 Hz) will not account for pattern of results.

Methods



Directed Facial Action Task (Coan et al., 2001; Levenson et al., 1990) expressions coded using Facial Action Coding System (Ekman & Friesen, 1978)

Data Collection, Reduction, and Analysis:

1K Hz sampling rate (bandpass 0-200 Hz) using online reference just posterior to Cz and then re-referenced offline to average reference (AVG) and averaged ("linked") mastoids (LM).

Data epoched into 117 2.048 s epochs per one-minute block, overlapping by 1.5 seconds, submitted to FFT

Asymmetry scores calculated by subtracting natural log transformed scores (i.e., Ln[Right] – Ln[Left]) for each homologous left and right frontal channel pair. Higher scores = relatively higher left frontal activity (i.e., relatively less frontal alpha; cf. Allen et al., 2004a)

Asymmetry scores computed for both resting sessions and each facial expression (angry, afraid, happy, sad) per day x four days x two references = 48 asymmetry scores per participant per channel pair

Results

EEG Asymmetry

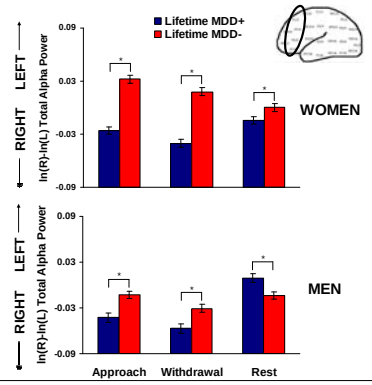
Linear Mixed Model Analysis
(Run for Men and Women separately)

Between-Subjects:
Lifetime MDD (MDD+/MDD-)

Within-Subjects:
Day
Condition (Approach/Withdrawal/Rest)
Session (1=Rest1/Happy/Sad, 2 =Rest2/Afraid/Angry)
Reference (AVG, LM)
Channel (F2-F1, F4-F3, F6-F5, F8-F7)

Dependent Variable:
Total Alpha (8-13 Hz) Asymmetry Score

MDD+ women displayed less relative left frontal activity than MDD- women across all conditions, although DFA approach and withdrawal conditions were a more powerful indicator of MDD status than the rest condition. Men showed a similar pattern of asymmetry as women for the DFA conditions but not for the rest condition.



EMG Residualization

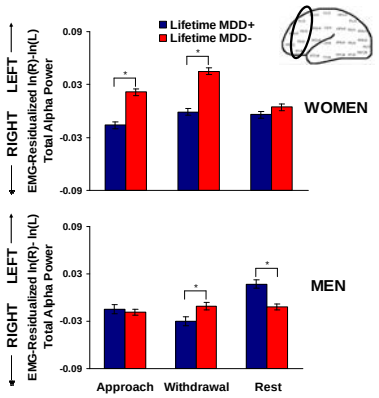
Linear Mixed Model Analysis
(Run for Men and Women separately)

Between-Subjects:
Lifetime MDD (MDD+/MDD-)

Within-Subjects:
Day
Condition (Approach/Withdrawal/Rest)
Session (1=Rest1/Happy/Sad, 2 =Rest2/Afraid/Angry)
Reference (AVG, LM)
Channel (F2-F1, F4-F3, F6-F5, F8-F7)

Dependent Variable:
EMG-Residualized Total Alpha (8-13 Hz) Asymmetry Score (McMenamin et al., 2009)

These results replicated the pattern of results seen in frontal alpha asymmetry, with the exception of approach motivation in men.



Total Power

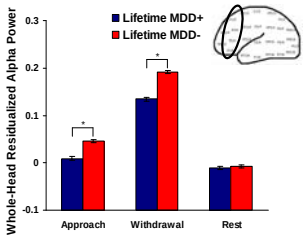
Linear Mixed Model Analysis (Women)

Between-Subjects:
Lifetime MDD (MDD+/MDD-)

Within-Subjects:
Day
Condition (Approach/Withdrawal/Rest)
Session (1=Rest1/Happy/Sad, 2 =Rest2/Afraid/Angry)
Reference (AVG, LM)
Channel (F2-F1, F4-F3, F6-F5, F8-F7)
Hemisphere (Left, Right)

Dependent Variable:
Whole-Head Residualized Total Alpha Power (8-13 Hz)

MDD+ women exhibited less bilateral alpha power than MDD- women for approach and withdrawal conditions.



Discussion

Results for women demonstrate that MDD+ was associated with less relative left frontal activity than MDD- across state emotion and trait resting sessions, consistent with hypotheses. Differences in frontal brain activity between MDD+ and MDD- women were stronger during approach and withdrawal state emotion than during rest, evidence in support of the capability model.

During the state emotion task, men and women showed similar patterns of asymmetry with respect to lifetime MDD, with less relative left frontal activity associated with MDD, consistent with hypotheses. At rest, however, sex-specific patterns emerged, with men showing the opposite relationship of frontal asymmetry to depression, findings consistent with a small literature on sex differences in depression and regional brain activity.

Although EMG activity did not account for the overall pattern of results, consistent with hypotheses, muscle movements did appear to account for MDD+ and MDD- differences for men during approach-related facial expressions, demonstrating that EMG can influence EEG asymmetry.

In summary, both state and trait frontal EEG asymmetry hold promise as a liability indicator for depression in women, although they may be indicators for different mechanisms, as evidenced by bilateral alpha power differences between state emotion and trait conditions.

References

❑ Allen, J.J.B., Coan, J.A., & Nazarian, M. (2004a). Issues and assumptions on the road from raw signals to metrics of frontal EEG asymmetry in emotion. *Biological Psychology, 67*, 183-218.
❑ Allen, J.J.B., Urry, H.L., Hitt, S.K., & Coan, J.A.. (2004b). The stability of resting frontal electroencephalographic asymmetry in depression. *Psychophysiology, 41*, 269-280.
❑ Coan, J.A., Allen, J.J.B., & Harmon-Jones, E. (2001). Voluntary facial expression and hemispheric asymmetry over the frontal cortex. *Psychophysiology, 38*, 912-925.
❑ Coan, J.A., Allen, J.J.B., & McKnight, P.E. (2006). A capability model of individual differences in frontal EEG asymmetry. *Biological Psychology, 72*, 198-207.
❑ Davidson, R.J. (1998). Anterior electrophysiological asymmetries, emotion, and depression: Conceptual and methodological conundrums. *Psychophysiology, 35*, 607-614.
❑ Davidson, R.J., Pizzagalli, D., Nitschke, J.B., & Putnam, K. (2002). Depression: Perspectives from affective neuroscience. *Annual Review of Psychology, 53*, 545-74.
❑ Ekman, P., & Friesen, W.V. (1978). *The Facial Action Coding System (FACS): A Technique for the Measurement of Facial Action*. Palo Alto, CA: Consulting Psychologists Press.
❑ Hagemann, D. (2004). Individual differences in anterior EEG asymmetry: Methodological problems and solutions. *Biological Psychology, 67*, 157-182.
❑ Levenson, R.W., Ekman, P., & Friesen, W.V. (1990). Voluntary facial action generates emotion-specific autonomic nervous system activity. *Psychophysiology, 27*, 363-384.
❑McMenamin, B.W., Shackman, A.J., Maxwell, J.S., Greischar, L.L., & Davidson, R.J. (2009). Validation of regression-base myogenic correction techniques for scalp and source-localized EEG. *Psychophysiology, 46*, 578-592.

The authors wish to thank Jamie Velo, Dara Halpern, Eliza Ferguson, Craig Santerre, Eynav Accortt, Jay Hegde, and a myriad of research assistants for their efforts in recruiting and testing participants, and to thank Jim Coan for his invaluable contributions leading to the receipt of NIMH R01-MH066902, which funded portions of the collection of these data. This work was also funded, in part, by a grant from the NARSAD foundation.

Reprints available from www.psychofizz.org