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Brief report

# Proneness to hypomania predicts EEG coherence between left motor cortex and left prefrontal cortex

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**Abstract**

Previous research has demonstrated that hypomania is associated with approach motivation and activity in the left prefrontal cortex (PFC). Other research has linked left motor cortex excitability to approach motivation, suggesting the existence of connections between the motor cortex and PFC. The present research extends this work using unilateral hand contractions to manipulate contralateral cortical activity, and examining the relationship between motor cortex and PFC inter-electrode EEG coherence and hypomania. Within the right-hand contraction condition, hypomania related to greater connectivity between the left motor cortex and left PFC, relative to connectivity between the left motor cortex and right PFC. No relationships were found within the left-hand condition. The present research provides additional support for the role of the left PFC in bipolar disorder, as well as an important extension of research linking motor cortex excitability to emotion and approach motivation.
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*Keywords:* Bipolar disorder; EEG coherence; Hypomania; Prefrontal cortex (PFC)

Asymmetrical prefrontal cortical activity is associated with motivational direction, with greater relative left prefrontal cortical (PFC) activity relating to approach motivation and greater relative right PFC activity relating to withdrawal motivation (Harmon-Jones, 2004). Activity in the left PFC also relates to bipolar disorder, specifically in approach motivational situations. For example, bipolar spectrum individuals in a manic state exhibit greater relative left PFC activation to challenging and rewarding goal-striving tasks compared to control participants (Harmon-Jones et al., in press). Also, individual differences in hypomania relate to greater relative left frontal cortical activity in response to anger-inducing events (Harmon-Jones et al., 2002).

Research using transcranial magnetic stimulation (TMS) has linked motor cortex excitability to emotion and to approach motivation, suggesting the existence of connections between the motor cortex and frontal cortical regions involved in emotive processes (Hajcak et al., 2007; Schutter et al., in press). One method of manipulating activation over the motor cortex without TMS uses unilateral hand contractions (Schiff et al., 1998; Schiff and Lamon, 1994). Muscle contractions on one side of the body affected emotive outcomes, presumably as a result of activation of the contralateral hemisphere (Schiff et al., 1998). In addition, right-hand contractions, compared to left-hand contractions, caused increased self-reported approach affect to a mildly positive approach-oriented stimulus (Harmon-Jones, 2006), greater behavioral aggression in response to an anger-inducing event (Peterson et al., 2008), and contralateral activations in the central region that spread to the PFC (Harmon-Jones, 2006; Peterson et al., 2008).

The present research utilized the method of unilateral hand contractions to manipulate activations over the central cortical regions. EEG coherence between central regions and PFC was examined and related to hypomania. Coherence measures the degree EEG signals (within a given frequency band) measured at two distinct scalp locations are linearly related to one another. High EEG coherence occurs between regions connected by known white matter tracts (Thatcher et al., 1986).

Previous research examining the effect of unilateral hand contractions on coherence found that while right-hand contractions caused greater motor cortex/anterior site coherence over the left hemisphere, this effect was not found during left-hand contractions (Peterson et al., 2008). Rather, left-hand contractions appeared to cause greater motor cortex/posterior site coherence over the left hemisphere. No effects of hand

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contractions on coherence were found over the right hemisphere.

Based on research demonstrating that right-hand contractions cause increased approach tendencies as well as greater coherence between the motor cortex and left PFC, we predicted that greater motor cortex/PFC coherence over the left hemisphere during right-hand contractions will be associated with proneness to hypomania. No relationships are predicted between hypomania and right motor cortex/PFC coherence, or during left-hand contractions. Additionally, hypomania and frontal alpha power asymmetry may not be correlated, because the hand contractions do not constitute a strong approach motivational situation, as used in past work. That is, although mania was found to relate to increased relative left frontal activity at resting baseline in one study (Kano et al., 1992), this relationship has not been replicated in two other studies (Harmon-Jones et al., 2002, in press). However, these latter two studies revealed that mania was associated with increased relative left frontal activity during approach motivational situations. These results are consistent with the capability model of frontal EEG asymmetry and personality, which posits that there are meaningful individual differences in approach and withdrawal tendencies, but these differences are best elicited in specific situations (Coan et al., 2006).

## 1. Method

### 1.1. Participants and design

Thirty-eight right-handed female introductory psychology students at Texas A&M University participated in exchange for course credit. A review of unobtrusive video recorded during the hand contractions indicated that two participants did not follow instructions and thus were removed from analyses, so that $n = 36$ (right hand: $n = 17$; left hand: $n = 19$).

### 1.2. Procedure

Participants were instructed to squeeze a ball as hard as they could with their right or left hand while their opposite hand remained flat with the palm facing down; hand contraction assignment was determined randomly and experimenters were blind to condition. Four 45 s contraction trials occurred with a 15 s relaxation period between each trial. The same procedure was used in Harmon-Jones (2006), Peterson et al. (2008), and Schiff et al. (1998). EEG was recorded during contractions. Then, participants completed a 15-question version of the hypomanic personality scale (HYP; Eckblad and Chapman, 1986; Klein et al., 1996). High scores on this HYP are associated with elevated rates of manic symptoms (Klein et al., 1996). Sample items include "In unfamiliar surroundings, I am often so assertive and sociable that I surprise myself" (true), and "I have often been so excited about an involving project that I did not care about eating or sleeping" (true).

### 1.3. Data collection and reduction

EEG was recorded from 27 tin electrodes mounted in a stretch-lycra electrode cap (Electro-Cap, Eaton, OH). The reference electrode was placed on the left ear (A1), and data were also acquired from an electrode on the right ear (A2), so that an off-line, averaged ears' reference could be computed. Vertical and horizontal eye movements (EOG) were also recorded to facilitate artifact correction of the EEG. All electrode impedances were under 5000 Ω, and homologous sites were within 1000 Ω of each other.

EEG and EOG were amplified (60 Hz notch filter) with Neuroscan Synamps (El Paso, TX), bandpass filtered (.1–100 Hz) and digitized at 500 Hz. The signals were visually scored and portions of the data that contained artifacts were removed. Then, a regression-based eye movement correction was applied (Semlitsch et al., 1986), after which the data were again visually inspected. All epochs 1.024 s in duration were extracted through a hamming window.

Coherence, the magnitude of squared coherency, was computed for the alpha band (8–13 Hz; no normalization; mean excluded) using Neuroscan software version 4.3 (El Paso, TX) for all four 45 s periods of hand contraction. Alpha power was used because it has been found to relate inversely with cortical activity and it is the frequency band used in past frontal asymmetry and emotive research. Coherence estimates then were square-root transformed, to more closely resemble the absolute value of Pearson correlation coefficients, and natural log transformed to normalize the distribution. Asymmetry indexes for frontal regions (mid-frontal (F3/4), lateral frontal (F7/8), frontal-temporal (Ft7/8), and frontal-central (Fc3/4)) and parietal region (P3/4; for comparison purposes) were then computed for each motor cortex hemisphere (C3/C4) by subtracting coherence between the motor cortex and right electrode from coherence between the same motor cortex and left electrode.[1] For example, the variable C3F3 coherence minus C3F4 coherence taps left motor – left PFC coherence relative to left motor – right PFC coherence. For all variables, higher scores indicate greater coherence between the motor cortex and the left electrode. Indexes were computed in this manner in order to control for the dynamic relationship between the left and right frontal cortices. That is, previous research using lesion patients (e.g. Robinson and Downhill, 1995) and TMS (Schutter et al., 2001) has revealed that the inactivation of one frontal hemisphere causes an over-activation of the opposite frontal hemisphere. These results suggest that each frontal hemisphere may regulate the other. Additionally, controlling for coherence between each motor cortex and the opposite hemisphere frontal electrode may tighten the specificity to coherence between electrodes of the same hemisphere. This process is similar to estimating partial coherence, which controls for volume conduction that may cause erroneous high coherence (Nunez et al., 1997). Partial coherence estimates are most useful when applied to specific hypotheses, such as those made in the present study (Nunez et al., 1997).

Asymmetry indexes were also created to examine relationships with EEG alpha power by subtracting the natural log of the right site from the natural log of the left site. Because alpha power is inversely related to cortical activity, higher scores indicate greater relative left than right cortical activity (Davidson et al., 2000). Because all *a priori* comparisons were directional and were derived from theory, which was based on past research, they were evaluated using a one-tailed criterion of significance (Hayes, 1988; Rosenthal et al., 2000)

## 2. Results

Zero-order correlations were computed within each condition to test our prediction of a relationship between proneness to hypomania and left motor cortex/relative left PFC coherence during right-hand contractions. Although correlations between hypomania and motor cortex/relative left frontal coherence were predicted based on prior research, the correlations involving the parietal region were not and thus a Bonferroni correction ($p = .0125$) was used.

For those who made right-hand contractions, proneness to hypomania related significantly to left motor cortex/relative left mid-frontal and frontal-central site alpha coherence ($r(15) = .57$, $p < .05$ and $r(15) = .54$, $p < .05$, respectively) (see Fig. 1). Relationships between hypomania and left motor cortex coherence with other frontal sites were positive but not

[1] An alternative method of computation could have been subtracting right motor cortex/right electrode coherence from left motor cortex/left electrode coherence, although this method would not control for volume conduction. No significant relationships with proneness to hypomania were found using this method ($r$'s $< .16$).

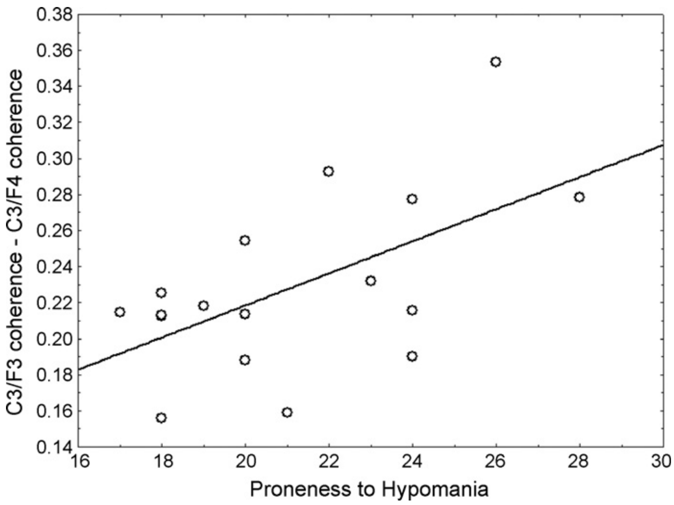


Fig. 1. Proneness to hypomania predicts left motor cortex/relative left mid-frontal site coherence during right-hand contractions.

significant (*ps* > .10). The relationship between hypomania and left motor cortex coherence with the parietal region was not significant ($p = .85$).

Right motor cortex/relative left frontal site coherence did not relate to hypomania (*ps* > .10), and these coherence values were significantly smaller than the left motor—left PFC coherence (mid-frontal: $t(15) = 3.4$, $p < .01$; frontal-central: $t(15) = 2.2$, $p < .05$). Right motor cortex/relative left parietal site coherence did not significantly relate to hypomania ($r(15) = -.48$, $p = .05$).

Additionally, the correlation between hypomania and left motor cortex/relative left mid-frontal site coherence differed significantly from the same relationships over the right motor cortex. See Table 1 for all correlations and *t*-scores for right-hand contractions.

Within the left-hand condition, no significant relationships between proneness to hypomania and motor cortex/PFC coherence occurred (*ps* > .50), and none of the relationships differed between hemispheres (*ps* > .55). In addition, the correlations between proneness to hypomania and left motor cortex/relative left mid-frontal site coherence ($r(17) = .07$, $p > .76$) and between proneness to hypomania and left motor cortex/relative left frontal-central site coherence ($r(17) = -.04$, $p > .86$) were smaller than the same relationships found within the right-hand contraction condition (mid-frontal: $z = 1.54$, $p = .06$; frontal-central: $z = 1.71$, $p < .05$).

Table 1
Zero-order correlations between proneness to hypomania and motor cortex/relative left PFC coherence during right-hand contractions

| Index | Motor cortex | | *t*-Score |
|---|---|---|---|
| | Left | Right | |
| Mid-frontal (F3–F4) | .57** | −.41 | 2.32* |
| Lateral frontal (F7–F8) | .41 | −.10 | 1.16 |
| Frontal-temporal (Ft7–Ft8) | .38 | −.17 | 1.22 |
| Frontal-central (Fc3–Fc4) | .54* | −.41 | 2.10* |
| Parietal (P3–P4) | .05 | −.48 | 1.22 |

*$p < .05$, **$p < .01$; *t*-scores indicate the difference in relationships between hypomania and right motor cortex/PFC coherence and hypomania and left motor cortex/PFC coherence, and were computed using formula recommended by Steiger (1980).

Zero-order correlations were also computed within-condition to examine the relationship between proneness to hypomania and EEG alpha power asymmetry. No significant relationships emerged in either condition (*ps* > .20).

## 3. Discussion

As predicted, greater connectivity between the left motor cortex and left PFC relative to connectivity between the left motor cortex and right PFC was associated with hypomania when the left motor cortex was activated by contralateral hand contractions. Motor cortex/parietal site coherence did not relate to hypomania, and no relationships were found between EEG coherence and proneness to hypomania during left-hand contractions. Additionally, no relationships were found between proneness to hypomania and EEG alpha power asymmetry. We would not necessarily expect the latter relationship, as the contraction of the hand muscles does not constitute a strong approach motivational situation as used in past work (Harmon-Jones et al., 2002, in press). That is, a right-hand contraction may ''prime'' approach motivation but evidence of this prime would only be seen given an approach motivation situation (Peterson et al., 2008).

These results suggest that individuals with hypomania have strong connectivity between the left motor cortex and left PFC. That this effect is only evident during right-hand contractions suggests that the activation in the left motor cortex associated with the muscle contraction is an important part of this relationship. Perhaps the appetitive behaviors associated with hypomania and activation of the left PFC, such as goal-striving and reward responsiveness (Harmon-Jones et al., in press), requires close connectivity with the motor cortex. Greater coherence between these regions may facilitate activation of approach ''motor''-vational behaviors, a notion consistent with research suggesting that individuals with hypomanic/manic tendencies show greater approach motivation sensitivity (Harmon-Jones et al., 2002, in press; Meyer et al., 1999; Nusslock et al., 2007). While the results are preliminary given that they are based on a small sample of only female participants, the present research extends recent work suggesting close connections between the motor cortex and frontal cortical regions (Hajcak et al., 2007; Schutter et al., in press) to an enhanced understanding of the neural circuitry underlying hypomania.

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