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Unilateral right-hand contractions cause contralateral alpha power suppression and approach motivational affective experience

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Abstract

Contractions of the left hand induce sadness and bias judgments negatively, whereas contractions of the right hand induce positive affect and assertiveness and bias judgments positively. These results have been explained as resulting from activation of right and left frontal cortices, respectively. However, no research has tested this explanation. The present experiment provided such a test by having participants contract the right or left hand while electroencephalographic activity was recorded. Results indicated that right-hand contractions produced greater left than right frontal activity, whereas left-hand contractions produced greater right than left frontal activity (inverse of alpha power). Similar activations occurred in central regions, perhaps due to mu rhythms. Moreover, as compared to left-hand contractions, right-hand contractions caused greater self-reported approach affect to a mildly positive radio editorial.

Descriptors: Asymmetrical frontal cortical activity, EEG, Alpha, Positive affect, Mu rhythm, Hand contraction

The cerebral lateralization of emotional and motivational functions is supported by much past research. For instance, contractions of the left hand and of the left side of the lower third of the face induce sadness and bias perceptions and judgments negatively. In contrast, contractions of the right hand and of the right side of the face induce positive affect and assertiveness and bias perceptions and judgments positively (Schiff & Lamon, 1989, 1994). Other research has found that as compared to left-sided contractions, right-sided contractions caused greater persistence in attempting to solve insoluble problems (Schiff, Guirguis, Kenwood, & Herman, 1998).[1]

The effects of contractions of muscles on one side of the body affecting emotional and motivational outcomes have been explained as a result of activation of the contralateral hemisphere. Innervation of facial muscles in the lower third of the face (Rinn, 1984) and of muscles in the hand is contralateral (Hellige, 1993). Thus, it has been assumed that the emotional and motivational outcomes produced by the contractions resulted from the spread of activation to, or recruitment of, contralateral frontal areas (Schiff & Lamon, 1989, 1994).

Consistent with this assumption, other research has found that approach motivational traits and states are related to greater relative left frontal cortical activity, whereas withdrawal-related traits and states are related to greater relative right frontal activity (Harmon-Jones, 2003). Depression and trait negative activation have been found to relate with greater relative right frontal activity during resting, baseline sessions (Field et al., 2000; Tomarken, Davidson, Wheeler, & Doss, 1992). In contrast, trait approach motivation sensitivity, trait positive activation, and trait anger have been found to relate with greater relative left frontal activity during resting sessions (Harmon-Jones, 2004; Harmon-Jones & Allen, 1997; Tomarken et al., 1992). In experimental research, approach motivated states, such as those evoked during certain types of positive affect and anger, have been found to cause increases in relative left frontal cortical activity (Coan, Allen, & Harmon-Jones, 2001; Harmon-Jones, Sigelman, Bohlig, & Harmon-Jones, 2003; Jones & Fox, 1992). Withdrawal motivated states, such as those evoked during disgust, have been found to cause increases in relative right frontal activity (Jones & Fox, 1992). These effects have been found to be specific to the frontal cortices and have been assessed using EEG alpha power, among other methods (Pizzagalli, Shackman, & Davidson, 2003). Recent source localization research on EEG alpha power over the frontal cortices has suggested that the frontal activations related to emotion and motivation are due to activations in the dorsolateral prefrontal cortex (PFC; Pizzagalli, Sherwood, Henriques, & Davidson, 2005).

Research on mu rhythm, an EEG oscillation with dominant frequencies in the 8–13-Hz band, suggests that contraction of unilateral muscles is associated with activation of the contralateral motor cortex (Andrew & Pfurtscheller, 1997; Pineda, 2005). This motor cortex activation might then spread to frontal areas, via cortio-cortical connections between the

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[1]Right-handed individuals participated in all research on body manipulations and asymmetrical cortical activations.

motor cortex and dorsolateral PFC, and cause these approach/withdrawal motivations.

The present research sought to link the body manipulation and emotion research literature with the research assessing asymmetrical frontal cortical activity in response to emotive manipulations. These two literatures have yet to be directly empirically integrated. To accomplish an empirical integration, the present research examined (1) whether right-sided muscular contractions caused greater relative left cortical activations (and vice versa), over central and frontal regions and (2) whether such contractions affected emotional reactions to a mildly positive and approach-oriented stimulus.

Methods

Participants and Design

Participants were 28 right-handed introductory psychology students (14 men) who participated in exchange for extra credit. No significant effects of gender emerged for any of the tests. The design was a two-condition between-subjects design.

Procedure

Participants were informed that the study concerned how various body and muscle movements affect the way in which information is processed. Written instructions, which the experimenter could not see, were presented to the participant over a computer monitor. Participants were randomly assigned to hold a ball (5-cm diameter) in either their left or right hand. Modeled after Schiff et al. (1998), the instructions told participants to squeeze the rubber ball as hard as they could, to remain still and look straight ahead while squeezing, and to pay attention to feelings and sensations experienced while squeezing the ball. The computer monitor signaled when they should start and stop squeezing the ball. Squeezing occurred for 45 s, followed by a 15-s rest. Then, another 45-s squeeze and 15-s rest occurred.

The computer then presented written information about a "Pilot Radio Broadcast" entitled "Where to Live?" It stated: "The question of where to live the following school year is an issue for most students. . . . In this broadcast, a senior . . . gives his opinions and advice regarding a variety of living options around campus. After hearing this editorial, you will evaluate it."

Once participants let the experimenter know they were done reading, the experimenter instructed participants to squeeze the ball continuously during the broadcast. The broadcast was 2 min 30 s long, and in it, a student discusses the pros and cons of living in three different areas around the university. In a mildly upbeat tone, he ends the editorial saying, "It's never too early to start thinking about where you want to reside for the next school year. Whether it is the West side of campus, East side of campus, or dorm life that you choose, you are sure to have a great time as a student."

When the broadcast finished, participants reported their emotional reactions (0 = *not at all*; 8 = *most in my life*), on a questionnaire that included items to assess approach affect (enthusiastic, active, interested, strong, excited, determined, inspired, alert, proud), anger (hostile, angry, irritated, agitated, frustrated), sadness (sad, hopeless, down, depressed), guilt (guilty, ashamed), and happiness (happy). The approach affect subscale measures approach motivational states regardless of emotional valence (Harmon-Jones, Vaughn-Scott, Mohr, Sigelman, & Harmon-Jones, 2004; Harmon-Jones et al., 2006). Other questions were included to bolster the cover story. In debriefing, no participants guessed the hypotheses being tested.

EEG Assessment and Processing

EEG was assessed during the two 45-s contraction periods. Fourteen electrodes mounted in a stretch-lycra electrode cap (Electro-Cap, Eaton, OH) were placed on the participant's head in the following locations: mid-frontal (F3, F4), lateral frontal (F7, F8), temporal (T3, T4, T5, and T6), central (C3, C4, and Cz), and parietal (P3, P4, and Pz). A ground electrode was mounted in the cap near the frontal pole. The reference electrode was placed on the left ear, and data were acquired from an electrode placed on the right ear, so that an off-line averaged ears' reference could be computed. Vertical eye movements were recorded from the supra- and suborbit of the left eye to facilitate artifact scoring of the EEG. All electrode impedances were under 5000 Ω, and homologous sites were within 1000 Ω of each other. Electro-Gel (Eaton, OH) was the conducting medium. Signals were amplified with Contact Precision Instruments EEG8 amplifier units (Cambridge, MA), bandpass filtered (0.1–100 Hz; 60-Hz notch filter enabled), and digitized at 500 Hz.

Portions of the data that contained eye-movement or muscle artifacts were removed manually (Harmon-Jones & Allen, 1998). All epochs 1.024 s in duration were extracted through a Hamming window. Contiguous epochs were overlapped by 75%, to minimize loss of data due to windowing. A fast Fourier transform was used to calculate the power spectra. These power values were averaged across epochs of the two 45-s periods (no significant effects involving time period emerged and thus the two periods were combined; M number of epochs = 78.77). Total power within the alpha (8–13 Hz) band was obtained, though both lower and upper alpha were examined, as some work suggests that low-frequency alpha power is more consistently related to affective constructs than high-frequency alpha (Davidson, Marshall, Tomarken, & Henriques, 2000). Asymmetry indexes (log right minus log left alpha power) were computed for all homologous sites. Because alpha power is inversely related to cortical activity (Lindsley & Wicke, 1974), higher scores indicate greater relative left hemisphere activity.

Results

Hand contractions were predicted to cause asymmetrical cortical differences at mid-frontal and central scalp sites. Results confirmed this prediction, indicating that the right-hand contraction caused greater relative left frontal and central activity than the left-hand contraction. See Table 1.

A MANOVA for all other asymmetry indexes revealed a significant effect for hand, Wilks lambda = .64, $F(4,22) = 3.08$, $p < .04$, partial $\eta^2 = .36$. It indicated that the right-hand contraction, as compared to the left-hand contraction, caused greater relative left hemispheric activation. ANOVAs revealed significant effects of hand in anterior temporal and parietal regions. See Table 1.

To explore the asymmetry effects, 2 (right, left hand contraction) between-participants × 2 (right, left hemisphere) within-participant ANOVAs were performed on each significant asymmetry. In each of these ANOVAs, no main effects were significant, but all interactions were. The interactions produced the same Fs as displayed in Table 1. For the mid-frontal region, the interaction indicated that the right-hand contraction produced greater left than right mid-frontal activity, whereas the left-hand contraction produced greater right than left mid-frontal activity. For anterior temporal activity, the interaction indicated that the left-hand contraction caused greater right than left

Table 1. *Mean (SD) Asymmetry Scores as a Function of Hand Contraction and Region*

Region	Hand contraction: Left	Hand contraction: Right	*F* test and effect size *r*
Mid-frontal	– 0.0324 (0.051)	0.035 (0.065)	$F(1,26) = 9.32$, $p = .005$, $r = .51$
Lateral frontal	– 0.0347 (0.103)	– 0.024 (0.228)	$F(1, 26) = .03$, $p = .87$, $r = .004$
Anterior temporal	– 0.0933 (0.107)	0.047 (0.227)	$F(1, 26) = 4.57$, $p = .04$, $r = .39$
Central	– 0.0674 (0.099)	0.102 (0.176)	$F(1, 26) = 10.19$, $p = .004$, $r = .53$
Parietal	– 0.0725 (0.065)	0.042 (0.129)	$F(1, 25) = 8.70$, $p = .007$, $r = .51$
Posterior temporal	– 0.0423 (0.165)	0.069 (0.245)	$F(1, 26) = 2.03$, $p = .17$, $r = .27$

Note: Asymmetry scores were created such that higher scores indicate greater relative left hemisphere activation.

anterior temporal activity. However, the right-hand contraction did not cause a difference in activity between right and left anterior temporal regions, $p > .34$. For central activity, the interaction indicated that the right-hand contraction caused greater left than right central activity. However, the left-hand contraction only caused a marginally significant difference in activity between right and left central regions, $p < .08$.[2] For parietal activity, the interaction indicated that the left-hand contraction caused greater right than left parietal activity.[3] However, the right-hand contraction did not cause a difference in activity between right and left parietal regions, $p > .14$. See Table 2.

To further explore the most significant asymmetry effects, an analysis of low versus high alpha power was conducted. In this 2 (hand contraction) $\times$ 3 (region: mid-frontal, central, parietal) $\times$ 2 (low alpha, high alpha) MANOVA, a significant effect of hand contraction emerged, $F(1,21) = 10.77$, $p < .01$, partial $\eta^2 = .34$. No other significant effects emerged, $p\text{s} > 18$. It is interesting and important to note, however, that follow-up univariate tests revealed that the largest *F* emerged in low alpha in the central region, $F(1,21) = 8.45$, $p < .01$. All other *F*s were 6.0 or less. Although these effects do not differ from one another, they are consistent with the idea that the hand contraction should exert strong effects at central regions, which are over the motor cortex.

For self-reported emotions, a MANOVA revealed a significant effect of hand, Wilks lambda $= .62$, $F(5,22) = 2.74$, $p < .05$, partial $\eta^2 = .38$. For approach affect, the right contraction condition produced greater approach affect ($M = 3.74$, $SD = 1.62$) than the left contraction condition ($M = 2.47$, $SD = 1.24$), $F(1,26) = 5.50$, $p < .05$, $r = .42$. None of the other emotions differed between conditions, $p\text{s} > .35$. Grand means (and *SD*) for each emotion were: sadness = 0.53 (0.77); guilt = 0.21 (0.63); happiness = 3.52 (1.84); anger = 0.96 (1.26).

Within-condition correlations were examined to assess whether approach affect related to asymmetry indices. These indices were used because they control for skull thickness and volume conduction, which could affect the alpha power observed at a single electrode site. Within the right-hand condition, approach affect related to greater relative left activity (low alpha) at mid-frontal sites, $r = .58$, $p < .05$. See Figure 1. Within the right-hand condition, all other correlations of approach affect and asymmetry indices were not significant, were negative, and were significantly different from the one obtained between approach affect and greater relative left activity at mid-frontal sites, $t\text{s} > 2.07$, $p\text{s} < .05$. Within the left-hand condition, no correlations were significant, all were negative, and all were significantly different from the one obtained between approach affect and greater relative left activity at mid-frontal sites in the right-hand condition, $z\text{s} > 1.88$, $p\text{s} < .05$.[4] These results support the hypothesis that the increase in relative left frontal cortical activation brought about by right-hand contraction was related to more self-reported approach affect.

Because the hand contractions likely suppressed mu rhythms (which are in the alpha frequency band) over contralateral central regions, it is important to assess whether the asymmetrical *frontal* cortical effects are directly related to the alpha activations over the central regions and thus only reflect mu rhythms. On the other hand, it is possible that the activation of the mu rhythms over the contralateral central regions activated ipsalateral dorsolateral PFC regions via cortico-cortical connections. Consequently, the central and frontal alpha activations may not be identical. In other words, the central motor activations may have caused activations of the "motivational regions" of the dorsolateral PFC. The activation of this region, in turn, led to the generation of motivated perceptual and cognitive responses that may have further activated the dorsolateral PFC. Recall that while participants performed the hand contraction, they did nothing else for those 90 s. Thus, it is possible that approach motivational percepts, memories, and other things unrelated to the experiment were activated by the right-hand contraction during this 90-s period. Then, when participants were confronted with the approach-oriented stimulus of the experiment, their already activated approach motivational system responded to it with greater approach affect.

To examine whether the central and frontal activations were identical and not somewhat independent, a regression analysis was conducted. It revealed that when central alpha asymmetry (where mu is maximal) and hand contraction condition were entered as predictors of mid-frontal alpha asymmetry, hand contraction was the only significant predictor, $\beta = .37$, $t(25) = 1.88$, $p < .04$ (one-tailed). The central alpha asymmetry was positively related to mid-frontal alpha asymmetry but was not significant in this regression, $\beta = .28$, $t(25) = 1.44$, $p > .15$. An additional regression in which parietal alpha asymmetry and hand contraction predicted mid-frontal alpha asymmetry also revealed that only hand contraction was a significant predictor,

[2]This marginally significant effect may be due to low statistical power. Most past unilateral body movement and EEG studies used within-subject designs, whereas the present one used a between-subjects design.

[3]One participants' parietal data were not analyzed because of a bad electrode.

[4]Examination of correlations of F3 and F4 low alpha power with approach affect revealed that neither was significant. This result is consistent with past research suggesting that the difference between left and right frontal activation is more related to affective and motivational variables than are independent activations of left or right frontal cortical regions (Harmon-Jones et al., 2002).

Table 2. *Mean (SD) Log Alpha Power as a Function of Hemisphere, Hand Contraction, and Region*

Region	Left hand		Right hand	
	Left hemis.	Right hemis.	Left hemis.	Right hemis.
Mid-front	$-0.653\ (0.407)_a$	$-0.685\ (0.403)_b$	$-0.911\ (0.348)_b$	$-0.876\ (0.347)_a$
Ant. Temp.	$-0.913 (0.466)_a$	$-1.006\ (0.488)_b$	$-1.161\ (0.357)_a$	$-1.114\ (0.438)_a$
Central	$-0.622\ (0.479)_a$	$-0.689\ (0.480)_a$	$-0.883\ (0.356)_b$	$-0.781\ (0.456)_a$
Parietal	$-0.369\ (0.519)_a$	$-0.442\ (0.490)_b$	$-0.639\ (0.436)_a$	$-0.597\ (0.494)_a$

Notes: Lower scores indicate greater cortical activation within the specified region. Within hand and region, means with different subscripts are significantly different, $p < .05$.

$\beta = .37$, $t(24) = 1.91$, $p < .04$ (one-tailed). In addition, parietal alpha asymmetry was positively related to mid-frontal alpha asymmetry but was not significant in this regression, $\beta = .30$, $t(24) = 1.56$, $p > .12$. These results suggest that the mid-frontal asymmetry effect produced by the hand contraction manipulation is somewhat independent of the other asymmetry effects.

Discussion

The present research found that the unilateral contraction of the hand increased the activation of the contralateral hemisphere, as measured by EEG alpha suppression. It also demonstrated that the hand contraction manipulation affected approach-oriented emotion, with the right-hand contraction causing greater approach emotion than the left-hand contraction. Finally, in the right-hand condition, approach affect related to greater relative left frontal activity (inverse of low alpha) at mid-frontal sites, but not other sites. These effects were predicated on the basis of two lines of research that had yet to be empirically integrated: (1) research that had found that contractions of muscles on the right (left) side of the body caused greater approach- (withdrawal-) oriented perceptions and behaviors, and (2) research that found that approach (withdrawal) motivated states and traits were related to greater relative left (right) frontal cortical activity.

The hand contraction manipulation used in the present experiment may have affected mu rhythm in addition to, or rather than, alpha. Distinguishing the two waves has proved difficult, as both occur within 8–13 Hz. Some have suggested that mu rhythm involves higher alpha frequencies but others have questioned this (Pineda, 2005). Source localization methods have suggested that mu rhythm originates in different areas than alpha; however, source generators could not be determined in the present experiment because too few electrodes were available. Because the present research was predicated on the literature suggesting that asymmetrical frontal alpha power relates to approach/withdrawal motivation, and because the mu-rhythm research had not suggested asymmetrical involvement of mu with motivational direction, the present findings are interpreted in light of the past work on frontal alpha asymmetry and motivation. It is possible that the hand contractions caused activation of mid-frontal regions, via cortico-cortical connections between the motor cortex and dorsolateral PFC. This activation of the dorsolateral PFC, in turn, might ready the participants for the mildly approach-motivating stimulus and cause those who contracted the right hand to respond with more approach affect to the stimulus. Future work should assess source localizations in combination with analyses of alpha phase/intersite (or intersource) synchrony, in addition to power analyses, as these analyses may help to better understand the functional relevance of the oscillations under consideration.

Perhaps the results for self-reported approach affect occurred for reasons other than the relative activation of left as compared to right frontal regions. For instance, people are stronger with their dominant hand, and so the effort involved with squeezing of a ball for several minutes with their nondominant hand might have involved greater effort and/or fatiguing of the muscle for the left hand. If this were the case, the affect participants reported would be expected to be more negative. However, in the current experiment, the hand contraction manipulation affected only self-reported approach affect, which is mostly positive. It did not affect sadness, guilt, happiness, or anger. Finally, this alternative explanation does not explain the correlation between relative left frontal activity and approach affect in the right-hand condition. The conceptual perspective on which this research is based does.

In past research, manipulations of emotive states affected asymmetrical cortical activity in frontal regions but not in other regions. In the current research, the unilateral body contractions caused asymmetrical activation in frontal regions as well as central, anterior temporal, and parietal regions. Thus, the past results that indicated that unilateral muscle contractions cause changes in emotive perceptions and behaviors could be interpreted as being due to asymmetrical activations in these other regions. However, such an interpretation would not be consistent with the research in which emotive states have been induced and consequent brain activation was measured, because in this work, only the frontal cortices were affected. This suggests that the neural explanation (i.e., asymmetrical frontal cortical activity) advanced by past researchers for the effects of body contractions

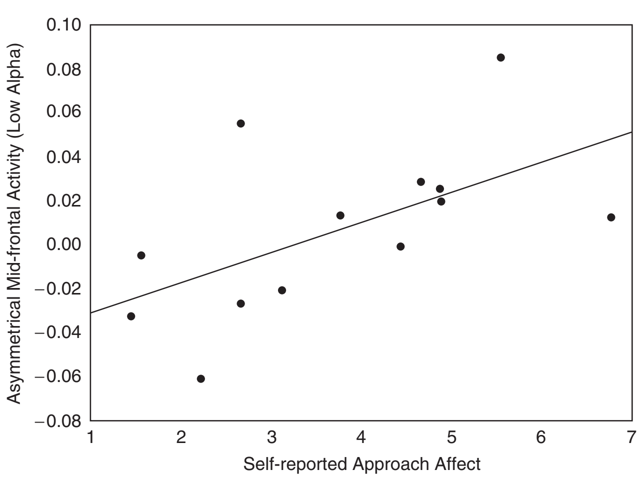

Figure 1. Scatterplot of correlation between self-reported approach affect and relative left mid-frontal activity (low alpha power) in right-hand contraction condition. Higher scores reflect more approach affect and more left than right mid-frontal cortical activity.

on emotive perceptions and behaviors was probably accurate, even though the body contractions affect more areas of the cortex. In addition, the correlational evidence in the present experiment—where only relative left frontal activity related to approach affect in the right-hand contraction condition—is supportive of the idea that emotive responses are due to asymmetrical frontal activations but not other asymmetrical activations.

The current research extends two previous lines of research and suggests an integration of two other lines of research. It provides physiological evidence supportive of the claims that were made by the body manipulation researchers. It also adds to the neuroimaging research, which has largely measured the physiological response (asymmetrical frontal activity) associated with a psychological construct (emotive responses). That is, the present research demonstrates that a manipulation of regional brain activation affects the psychological outcome of affective experience.

In addition, the present results suggest an integration of the frontal alpha asymmetry and emotive research with the mu-rhythm research. Whereas the frontal alpha asymmetry and emotive research has suggested that alpha suppression reflects cortical activation, other research on alpha power has suggested that different tasks and stimulus contexts cause alpha enhancements and/or reductions. That is, alpha reductions are not simply related to cortical activations; whether alpha reductions are related to cortical activations depends heavily on the stimulus context and task. However, as Klimesch, Sauseng, and Hanslmayr (in press) recently suggested, widespread alpha reductions can be expected in simple tasks involving not much top-down inhibition, as in the present experiment. This interpretation fits with the present results and suggests further links of the alpha asymmetry and mu research lines.

It is possible that the activation of both the left motor cortex and left dorsolateral PFC during right-hand contractions may assist in explaining why approach motivational processes are lateralized to the left dorsolateral PFC. That is, perhaps basic approach motivational movements are accomplished more often and/or efficiently via the right hand or right side of the body, as suggested by some prior animal research (Vallortigara & Rogers, 2005). In humans, the relatively close cortico-cortical connections between the left motor cortex and left dorsolateral PFC may assist in the efficient execution of approach motivational processes and behaviors.

Future studies should attempt to further integrate the literatures on mu, alpha asymmetries, and motivation by examining source generators of the central and frontal activations and the cortico-cortical connections between the motor cortex and mid-frontal regions in experimental paradigms in which unilateral body contractions and emotive responses are incorporated. Moreover, whereas much past research has examined hemispheric lateralization of perceptual processes, relatively less research has examined hemispheric lateralization of behavioral responses. The present research integrating mu-rhythm research with asymmetrical frontal cortical research on motivational direction suggests interesting avenues for future research along these lines.

REFERENCES

Andrew, C., & Pfurtscheller, G. (1997). On the existence of different alpha band rhythms in the hand area of man. *Neuroscience Letters*, *222*, 103–106.

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.

Davidson, R. J., Marshall, J. R., Tomarken, A. J., & Henriques, J. B. (2000). While a phobic waits: Regional brain electrical and autonomic activity in social phobics during anticipation of public speaking. *Biological Psychiatry*, *47*, 85–95.

Field, T., Pickens, J., Prodromidis, M., Malphurs, J., Fox, N., Bendell, D., et al. (2000). Targeting adolescent mothers with depressive symptoms for early intervention. *Adolescence*, *35*, 381–414.

Harmon-Jones, E. (2003). Clarifying the emotive functions of asymmetrical frontal cortical activity. *Psychophysiology*, *40*, 838–848.

Harmon-Jones, E. (2004). On the relationship of anterior brain activity and anger: Examining the role of attitude toward anger. *Cognition and Emotion*, *18*, 337–361.

Harmon-Jones, E., Abramson, L. Y., Sigelman, J., Bohlig, A., Hogan, M. E., & Harmon-Jones, C. (2002). Proneness to hypomania/mania or depression and asymmetrical frontal cortical responses to an anger-evoking event. *Journal of Personality and Social Psychology*, *82*, 610–618.

Harmon-Jones, E., & Allen, J. J. B. (1997). Behavioral activation sensitivity and resting frontal EEG asymmetry: Covariation of putative indicators related to risk for mood disorders. *Journal of Abnormal Psychology*, *106*, 159–163.

Harmon-Jones, E., & Allen, J. J. B. (1998). Anger and prefrontal brain activity: EEG asymmetry consistent with approach motivation despite negative affective valence. *Journal of Personality and Social Psychology*, *74*, 1310–1316.

Harmon-Jones, E., Harmon-Jones, C., Abramson, L., Nelson, B. W., Rupsis, M., Burck, A., et al. (2006). PANAS Positive Affect is Associated with State and Trait Anger. Manuscript submitted for publication.

Harmon-Jones, E., Sigelman, J., Bohlig, A., & Harmon-Jones, C. (2003). Anger, coping, and frontal cortical activity: The effect of coping potential on anger-induced left frontal activity. *Cognition and Emotion*, *17*, 1–24.

Harmon-Jones, E., Vaughn-Scott, K., Mohr, S., Sigelman, J., & Harmon-Jones, C. (2004). The effect of manipulated sympathy and anger on left and right frontal cortical activity. *Emotion*, *4*, 95–101.

Hellige, J. B. (1993). *Hemispheric asymmetry: What's right and what's left*. Cambridge, MA: Harvard University Press.

Jones, N. A., & Fox, N. A. (1992). Electroencephalogram asymmetry during emotionally evocative films and its relation to positive and negative affectivity. *Brain and Cognition*, *20*, 280–299.

Klimesch, W., Sauseng, P., & Hanslmayr, S. (in press) EEG alpha oscillations: The inhibition-timing hypothesis. *Brain Research Reviews*.

Lindsley, D. B., & Wicke, J. D. (1974). The electroencephalogram: Autonomous electrical activity in man and animals. In R. Thompson & M. N. Patterson (Eds.), *Bioelectric recording techniques* (pp. 3–79). New York: Academic Press.

Pineda, J. A. (2005). The functional significance of mu rhythms: Translating "seeing" and "hearing" into "doing". *Brain Research Reviews*, *50*, 57–68.

Pizzagalli, D., Shackman, A. J., & Davidson, R. J. (2003). The functional neuroimaging of human emotion: Asymmetric contributions of cortical and subcortical circuitry. In K. Hugdahl & R. J. Davidson (Eds.), *The asymmetrical brain* (pp. 511–532). Cambridge, MA: MIT Press.

Pizzagalli, D. A., Sherwood, R. J., Henriques, J. B., & Davidson, R. J. (2005). Frontal brain asymmetry and reward responsiveness. A source-localization study. *Psychological Science*, *16*(10), 805–813.

Rinn, W. E. (1984). The neuropsychology of facial expression: A review of the neurological and psychological mechanisms for producing facial expressions. *Psychological Bulletin*, *95*, 52–77.

Schiff, B. B., Guirguis, M., Kenwood, C., & Herman, C. P. (1998). Asymmetrical hemispheric activation and behavioral persistence: Effects of unilateral muscle contractions. *Neuropsychology*, *12*, 526–532.

Schiff, B. B., & Lamon, M. (1989). Inducing emotion by unilateral contraction of facial muscles: A new look at hemispheric specialization and the experience of emotion. *Neuropsychologia*, *27*, 923–935.
Schiff, B. B., & Lamon, M. (1994). Inducing emotion by unilateral contraction of hand muscles. *Cortex*, *30*, 247–254.
Tomarken, A. J., Davidson, R. J., Wheeler, R. E., & Doss, R. (1992). Individual differences in anterior brain asymmetry and fundamental dimensions of emotion. *Journal of Personality and Social Psychology*, *62*, 676–687.
Vallortigara, G., & Rogers, L. (2005). Survival with an asymmetrical brain: Advantages and disadvantages of cerebral lateralization. *Behavioral and Brain Sciences*, *28*, 575–633.

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