Asymmetric frontal cortical activity and negative affective responses to ostracism

Carly K. Peterson, Laura C. Gravens, and Eddie Harmon-Jones
Department of Psychology, Texas A&M University, 4235 TAMU, College Station, TX 77843, USA

Ostracism arouses negative affect. However, little is known about variables that influence the intensity of these negative affective responses. Two studies fill this void by incorporating work on approach- and withdrawal-related emotional states and their associated cortical activations. Study 1 found that following ostracism anger related directly to relative left frontal cortical activation. Study 2 used unilateral hand contractions to manipulate frontal cortical activity prior to an ostracizing event. Right-hand contractions, compared to left-hand contractions, caused greater relative left frontal cortical activation during the hand contractions as well as ostracism. Also, right-hand contractions caused more self-reported anger in response to being ostracized. Within-condition correlations revealed patterns of associations between ostracism-induced frontal asymmetry and emotive responses to ostracism consistent with Study 1. Taken together, these results suggest that asymmetrical frontal cortical activity is related to angry responses to ostracism, with greater relative left frontal cortical activity being associated with increased anger.

Keywords: ostracism; anger; sadness; asymmetrical frontal cortical activity; approach motivation

INTRODUCTION

We often learn much about the power of psychological variables to influence important outcomes when we strip the variables down to minimal manipulations (Prentice and Miller, 1992). Attesting to the pervasiveness of our liking for our own groups, the minimal group paradigm revealed that simply assigning individuals to groups on the bias of random criteria causes individuals to evaluate their own group more positively (Tajfel *et al.*, 1971). Attesting to the ease with which we can learn to like things, the mere exposure paradigm revealed that simply repeatedly presenting individuals with unreinforced stimuli causes them to like those stimuli more (Zajonc, 1968). More recently, the Cyberball paradigm has revealed that, when ostracized from a group, individuals will feel negative emotions (Williams, 2007a), even when they know the group is fictitious (Zadro *et al.*, 2004). These results suggest that individuals easily bond with others and feel powerful negative—even painful—feelings when left out (Eisenberger and Lieberman, 2004; MacDonald and Leary, 2005).

We might imagine, based on our own experiences, that there are reliable individual differences in how bad individuals feel when ostracized. However, we would be wrong: research has been unable to find reliable predictors of the degree of negative affect individuals feel when ostracized[1] (Williams, 2007a). In fact, Williams (2007b) has even said, 'we have measured these individual differences [social anxiety, introversion/extraversion, secure attachment, self-esteem, loneliness, individualism and agreeableness] and so far found no moderation on the reflexive self-reports of distress, negative affect or need threat' (p. 239; bracketed information added from other parts of the article). The present studies sought to address this issue by taking a social neuroscience approach.

In ostracism research, negative affect usually describes both anger and sadness, and these distinct emotions are typically combined and referred to as 'distress' (Williams, 2007a, b). When these distinct emotions have been examined separately following ostracism, anger is more affected than sadness by the ostracism manipulation (Chow *et al.*, 2008). This ostracism-induced negative affect link has been shown to be unaffected by a number of situational and individual difference variables (see Williams, 2007a). Understanding variables that influence the intensity of negative affective responses to ostracism is important for predicting emotional consequences of ostracism.

Subjective emotional responses associated with approach *vs* withdrawal motivation are influenced by asymmetric frontal cortical activity (Harmon-Jones, 2003; Schutter *et al.*, 2008; Carver and Harmon-Jones, 2009). Relative left frontal cortical activity relates to approach-oriented

[1] One individual difference that may relate to affective responses to ostracism is rejection sensitivity (Downey and Feldman, 1996). However, most research on rejection sensitivity and affective responses is correlational. Buckley *et al.* (2004) conducted an experiment that presented acceptance *vs* rejection feedback but found that individuals high in rejection sensitivity reported more negative affect regardless of the acceptance-rejection manipulation.

emotions such as anger (e.g. Harmon-Jones and Sigelman, 2001; van Honk and Schutter, 2006; Verona *et al.*, 2009) and desire (Harmon-Jones and Gable, 2009; Harmon-Jones *et al.*, 2008), whereas relative right frontal cortical activity relates to withdrawal-oriented emotions such as sadness (Jones and Fox, 1992; Jacobs and Snyder, 1996; Schmidt and Trainor, 2001), fear and disgust (Coan *et al.*, 2001).

Study 1 was designed to test whether the pattern of asymmetric frontal cortical activity to ostracism would assist in predicting the degree and type of negative emotional experience ostracism evokes. Based on past research, we would predict that anger should be associated with greater relative left frontal activation, whereas sadness should be associated with greater relative right frontal activation. This prediction would lead us to expect ostracism to not evoke greater relative left or greater relative right frontal cortical activity (i.e. no main effect of ostracism on left *vs* right frontal activity), given that ostracism can evoke varying degrees of these negative affects in individuals (e.g. Williams, 2007a). That is, while one individual may respond to ostracism with anger and thus greater relative left frontal cortical activity, another may respond to the same event with sadness and display the opposite pattern of frontal asymmetry. Instead, our prediction would suggest that the pattern of asymmetric frontal activity would predict the subjective emotional response. Consequently, this would benefit understanding of reflexive emotional responses to ostracism by providing a pattern of neural activation that predicts the extent to which an individual feels distinct negative emotions to being ostracized.

In Study 2, frontal asymmetry was manipulated via unilateral hand contractions, to assess whether asymmetric frontal cortical activations were causally involved in the emotional experiences associated with ostracism. This manipulation was predicated on past research that suggested that unilateral hand contractions activate the contralateral motor cortex and these motor cortex activations spread to the dorsolateral prefrontal cortex and prime approach or withdrawal motivational processes (Schiff and Lamon, 1994; Schiff *et al.*, 1998; Harmon-Jones, 2006; Peterson, *et al.*, 2008). Based on this past research, it was predicted that in Study 2 unilateral hand contractions would show the same pattern of contralateral activation in the central, frontal–central and frontal regions of the brain. Furthermore, right-hand contractions should be associated with an increase in self-reported anger to ostracism, whereas left-hand contraction should be associated with an increase in self-reported sadness to ostracism. Finally, we expect to find the same relationships as Study 1 between frontal cortical activity during ostracism and self-reported emotions. Together, both studies aim to shed light on the emotional consequences of ostracism, specifically in terms of the effect of asymmetrical frontal cortical activity on the intensity and type of responses.

STUDY 1
Method
Participants and procedure

Forty (20 male) right-handed introductory psychology students participated in exchange for partial course credit. Instructions for Cyberball were presented on the computer monitor. All participants were instructed to practice their mental visualization skills during the game, and to pretend as if they were playing the game in real life. All participants were aware that the other players did not actually exist, as in Zadro *et al.* (2004). The game was programmed in one of two ways, and condition assignment was determined randomly. In the ostracism condition, participants were included the first part of the game (approximately eight throws) and then ostracized during the second half (approximately 16 throws). In the inclusion condition, participants were included during the entire game. This was done because research has shown that this type of inclusion does not affect mood and thus is an appropriate control condition (Gerber and Wheeler, 2009). EEG was recorded during the task.

When the game was over ($\sim$ 4 min later), participants completed a questionnaire assessing their perceived level of anger, enjoyment and the four fundamental needs (belonging, control, meaningful existence and self-esteem; Zadro *et al.*, 2004). Responses were made on a 9-point scale (1 = not at all, 9 = very much so). A manipulation check was included to assess participants' perceived level of inclusion during the game (i.e. 'what percent of the throws were thrown to you? Circle your best guess' with possible answers ranging from 0% to 100% in 10% intervals). In this study, participants also reported their sadness (sad, gloomy, down, discouraged; *Cronbach's* $\alpha = 0.76$), distress (distress, disgust, afraid, nervous; *Cronbach's* $\alpha = 0.56$) and positive affect (happy, good mood, satisfied, glad, content, eager, excited, interested; *Cronbach's* $\alpha = 0.87$). All responses were made on 9-point scales (1 = not at all, 9 = very much so).

Data collection and reduction

EEG, rereferenced globally to the whole head from the left ear, was recorded from 59 tin electrodes mounted in a stretch-lycra electrode cap (Electro-Cap International, Eaton, OH). Impedances were under $5000\,\Omega$; homologous sites were within $1000\,\Omega$ of each other. Signals were amplified (60-Hz notch filter), bandpass filtered (0.05–100 Hz) and digitized at 500 Hz. Signals were manually scored for artefacts. Then, a regression-based eye movement correction was applied (Semlitsch *et al.*, 1986). All 1.024-s epochs were extracted through a Hamming window. A fast Fourier transform extracted power within the lower alpha (8–10.25 Hz) and upper alpha (10.25–12.50 Hz) bands. Preliminary analyses revealed that effects were found in the upper alpha band, and thus statistical analyses focus there. Power was averaged across epochs during the two parts of the game. Asymmetry indices were created for homologous sites (natural log right minus natural log left). Because alpha power is

Table 1 Between-condition means (s.d.) of cyberball variables in Studies 1 and 2

	Study 1			Study 2		
	Inclusion	Ostracism	t	Left hand	Right hand	t
Percent included	44.50 (10.50)	23.00 (9.23)	6.88***	26.43 (8.42)	20.00 (11.28)	1.66
Included	6.26 (1.15)	2.80 (1.20)	9.22***	3.29 (1.44)	2.50 (0.90)	1.63
Belonging	5.93 (0.98)	3.02 (1.47)	7.38***	3.24 (1.07)	3.06 (1.33)	0.39
Control	5.58 (1.58)	2.80 (1.18)	6.31***	2.86 (0.79)	2.92 (1.26)	0.15
Self-esteem	1.42 (1.17)	1.15 (1.06)	0.76	1.50 (0.89)	0.97 (0.88)	1.51
Meaningful existence	6.78 (1.87)	3.85 (1.69)	5.20***	4.29 (1.96)	3.58 (1.25)	1.07
Enjoyment	4.60 (2.68)	2.10 (1.25)	3.78***	3.36 (1.86)	3.25 (2.01)	0.14
Anger	1.75 (1.16)	3.30 (2.11)	2.88**	2.43 (1.70)	4.17 (2.62)	2.04**
Sadness	1.56 (0.76)	2.05 (0.98)	1.65*	2.63 (1.37)	2.65 (1.60)	0.04
Distress	1.53 (0.71)	1.71 (0.65)	0.80	1.73 (0.76)	1.81 (0.93)	0.24
Positive mood	3.82 (1.14)	2.85 (0.94)	2.64***	2.66 (0.90)	2.62 (1.08)	0.11
Mid-frontal asymm	−0.03 (0.33)	0.00 (0.17)	0.39	−0.20 (0.42)	−0.05 (0.30)	0.97
Lat-frontal asymm	−0.04 (0.34)	−0.04 (0.26)	0.04	−0.29 (0.52)	0.04 (0.31)	1.95**
Frontal-central asymm	−0.01 (0.35)	0.01 (0.27)	0.26	−0.07 (0.58)	−0.05 (0.39)	0.13

Note: ***$P < 0.01$; **$P < 0.05$; *$P < 0.06$.

inversely related to cortical activity, higher scores indicate greater left than right activity (Davidson *et al.*, 2000). The primary variable of interest was created by subtracting the asymmetry index from the first half of the game (an inclusion period of all participants) from the asymmetry index from the second half of the game (an ostracism period for half of the participants and an inclusion period for the other half of the participants). Higher scores indicated greater relative left frontal activity during the second half of the game. Due to our interest in asymmetrical frontal cortical activity, a mid-frontal (F1/2, F3/4), lateral frontal (F5/6, F7/8) and frontal–central (FC1/2, FC3/4 and FC5/6) asymmetry index was created by combining the two mid-frontal electrodes, the two lateral frontal electrodes and the three frontal central electrodes. Degrees of freedom differ for some analyses because some participants did not complete all self-report measures. Because predictions for all studies were directional, derived from theory and specified in advance, they were evaluated using a one-tailed criterion of significance (Rosenthal *et al.*, 2000).

Results and discussion

Regression analyses in which condition (included *vs* ostracized, effect coded), frontal asymmetry and their interaction predicted subjective anger response were used to test predictions. Mid-frontal asymmetry ($F(1,36) = 10.43$, $P < 0.01$), condition ($F(1,36) = 11.36$, $P < 0.01$) and their interaction ($F(1,36) = 13.39$, $P < 0.001$) predicted anger. To follow up the interaction, within-condition correlations between anger and mid-frontal asymmetry were examined. As predicted, within the ostracism condition, anger was significantly related to relatively greater left mid-frontal activation from the period of inclusion to the period of ostracism ($r = 0.62$, $P < 0.01$). Within the inclusion condition, anger did not

relate to asymmetrical mid-frontal activation ($r < −0.14$, $P > 0.56$).

Similar effects emerged for frontal–central asymmetry. That is, frontal–central asymmetry ($F(1,36) = 8.13$, $P < 0.01$), condition ($F(1,36) = 9.09$, $P < 0.01$) and their interaction marginally predicted anger ($F(1,36) = 3.40$, $P = 0.07$). Within the ostracism condition, anger was significantly related to greater left frontal–central activation ($r = 0.50$, $P < 0.05$). Within the inclusion condition, anger did not relate to left frontal–central activation ($r < 0.26$, $P > 0.27$). No other cortical asymmetries interacted with condition to predict anger.[2] See Figure 1 for a topographic map displaying correlations between frontal asymmetry and anger within the ostracism condition.

The same type of interaction regression analyses were performed for self-reported sadness, distress, meaningful existence, control, enjoyment, positive mood, self-esteem and belonging. Only control produced a significant interaction with mid-frontal ($F(1, 36) = 7.57$, $P < 0.01$) and frontal–central ($F(1, 36) = 8.08$, $P < 0.01$) asymmetries. Within-condition correlations revealed that during ostracism, control correlated inversely with mid-frontal ($r = −0.39$, $P = 0.09$) and frontal–central ($r = −0.53$, $P < 0.05$) asymmetries, but during inclusion, control correlated directly with mid-frontal asymmetry ($r = 0.53$, $P < 0.05$).

Replicating past research, as compared to participants who were included, participants who were ostracized reported being included in a smaller percentage of throws, and they reported greater levels of anger and lower levels of positive mood, enjoyment, belonging, control and

[2] Two self-report anger measures were included. The first asked participants to rate their agreement with the statement: 'I felt angry during the Cyberball game.' The second was presented after this as part of a myriad possible emotions (anger words were anger, irritated, and mad; *Cronbach's* $\alpha = 0.83$). The two anger measures were only marginally correlated and the second anger measure was not related to frontal asymmetry. It is possible that the second anger measure was less sensitive because of its placement behind the first anger measure.

meaningful existence. Participants who were ostracized also reported marginally greater levels of sadness compared to participants who were included. There were no significant condition differences in self-esteem, distress or frontal cortical asymmetries (Table 1).

The results of Study 1 suggest that reflexive emotional responses to ostracism involve anger and the degree of anger depends critically on the degree of relative left cortical activation aroused by ostracism. Also, results suggest that both condition and relative left frontal cortical activation play a role in perceived control, so that during ostracism increased left frontal activation was associated with decreased control, whereas during inclusion the opposite effect was found. Because this effect was not predicted, we will see if it replicates in Study 2.

Study 2 extends the correlational results of Study 1 by examining whether emotional consequences of ostracism, specifically anger and sadness, are affected by manipulating frontal asymmetry with unilateral hand contractions. Furthermore, it is possible that the predicted interaction involving sadness was not found in Study 1 due to the small effect of ostracism on sadness and to restricted range of frontal asymmetry scores. Perhaps the direct manipulation of frontal asymmetry will create greater variance in the asymmetric frontal activity and allow the predicted effect to emerge. Finally, we altered the manipulation of ostracism to include ostensibly real participants, to assess whether the effects generalize to another ostracism paradigm.

STUDY 2
Method
Participants and procedure

Twenty-six[3] right-handed introductory psychology students (17 women, 9 men) participated in exchange for partial course credit. Participants were brought to the lab under the guise that they were participating in an experiment examining how personality, brain activity and the muscular system interact to affect cognitive performance during a task with other ostensible participants in the laboratory. Participants were told that the other individuals were asked to wait in another location in order to avoid coming into contact with him or her before the experiment began. After obtaining consent, the experimenter asked the participant to step out into the hall so a photograph could be taken

of the participant. They explained that it would be used later in the experiment; no other instructions were given. Then, EEG and EMG were attached.

After EEG and EMG attachments, face-to-face contact with the participant ceased and all instructions were given via envelope, computer or intercom. Next, participants were instructed to hold a toy ball in their right or left hand with the palm facing up. They were asked to squeeze the ball as hard as they could while the 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 and forearm EMG were recorded during contractions.

In the current study, the participant was told that they were playing Cyberball against two other participants. To bolster the story that the other players were real, photographs of real individuals (gender matched) were shown next to each cartoon player. In this version, all participants were in the ostracism condition. All other instructions and procedures for the game and post-game questionnaires were identical to Study 1.
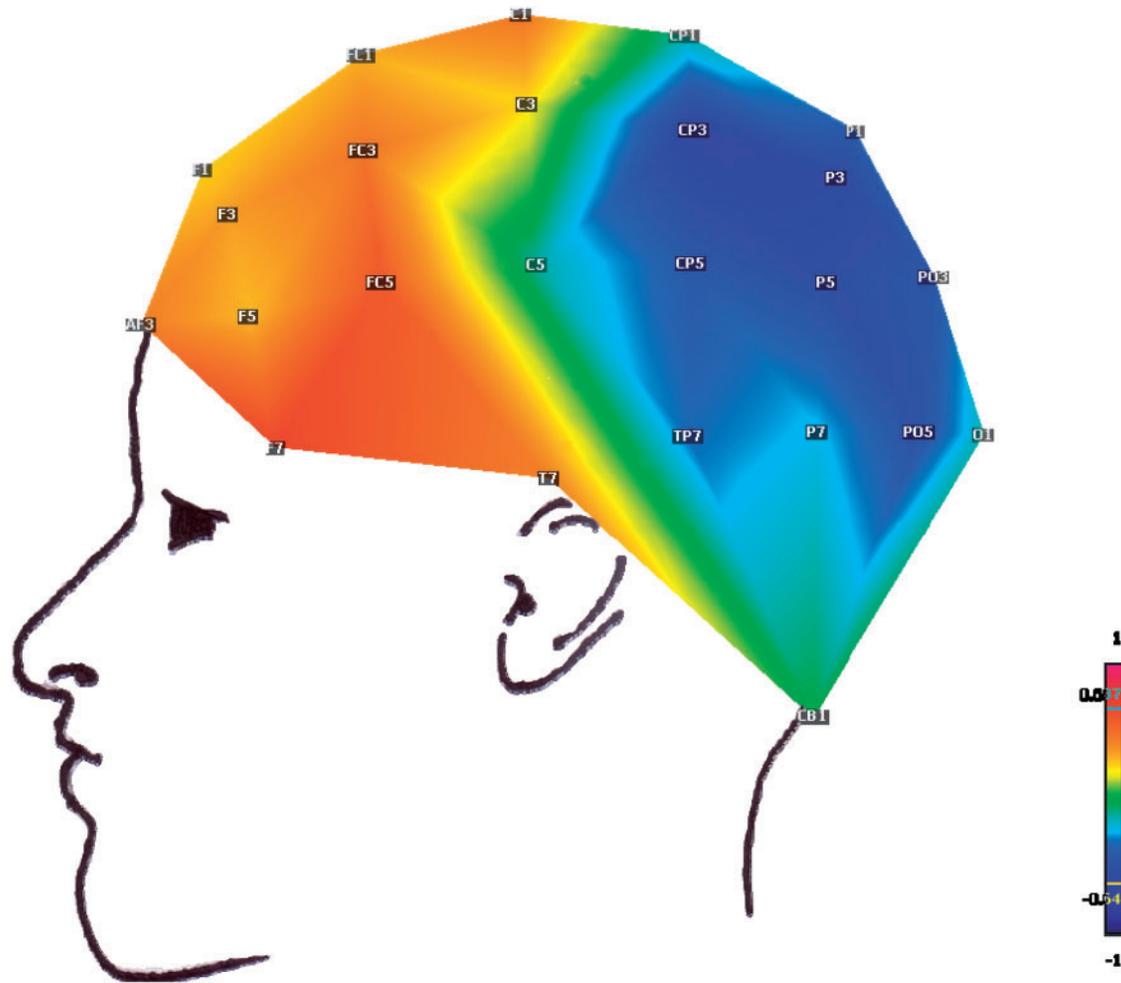
Data collection and processing

Forearm EMG was recorded by placing tin electrodes (Electro-Cap International, Eaton, OH) on each forearm flexor. One electrode was placed one-third of the distance from the medial epicondyle of humerus to the styloid process of radius. The other electrode was placed 5 cm from the first electrode along the same line. Impedance levels were $10\,000\,\Omega$ or below.

EMG signals were amplified online (an analogue 60-Hz notch filter was enabled) with Neuroscan Synamps (El Paso, TX), bandpass filtered (0.05–500 Hz) and digitized at 2500 Hz. Offline, the signals were visually scored and portions of the data that contained artifacts were removed prior to being bandpass filtered (30–500 Hz) and rectified. All epochs 1.024 s in duration were extracted through a 20% tapered (10% at each end) cosine window. A fast Fourier transform was used to calculate the power spectra, which was averaged across each period of the hand contractions. Total power within 30–500 Hz was obtained. Values were then log transformed to normalize across participants. The methods for processing EMG signals are similar to those described by Fridlund and Cacioppo (1986). All procedures for acquiring and processing EEG data were identical to those used in Study 1. Also, as in Study 1, frontal asymmetry was examined using asymmetry indexes where the natural log of the left electrode was subtracted from the natural log of the right electrode. As such, higher scores indicate greater relative left than right activity (Davidson *et al.*, 2000).

---

[3] Following earlier suggestions (e.g. Basso *et al.*, 1994; Peterson *et al.*, 2008; Stemmler, 2003), we excluded participants who failed to show an asymmetric effect of the unilateral contraction manipulation on contralateral motor strip; data from 22 participants who failed to show greater relative left (right) activation in contralateral central electrodes (average of C3/4 and C5/6) during unilateral right (left) contractions were discarded. Two other participants were removed from analyses due to suspicion. Because of this loss of participants and because the procedure of Study 2 involved deception, we conducted another experiment (without EEG) using the procedure of Study 1 to assess whether the hand contraction manipulation affected self-reported anger. It did. Self-reported anger was greater for individuals who made right-hand contractions ($M = 5.41$, s.d. $= 2.32$) compared to individuals who made left-hand contractions ($M = 3.63$, s.d. $= 1.95$), $t(34) = 2.5$, $P < 0.01$.

Fig. 1 Topographic map displaying correlations between relative left hemispheric activation during ostracism and anger in Study 1. The display is a left lateral head view. Areas in red and orange correlated directly with anger.

Results and discussion

Between-group differences

EMG activity.   EMG activity in the right and left forearms was measured during hand contractions to ensure that participants were indeed squeezing the ball as instructed. Data from two participants, both in the left-hand condition, were lost due to equipment failure. Of the remaining 24 participants, all showed the predicted EMG asymmetry. A 2 (hand contraction: right, left) × 2 (forearm: right, left) ANOVA revealed that the hand contractions differentially affected EMG activity in the forearms, $F(1,22) = 424.58$, $P < 0.001$. Greater EMG activity occurred in the right forearm during right-hand contractions ($M = 3.20$, s.d. $= 1.18$) compared to left-hand contractions ($M = -2.42$, s.d. $= 0.96$), $t(22) = 12.81$, $P < 0.001$, whereas greater EMG activity

occurred in the left forearm during left-hand contractions ($M = 2.68$, s.d. $= 0.84$) compared to right-hand contractions ($M = -2.88$, s.d. $= 0.99$), $t(22) = 14.84$, $P < 0.001$.

As a manipulation check, we examined correlations between left frontal cortical activation and EMG activity during the contractions. As expected, greater relative EMG activity in the right forearm compared to left forearm during contractions related to greater relative left lateral frontal ($r = 0.40$, $P < 0.05$) and frontal–central ($r = 0.35$, $P < 0.05$) activation during the hand contractions.

Frontal asymmetry during hand contractions.   As predicted, the hand contraction manipulation affected lateral frontal ($t(24) = 2.39$, $P < 0.05$) and frontal–central ($t(24) = 1.92$, $P < 0.05$) activation. Participants who made

Fig. 2 Topographic map displaying correlations between relative left hemispheric activation during ostracism and anger within the right-hand contraction condition in Study 2. The display is a left lateral head view. Areas in red and orange correlated directly with anger.

right-hand contractions evidenced greater relative left (or reduced relative right) lateral frontal activation ($M = 0.15$, s.d. $= 0.19$) and frontal–central activation ($M = 0.12$, s.d. $= 0.25$) than those who made left-hand contractions ($M = -00.07$, s.d. $= 0.26$ and $M = -0.10$, s.d. $= 0.32$, respectively). Hand contraction condition did not affect mid-frontal asymmetry, $t < 0.93$.

Frontal asymmetry in response to ostracism. Change in frontal EEG asymmetry from the period of inclusion to the period of ostracism was next examined. Consistent with predictions, relative left lateral frontal activation was greatest (and thus relative right lateral frontal activation was lowest) for right-hand contractions compared to left-hand contractions. Relative left mid-frontal and frontal–central activation did not differ between right- and left-hand contractions.

Emotions and basic needs in response to ostracism. Consistent with our primary prediction, self-reported anger in response to ostracism was significantly greater after right-hand contractions compared to left-hand

contractions. See Table 1 for all other between-condition effects involving emotions and basic needs, none of which was significant ($t < 1.66$).

Relationships between frontal asymmetry and emotive responses

Within the right-hand condition, ostracism-induced anger was associated with greater relative left lateral frontal ($r = 0.50$, $P < 0.05$) and frontal–central ($r = 0.50$, $P < 0.05$) activation (Figure 2). Within the left-hand contraction condition, ostracism-induced sadness was associated with decreased relative left frontal central activation ($r = -0.52$, $P < 0.05$) (Figure 3). Also within the left-hand contraction condition, ostracism-induced distress related to decreased relative left mid-frontal ($r = -0.49$, $P < 0.05$) and frontal–central ($r = -0.60$, $P < 0.05$) activation.

Study 2 extended Study 1 by showing that greater relative left frontal cortical activity is causally involved in the anger response to ostracism. Right-hand contractions, relative to left-hand contractions, caused increased left frontal cortical activity (during the contractions and during ostracism) and
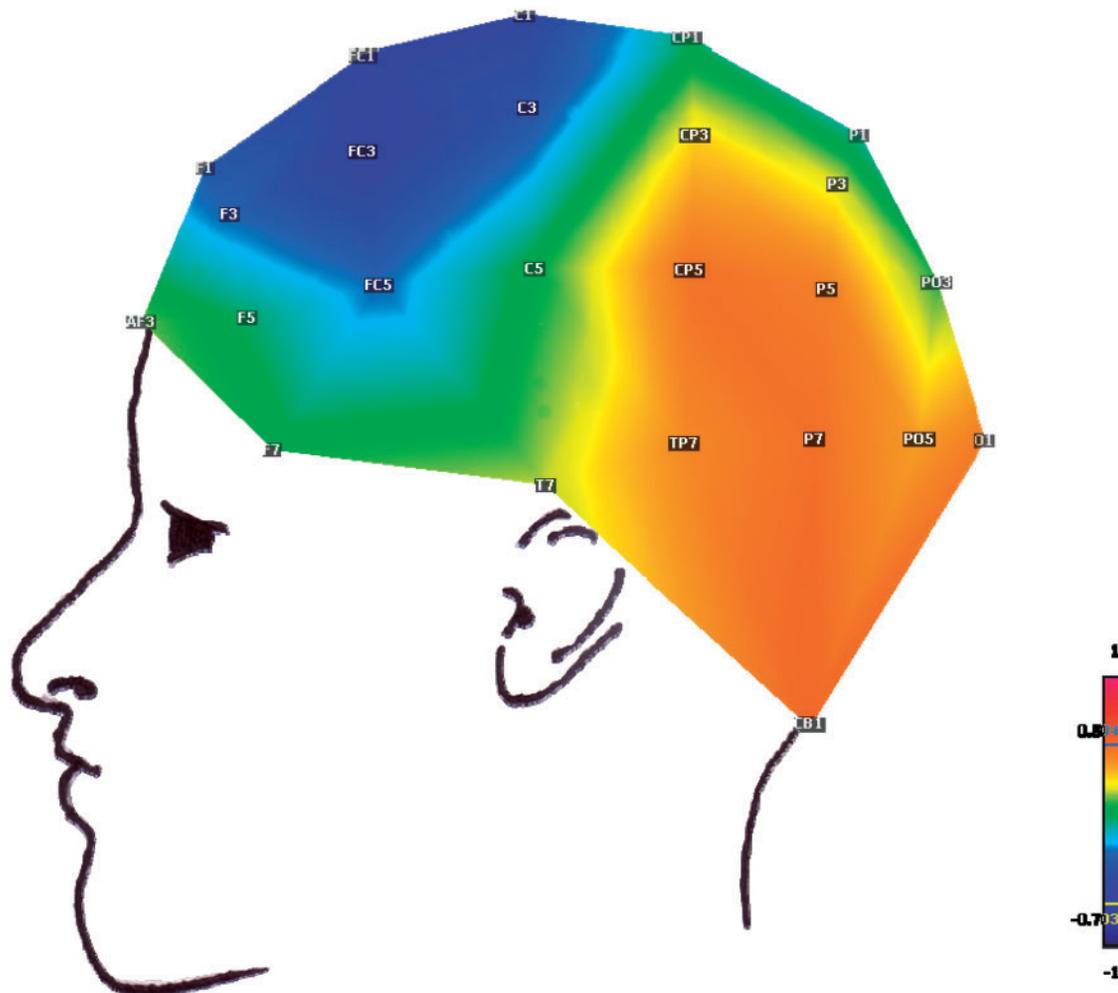
Fig. 3 Topographic map displaying correlations between relative left hemispheric activation during ostracism and sadness within the left-hand contraction condition in Study 2. The display is a left lateral head view. Areas in blue correlated inversely with sadness.

increased self-reported anger. Furthermore, within-condition correlations replicated Study 1 in that left frontal activation related directly to anger within the right-hand condition. Adding to Study 1, Study 2 also showed that, within the left-hand condition, relative right frontal activation related to sadness and distress.

We also examined whether frontal asymmetry mediated the effect of hand contraction condition on anger using steps stipulated by Baron and Kenny (1986) (all tests are one tailed). Results revealed that (1) hand contractions affected the anger response ($\beta = 0.38$, $P = 0.03$), (2) hand contractions affected lateral frontal asymmetry during ostracism ($\beta = 0.38$, $P = 0.03$) and (3) when both hand contractions and lateral frontal asymmetry were entered as predictors, hand contractions did not affect the anger response ($\beta = 0.21$, $P = 0.28$) whereas lateral frontal asymmetry did ($\beta = 0.42$, $P = 0.02$). These results suggest partial mediation occurred. Full mediation was marginally supported (Sobel's test $z = 1.45$, $P = 0.08$). Thus, relative left lateral frontal activation during ostracism is partially responsible for the effect of right-hand contractions on ostracism-induced anger.

GENERAL DISCUSSION

Study 1 found that ostracism-induced anger is directly correlated with increased relative left frontal activity. Supporting these findings, Study 2 demonstrated that right-hand, as compared to left-hand, contractions caused greater relative left frontal cortical activation during the hand contractions as well as during ostracism, and caused greater self-reported anger in response to ostracism. Within-condition correlations revealed patterns of associations between frontal activation and angry responses to ostracism consistent with Study 1. These results suggest that greater relative left frontal activity is associated with increased anger to ostracism. These results are consistent with the motivational direction model of asymmetric frontal cortical activity (Harmon-Jones, 2004)

Another possible explanation for the ostracism-induced anger is that the right-hand contractions are similar to the muscle contractions one might use to prime an angry response and this prime (for right-handed individuals) caused the anger response following ostracism. One way to test this

would be to see if left-handed individuals show the same increase in anger when contracting their left hands. However, given that some left-handed individuals show functional lateralizations similar to right-handed individuals, whereas other left-handed individuals show opposite patterns of lateralizations from right-handed individuals, this explanation would be difficult to test. On the other hand, we took precautions in the methods of the current experiment to make the manipulation as dissimilar as possible from an angry pose. The contractions used in the current experiment involved squeezing a toy ball with the palm facing upwards, an action quite dissimilar from the action made in displaying a fist in anger. Perhaps most importantly, this alternative explanation would be unable to explain the correlation observed between relative left frontal activation and anger as well as the partial mediation evidence.

Only subjective anger was affected by the ostracism manipulation of Study 1 and the hand contraction manipulation of Study 2. Sadness and distress were not significantly affected by these manipulations. However, in Study 2, relative right frontal activation related directly with sadness and distress, only within the left-hand contraction condition. Study 1 did not reveal similar correlations when hemispheric dominance was not manipulated. Perhaps the manipulated increase in relative right frontal activation was necessary to cause the association of relative right frontal activation and sadness/distress to ostracism. It may also be possible that these relationships may not have been evident in Study 1 due to restricted variance. That is, the left-hand contraction condition of Study 2 demonstrated larger standard deviations in frontal asymmetry than the right-hand condition of Study 2 and both conditions of Study 1. The left-hand contractions apparently 'freed' up additional relative right-frontal variance, making that variable more able to correlate with sadness and distress in Study 2. In addition, it is possible that the distribution of males vs females in each study may have contributed to these differences. That is, an equal number of each sex participated in Study 1, whereas twice as many females as males participated in Study 2. If such an explanation is true, we should find the predicted effects for females in Study 1; re-examination of the data found that such was not the case ($r < 0.46$, $P > 0.21$). Correlations between frontal asymmetry and ostracism-induced sadness and distress did not differ significantly for males vs females ($P > 0.15$).

In the present studies, asymmetric frontal cortical activity was assessed by combining individual channels into three main indexes covering a large anterior area of the brain. Consistent with recent fMRI research, this suggests that the dorsolateral prefrontal cortex's involvement in motivational direction spans a large area (Berkman and Lieberman, in press). Although frontal asymmetry effects were found at each index, they were not consistent across studies. This variation in effect location is not uncommon, as Allen *et al.* (2004) reviewed evidence from 70+ studies that

showed that 'relationships with frontal EEG asymmetry appear...at different regions at different times' (p. 26).

This research illustrates the importance of examining distinct negative affects rather than clustering all negative affects into one index, which has been encouraged by factor analytic studies that suggest that all negative affects load on one factor. Recent research has revealed that one of the most often used measures of negative affect splits into distinct factors of anger *vs* fear/distress when individuals are actually experiencing strong bouts of affect caused by distinct emotion manipulations (Harmon-Jones *et al.*, 2009) as opposed to how they felt over long periods of time (Watson, 2000).

The current research assists in understanding 'reflexive' emotional responses to ostracism noted by Williams (2007a) and suggest some interesting avenues for further research on moderators of such responses to ostracism. Past research has suggested that ostracism-induced negative affect emerges regardless of several moderators (Williams, 2007a). Perhaps neural measures, like EEG, provide more direct assessments of approach and withdrawal motivation that may relate better to reflexive emotion responses such as anger than other measures used in past research.

In the end, this work illustrates two benefits of a social neuroscience approach (Ochsner and Lieberman, 2001; Adolphs, 2003; Harmon-Jones and Devine, 2003; Lieberman, in press): it generated a novel hypothesis derived from a neuroscience approach that shed light on a problem in social psychological research on ostracism, and it used social psychological methods to further our understanding of the role of a pattern of neural activation in psychological processes.

REFERENCES

Adolphs, R. (2003). Investigating the cognitive neuroscience of social behavior. *Neuropsychologia*, 41, 119–26.

Allen, J.J.B., Coan, J.A., Nazarian, M. (2004). Issues and assumptions on the road from raw signals to metrics of frontal EEG asymmetry in emotion. *Biological Psychology*, 67, 183–218.

Baron, R.M., Kenny, D.A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*, 51, 1173–82.

Basso, M.R., Schefft, B.K., Hoffmann, R.G. (1994). Mood-moderating effects of affect intensity on cognition: Sometimes euphoria is not beneficial and dysphoria is not detrimental. *Journal of Personality and Social Psychology*, 66, 363–68.

Berkman, E.T., Lieberman, M.D. (in press). Approaching the bad and avoiding the good: Lateral prefrontal cortical asymmetry distinguishes between action and valence. *Journal of Cognitive Neuroscience*.

Buckley, K., Winkel, R., Leary, M. (2004). Reactions to acceptance and rejection: Effects of level and sequence of relational evaluation. *Journal of Experimental Social Psychology*, 40, 14–28.

Carver, C.S., Harmon-Jones, E. (2009). Anger is an approach-related affect: Evidence and implications. *Psychological Bulletin*, 135, 183–204.

Chow, R.M., Tiedens, L.Z., Govan, C.L. (2008). Excluded emotions: The role of anger in antisocial responses to ostracism. *Journal of Experimental Social Psychology*, 44, 896–903.

Coan, J.A., Allen, J.J.B., Harmon-Jones, E. (2001). Voluntary facial expression and hemispheric asymmetry over the frontal cortex. *Psychophysiology*, 38, 912–25.

Davidson, R.J., Jackson, D.C., Larson, C.L. (2000). Human electroencephalography. In: Cacioppo, J.T., Tassinary, L.G., Berntson, G.G., editors. *Handbook of psychophysiology,* 2nd edn. New York: Cambridge University Press, pp. 27–52.

Downey, G., Feldman, S.I. (1996). Implications of rejection sensitivity for intimate relationships. *Journal of Personality and Social Psychology, 70,* 1327–43.

Eisenberger, N.I., Lieberman, M.D. (2004). Why rejection hurts: A common neural alarm system for physical and social pain. *Trends in Cognitive Science, 8,* 294–300.

Fridlund, A.J., Cacioppo, J.T. (1986). Guidelines for human electromyographic research. *Psychophysiology, 23,* 567–89.

Gerber, J., Wheeler, L. (2009). On being rejected: A meta-analysis of experimental research on rejection. *Perspectives on Psychological Science, 4,* 468–88.

Harmon-Jones, E. (2003). Clarifying the emotive functions of asymmetrical frontal cortical activity. *Psychophysiology, 40,* 838–48.

Harmon-Jones, E. (2004). Insights on asymmetrical frontal brain activity gleaned from research on anger and cognitive dissonance. *Biological Psychology, 67,* 51–76.

Harmon-Jones, E. (2006). Unilateral right-hand contractions cause contralateral alpha power suppression and approach motivational affective experience. *Psychophysiology, 43,* 598–603.

Harmon-Jones, E., Sigelman, J. (2001). State anger and prefrontal brain activity: Evidence that insult-related relative left-prefrontal activation is associated with experienced anger and aggression. *Journal of Personality and Social Psychology, 80,* 797–803.

Harmon-Jones, E., Devine, P.G. (2003). Introduction to the special section on social neuroscience: Promise and caveats. *Journal of Personality and Social Psychology, 85,* 589–93.

Harmon-Jones, E., Gable, P. (2009). Neural activity underlying the effect of approach-motivated positive affect on narrowed attention. *Psychological Science, 20,* 406–09.

Harmon-Jones, E., Harmon-Jones, C., Fearn, M., Sigelman, J.D., Johnson, P. (2008). Action orientation, relative left frontal cortical activation, and spreading of alternatives: A test of the action-based model of dissonance. *Journal of Personality and Social Psychology, 94,* 1–15.

Harmon-Jones, E., Harmon-Jones, C., Abramson, L.Y., Peterson, C.K. (2009). PANAS positive activation is associated with anger. *Emotion, 9,* 183–96.

Jacobs, G.D., Snyder, D. (1996). Frontal brain asymmetry predicts affective style in men. *Behavioral Neuroscience, 110,* 3–6.

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,* 280–99.

Lieberman, M.D. (2010). Social cognitive neuroscience. In: Fiske, S.T., Gilbert, D.T., Lindzey, G., editors. *Handbook of Social Psychology,* 5th edn. New York, NY: McGraw-Hill, pp. 143–93.

MacDonald, G., Leary, M.R. (2005). Why does social exclusion hurt? The relationship between social and physical pain. *Psychological Bulletin, 131,* 202–223.

Ochsner, K.N., Lieberman, M.D. (2001). The emergence of social cognitive neuroscience. *American Psychologist, 56,* 717–34.

Peterson, C.K., Shackman, A.J., Harmon-Jones, E. (2008). The role of asymmetrical frontal cortical activity in aggression. *Psychophysiology,* 86–92.

Prentice, D.A., Miller, D.T. (1992). When small effects are impressive. *Psychological Bulletin, 112,* 160–64.

Rosenthal, R., Rosnow, R.L, Rubin, D.B. (2000). *Contrasts and effect sizes in behavioral research: A correlational approach.* New York: Cambridge University Press.

Schiff, B.B., Lamon, M. (1994). Inducing emotion by unilateral contraction of hand muscles. *Cortex, 30,* 247–54.

Schiff, B.B., Guirguis, M., Kenwood, C., Herman, C.P. (1998). Asymmetrical hemispheric activation and behavioral persistence: effects of unilateral muscle contractions. *Neurospychology, 12,* 526–32.

Schutter, D.J.L.G., de Weijer, A.D., Meuwese, J.D.I., Morgan, B., van Honk, J. (2008). Interrelations between motivational stance, cortical excitability, and the frontal electroencephalogram asymmetry of emotion: A transcranial magnetic stimulation study. *Human Brain Mapping, 29,* 574–80.

Semlitsch, H.V., Anderer, P., Schuster, P., Presslich, O. (1986). A solution for reliable and valid reduction of ocular artifacts, applied to the P300 ERP. *Psychophysiology, 23,* 695–703.

Stemmler, G. (2003). Methodological considerations in the psychophysiological study of emotion. In: Davidson, R.J., Goldsmith, H.H., Scherer, K.R., editors. *Handbook of affective sciences.* New York: Oxford University Press, pp. 225–55.

Tajfel, H., Billig, M.G., Bundy, R.P., Flament, C. (1971). Social categorization and intergroup behavior. *European Journal of Social Psychology, 1,* 149–78.

van Honk, J., Schutter, D.J.L.G. (2006). From affective valence to motivational direction: The frontal asymmetry of emotion revised. *Psychological Science, 17,* 963–65.

Verona, E., Sadeh, N., Curtin, J. (2009). Stress-induced asymmetric frontal brain activity and aggression risk. *Journal of Abnormal Psychology, 118,* 131–45.

Watson, D. (2000). *Mood and temperament.* New York: Guilford Press.

Williams, K.D. (2007a). Ostracism. *Annual Review of Psychology, 58,* 425–52.

Williams, K.D. (2007b). Ostracism: The kiss of social death. *Social and Personality Psychology Compass, 1,* 236–47.

Zadro, L., Williams, K.D., Richardson, R. (2004). How low can you go? Ostracism by a computer is sufficient to lower self-reported levels of belonging, control, self-esteem, and meaningful existence. *Journal of Experimental Social Psychology, 40,* 560–67.

Zajonc, R.B. (1968). Attitudinal effects to mere exposure. *Journal of Personality and Social Psychology, 9,* 1–27.