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Right frontal cortical asymmetry predicts empathic reactions: Support for a link between withdrawal motivation and empathy

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Abstract

Depression, diminished positive affect, and exaggerated negative affect have all been linked to right frontal cortical asymmetry as measured by electroencephalography (EEG). Emerging evidence, however, suggests that right frontal EEG asymmetry might be linked to empathic responding. EEG was used to assess baseline asymmetries in frontal brain activity. Participants viewed images associated with a charity and then rated their sadness, personal distress, perspective-taking, and empathic concern towards the images. We found that baseline measures of right frontal asymmetry were a significant predictor of empathic concern, a relationship that was mediated by feelings of sadness. These results provide a more complex view of right frontal asymmetry and suggest that this pattern of brain activity might facilitate sensitivity towards the suffering of others.

Descriptors: Asymmetrical frontal cortical activity, Empathy, EEG/ERP, Emotion, Individual differences

From the early days of neuroscience, scientists and laypeople alike have been fascinated by differences between the left and right hemispheres of the brain. Though the complexity and diversity of research findings has long since debunked simplistic notions of right brain mathematicians and left brain artists, there do appear to be real and consequential differences between people that can be linked to chronic differences in the relative activity of the left and right frontal cortices. Various models have been proposed in attempts to characterize these dispositional asymmetries in frontal activation, but there is a prevalent view that emerges in many interpretations: left frontal asymmetry is good, and right frontal asymmetry is bad.

Certainly, there is evidence to suggest that higher levels of left frontal asymmetry, measured using electroencephalography (EEG), can be beneficial for the individual. For example, people with relatively greater left frontal EEG activity experience more positive affect, less negative affect, and are less likely to develop depression (Jacobs & Snyder, 1996; Nusslock et al., 2011; Tomarken, Davidson, Wheeler, & Doss, 1992; Wheeler, Davidson, & Tomarken, 1993). There is mounting evidence, however, to suggest that a rightward bias in brain activity may contribute to desirable interpersonal abilities (Eslinger et al., 2007; Quirin, Kazén, Hardung, & Kuhl, 2012; Shamay-Tsoory, Tomer, Berger, Goldsher, & Aharon-Peretz, 2005). Here, we tested the hypothesis that right frontal EEG asymmetry might be a predictor of an important interpersonal capacity: empathy for the suffering of others.

Frontal EEG Asymmetry

With the accumulation of evidence regarding the emotional and behavioral consequences of frontal EEG asymmetry, the motivational direction model has become a widely accepted account of the differences between relative left and right brain activity (Davidson, 1995; Harmon-Jones, 2004; Harmon-Jones, Gable, & Peterson, 2010; van Honk & Schutter, 2006). This account posits that basic motivational direction—whether people are driven to approach things or to withdraw from them—maps on to patterns of asymmetrical cortical activation such that withdrawal motivation has been associated with relative right frontal activity, while approach has been associated with relative left frontal activity (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997; cf. Wacker, Chavanon, & Stemmler, 2010).

Withdrawal motivation ensures that we evade punishment and threat, whereas approach motivation is what prompts us to pursue desired goals and rewards (Gray & McNaughton, 2000; Sutton & Davidson, 1997). In a broad analysis of personality and temperament, withdrawal motivation was linked to neuroticism, negative emotionality, and the behavioral inhibition system, whereas approach motivation was associated with extraversion, positive emotionality, and the behavioral activation system (Elliot & Thrash, 2002). In a performance context, withdrawal motivation stems from fear of failure and low performance expectancies, while approach motivation stems from striving to succeed and high performance expectancies (Elliot & Church, 1997).

Consistent with this formulation, asymmetric frontal cortical activation is also closely tied with patterns of emotional responding. Emotions like happiness and anger, which are associated with

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approach motivation, are linked with relative left frontal asymmetry (Coan, Allen, & Harmon-Jones, 2001; Davidson, Schaffer, & Saron, 1985; Harmon-Jones & Allen, 1998). Meanwhile, emotions like disgust, fear, and sadness, which are associated with withdrawal, are linked with relative right frontal activity (Coan et al., 2001, Dawson, Panagiotides, Kinger, & Hill, 1992). At a dispositional level, baseline levels of frontal asymmetry reflect susceptibility to approach- and withdrawal-related emotions. For example, people who have dispositionally higher levels of right frontal asymmetry show stronger negative affect to fearful or disgusting stimuli and weaker positive affect to happy stimuli (Tomarken et al., 1992; Wheeler et al., 1993). These dispositional differences have also been shown to have clinical implications, with research showing that right frontal asymmetry is associated with increased risk for depression (Henriques & Davidson, 1990, 1991; Nusslock et al., 2011; Schaffer, Davidson, & Saron, 1983).

Because frontal EEG asymmetry has proven to be a stable and reliable measure of individual differences (Tomarken, Davidson, Wheeler, & Kinney, 1992), trait measures of frontal asymmetry can provide a valuable tool in assessing susceptibility to sadness and withdrawal-related affect. If a proneness to feeling sadness translates into a heightened responsiveness to the sadness of others, we would expect greater right frontal EEG asymmetry to be associated with greater empathic responding to the suffering of others.

Varieties of Empathic Experience

From an evolutionary perspective, empathy is often touted as an adaptive capacity in that it contributes to helping behavior, which in turn contributes to inclusive fitness (Batson, Lishner, Cook, & Sawyer, 2005; de Waal, 2008; Eisenberg & Miller, 1987). At a fundamental level, however, empathic processes can serve to provide information about relevant aspects of the environment, such as danger or threat (de Waal, 2008; Hatfield, Cacioppo, & Rapson, 1994). Humans and other animals have evolved ways of "catching" the emotions of others, a process referred to as emotional contagion (Gutsell & Inzlicht, in press; Preston & de Waal, 2002; see also Gutsell & Inzlicht, 2010). According to the Russian doll model of empathy (de Waal, 2008), emotional contagion is the most basic type of empathy that humans exhibit, and is thought to rely on a perception-action mechanism that involves the automatic activation of neural representations consistent with the feelings of another person (Jackson, Meltzoff, & Decety, 2004; Singer et al., 2004). One example of emotional contagion is personal distress, the self-oriented negative affect we experience when we are exposed to the suffering of others. Sympathetic concern (also called empathic concern), the second level of empathy, is thought to stem from emotional contagion and to involve the further step of distinguishing between internally and externally generated emotions. Finally, the most recently evolved form of empathy, perspective-taking, occurs when we deliberately take another person's point of view.

Research on empathy and its role in helping behavior has demonstrated that emotional contagion and personal distress are not easily disentangled from empathic concern. In contrast to the intuitive idea that empathic concern must reflect the approach-related motivation to help, this work suggests that empathic concern may, instead, reflect the withdrawal-related motivation to avoid personal feelings of distress. Distress-relief models, such as the negative-state relief model (Cialdini, Darby, & Vincent, 1973) and the aversive-arousal reduction model (Piliavin, Dovidio, Gaertner, & Clark, 1981), posit that we help others in order to relieve our own personal distress caused by their undesirable situation. In support of these models, research has shown that when the negative emotions elicited by others' suffering are alleviated by a reward or positive mood induction, people help less (Cialdini et al., 1987; Schaller & Cialdini, 1988, c.f. Batson, Fultz, & Schoenrade, 1987). Along these lines, in some cases perceived self–other overlap has been found to account for the connection between empathy and helping, suggesting that empathy leads to helping when we adopt the distress of the victim (Cialdini, Brown, Lewis, Luce, & Neuberg, 1997; Maner et al., 2002). Furthermore, recent work has demonstrated that when people are faced with suffering they use emotion regulation strategies to prevent themselves from being overwhelmed with the negative emotions that accompany compassion (Cameron & Payne, 2011; Shaw, Batson, & Todd, 1994).

Empathy and Frontal EEG Asymmetry

Because empathy is often viewed as an other-oriented reaction to suffering—a kind of "reaching out"—it has been posited that it should be associated with left frontal asymmetry (e.g., Goetz, Keltner, & Simon-Thomas, 2010; Lamm, Batson, & Decety, 2007). On the other hand, conceptualizations of empathy that emphasize vicarious sharing of pain or sorrow (Ikes, 1997) or that propose a critical role for feelings of personal distress (Cialdini et al., 1973; Ikes, 1997; Piliavin et al., 1981) raise the possibility that empathy might be linked to right frontal asymmetry.

Some neuroscientific data already hint at a possible link between right frontal asymmetry and empathic reactions. For instance, children who show greater right frontopolar EEG activity during a task designed to elicit positive emotion were more likely to show empathic concern in response to pain expressed by the experimenter (Light et al., 2009). People with lesions to the right ventromedial frontal cortex showed deficits in affective components of "mind-reading" (Shamay-Tsoory et al., 2005), while cortical atrophy in the right frontal temporal neural network has been associated with difficulties in resolving social dilemmas (Eslinger et al., 2007). In a meta-analysis of the neural regions involved in empathy, the right anterior insula and inferior frontal gyrus were found to be involved in affective-perceptual empathy (Fan, Duncan, de Greck, & Northoff, 2011). Prosocial behavior also appears to be linked with right frontal activity, as demonstrated by findings showing that disrupting the functioning of the right, but not left, dorsolateral prefrontal cortex using transcranial magnetic stimulation causes people to be less fair during an economic game (Knoch, Pascual-Leone, Meyer, Treyer, & Fehr, 2006). Integrating work on the neurobiology of psychopaths, Hecht (2011) has suggested that the affective and empathic deficits displayed by these individuals are associated with hypoactivity in the right hemisphere.

Due to the paucity of work identifying the neural sources of frontal EEG asymmetry, it is not clear whether all of the neural regions described above contribute to frontal asymmetry measures (Pizzagalli, Sherwood, Henriques, & Davidson, 2005). Nevertheless, consistent findings demonstrating a link between reduced right frontal activity and empathy suggests that this relationship should be reflected in measures of frontal alpha asymmetry. This work, combined with the reasoning that susceptibility to withdrawal-related emotions could lead people to be better able to feel for the suffering of other people, leads to the prediction that right frontal EEG asymmetry may relate to empathic reactions.

The Present Study

In this study, we explored the links between baseline right frontal asymmetry, empathic reactions towards others' suffering, and intentions to help. To do this, we assessed resting measures of frontal EEG asymmetry and analyzed self-reported sadness, personal distress, empathic concern, and perspective-taking to images of African children ostensibly associated with a charity campaign. Participants also indicated the extent to which they intended to help the children in the images. We predicted that baseline (i.e., trait) levels of right frontal asymmetry would predict feelings of personal distress, sadness, and empathic concern towards the images. Furthermore, if the relationship between right frontal EEG asymmetry and empathy can be explained by an increased susceptibility to withdrawal-related emotions, we should also find that sadness and personal distress mediate this relationship.[1]

Methods

Participants

Thirty-two introductory psychology students (23 female, $M_{age} = 19.34$ years, $SD_{age} = 2.37$ years) participated for course credit and $5. One participant was excluded due to an outlying F4F3 asymmetry value ($Z > 3.0$), and another was excluded due to technical malfunction during baseline EEG recording. For all retained participants, *Z* scores for F4F3 asymmetry values fell within the range of −1.00 to 1.00. For three participants, specific electrode sites were excluded prior to data analysis due to noisy data in those channels. As a result, *N*s for analyses involving asymmetry values varied from 27 to 30.

Procedure

At the start of the experiment, the participant was fitted with an EEG cap. First, baseline EEG was recorded while participants sat still with their eyes alternately open and closed for four blocks of 30 s each.[2] Participants were then told they would view two sets of 10 images of African children, each associated with a charity. These charity images were found through a search of publically available online sources (i.e., Google image search).[3] Participants viewed the images as two counterbalanced blocks, each consisting of 10 charity images interspersed with 10 scenery images. Images were presented in random order with the restriction that scenery and charity images alternated. Each image was displayed for 8 s, followed by an 8-s intertrial interval. During this part of the experiment, participants were asked to simply sit still and concentrate on the images. To ensure that participants were paying attention, they were told that they might be asked questions about the images later in the experiment. Following this phase of the experiment, participants viewed the two sets of charity images again and rated their affective responses to each set of 10 images as a whole.[4]

Table 1. *Reliabilities and Descriptive Statistics for Key Variables*

	α	*M*	*SD*
1. Empathic Concern	.86	2.81	.63
2. Sadness	.89	2.68	.85
3. Personal Distress	.93	2.80	.87
4. Perspective-taking	.79	3.01	.75
5. Volunteering	.74	3.82	.67
6. F4F3	–	.12	.33
7. FC4FC3	–	.04	.12
8. CP4CP3	–	.01	.22
9. P4P3	–	.06	.21

Self-report Measures

In response to the charity images, participants used a 5-point scale (1 = *strongly disagree*, 5 = *strongly agree*) to indicate empathic concern (*moved, sympathetic, compassionate, warm, tender, soft-hearted*), sadness (*sad, feeling low, low-spirited, heavy-hearted*), personal distress (*alarmed, grieved, troubled, upset, disturbed, worried, perturbed*), and perspective-taking (*I can imagine what this person is thinking, I am able to put myself in this person's situation, I am similar to the person in this profile*; see Table 1 for descriptive statistics). Empathic concern, sadness, personal distress, and perspective-taking were analyzed independently (Batson, 1987; Fultz, Schaller, & Cialdini, 1988). Ratings for each of these four constructs were averaged across the two sets of charity images (αs > .75). To measure prosocial intentions, we asked participants to indicate, on a 5-point scale, their willingness to volunteer to help the children in the images by interacting directly with them or by helping from a distance. These ratings showed no differences with respect to their correlations with other variables, and thus were averaged across the two sets of charity images to form a composite measure of intentions to volunteer (α = .74).

EEG Recording and Processing

EEG was recorded throughout the experiment using a stretch Lycra cap containing 32 tin electrodes. Electrode placement followed the 10–20 system, and a digital average earlobe reference was used. Data was acquired from electrodes Fp1, Fpz, Fp2, FCz, F7, F3, Fz, F4, F8, FT7, FC3, FC4, FT8, T3, C3, Cz, C4, T4, TP7, CP3, CP4, TP8, T5, P3, Pz, P4, T6, CPz, O1, Oz, O2. Electrode impedances were below 10 kΩ. Vertical eye movements were recorded to facilitate artifact identification. Recordings were digitized at 1,024 Hz using ASA acquisition software (Advanced Neuro Technology, Enschede, The Netherlands). EEG was digitally filtered offline between 1 and 15 Hz, and corrected for vertical electrooculogram artifacts (Gratton, Coles, & Donchin, 1983), with signal exceeding

1. Here, we conceptualize sadness as a withdrawal-related emotion. It should be noted, however, that sadness may be associated with approach motivation in certain contexts, such as when one attempts to regain a lost object of attachment (Harmon-Jones & Allen, 1998; Shackman, 2000).

2. Compared to studies that use longer time periods to assess baseline EEG, the correlations reported here may be slightly attenuated. Some researchers (e.g., Tomarken et al., 1992) recommend sampling for at least 6 min, although others have found that 4 min, or even 20 s, is enough time to obtain a reliable measure of asymmetry (Gasser, Bacher, & Steinberg, 1985; Harmon-Jones & Allen, 1997).

3. A separate sample of introductory psychology students ($N = 16$) provided normative ratings of emotions elicited by each of these charity images using a 5-point scale (1 = *not at all* to 5 = *extremely*). Ratings were provided for *joy* ($M = 1.36$, $SD = .34$), *anger* ($M = 1.57$, $SD = .43$), *disgust* ($M = 1.64$, $SD = .53$), *sadness* ($M = 2.75$, $SD = .34$), *surprise* ($M = 1.57$, $SD = .43$), and *fear* ($M = 1.96$, $SD = .47$).

4. Some methodological choices (e.g., the duration of the intertrial interval and the decision to have participants view the images for the first time without providing ratings) were made because electromyography (EMG) was recorded during this experiment. Because the focus of this manuscript is the link between baseline EEG asymmetry and empathy, details on EMG results are not discussed here.

Table 2. *Intercorrelations Between Key Variables*

	1	2	3	4	5	6	7	8	9
1. Empathic Concern	–	.78**	.67**	.61**	.60**	−.41*	−.05	.33†	.62**
2. Sadness	–	–	.90**	.51**	.50**	−.52**	−.12	.16	.37*
3. Personal Distress	–	–	–	.43*	.38*	−.60**	−.22	.15	.22
4. Perspective-taking	–	–	–	–	.26	−.31	−.35†	−.19	.25
5. Volunteering	–	–	–	–	–	.01	.21	.14	.30
6. F4F3	–	–	–	–	–	–	.57**	−.17	−.10
7. FC4FC3	–	–	–	–	–	–	–	.40*	.06
8. CP4CP3	–	–	–	–	–	–	–	–	.59
9. P4P3	–	–	–	–	–	–	–	–	–

Notes. *N*s vary between 27 and 30 due to excluded electrode sites. Negative correlations indicate a positive relationship between right frontal asymmetry and the variable of interest.
**$p < .01$. *$p < .05$. †$p < .1$.

±75 μV rejected by computer algorithm. Artifact-free 2-s epochs were extracted through a Hamming window (75% overlap) and submitted to fast Fourier transform. Spectral power at each electrode was averaged across the 2 min of eyes-open and eyes-closed blocks of baseline. Power values were log-transformed, and asymmetry scores were calculated by subtracting left- from right-sided alpha at homologous sites. Asymmetry scores at F4F3 were taken as indices of frontal asymmetry, while scores at FC4FC3, CP4CP3, and P4P3 were used as nonfrontal control values.[5] Because alpha power (8–12 Hz) is inversely related to cortical activity (Lindsley & Wicke, 1974), higher values on our difference score indicate greater left hemisphere activity. We have chosen to use this metric because it is the most common in the frontal asymmetry literature, but we discuss our results in terms of right frontal asymmetry as that is the focus of the present study. As such, *negative* correlations will indicate a *positive* relationship between right frontal asymmetry and other variables.

Results

As we hypothesized, asymmetry scores at the F4F3 site were significantly correlated with empathic concern, sadness, and personal distress (Table 2; Figure 1).[6] No significant zero-order correlations were found between asymmetry at F4F3 and perspective-taking or intentions to volunteer. If the relationship between asymmetry and empathy is specific to frontal regions, as we would expect, these correlations should not be present for electrodes in central or parietal areas. At FC4FC3 and CP4CP3, asymmetry scores were not correlated with any of the variables of interest, with the exception of marginal relationships between FC4FC3 and perspective-taking, and between CP4CP3 and empathic concern. At P4P3, there were no significant relationships between asymmetry and personal distress, perspective-taking, or volunteering. For empathic concern and sadness, the correlations were the reverse of what we found for frontal regions. Thus, it appears that the relationship between rightward EEG asymmetry and empathy is specific to frontal regions.

According to the Russian doll model of empathy, sadness and personal distress reflect phylogenetically older processes of emotional contagion compared to empathic concern, which involves the additional step of recognizing a distinction between self and other (de Waal, 2008). To test whether the relationship between frontal EEG asymmetry and empathic concern could be accounted for by increased withdrawal-related emotional contagion, we ran a multiple mediation model testing the relationship between baseline frontal asymmetry and empathic concern with sadness and personal distress as mediators. Parameter estimates were obtained using bootstrap analysis with 5,000 resamples (Preacher & Hayes, 2008). Mediation is said to be significant if the 95% bias-corrected confidence interval for the parameter estimate does not contain 0. In this model, personal distress did not emerge as a significant

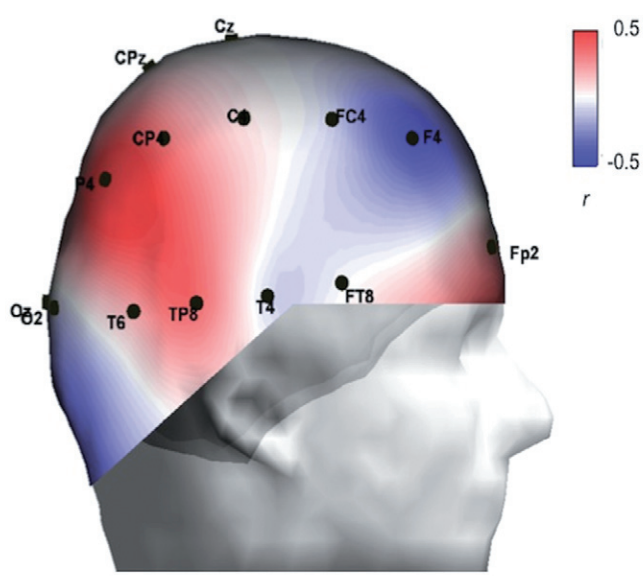

Figure 1. Topographic map of the correlation between asymmetry scores, [log(right)—log(left)], and empathic concern. Blue values indicate a positive relationship between right frontal asymmetry and empathic concern, while red values indicate a negative relationship.

5. Frontal asymmetry scores are also commonly analyzed at electrodes F8F7. In our sample, however, the F7 electrode site was excluded for 12 participants because of excessive noise identified prior to data analysis. Due to the substantially reduced sample size of participants with F8F7 data, we have not included analyses of these electrode sites. For the 18 participants with usable F8F7 data, the correlation between this asymmetry index and empathic concern is $r = .01$, $p = .96$, and the correlation between F4F3 asymmetry and empathic concern is $r = -.42$, $p = .08$.

6. With the outlier included, the correlations between F4F3 asymmetry scores and empathy, $r = -.27$, $p = .25$; personal distress, $r = -.21$, $p = .28$; and sadness, $r = -.17$, $p = .39$, were nonsignificant. Throughout the manuscript, we exclude this participant as outliers of this magnitude ($Z > 3.0$) have the potential to disproportionately influence correlation coefficients and to obscure relationships between variables (Osbourne & Overbay, 2004).

Figure 2. A mediation model depicting the relationship between frontal EEG asymmetry and empathic concern with sadness as a mediator; *c* is the total effect of frontal asymmetry on empathic concern and *c′* is the direct effect of frontal asymmetry on empathic concern. Negative values for *a* and *c* paths indicate a positive relationship between right frontal asymmetry and the relevant variables. Unstandardized regression coefficients from a bootstrap procedure are provided along with their associated standard errors. $N = 27$. **$p < .01$, *$p < .05$.

mediator, *CI*: (−1.62, 3.29), and as such we reran this model excluding personal distress (Figure 2; Figure 3). For the new model predicting empathic concern from right frontal asymmetry with sadness as a mediator, the confidence interval for sadness did not contain 0, *CI*: (−4.18, −.70), indicating that sadness was a significant mediator of the relationship between baseline frontal EEG asymmetry and empathic concern. Normal theory tests (Sobel, 1982) also indicate significant mediation, $Z = -2.67$, $p < .01$. When sadness is accounted for, the relationship between right frontal asymmetry and empathic concern is no longer significant, $c' = -.03$, $p = .97$.

We then examined the extent to which each hemisphere contributes to the link between frontal asymmetry and empathic concern and sadness. In order to control for variations in skull thickness and volume conduction, we used a hierarchical linear regression model that first controls for whole head power (Allen, Coan, & Nazarian, 2004). In the first step, we entered the average of log-transformed power values across all electrodes; in the second step, we entered the log-transformed power values at F4, F3, and their interaction; and in the third step, we entered the log-transformed power values at P4, P3, and their interaction. Using this model to predict empathic concern, we found that the overall model was significant, $F(7,19) = 4.31$, $p < .01$, adjusted $R^2 = .47$. Results indicated a main effect of the left hemisphere at F3, $t(19) = 2.56$, $p = .02$, a main effect of the left hemisphere at P3, $t(19) = -2.65$, $p = .02$, and a main effect of the right hemisphere at P4, $t(19) = 3.51$, $p < .01$. There was no significant effect of the right hemisphere at F4, $t(19) = -.51$, $p = .62$, and no other significant main effects or interactions, *t*s < 1.5, *p*s > .25. Using the same model to predict sadness, we found that the overall model was significant, $F(7,19) = 2.52$, $p = .05$, adjusted $R^2 = .29$. Again, there was a main effect of the left hemisphere at F3, $t(19) = 2.96$, $p < .01$, but no significant main affect for the right hemisphere at F4, $t(19) = -.88$, $p = .39$, and no other significant main effects or interactions, *t*s < 2, *p*s > .10. These results suggest that diminished left frontal activity, rather than enhanced right frontal activity, may largely account for enhanced empathy and sadness in participants with greater right frontal EEG asymmetry scores.

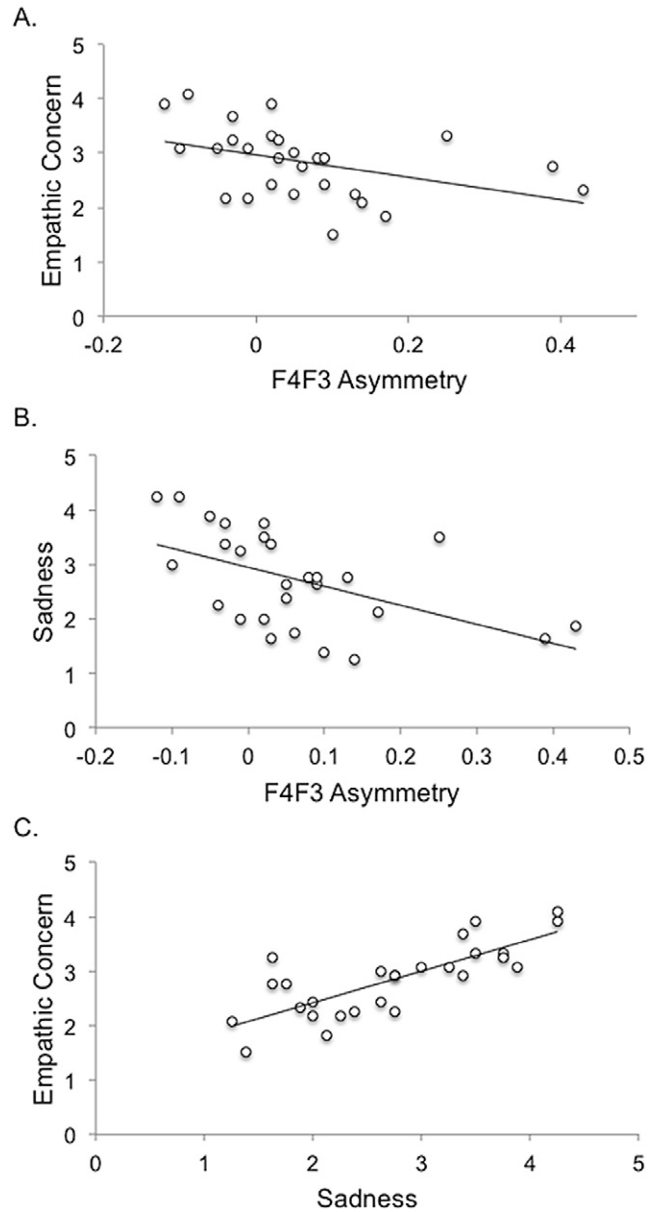

Figure 3. Scatterplots showing the relationships between: (A) frontal asymmetry [log(F4)—log(F3)] and empathic concern, (B) frontal asymmetry [log(F4)—log(F3)] and sadness, and (C) sadness and empathic concern. Negative slopes represent a positive relationship between right frontal asymmetry and the relevant variables.

Discussion

Consistent with our predictions, results indicated that individuals who displayed more dispositional right frontal EEG asymmetry were more likely to experience empathic concern when viewing charity images. In addition, this relationship was fully mediated by feelings of sadness in response to these images. These findings expand our understanding of right frontal EEG asymmetry by revealing that this pattern of brain activity is not only associated with the experience of withdrawal-related emotions, but also with feelings of compassion and concern.

One implication of our findings is that empathy, although measured with positive-sounding words like "warmth" and "compassion," might be an unpleasant emotional state. People who showed neural activity suggestive of a heightened tendency to experience withdrawal-related emotions were also the ones who were most likely to report empathic concern. Consistent with distress-relief models of helping, these results suggest that people who are more susceptible to "feeling the pain" of others are the ones who are most likely to empathize. This interpretation raises an important question: is baseline right frontal asymmetry associated with empathy only when the target is displaying withdrawal-related emotions? Theories of empathy that focus on internal simulation of others' affective states have led to the hypothesis that empathy may be augmented when there is overlap between the affective state of the observer and target (Preston & de Waal, 2002). Thus, people who show a dispositional rightward bias in frontal asymmetry may empathize with suffering targets because their withdrawal tendencies are congruent with the withdrawal-related emotions of the targets. Alternatively, right frontal asymmetry may be associated with greater empathy to both positive and negative targets, suggesting that this pattern of brain activity encourages a generalized increase in empathic concern regardless of the affective state of the target. Future research exploring this possibility has the potential to refine our understanding of empathic responding.

Our interpretation of our findings is also informed by emerging research on empathy's relationship with the error-related negativity (ERN; Gehring, Goss, Coles, Meyer, & Donchin, 1993). The ERN is a neural signal that is involved in the aversive affective reaction to conflict and error (Hajcak & Foti, 2008; Inzlicht & Al-Khindi, in press; Inzlicht & Tullett, 2010; Luu, Collins, & Tucker, 2000; Yeung, 2004; see Olvet & Hajcak, 2008, for a review). Consistent with these findings, the ERN is thought to be generated by the midcingulate cortex (MCC), a brain region involved in the integration of cognitive control, pain, and negative affect (Shackman et al., 2011). Importantly, new research finds that ERN amplitude is larger for those with greater baseline right frontal asymmetry (Nash, Inzlicht, & McGregor, in press), and for those who report high levels of dispositional empathy (Larson, Fair, Good, & Baldwin, 2010; Santesso & Segalowitz, 2009). Furthermore, fMRI research suggests that the MCC is part of a neural network involved in empathy (Fan et al., 2011). Because the amplitude of the ERN is associated with a susceptibility to negative affect, distress, and anxiety (Hajcak & Foti, 2008; Hajcak, McDonald, & Simons, 2003, 2004), these data suggest that this susceptibility is conducive to increased empathic responding.

It should be noted that, although we interpret our findings as supportive of a link between empathy and withdrawal motivation, others have suggested that empathy is inherently approach-motivated and would thus see our results as an indication that right frontal asymmetry can reflect approach motivation (e.g., Quirin et al., 2012). Because a substantive body of work supports the contention that right frontal asymmetry is associated with withdrawal, this alternative interpretation would require a greater departure from the existing literature (e.g., Davidson, 1995; Harmon-Jones & Allen, 1998). Nevertheless, future investigations in which motivational direction, frontal asymmetry, and empathy are independently assessed would help to address this possibility.

Although we found a relationship between right frontal asymmetry and empathy, and also between empathy and intentions to volunteer, there was no significant relationship between right frontal asymmetry and intentions to volunteer. This pattern of findings suggests that right frontal asymmetry may not be associated with helping, despite its connection to empathic responding. One limitation of the current work is that we did not include a behavioral measure of prosociality—our measure only assessed intentions. While the link between right frontal asymmetry and prosocial behavior remains to be investigated, the current pattern suggests that right frontal asymmetry leads to an empathic emotional response, but not necessarily to intentions to take action. This result may be clarified by theoretical accounts that link right prefrontal cortical activity to behavioral inhibition (Shackman, McMenamin, Maxwell, Greischar, & Davidson, 2009; Sutton & Davidson, 1997; cf. Coan & Allen, 2003), as well as findings documenting a relationship between negative affect and decreased helping in children (Moore, Underwood, & Rosenhan, 1973; Rosenhan, Underwood, & Moore, 1974).

In addition to the predicted relationship between asymmetry and empathy at frontal regions, we also found an unanticipated negative relationship between right parietal asymmetry (at sites P4P3) and empathy. For frontal regions, relatively greater right-than-left activity was associated with empathy, while in parietal regions this relationship was reversed. Although we are cautious in interpreting these results given inconsistencies in the literature regarding resting parietal EEG asymmetry (Henriques & Davidson, 1997; Kentgen et al., 2000), research on depression provides some precedent for a dissociation between frontal and parietal activation patterns. Whereas depression has frequently been associated with hypoactivity in *left frontal* regions (Henriques & Davidson, 1990, 1991; Nusslock et al, 2011; Schaffer et al., 1983), several studies have found that depressed participants show hypoactivity in *right posterior* regions (Allen, Iacono, Depue, & Abrisi, 1993; Henriques & Davidson, 1990, 1997). This pattern appears to best characterize a subset of depressed patients who do not have comorbid anxiety disorders (Bruder et al., 1997) or who show a pattern of underarousal (Stewart, Towers, Coan, & Allen, 2011). This pattern of relative reductions in left frontal activity and right parietal activity in depression also characterizes empathic responding in the current study, perhaps suggesting that some of the same factors that underlie susceptibility to depression also underlie a propensity to feel empathy. Further research that investigates EEG asymmetry, depression, and empathy in a single study could shed light on this possibility. Currently, however, this explanation remains speculative, and indeed research demonstrating the involvement of the right temporoparietal junction in empathy could lead to the opposing prediction that hyperactivity in right posterior regions should be positively associated with empathy (Decety & Lamm, 2007).

When we analyzed the contributions of the left and right hemisphere independently, empathy and sadness were more strongly related to reductions in activity at the left frontal F3 site than to increases in activity at the right frontal F4 site. Although these results suggest a stronger influence of reduced left frontal activity in the observed effects, most past research has suggested that the critical variable related to emotive processes is the asymmetry index. For instance, research with persons with damage to left or right frontal cortex (Goldstein, 1939), research with the Wada test (Terzian & Cecotto, 1959), and research using repetitive transcranial magnetic stimulation (Schutter, van Honk, d'Alfonso, Postma,

& de Haan, 2001) suggest that it is the reciprocal relationship between left and right frontal cortical activity that matters most for emotive processes (for a review, see Harmon-Jones et al., 2010).

Overall, these findings implicate right frontal EEG asymmetry in empathic responses; our results show that this pattern of brain activity translates to compassion and concern for other people who are enduring pain and suffering. Conversely, left frontal asymmetry may dampen other-oriented responses (or even encourage aggression; Harmon-Jones & Sigelman, 2001; Peterson, Shackman, & Harmon-Jones, 2008), as suggested by its association with decreased empathic reactivity towards others in need. We anticipate that further investigations of frontal cortical asymmetry and empathy could do much to clarify our understanding of the things that motivate people to care about the suffering of others.

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