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On the relationship of frontal brain activity and anger: Examining the role of attitude toward anger

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Activity in the left frontal cortex has been associated with positive affective traits, and activity in the right frontal cortex has been associated with negative affective traits. However, in this past research, the valence of the affect (positive vs. negative) was confounded with the direction of the motivation (approach vs. withdrawal). Recent research found that trait anger, a negative affect with approach tendencies, relates to increased left frontal activity. The present research addressed an alternative explanation for these past results—that the relationship between anger and increased left frontal activity is due to anger being regarded as a positive feeling. After developing a reliable and valid instrument that measures attitude toward anger, research indicated that trait anger related to relative left frontal activity and this relationship was not due to the anger being associated with a positive attitude toward anger.

Individual differences in temperament and affective traits have significant impacts on behaviour and well-being, and much recent research has been devoted to understanding them. One of the major foci has been the understanding of positive and negative affective traits (e.g., Watson, Wiese, Vaidya, & Tellegen, 1999), and a variety of methods have been used to assess them. Although the bulk of this research has used self-reported assessments, other research has demonstrated that individual differences in affective traits are associated with differences in regional brain activity, as assessed by alpha power in the electroencephalogram (EEG). Much of this research has focused on the

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roles of the left and right frontal regions of the brain, and has demonstrated that left frontal activity is associated with positive affective traits, and that right frontal activity is associated with negative affective traits (for reviews, see Davidson, 1995; Davidson, Jackson, & Kalin, 2000; Fox, 1991; Silberman & Weingartner, 1986). Moreover, research has demonstrated that individual differences in resting frontal asymmetrical activity are stable in humans (Tomarken, Davidson, Wheeler, & Kinney, 1992) and rhesus monkeys (Kalin, Larson, Shelton, & Davidson, 1998).

In the research on the frontal asymmetry, the valence of the emotion (positivity-negativity) has often been confounded with the direction of motivation (approach-withdrawal) in theoretical models, and consequently, some scientists have posited that the left frontal region is involved in only positive emotion and that the right frontal region is involved in only negative emotion (e.g., Ahern & Schwartz, 1985; Gotlib, Ranganath, & Rosenfeld, 1998; Heller & Nitschke, 1998; Silberman & Weingartner, 1986). Indeed, this theoretical model is widely accepted (e.g., Oatley & Jenkins, 1996; Zajonc & McIntosh, 1992). Still others have posited that the left frontal region is involved in positive, approach-related emotions and that the right frontal region is involved in negative, withdrawal-related emotions (Davidson, 1998). An alternative model suggests that the left frontal region is involved in approach motivation and that the right frontal region is involved in withdrawal motivation. Recent research has demonstrated a relationship between left frontal cortical activity and individual differences in behavioural approach sensitivity (BAS; Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997), consistent with this model (for reviews, see Davidson, 1995; Fox, 1991). However, in this research, BAS was related to positive affect, rendering it impossible to infer whether approach motivation or positive affect was responsible for the relationship of left frontal activity with BAS.

Often, positive emotion is associated with approach-related motivation, whereas negative emotion is associated with withdrawal-related motivation. Indeed, most contemporary theories of emotion posit that positive emotion is always associated with approach motivation and that negative emotion is always associated with withdrawal motivation (e.g., Lang, Bradley, & Cuthbert, 1997; Watson, 2000). However, certain emotions violate this relationship between the valence of emotion and the direction of motivation. Anger is an example of a violation of the relationship, because anger is considered negative in valence (e.g., Lazarus, 1991; Watson et al., 1999), but it often evokes approach motivation (e.g., Berkowitz, 1999, 2000; Darwin, 1872/1965; Plutchik, 1980; Young, 1943). Thus, anger provides an optimal means of testing the emotional and motivational functions of the frontal regions of the brain. That is, does the frontal asymmetry reflect the valence of the emotion or the direction of the motivation?

Anger as approach

Research is consistent with the conceptual view that anger is an emotion that elicits approach tendencies. Careful observations of animal behaviour have revealed different types of aggression, presumably motivated by different systems. For instance, research has separated defensive aggression from offensive aggression (Blanchard & Blanchard, 1984; Flynn, Vanegas, Foote, & Edwards, 1970; Moyer, 1976). It has been posited that offensive aggression results from anger and that pure offensive (approach-related) aggression ''involves attack without attempts to escape from the object being attacked'' (Moyer, 1976, p.187). Further evidence supporting the conceptualisation of anger as being associated with approach comes from research on testosterone, which has been found to be associated with anger and aggression in humans (e.g., Olweus, 1986). In other research, testosterone treatments have been found to decrease withdrawal (fear) responses in a number of species (e.g., Boissy & Bouissou, 1994; Vandenheede & Bouissou, 1993).

Other evidence is consistent with the view that anger often evokes approach motivation. For instance, Mikulincer (1988) found that participants who exhibited anger in response to one unsolvable problem performed better on a subsequent cognitive task than did participants who exhibited less anger. In addition, Lewis, Sullivan, Ramsay, and Alessandri (1992) found that, during conditioning research, infants who expressed anger during extinction maintained interest during subsequent relearning, whereas infants who expressed sadness during extinction evidenced decreased interest during relearning. Thus, subsequent to frustrating events, anger may maintain and increase task engagement and approach motivation. Also consistent with the view that anger is associated with approach motivation is research indicating that trait anger is associated with trait assertiveness and competitiveness, which are approach tendencies (Buss & Perry, 1992). Trait anger has also been found to relate positively to individual differences in BAS (as measured by Carver & White's, 1994, questionnaire; Harmon-Jones, in press). Moreover, individual differences in BAS have been found to relate to increased reports of anger in response to frustrating events (Carver, 2002).

Additional evidence for the present conceptualisation of anger as approach comes from research that has found that mania is associated with irritability (Cassidy, Forest, Murry, & Carroll, 1998). Mania can be conceptualised as an approach tendency (Depue & Iacono, 1989; Fowles, 1993), as the major symptoms of mania involve approach-related behaviours and cognitions (e.g., grandiosity). Other research has found mania to be associated with damage to right frontal cortex (see review by Robinson & Downhill, 1995). Damage to the right frontal cortex may cause increased approach tendencies because the approach motivation functions of the left frontal cortex are released and not

restrained by the right frontal withdrawal system. Consistent with this line of reasoning, recent research has demonstrated that individuals with proneness toward mania respond with increased left frontal activity when confronted with an anger-inducing situation (Harmon-Jones et al., 2002).

Finally, other research has revealed that when individuals are angered, they respond with increased relative left frontal activity (Harmon-Jones & Sigelman, 2001; Harmon-Jones, Vaughn, Mohr, Sigelman, & Harmon-Jones, 2001), but only if there is an opportunity to approach the source of the anger (Harmon-Jones, Sigelman, Bohlig, & Harmon-Jones, 2003).

Anger and asymmetrical frontal cortical activity

One previous study has found that high levels of trait anger were associated with increased left frontal activity and decreased right frontal activity (Harmon-Jones & Allen, 1998), suggesting that the frontal asymmetry is associated with motivational direction (approach vs. withdrawal) rather than emotional valence. Moreover, in this study, general positive and negative affect, as assessed by the Positive and Negative Affect Schedule-Children's version (PANAS-C; Laurent, Potter, & Catanzaro, 1994), related to the frontal asymmetry in magnitudes similar to those found in previous research (Sutton & Davidson, 1997). That is, positive affect related to relative left frontal activity and negative affect related to relative right frontal activity. Positive affect and anger related to relative left frontal activity presumably because both affects are approach-related. Moreover, controlling for positive and negative affect, separately and together, did not alter the magnitude of the anger-frontal asymmetry relationship. These results suggest that anger is related to relative left frontal activity, independent of general positive and negative affect.[1]

However, an alternative explanation exists for the past research that revealed a relationship between trait anger and relative left frontal activity (Harmon-Jones & Allen, 1998). That is, for persons with high levels of trait anger, perhaps anger is a positive emotion, and this positive feeling or attitude toward anger is responsible for anger being associated with relative left frontal activity. To understand why anger might be regarded positively, it is important to consider

[1] In the original Harmon-Jones and Allen (1998) article, the results of controlling for the effects of positive and negative affect on the anger—frontal asymmetry relationship were not reported; only the bivariate correlations were reported. When negative affect and anger were used to predict the frontal asymmetry, negative affect related negatively to relative left frontal activity (*partial r* = −.28) and anger related positively to relative left frontal activity (*partial r* = .51). When positive affect and anger were used to predict the frontal asymmetry, positive affect related positively to relative left frontal activity (*partial r* = .24) and anger related positively to relative left frontal activity (*partial r* = .50). When negative affect, positive affect, and anger were used to predict the frontal asymmetry, negative affect related negatively to the relative left frontal activity (*partial r* = −.23), positive affect related positively to relative left frontal activity (*partial r* = .18), and anger related positively to relative left frontal activity (*partial r* = .53).

what is meant by positivity and negativity of emotion. As Lazarus (1991) and others have suggested, emotions can be regarded as positive or negative: (1) *because of the conditions that evoked the emotion*; (2) *because of the emotion's adaptive consequences*; or (3) *because of the emotion's subjective feel*. In fact, many emotion scientists are not explicit by what they mean by the positivity and negativity of emotion. The emotion of anger can be viewed as negative when considering the conditions that evoked the emotion, because anger is evoked by aversive events. Anger could be viewed as either positive or negative when considering its adaptive consequences, depending upon the outcome of a particular situation. And finally, anger could be viewed as either positive or negative when considering the subjective feel or evaluation of the emotion, depending on whether an individual likes or dislikes the subjective experience of anger.

When discussing the valence of emotion, it is important to consider the definition of emotion. Although there is no completely accepted definition of emotion, some scientists focus on the stimulus conditions when defining emotion (e.g., a perceived offence causes anger), whereas others focus on the responses evoked when defining emotion (e.g., anger involves certain physiological changes, behavioural expressions, and subjective feelings). The stimulus-based definitions indicate that the individual's evaluation of the stimulus causing the emotion determines the valence of the emotion (Lazarus, 1991). Lazarus (1991) and other appraisal theorists regard definition 1—the beneficial or harmful person-environment relationship—as the most important and frequent way of distinguishing positive from negative emotions. By this definition, then anger is clearly a negative emotion.

Response-based definitions indicate that the individual's subjective evaluation of the feeling determines valence. As Jung (1923) suggested: ''Feeling is also a kind of judging, differing, however, from an intellectual judgment, in that it does not aim at establishing an intellectual connection but is solely concerned with the setting up of a subjective criterion of acceptance or rejection.'' When anger is examined as a subjective experience, however, it is not necessarily negative; it can be subjectively accepted or rejected. Anger can be evaluated positively by the person experiencing the emotion, as when an individual says, ''I like how it feels when I am furious''. Indeed, the very idea of emotion regulation implicitly assumes that individuals either like or dislike the experienced emotional state and act in ways to maintain or alter the emotion. Although many persons find the experience of anger unpleasant, some individuals may find it relatively more pleasant. As Ekman and Friesen (1975) wrote: ''Some people take considerable pleasure in the experience of anger'' (p. 81). The poet Homer vividly expressed this idea in the following quote:

> O how I wish all strife would die among gods and men and with it anger, that causes the wisest to sulk and storm, resentment that is more delicious than trickling

> honey and spreads like smoke in the hearts of mortals, as mine most surely did when King Agamemnon provoked me. (*The Iliad of Homer*, 1977, p. 375)

One way in which subjective feelings about anger could be measured is through the use of an attitude questionnaire. Attitudes are considered evaluations; they are posited to have cognitive, emotional, and behavioural components (e.g., Breckler, 1984; Katz & Stotland, 1959; Rosenberg & Hovland, 1960). They are ''general and enduring favorable or unfavorable feelings about, evaluative categorizations of, and action predispositions toward stimuli'' (Cacioppo & Berntson, 1994, p. 401). They are ''very general evaluations that people hold of themselves, other people, objects, and issues'' (Petty, 1995, p. 196).

Anger as positive

One possible explanation for the relationship of anger with increased left frontal activity could be the fact that individuals with high levels of trait anger enjoy the experience of anger more than individuals with low levels of trait anger, and this enjoyment of anger rather than the approach motivation characteristics of anger accounts for the relationship of trait anger and left frontal activity. Indeed, most past emotion and frontal asymmetry research could be explained in such a manner. For example, behavioural approach sensitivity (BAS) may relate positively with left frontal activity because it is positively related to positive attitudes toward positive affect (which are related to BAS). Similarly, depression may relate negatively with left frontal activity because it is negatively related to positive attitudes toward positive affect. The state research suffers the same limitation. When participants in Sobotka, Davidson, and Senulis (1992) evidenced increased left frontal activity to the promise of reward, was it because of the pre-goal positive affect that was presumably evoked or was it because they liked the feeling of pre-goal positive affect? The idea that attitudes can be associated with frontal cortical activity has yet to be evaluated empirically, though one past study suggested that resting frontal cortical asymmetry but not resting parietal cortical asymmetry predicts attitudes toward merely exposed stimuli (Harmon-Jones & Allen, 2001).

Thus, the primary purpose of the present study was to examine the relationship of attitude toward anger with the resting frontal asymmetry in brain activity. To examine this alternative hypothesis, a measure of attitude toward anger was needed. Therefore, the first three studies were designed to create and then assess the reliability and validity of a scale that would assess attitude toward anger.

STUDY 1

In Study 1, the Attitude Toward Anger (ATA) scale was created and then its reliability was assessed. The creation of the scale involved the generation of 32 items that assessed at face value the extent to which individuals liked or disliked the feeling of anger.

Methods and results

A total of 1040 introductory psychology students completed the scale in a mass survey session. The initial ATA was a 32-item scale that asks persons to rate how much they like or dislike feelings of anger.

The dataset was randomly divided into two sets—one composed of 700 participants and one composed of 340 participants. With the set of 700, an initial exploratory factor analysis was conducted to determine whether the scale contained more than one factor and to determine which items loaded highly on the factor(s). A principal-components analysis was performed on the 32 items, and the scree plot suggested that one factor comprised the data. This factor accounted for 36% of the variance (eigenvalue of 11.50), and every other factor accounted for less than 7% of the variance (eigenvalues < 2.25). Only items with loadings greater than .60 were retained. To further reduce the number of items and create a better balance between ''like'' and ''dislike'' statements, an additional six items were removed, leaving 11 items. With the remaining 340 participants, the internal reliability of the scale was computed and found to be acceptable (Cronbach's coefficient alpha = .89). In addition, the same one-factor solution emerged in this group of 340 participants (eigenvalue = 5.45; 50% of variance; other factors' eigenvalues < 1.05; all loadings > .59). The 11-item ATA questionnaire is presented in the Appendix.

Ten weeks after the mass testing session, 46 participants completed the ATA and the test-retest reliability was examined. The scale demonstrated reasonable 10 week test-retest reliability ($r = .62$, $p < .001$).

STUDY 2

The Attitude Toward Anger (ATA) scale has the advantage of face validity. In addition, the results presented thus far suggest that the ATA assesses a unitary construct that is internally consistent and reliable across time. To assess the convergent and discriminant validity of the ATA, a second study was conducted in which relationships between the ATA and constructs that should converge with the ATA and discriminate from the ATA were assessed. Regarding convergent validity, it was predicted that individuals who were higher in trait anger would have more positive attitudes toward anger. Such a prediction follows from self-perception theory. According to self-perception theory, individuals who often behave in certain ways may infer that they enjoy behaving in those ways (Bem, 1972). When applied to anger, individuals who often experience anger may infer that they enjoy being angry. Of course, there may be other factors that cause and/or influence trait attitude toward anger. To test the prediction that attitude toward anger would relate to trait anger, individuals completed the ATA and two measures of trait anger.

To differentiate the measure of ATA from other measures of trait affect, the ATA was compared with other measures of trait negative affect and a measure of affect intensity. It was predicted that the ATA would not relate to affect

intensity, which assesses a general tendency to respond with intense affects regardless of their type or valence. It was also predicted that ATA would not relate to negative affects other than anger. Thus, ATA should not relate positively to fear, guilt, shyness, fatigue, or sadness.

Methods

Participants were 194 students (55 men and 139 women) introductory psychology students at the University of Wisconsin–Madison who took part in the study in exchange for extra credit in their psychology course.

The individuals participated in small groups of 8 to 12 in a room with chairs spaced apart so that each individual felt a sense of privacy when completing questionnaires. The experimenter explained that the study was concerned with the relationship between various personality questionnaires and that the participants would be asked to complete several personality questionnaires. After providing informed consent, the participants completed a packet of personality questionnaires (in a random order), which included: the Attitude Toward Anger scale, the Buss and Perry (1992) Aggression Questionnaire, the Positive and Negative Affect Schedule-Expanded Form (PANAS-X; Watson & Clark, 1991), and the Affect Intensity Measure (Larsen & Diener, 1987).

The Buss and Perry (1992) Aggression Questionnaire has 29 items that form four subscales: (1) physical aggression, which assesses the frequency of acting aggressively; (2) verbal aggression, which assesses the frequency of behaving verbally aggressively; (3) anger, which assesses the emotional component of aggression; and (4) hostility, which assesses the cognitive component of aggression that can be described as ''feelings of ill will and injustice'' (Buss & Perry, 1992, p. 457). As in past research (Harmon-Jones & Allen, 1998), anger was the focus of the present study, though results for the other subscales are also presented. All subscales were internally consistent in the present study (Cronbach's alphas > .78).

The PANAS-X (Watson & Clark, 1991) is an expansion of the original PANAS (Watson, Clark, & Tellegen, 1988). It contains 60 items designed to assess 11 specific affective states: fear (e.g., afraid, scared), sadness (e.g., sad, blue), guilt (e.g., guilty, ashamed), hostility (angry, hostile, irritable, scornful, disgusted, loathing), shyness (e.g., shy, bashful), fatigue (e.g., sleepy, tired), surprise (e.g., amazed, surprised), joviality (e.g., happy, joyful), self-assurance (e.g., proud, strong), attentiveness (e.g., alert, attentive), and serenity (e.g., calm, relaxed). Participants were asked to indicate to what extent they had felt each of the feelings ''in general, that is, on the average''. All subscales were internally consistent in the present study (Cronbach's alphas > .75).

The Affect Intensity Measure (Larsen & Diener, 1987) is designed to assess individual differences in typical strength of responsiveness to emotional events. It contains 40 items (e.g., Sad movies touch me deeply; When I'm happy I

bubble over with energy). It was internally consistent in the present study (Cronbach's alpha = .83).

Results

As predicted, ATA related positively to both measures of trait anger (see Table 1), thus establishing the convergent validity of the ATA. It is important to note that the correlations of the ATA with the trait anger indices were not very large, suggesting that the ATA assesses more than trait anger.

Also as predicted, bivariate correlations revealed that ATA did not significantly relate to fear, shyness, or fatigue (see Table 1). However, ATA did relate positively to guilt and sadness. Because these negative affects are highly correlated with a general negative affect factor (Watson & Clark, 1991), it is important to control for this general negativity when examining the relationship of ATA with each of these negative affects. To accomplish this, a simultaneous regression analysis was performed in which ATA was predicted by PANAS hostility, fear, guilt, sadness, shyness, and fatigue. The overall analysis produced a *multiple* $R = .41$, $p < .001$. Only PANAS hostility related positively to ATA ($\beta = .41$, *partial* $r = .32$, $p < .001$). None of the other affects related positively and

TABLE 1
Correlations of variables with ATA: Study 2

Variable	*ATA*
B&P Anger	.39***
PANAS-X Hostility	.33***
PANAS-X Fear	.02
PANAS-X Shyness	.09
PANAS-X Fatigue	.10
PANAS-X Guilt	.23**
PANAS-X Sadness	.18*
PANAS-X Jovial	−.17*
PANAS-X Self-assurance	.04
PANAS-X Attentive	−.25***
PANAS-X Serenity	−.17*
PANAS-X Surprise	−.08
B&P Physical Aggression	.38***
B&P Verbal Aggression	.21**
B&P Hostility	.23**
Affect Intensity	−.02

ATA = attitude toward anger; B&P = Buss and Perry scales; all emotion scales are from Positive and Negative Affect Scales-Expanded (PANAS-X). For each individual difference index, greater scores reflect more of the construct. *** $p < .001$; ** $p < .01$; * $p < .05$.

significantly to ATA (all *p*s > .07). Interestingly, in this analysis, fear related negatively to ATA (β = −.25, *partial r* = −.22, $p < .01$). Whatever the interpretation for this latter finding, the results suggest that ATA is only positively related to PANAS hostility as predicted.

No predictions were advanced for the relationships between ATA and positive affects. Results indicated that ATA correlated negatively with joviality, attentiveness, and serenity. ATA was not significantly correlated with self-assurance or surprise. These relationships of ATA with some positive affects may have occurred because these positive affects were related to hostility. To control for these interrelationships, a simultaneous regression was performed in which joviality, attentiveness, serenity, and hostility predicted ATA. The overall analysis produced a *multiple R* = .37, $p < .001$. Only attentiveness (β = −.17, *partial r* = −.16, $p < .05$) and hostility (β = .28, *partial r* = .26, $p < .001$) predicted ATA (all other *p*s > .95).

Finally, the ATA did not relate to the affect intensity measure, suggesting that the ATA taps something other than affect intensity.

STUDY 3

Results of Studies 1 and 2 suggest that the ATA is a reliable and valid instrument for assessing individual differences in attitudes toward anger. However, such validity would be compromised if the ATA related to concerns with social desirability. In other words, if individuals failed to accurately report their positive attitudes toward anger because of concerns about appearing socially undesirable, then results obtained with the ATA would potentially be invalid.

In addition, if ATA is negatively correlated with social desirability concerns, then this negative correlation might prevent ATA from being associated with left frontal activity. To understand why this might be the case, it is important to know that past research has found a significant relationship between social desirability and asymmetrical frontal activity, such that low social desirability is associated with greater relative right frontal activity (Tomarken & Davidson, 1994; but see Kline, Allen and Schwartz, 1998, for evidence suggesting that this relationship applies only to women and not men). Thus, if individuals who score high on ATA also score low on social desirability, then they may be more likely to evidence greater relative right frontal activity, thus preventing a significant positive relationship between ATA and relative left frontal activity. Of course, the same concern could be expressed about trait anger, which has been found to relate negatively to social desirability (Harris, 1997). But even though trait anger correlates with social desirability, it has been found to relate to relative left frontal activity (Harmon-Jones & Allen, 1998).

To assess whether ATA correlated with social desirability, a study was conducted in which participants completed the ATA, the Buss and Perry (1992)

Aggression Questionnaire, and the Marlowe-Crowne (1960) Social Desirability Scale.

Method

Participants were 41 students (15 men and 26 women) introductory psychology students at the University of Wisconsin–Madison who took part in the study in exchange for extra credit in their psychology course.

The individuals participated in small groups of 4–8 in a room with chairs spaced apart so that each individual felt a sense of privacy when completing questionnaires. The experimenter explained that the study was concerned with the relationship between various personality questionnaires and that the participants would be asked to complete several personality questionnaires. After providing informed consent, the participants completed a packet of personality questionnaires, which included (in a random order): the ATA scale, the Buss and Perry (1992) Aggression Questionnaire, and the Marlowe-Crowne Social Desirability Scale (Crowne & Marlowe, 1960). Cronbach's alphas for all questionnaires were greater than .70. Analyses focused on the ATA, the social desirability scale, and the trait anger subscale of the Buss and Perry (1992) Aggression Questionnaire.

Results

Replicating Study 2, the ATA related positively to trait anger ($r = .45$, $p < .01$). Replicating past research (Harris, 1997), trait anger was related to social desirability ($r = -.26$, $p < .10$; this correlation was significant in past research with a larger sample), indicating that greater anger was associated with lesser social desirability. ATA, however, was not significantly related to social desirability ($r = -.01$, $p > .90$). These results suggest that concerns about ATA being related to social desirability are unwarranted. Perhaps anger correlates with social desirability because anger, as assessed by the Buss and Perry (1992) questionnaire, is often publicly expressed. On the other hand, ATA may not correlate with social desirability because attitudes toward anger may rarely be publicly expressed.

STUDY 4

Studies 1–3 suggested that the ATA is a reliable and valid instrument for assessing the attitude toward anger. Moreover, results suggest that ATA is not contaminated by social desirability concerns. Study 4 was designed to assess whether ATA mediated the relationship between resting left frontal activity and anger. As demonstrated in Studies 2 and 3, anger relates to a more positive attitude toward anger, and thus it is plausible that the more positive attitude toward anger relates to left frontal activity. Such a finding would be

consistent with valence models of asymmetrical frontal activity that predict that relative left frontal activity is associated with positive affect and relative right frontal activity is associated with negative affect, because anger may be a relatively positive emotion for individuals who like anger (see definition 3, p. 341, this paper). On the other hand, motivational models of asymmetrical frontal activity would predict that anger relates to relative left frontal activity because anger is an approach motivational tendency. Consequently, anger and not necessarily the positive feelings about anger should relate to relative left frontal activity. To test these competing predictions, resting asymmetrical frontal activity was assessed using EEG as in past research (Harmon-Jones & Allen, 1997, 1998; Tomarken et al., 1992). It was then related to trait anger and attitude toward anger. According to the valence model, anger should relate to relative left frontal activity, and this relationship *should* be mediated by attitude toward anger. Therefore, when attitude toward anger and anger are used to predict left frontal activity, ATA should be a significant predictor but anger should not be. According to the motivational model, anger should relate to relative left frontal activity, and this relationship *should not* be mediated by attitude toward anger. Therefore, when ATA and anger are used to predict left frontal activity, anger should be a significant predictor and the relationship between anger and left frontal activity should not be attenuated by ATA.

Methods

Participants. Participants were 97 right-handed students, 47 men and 50 women, who were currently enrolled in an introductory psychology course at the University of Wisconsin–Madison.[2] The participants volunteered to take part in the study and were given extra credit for their participation. Participants were right-handed (score <= 17 on the Chapman & Chapman, 1987, handedness questionnaire), and reported no history of psychiatric disorder, neurologic disorder, or brain trauma. Only right-handed participants were invited to participate in the experiment because research suggests that right- and left-handed persons may differ in hemispheric specialisation of emotion (Heller & Levy, 1981).

Procedure. Prior to the experiment, a phone interview was conducted. Participants were informed that we would be measuring brain activity using an EEG cap, that the study would last approximately two hours, and that the study would contribute to understanding the brain mechanisms involved in emotion. Handedness was assessed using Chapman and Chapman's (1987) questionnaire.

[2] An additional 3 men and 1 woman did not complete the trait anger questionnaire (a total of 101 participants were run). Also, ATA data were missing from 1 man and 2 women.

Participants were also asked if they were currently taking any psychoactive medications and if they had seen a health care professional for emotional or psychiatric problems; those who responded affirmatively to these questions were not invited to participate.

Upon arrival for the experiment, each participant was given a brief explanation of EEG recording and then asked to read and sign a consent form. A stretch-lycra electrode cap (Electro Cap; Eaton, OH) was then applied to the participant. When the cap application was complete, 8 minutes of recordings were made while the participant sat in a dimly lit, sound-attenuated room, in a comfortable chair. Participants were asked to relax with their eyes closed (C) or open (O) in one of two alternating orders of 1 minute intervals (O, C, C, O, C, O, O, C or C, O, O, C, O, C, C, O). Participants were asked to keep their head and body as still as possible during the recording, and they were given instructions via intercom by the experimenter, who was in an adjacent room, which contained the amplifiers and computers.

After the recordings were taken, participants completed in a random order the ATA and Buss and Perry's (1992) Aggression Questionnaire, which contains four subscales including anger. Upon completion, participants were debriefed. Then, they completed another short study unrelated to the present one.

EEG recording. EEG recording and data analyses followed recommendations by Pivik et al. (1993). To record EEG, 27 (22 homologous and 5 midline) electrodes mounted in a stretch-lycra electrode cap (Electro-Cap, Eaton, OH) were placed on the participant's head using known anatomical landmarks (Blom & Anneveldt, 1982). EEG was recorded from the frontal, central, temporal, parietal, and occipital regions of the brain, using the 10% electrode system (Chatrian, Lettich, & Nelson, 1985), which was based on the 10–20 international system (Jasper, 1958). The ground electrode was mounted in the cap on the midline between the frontal pole (Fpz) and the frontal site (Fz). The reference electrode was placed on the left ear (A1), and data were also acquired from an electrode placed on the right ear (A2), so that an off-line digitally derived, averaged ears' reference could be computed. Eye movements (EOG) were also recorded to facilitate artifact scoring of the EEG. EOG was recorded from the supra- and suborbit of the left eye, to assess vertical eye movements, and from the left and right outer canthus, to assess horizontal eye movements. All electrode impedances were under 5000 ohms, and homologous sites (e.g., F3 and F4) were within 1000 ohms of each other. Electro-Gel (Eaton, OH) was used as the conducting medium. EEG and EOG were amplified with Neuroscan Synamps (Herndon, VA), bandpass filtered (0.1–100 Hz; 60 Hz notch filter enabled), digitised at 500 Hz, and stored onto the hard drive of a Pentium 200 MMX computer. Prior to running each participant, to assess the technical integrity of the recording system, 400 microvolts 20 Hz calibration signals were run and inspected.

Data analysis. The EEG and EOG signals were visually scored on a high resolution computer monitor and portions of the data that contained eye movements, muscle movements, or other sources of artifact were removed. When artifact occurred in one channel at a point in time, data from all channels were removed at that point in time. Derived averaged-ears reference was used for further data reduction (e.g., Harmon-Jones & Sigelman, 2001; Harmon-Jones et al., 2003). All artifact-free epochs that were 2.048 seconds in duration were extracted through a Hamming window, which was used to prevent spurious estimates of spectral power. Contiguous epochs were overlapped by 75%, to minimise loss of data due to Hamming window extraction. A fast Fourier transform (FFT) was used to calculate the power spectra. These power values were averaged across the 2.048 s epochs of a given resting trial (open and closed). Because alpha power is inversely related to cortical activity (Cook, O'Hara, Uijtdehaage, Mandelkern, & Leuchter, 1998; Davidson, Chapman, Chapman, & Henriques, 1990; Lindsley & Wicke, 1974), total power within the alpha (8–13 Hz) frequency range was obtained. The power values were log transformed for all sites, to normalise the distributions. All asymmetry indexes (log right minus log left alpha power) were computed. Because alpha power is inversely related to cortical activity, higher scores on the indexes indicate greater relative left hemisphere activity. Data were averaged across eyes-open and eyes-closed minutes. An average of 816.81 artifact-free epochs (SD = 112.25) comprised the resting data, and all participants had greater than 500 artifact-free epochs.

Results

Bivariate correlations are displayed in Table 2. Trait anger correlated positively with relative left frontal activity during resting, in midfrontal, lateral frontal, frontal temporal, and frontal central regions. In contrast, attitude toward anger did not correlate with the frontal asymmetry, suggesting that a relatively positive attitude toward angry feelings does not account for the relation of trait anger with the frontal asymmetry. Physical aggression and verbal aggression did not correlate with asymmetrical cortical activity, which is consistent with past research (Harmon-Jones & Allen, 1998). These results suggest that trait physical aggression and verbal aggression may not solely tap approach motivation. For example, aggression may result from defensive motivation and may not be motivated by angry, approach-related motivation. Hostility correlated with relative right central parietal activity. This correlation was not predicted and at present cannot be explained.

As shown in Table 2, anger was significantly related to asymmetrical activity only in the frontal regions. Anger did not relate significantly to asymmetrical activity in the frontal pole, anterior temporal, posterior temporal, central, central parietal, parietal, or occipital regions. Taken together, the results suggest that the relationship of anger to the EEG asymmetry was specific to the frontal regions and not a general hemispheric effect.

TABLE 2
Correlations among variables: Study 4

Variable	*ATA*	*P-Agg*	*V-Agg*	*Ang*	*Hos*	*F43*	*F87*	*T43*	*T65*	*FP21*	*FT87*	*O21*	*C43*	*CP43*	*FC43*
P-Agg	.21*														
V-Agg	.17	.38***													
Ang	.25*	.56***	.44***												
Hos	.05	.31**	.34**	.58***											
F43	−.01	.07	.07	.29**	.11										
F87	.11	.09	.19	.35**	.14	.77***									
T43	−.16	.04	−.14	.14	.05	.18	.20								
T65	−.14	.03	−.13	−.16	−.19	−.12	−.31**	.10							
FP21	.10	.03	−.05	.07	.04	.44***	.46***	.13	−.19						
FT87	.09	.10	.13	.31**	.06	.69***	.83***	.26	−.17	.27					
O21	−.16	.04	−.13	−.01	−.06	.01	−.00	.01	.20	.03	−.03				
C43	−.14	−.02	−.00	−.07	−.09	.23*	.02	.08	.25	−.00	.26	−.04			
CP43	−.14	−.11	−.11	−.14	−.23*	.24*	.01	.09	.37	−.04	.22	.14	.79		
FC43	−.10	.10	−.00	.24*	.18	.53***	.44***	.13	.02	.27	.51	.07	.61	.38	
P43	−.10	−.12	−.07	−.11	−.10	.08	−.02	.06	.33	−.04	−.01	.22	.29	.44	.14

ATA = attitude toward anger; P-Agg = physical aggression subscale of Buss and Perry aggression questionnaire (AQ); V-Agg = verbal aggression subscale of Buss and Perry AQ; Ang = anger subscale of Buss and Perry AQ; Hos = hostility of Buss and Perry AQ; F43 = asymmetry index at midfrontal sites; F87 = asymmetry index at lateral frontal sites; T43 = asymmetry index at anterior temporal sites; T65 = asymmetry index at posterior temporal sites; FP21 = asymmetry index at frontal pole sites; FT87 = asymmetry index at frontal temporal sites; O21 = asymmetry index at occipital sites; C43 = asymmetry index at central sites; CP43 = asymmetry index at central parietal sites; FC43 = asymmetry index at frontal central sites; P43 = asymmetry index at parietal sites; for all questionnaires, higher scores reflect more of the construct; for the asymmetry indexes, higher scores reflect greater left-sided activity. *** $p < .001$; ** $p < .01$; * $p < .05$.

Mediation. To provide a test for the independent contributions of anger and attitude toward anger on the frontal asymmetry, regression analyses were performed in which the frontal asymmetry was predicted simultaneously by anger and attitude toward anger. Results from these analyses indicated that anger significantly predicted relative left frontal activity (lateral frontal $\beta = .34$, partial $r = .33$, $p < .005$; midfrontal $\beta = .30$, partial $r = .29$, $p < .005$; frontal temporal $\beta = .31$, partial $r = .30$, $p < .005$; frontal central $\beta = .28$, partial $r = .27$, $p < .01$). Attitude toward anger did not predict relative left frontal activity (lateral frontal $\beta = .03$, partial $r = .04$, $p = .73$; midfrontal $\beta = -.09$, partial $r = -.09$, $p = .41$; frontal temporal $\beta = .01$, partial $r = .01$, $p < .92$; frontal central $\beta = -.16$, partial $r = -.16$, $p = .11$). The overall multiple *R*s for each of these analyses were: lateral frontal *multiple* $R = .35$, $p < .003$; midfrontal *multiple* $R = .29$, $p < .02$; frontal temporal *multiple* $R = .31$, $p < .01$; frontal central *multiple* $R = .28$, $p < .03$. These results suggest that ATA did not statistically mediate the relationship between trait anger and relative left frontal cortical activity (Baron & Kenny, 1986).

Moderation. To examine whether ATA moderated the relationship between anger and the frontal asymmetry, a regression analysis was conducted in which ATA, anger, and the ATA $\times$ Anger interaction predicted the frontal asymmetry. A significant interaction would suggest that the relationship between trait anger and frontal asymmetry varied as a function of level of ATA. Another way to phrase the moderation issue is through the question, do individuals who are angry and like their anger evidence greater relative left frontal activity? To test for moderation, on the first step of the regression, ATA and anger were entered, and on the second step, the interaction was entered. The criterion variable was the frontal asymmetry. Because the midfrontal, lateral frontal, frontal temporal, and frontal central sites were highly intercorrelated and produced similar relationships with anger, one frontal asymmetry index was created by averaging the four asymmetry indexes together. All variables were first converted to *z*-scores, so that standardised regression coefficients could be obtained (Friedrich, 1982). Results revealed that ATA and anger did not interact significantly to predict the frontal asymmetry (ATA $\beta = -.07$, $p > .52$; anger $\beta = .39$, $p < .001$; interaction $\beta = -.18$, $p > .08$; overall *multiple* $R = .39$, $p < .002$).[3]

[3] The marginally significant interaction was further explored by examining the relationship of anger and frontal asymmetry one *SD* above and below mean ATA. At one *SD* above mean ATA, anger was marginally positively related to frontal asymmetry ($\beta = .21$, *partial* $r = .17$, $p = .10$). At one *SD* below mean ATA, anger was significantly positively related to frontal asymmetry ($\beta = .56$, *partial* $r = .36$, $p < .001$). This marginally significant interaction was not predicted and cannot be easily interpreted. Moreover, it is completely inconsistent with a valence interpretation of the frontal asymmetry. Future research is needed to assess whether it is replicable or spurious. None of the gender by individual differences measure (anger, attitude, toward anger) interactions significantly predicted the frontal asymmetry (*p*s > .20).

Assessing left and right frontal activity separately. The asymmetry index provides information about the difference between left and right frontal activation. It is a useful index in that it controls for individual differences in skull thickness and volume conduction, which could produce differences in alpha power. To assess the effects of left and right hemispheres separately, individual differences in skull thickness and volume conduction need to be controlled. To accomplish this control, regression analyses can be performed in which alpha power at one site is regressed on to alpha power averaged across all sites, alpha power at the homologous site, and another individual difference (e.g., trait anger) of interest (see, e.g., Harmon-Jones & Allen, 1998; Wheeler, Davidson, & Tomarken, 1993). Such analyses were performed in the present study to assess the relationship between anger, attitude toward anger, and left and right frontal activity. For these analyses, alpha power at each site served as the criterion; thus, when interpreting these results, it is important to recall that increased alpha power reflects decreased cortical activity. In addition, because the midfrontal, lateral frontal, frontal temporal, and frontal central sites were highly intercorrelated (Cronbach's alphas > .90) and produced similar relationships with anger, one left frontal index and one right frontal index was created by averaging the four left and four right sites together.

The regression analyses revealed that anger was associated with increased left frontal activity (alpha power $\beta = -.29$, partial $r = -.29$, $p < .005$), but that ATA was not (alpha power $\beta = -.08$, partial $r = -.08$, $p > .40$). Moreover, the relationship between anger and left frontal activity remained significant when both anger and ATA were simultaneously entered into the regression equation, suggesting that ATA did not mediate the relationship of anger and left frontal activity (alpha power $\beta = -.28$, partial $r = -.27$, $p < .008$). In addition, ATA was not a significant predictor in this regression equation (alpha power $\beta = -.01$, partial $r = -.01$, $p > .90$; overall *multiple* $R = .28$, $p < .03$).

Additional regression analyses revealed that anger was associated with decreased right frontal activity (alpha power $\beta = .36$, partial $r = .36$, $p < .001$), but that ATA was not (alpha power $\beta = -.004$, partial $r = -.004$, $p > .90$). The relationship between anger and right frontal activity remained significant when both anger and ATA were simultaneously entered into the regression equation (alpha power $\beta = .38$, partial $r = .37$, $p < .001$), suggesting that ATA did not mediate the relationship of anger and right frontal activity. In addition, ATA was not a significant predictor in this regression equation (alpha power $\beta = -.10$, partial $r = -.10$, $p > .30$; overall *multiple* $R = .37$, $p < .002$).

GENERAL DISCUSSION

As expected, trait anger related to relative left frontal activity as measured by the frontal asymmetry. Moreover, separate analyses revealed that trait anger related to increased left and decreased right frontal activity. These effects replicate

previous research (Harmon-Jones & Allen, 1998) with a younger sample (mean age 13), who might be less controlled and more likely to translate an angry intention into aggressive behaviour. That anger related with relative left frontal activity in young adults (mean age 19) suggests that the relationship is not limited to young adolescents.

Attitude toward anger

The relationship of anger with left frontal activity was not the result of persons with higher levels of trait anger regarding anger as a positive emotion. That is, although a measure of attitude toward anger revealed that persons with higher levels of trait anger regard the experience of anger more positively, this more positive attitude toward anger did not account for the relation between anger and left frontal activity. The present results demonstrate that the association of anger and left frontal activity is not the result of positive feelings toward anger.

It is important to note that the attitude toward anger measure developed in the present research is a self-report measure, and is therefore subject to the same methodological concerns some scientists may have about self-report instruments. Nevertheless, the trait measure of anger used in the present research, which is also a self-report measure, is subject to these same concerns, but has been found to relate to relative left frontal activity in two separate studies, the current one and Harmon-Jones and Allen (1998). Thus, self-reported attitude toward anger has many of the same limitations that self-reported trait anger has, but only the latter relates to relative left frontal activity.

Why do some individuals have relatively more positive attitudes toward anger? Although the present research was not designed to address this question, I will provide some speculations. One possibility is that individuals like anger because they foresee positive consequences resulting from their anger, as Aristotle expressed in the *Rhetoric*, ''. . . anger is always attended by a certain pleasure arising from the expectation of revenge'' (p. 93, Aristotle, 1960). While receiving positive consequences from anger is one plausible cause of a positive attitude toward anger, it is also likely that attitudes toward anger can be formed in other ways. For example, mere exposure to angry feelings may cause positive attitudes toward anger. In other words, repeatedly experiencing anger may cause individuals to have relatively more positive attitudes toward it, just as repeatedly being exposed to other stimuli can increase positive attitudes toward the stimuli (e.g., Bornstein, 1989; Zajonc, 1968). In addition, anger may be regarded positively because of cognitive dissonance reduction. That is, a predisposition to experience high levels of anger may cause an individual to experience multiple bouts of anger, which may initially feel unpleasant. These unpleasant feelings are inconsistent (dissonant) with the individual's desire to feel pleasure. Thus, the individual may feel dissonance because the unpleasant feelings (e.g., anger) are inconsistent with the desire to feel pleasant. To reduce the dissonance, an

individual may justify the angry feelings by reducing the negative attitude toward the angry feelings. Consistent with this prediction, other research has found that when individuals are run through an induced compliance paradigm used in dissonance research (Harmon-Jones & Mills, 1999) and subtly induced (as compared to forced) to view disgusting pictures, their attitude toward disgust becomes more positive (Harmon-Jones & Sigelman, 2002). Finally, individuals may regard anger more positively because of self-acceptance. In other words, individuals who are dispositionally high in anger may like their angry feelings because they prefer to accept themselves and their feelings rather than change themselves and their feelings. Of course, there may be other reasons individuals form relatively more positive attitudes toward anger (e.g., enjoyment of the arousing properties of anger). The present discussion was designed merely to suggest that there are multiple potential causes of attitudes toward anger, and that one single cause may not be sufficient to explain why all individuals who have positive attitudes toward anger have those attitudes.

Mediation of the relationship between trait anger and resting left frontal activity

The primary purpose of the present research was to assess whether a positive attitude toward anger explained why trait anger related to relative left frontal activity. That is, Study 4 was designed to examine whether one personality characteristic (ATA) mediated the relationship between two other personality characteristics (trait anger and left frontal activity). The regression results suggested that a positive attitude toward anger did not statistically mediate the relationship between trait anger and relative left frontal activity. Of course, the test of statistical mediation was only correlational and is thus subject to problems inherent in correlational tests. Future research will need to find a way to experimentally and independently manipulate attitude toward anger and anger to assess whether attitude toward anger mediates the relationship between anger and left frontal activity. Another way to conceive of mediation is situationally. That is, exposure to an angry stimulus might evoke a positive valenced or approach motivational response, which then causes left frontal activity. The present research was not designed to address the mediation of situationally induced anger, though some recent research was (Harmon-Jones et al., 2003).

Considering anger as approach motivation

Together with past research (Harmon-Jones & Allen, 1998), the present research suggests that trait anger, an approach-related action tendency associated with negative affect, relates to left frontal activity. Most of the research on the frontal asymmetry has been derived from models concerned with approach and withdrawal motivation or models concerned with positive and negative affect. The present conceptualisation considers trait anger to involve approach tendencies.

Indeed, that trait anger is associated with aggression, competitiveness, and assertiveness is consistent with this conceptualisation. However, in some emotion theories, anger is considered a defensive motivation that is part of a larger aversive/defensive system occupied by fear, disgust, and other negative emotions (e.g., Lang et al., 1997). It is possible that some forms of angry feelings may be associated with aversion, but the form of anger assessed by the Buss and Perry (1992) trait questionnaire is most likely approach oriented (see Buss & Perry, 1992, for relevant data). Consistent with this interpretation is research that has found trait anger to be positively associated with trait BAS (Harmon-Jones, in press). Indeed, recent research with state anger has revealed that not all forms of situationally induced angry feelings are associated with increased left frontal activity (Harmon-Jones et al., 2003). Only angry feelings associated with approach motivation were found to be associated with increased left frontal activity. Future research will need to develop instruments to assess trait angry feelings associated with withdrawal motivation.

The present results favour the motivational direction model of the frontal asymmetry over the valence model. As this research began with questioning what is meant by the valence of emotion, it is appropriate to ask what is meant by approach and withdrawal motivation. For instance, is active avoidance (active task engagement to avoid possible punishment) considered approach motivation, as Gray (1982) does in his theory? Although the terms ''approach'' and ''withdrawal'' have been used to apply to a range of motivations and behaviours, based on what is currently known about the functions of asymmetrical frontal activity, it would be safest to say that approach and withdrawal refer to behavioural tendencies. Considering active avoidance, Gray would argue that the behavioural approach system is activated (and it may be at some levels of analysis). However, at the level of the frontal cortex, it seems that the left frontal approach system is not activated, as research has indicated that active avoidance evokes increased right frontal activity (Sobotka et al., 1992).

Conclusion

The present research points to the importance of considering motivational direction in models of affect. Past research has demonstrated that trait positive affect relates to relative left frontal activity, and that trait negative affect relates to relative right frontal activity (e.g., Tomarken, Davidson, Wheeler, & Doss, 1992). More recent research has suggested, however, that measures of BAS relate more strongly to relative left frontal activity (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997), suggesting that relative left frontal activity may be more involved in the expression and experience of approach motivation rather than positive affect. Models of affect should consider the possibility that the valence of affect is independent of the direction of motivation—that is, that approach motivation can be positive or negative in affective valence, a point not

recognised in most models (e.g., Lang et al., 1997; Watson et al., 1999; but see Carver, 2001, for a view compatible with the one advanced here). The present research further supported this idea by demonstrating that anger, an approach-related tendency with negative affective valence, related to relative left frontal activity. Recent experimental research has also found that state inductions of anger are related to increased left frontal activity (Harmon-Jones & Sigelman, 2001; Harmon-Jones et al., 2003).

The present research underscores the usefulness of approach and withdrawal as central concepts in the study of affective traits and temperament, and further demonstrates that affective valence (positivity/negativity) can be independent of motivational direction (approach/withdrawal). The valence of affect is a complex concept and has a number of meanings. In the present research, one meaning—the subjective feeling or attitude toward anger—was explored as an alternative explanation of the relationship between anger and relative left frontal activity. Results suggested that while the attitude toward anger is meaningful, it could not account for the trait anger-relative left frontal relationship.

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APPENDIX

Instructions. There are no right or wrong answers for the following questions. Please answer honestly based on how *you* feel. Thank you very much for your participation. Please answer each question using the scale provided below.

1	2	3	4	5
Strongly Disagree				Strongly Agree

1. I like the feeling of power I get from expressing my anger.
2. When I feel like breaking things I dislike the feeling.
3. When I feel like hitting someone, I dislike the feeling.
4. I like it when I feel like yelling at someone.
5. I like it when I get frustrated, and I let my irritation show.
6. I like that sometimes I get angry and hit someone.
7. When I feel like a powder keg ready to explode, I like that feeling.
8. I like that sometimes I fly off the handle for no good reason.
9. When I feel like banging on a table, I dislike the feeling.
10. I dislike it when I feel mad.
11. I like how it feels when I am furious.