

## Anger and Frontal Brain Activity: EEG Asymmetry Consistent With Approach Motivation Despite Negative Affective Valence

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The anterior regions of the left and right cerebral hemispheres have been posited to be specialized for expression and experience of approach and withdrawal processes, respectively. Much of the evidence supporting this hypothesis has been obtained by use of the anterior asymmetry in electroencephalographic alpha activity. In most of this research, however, motivational direction has been confounded with affective valence such that, for instance, approach motivation relates positively with positive affect. In the present research, we tested the hypothesis that dispositional anger, an approach-related motivational tendency with negative valence, would be associated with greater left- than right-anterior activity. Results supported the hypothesis, suggesting that the anterior asymmetry varies as a function of motivational direction rather than affective valence.

A variety of methods have demonstrated that the left-anterior region of the brain is involved in the expression and experience of approach-related motivation and affect and that the right-anterior region of the brain is involved in the expression and experience of avoidance-related motivation and affect (for reviews, see Davidson, 1995, and Silberman & Weingartner, 1986). For example, research has shown that left-anterior brain lesions are likely to lead to major depression and that right-anterior brain lesions are likely to lead to mania (for a review, see Robinson & Downhill, 1995). In addition, research assessing electroencephalographic (EEG) activity, particularly in the alpha band (8–13 Hz), has supported the idea that the left- and right-anterior regions of the cortex are differentially involved in emotional and motivational processes. Specifically, research has shown that both currently depressed and previously depressed individuals have more left than right anterior alpha power than do nondepressed and never-depressed individuals (Allen, Iacono, Depue, & Arbisi, 1993; Henriques & Davidson, 1990, 1991; Schaffer, Davidson, & Saron, 1983). Because alpha power relates inversely with cortical activity (Lindsley & Wicke, 1974), these findings suggest that depressed individuals have decreased left-anterior cortical activity. Moreover, the resting anterior EEG asymmetry has been found

to relate to individual differences in dispositional positive and negative affect such that individuals with extreme and stable relative left-anterior cortical activity report increased positive affect and decreased negative affect relative to individuals with extreme and stable right-anterior cortical activity (Tomarken, Davidson, Wheeler, & Doss, 1992). The resting asymmetry has also been found to predict affective responses to stimuli such that individuals with stable and extreme relative left-anterior activity report more intense positive affect to positive films and individuals with stable and extreme relative right-anterior activity report more intense negative affect to negative films (Wheeler, Davidson, & Tomarken, 1993). Of importance, research has shown that anterior asymmetrical cortical activity yields high test–retest reliability (Tomarken et al., 1992), which suggests that the asymmetry index reflects a trait.

Although much research has demonstrated the role of affect in the anterior asymmetry and some explanations of the asymmetry effects posit that the valence dimension underlies the asymmetry (e.g., Heller, 1990), most explanations for these effects (Davidson, 1992; Fox, 1991) posit that the approach–withdrawal (or direction) dimension rather than the positive–negative (or valence) dimension underlies the asymmetry. That is, the above-mentioned effects are hypothesized to have resulted because of the motivational implications of the affective states so that positive affective states are inferred to reflect approach tendencies and negative affective states are inferred to reflect withdrawal tendencies. Recent research has directly tested the idea that motivational tendencies relate to the anterior asymmetry and has found that increased left cortical activity relates to increased dispositional tendencies toward approach motivation (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997). However, even in this research, motivational direction was confounded with affective valence; that is, individuals with high levels of approach motivation also had high levels of positive affect. For a compelling test of whether direction or valence underlies the anterior asymmetry, an approach motivational tendency that is negatively valenced is needed. Such a tendency can be found in the emotion of anger.

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### Anger as Approach

Emotions are complex phenomena, and a discrete emotion can elicit both approach and withdrawal tendencies. Sadness, for instance, might impel one simultaneously to attempt to regain a lost object of attachment and to withdraw from the event that caused the loss. Similarly, anger may prompt both approach and withdrawal tendencies. However, we suspect that the dominant tendency evoked by anger is one of approach.

For quite some time (e.g., Darwin, 1872/1965; Homer, 1963), anger has been described as an emotion with approach-related tendencies, one that evokes behavioral tendencies toward aggression. Anger is typically thought of as an emotional response to the blocking of obtaining an expected goal (Ekman & Friesen, 1975; Plutchik, 1980).

Following frustrating events, anger may serve to maintain task involvement and approach motivation. Supportive of this idea, Lewis, Sullivan, Ramsay, and Alessandri (1992) found that infants who showed anger during extinction maintained interest during subsequent relearning, whereas those who showed sadness during extinction showed decreased interest during relearning. Thus, the anger of the former group of infants may have disposed them to react with increased approach motivation during the relearning task, whereas the sadness of the latter group may have disposed them to react with decreased approach motivation (learned helplessness). In addition, trait anger has been found to correlate positively with trait assertiveness and competitiveness, both of which are approach tendencies (Buss & Perry, 1992). Thus, these results suggest that anger may be an approach-related emotion.

### The Present Research

A few experiments have provided preliminary examinations of the association of anger with the anterior EEG asymmetry. Because of the difficulty of conducting this type of experiment, relatively few participants have been examined, and the results have been mixed. In one of these experiments (Dawson, Panagiotides, Klinger, & Hill, 1992), 21-month-old infants' facial expressions were recorded during emotion-eliciting situations. During expressions of anger, relatively greater left-anterior cortical activity than right activity occurred, and during expressions of sadness, relatively greater right than left activity occurred. However, the anterior asymmetry was significantly different from neutral expressions only with sad expressions and not with angry expressions. In another experiment (Fox & Davidson, 1988), 10-month-old infants evidenced greater left-anterior cortical activity during angry facial expressions not accompanied by crying and greater right-anterior activity during angry facial expressions accompanied by crying. Effects of identical direction occurred with sad facial expressions, that is, greater left-anterior activity occurred during sad facial expressions not accompanied by crying, and greater right-anterior activity occurred during sad facial expressions accompanied by crying. Because sadness and anger showed similar relations with the anterior asymmetry, it is difficult to infer from these effects whether the anterior asymmetry reflects valence or direction.

Although this previous research tentatively supports the hy-

pothesis that anger is associated with increased left-anterior cortical activity, the previous findings are far from unequivocal. The only direct test of anger comes from data from infants, and these data provide a mixed picture. Moreover, these infant data involved EEG activity during transient states of anger. To provide a more definitive test of whether the anterior EEG asymmetry is associated with approach-related negatively valenced affect, we examined anger in adolescents. Moreover, we tested the hypothesis that the asymmetry is related to dispositional anger.

Thus, the present research tested competing hypotheses regarding the relationship of anger to the anterior asymmetry in cortical activity. If the anterior asymmetry varies as a function of affective valence, then increased anger should be associated with increased right-anterior activity. If, however, the anterior asymmetry varies as a function of motivational direction, then increased anger should be associated with increased left-anterior activity. On the basis of the preceding overview, we predicted that increased anger would be related to increased left-anterior activity.

## Method

### Participants

Participants were 15 boys and 11 girls between the ages of 11 and 17 years ( $M = 13.0$ ) selected from two middle schools ( $n = 19$ ) or an adolescent psychiatric inpatient unit ( $n = 7$ ). Thus, data were available for 26 participants on all measures except positive and negative affect, in which case one participant did not complete the questionnaire. The adolescents from the inpatient unit were admitted to the unit because of affective and impulse-control problems. The participants (with consent from their primary caretakers) volunteered to participate, and no one received compensation for participation. The racial composition of the sample was 10 Whites, 8 Blacks, 7 Hispanics, and 1 Asian. Only right-handed participants were selected to control for hemisphere specialization.

### Procedure

After responding to a questionnaire assessing handedness (Chapman & Chapman, 1987), participants were prepared for EEG recording. EEGs were recorded for 6 min as participants were asked to relax with their eyes open (O) and closed (C) in one of two alternating orders of 1-min intervals (O, C, O, C, O, C; or C, O, C, O, C, O).

Participants were then administered the Aggression Questionnaire (Buss & Perry, 1992) and the Positive and Negative Affect Schedule—Children's Version (PANAS-C) (Laurent, Potter, & Catanzaro, 1994). The Buss and Perry Aggression Questionnaire (1992), a self-report questionnaire, was administered to assess levels of trait anger. It is composed of four factors: (a) physical aggression, which assesses the frequency of acting aggressively; (b) verbal aggression, which assesses the frequency of behaving verbally aggressively; (c) anger, which assesses the emotional component of aggression; and (d) hostility, which assesses the cognitive component of aggression that can be described as "feelings of ill will and injustice" (Buss & Perry, 1992, p. 457). The PANAS-C (Laurent et al., 1994), a self-report questionnaire, was administered to assess positive affect, the extent to which an individual feels enthusiastic, active, and alert; and negative affect, the extent to which an individual feels distressed and unpleasant. Following the work of Watson, Clark, and Tellegen (1988), the PANAS-C was developed to assess positive and negative affect in children. It consists of 20 items,

10 that assess positive affect and 10 that assess negative affect. The PANAS-C has acceptable internal reliability and convergent validity.

All self-report questionnaires were read aloud to the participants by the experimenter so that participants would be able to better understand the questions. Participants were asked to indicate if they needed assistance in understanding the meaning of questions. Participants gave their responses to the questions aloud to the experimenter, who recorded the responses. The experimenter was not aware of the participants' levels of anterior EEG asymmetry.

### EEG Assessment

Participants were seated in a comfortable chair in a dimly lit room. They wore stereo headphones that emitted continuous white noise (in the 45–60 dB range) that masked extraneous sounds. EEG activity was recorded monopolarly with tin electrodes that were in a stretch-Lycra cap (Electrocap [Electro-Cap International, Eaton, Ohio]). EEG activity was recorded from frontal poles (FP1, FP2), and frontal (F3, Fz, F4), central (C3, Cz, C4), parietal (P3, Pz, P4), temporal (T5, T3, T4, T6), and occipital (O1, O2) scalp sites (International 10-20 system; Jasper, 1958).<sup>1</sup> All scalp sites were referenced on-line to linked ear lobes. All electrode impedances were less than 5,000 ohms. A Nihon Kohden Electroencephalograph Model 4221 (Tokyo, Japan) amplified signals by a factor of 20,000 (bandpass 0.026–35 Hz). The EEG was digitized continuously at 512 Hz. Data were re-referenced off-line to Cz. Cz was used as the reference because it has been used in our previous research (Harmon-Jones & Allen, 1997) and because previous research has compared Cz with averaged ears and found similar effects for each (e.g., Tomarken, Davidson, Wheeler, & Kinney, 1992).

### Data Analyses

As in previous research (Harmon-Jones & Allen, 1997), EEGs were first screened for eye-movement and muscle artifacts, and data containing artifacts were rejected.<sup>2</sup> Data were then epoched into 2-s epochs overlapping by 75%. The power spectra were derived by the fast Fourier transform method with a Hamming window (applied to the distal 10% at each end of the epoch) for each 2-s epoch, and then the spectra were averaged across epochs within each baseline type (eyes open, eyes closed) for each participant to produce the total power in the alpha range (8–13 Hz). An average of 132.86 2-s epochs ( $SD = 65.85$ ) comprised the eyes-open data, and an average of 201.25 2-s epochs ( $SD = 53.49$ ) comprised the eyes-closed data.

As in previous research (Harmon-Jones & Allen, 1997; Tomarken, Davidson, Wheeler, & Doss, 1992), the alpha band was used to quantify differences in hemispheric activity, and the power density values were log transformed to normalize the distributions. To assess the relation between baseline anterior asymmetries in cortical activity and anger, we computed an anterior-asymmetry index (log right alpha power minus log left alpha power). Because alpha power is inversely related to activity (Lindsley & Wicke, 1974), higher scores on the index indicate greater left-hemisphere activity. Relations between personality scores and the averages of eyes-open and eyes-closed anterior EEG asymmetries were computed because the eyes-open and eyes-closed asymmetry indexes were highly correlated ( $r_s > .89$ ).

## Results

### Relation of Cortical Activity to Anger

We first assessed whether the anterior asymmetry in alpha activity related to dispositional anger. As predicted and as shown in Table 1, anger correlated positively with the anterior asymme-

try in alpha activity, which suggests that anger relates to greater left (than right) cortical activity.<sup>3</sup> A scatterplot of this anger–anterior-asymmetry correlation, shown in Figure 1, indicates that the significant correlation was not driven by outliers. Correlations of similar direction but of smaller magnitude emerged for physical aggression, verbal aggression, and hostility (see Table 1).

We then assessed which hemisphere accounted for the significant relationships between the anterior asymmetry and anger. Because variations in skull thickness and volume conduction from the homologous site contribute to the absolute power at a given site, it is not appropriate to merely compute power at individual sites and then correlate the power values with anger. Therefore, to predict the power in a specific electrode, we used a hierarchical regression model (following Wheeler et al., 1993) in which the average power across all 16 electrodes was entered, and then power at the homologous electrode was entered. In effect, this hierarchical regression model provides power at the criterion site following statistical removal of the variance associated with whole-head power and power at the homologous site. The residual power at the criterion electrode (anterior left or anterior right) was then correlated with anger. Using this method, we found that anger correlated positively with right alpha power ( $r = .45, p < .02$ ) and negatively with left alpha power ( $r = -.46, p < .02$ ). These correlations suggest that dispositional anger was related to greater left-anterior cortical activity and lesser right-anterior cortical activity, which suggests that dispositional anger is positively associated with approach motivation and negatively associated with withdrawal motivation.

As shown in Figure 2, although anger correlated significantly with the anterior asymmetry, it did not correlate significantly with the asymmetry indexes computed at the other cortical regions. These results show the topographical specificity of the anger–alpha relationship.

We then assessed whether the anterior asymmetry in the other frequency bands (i.e., delta [1–4 Hz], theta [4–8 Hz], and beta [13–20 Hz]) related to dispositional anger. As shown in Table 1, anger did not significantly relate to delta activity, but anger did relate significantly to theta activity and beta activity. These results are consistent with research that has found that

<sup>1</sup> The F7 amplifier was not functioning properly. Thus, the F7/F8 data for participants were not analyzed.

<sup>2</sup> Two independent raters coded the EEG data of a randomly selected subsample of participants (4 participants, with 1,440 1-s segments of data) for eye movement and muscle artifacts. Overall agreement was obtained for over 99% of the data segments, and the chance-adjusted index of agreement was acceptably high (Cohen's kappa = .76).

<sup>3</sup> The correlation coefficient for the anger, eyes-open anterior alpha asymmetry relationship was  $r = .44, p < .05$ , and the coefficient for the anger, eyes-closed anterior alpha asymmetry relationship was  $r = .49, p < .02$ . The correlation between anger and the anterior asymmetry was also computed on EEG data that were referenced to linked ears. Correlations were similar in direction and magnitude to those observed with Cz-referenced data. That is, anger related positively with the anterior asymmetry ( $r = .30, ns$  for averages of eyes-open and eyes-closed data;  $r = .40, p < .05$  for eyes-closed data;  $r = .17, ns$  for eyes-open data).

Table 1  
Correlations Among Self-Report Personality Measures and Anterior Asymmetry Indexes

Variable	Anger	Phys.	Verb.	Host.	PA	NA	Delta	Theta	Alpha	Beta
Anger	—									
Phys.	.74***	—								
Verb.	.50***	.54***	—							
Host.	.25	.44*	.18	—						
PA	-.28	-.50***	-.44*	-.01	—					
NA	.23	.21	.09	.15	-.31	—				
Delta	.29	.08	.13	.09	.07	.00	—			
Theta	.41*	.27	.18	.16	-.07	.12	.90***	—		
Alpha	.48**	.25	.28	.12	.07	-.14	.73***	.76***	—	
Beta	.48**	.25	.23	.14	.15	-.14	.82***	.83***	.83***	—

Note. Correlations are for all participants. Phys. = physical aggression; verb. = verbal aggression; host. = hostile aggression; PA = positive affect; NA = negative affect.  
\*  $p < .05$ . \*\*  $p < .02$ . \*\*\*  $p < .01$ .

the power in these bands is positively correlated (Davidson, Chapman, Chapman, & Henriques, 1990). Research on the anterior asymmetry and affect has typically reported significant effects in the alpha band but not in other frequency bands. Because relationships in other bands typically have not been reported or have been dismissed as nonsignificant without report on their magnitude, it is possible that a similar relationship exists in the other frequency bands but that the effect sizes are smaller than those of the alpha band and therefore do not achieve statistical significance because of a lack of statistical power.

Relation of Brain Activity to Positive and Negative Affect

In addition, we assessed whether the anterior asymmetry in alpha activity related to dispositional positive and negative affect. As shown in Table 1, the correlations between the anterior asymmetry in alpha activity and positive and negative affect were not significant; the magnitude and direction of these correlations are consistent with past research (e.g., Sutton & David-

son, 1997).<sup>4</sup> Moreover, positive or negative affect did not correlate significantly with the alpha asymmetry indexes computed at the other cortical regions.

With the hierarchical regression model discussed above, left- and right-anterior alpha power were computed and related to positive and negative affect. None of the correlations was significant, but they were in expected directions; positive affect correlated positively with right alpha power ( $r = .12, ns$ ) and negatively with left alpha power ( $r = -.18, ns$ ), and negative affect correlated negatively with right alpha power ( $r = -.26, ns$ ) and positively with left alpha power ( $r = .32, ns$ ).

Relations Within Each Group of Participants

To ensure that the significant correlations between anger and the anterior asymmetry in alpha activity were not the result of outliers created by the psychiatric inpatients, the correlations were also computed separately for each group of adolescents (middle school and inpatient). The results were almost identical with those for the full sample. With the middle-school children ( $n = 19$ ), the correlations were as follows: anger–anterior-alpha asymmetry ( $r = .43, p < .10$ ), positive affect–anterior-alpha asymmetry ( $r = .15, ns$ ), and negative affect–anterior-

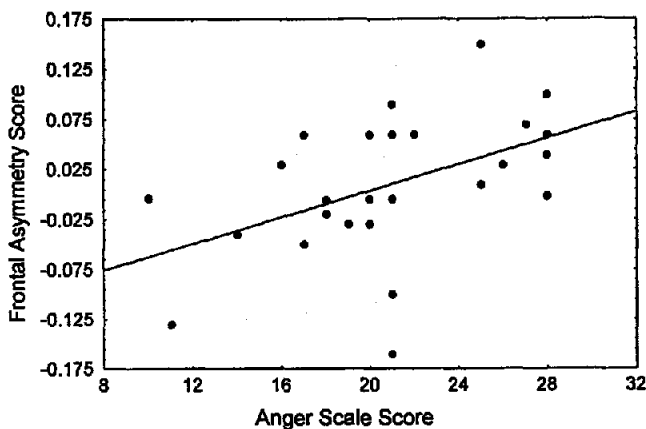


Figure 1. Scatterplot of anterior alpha asymmetry index–dispositional anger relationship.

<sup>4</sup> The correlation coefficient for the positive affect, eyes-open anterior alpha asymmetry relationship was  $r = .08, ns$ , and the coefficient for the positive affect, eyes-closed anterior alpha asymmetry relationship was  $r = .07, ns$ . The correlation coefficient for the negative affect, eyes-open anterior alpha asymmetry relationship was  $r = -.18, ns$ , and the coefficient for the negative affect, eyes-closed anterior alpha asymmetry relationship was  $r = -.08, ns$ . Correlations between positive affect, negative affect, and the anterior asymmetry were also computed on EEG data that were referenced to linked ears. Correlations were similar to those observed using Cz-referenced data. That is, positive affect related positively with the anterior asymmetry ( $r = .32, ns$  for average of eyes-open data and eyes-closed data;  $r = .26, ns$  for eyes-closed data;  $r = .35, p < .10$  for eyes-open data). Negative affect related negatively with the anterior asymmetry ( $r = -.15, ns$  for average of eyes-open and eyes-closed data;  $r = -.18, ns$  for eyes-closed data;  $r = -.10, ns$  for eyes-open data).

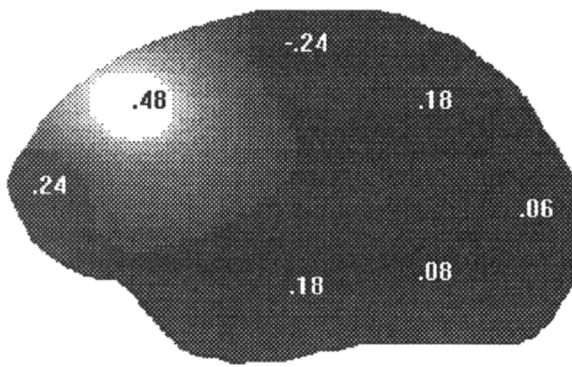


Figure 2. Topographic map displaying correlations between alpha asymmetry indexes and dispositional anger. The display is a left lateral head view. The correlation coefficient displayed in the lighter area is significant at  $p < .02$ . The correlation coefficients displayed in the darker areas are not significant.

alpha asymmetry ( $r = -.19, ns$ ). For the adolescents in the inpatient unit ( $n = 7$ ), the correlations were as follows: anger–anterior-alpha asymmetry ( $r = .72, p < .10$ ), positive affect–anterior-alpha asymmetry ( $r = .20, ns$ ), and negative affect–anterior-alpha asymmetry ( $r = -.18, ns$ ). The anger–anterior-alpha asymmetry did not differ significantly between the two groups ( $z = .80, ns$ ).<sup>5,6</sup>

### Discussion

The present results are consistent with recent evidence demonstrating significant relationships between dispositional approach motivation and the anterior asymmetry in alpha activity (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997). However, as mentioned earlier, this past research showed dispositional approach motivation correlating positively with positive affect, which renders it difficult to determine whether approach motivation or positive affect was primarily responsible for the relationship with the EEG asymmetry. The present research was able to disentangle whether approach motivation or positive affect underlied the relationship with the asymmetry by assessing the relationship of anger with the EEG asymmetry. By demonstrating that dispositional anger, an approach-related motivational tendency with negative affective valence, is related positively to the anterior asymmetry in alpha activity, the present results support the idea that the anterior asymmetry in alpha activity reflects motivational direction rather than merely affective valence.

In addition, the present research found that the anterior asymmetry in alpha activity did not correlate significantly with positive or negative affect. These results are consistent with past results showing that the relationships between the asymmetry and dispositional positive and negative affect typically are not significant when examined in participants who were not selected for extreme left- or right-anterior alpha asymmetry (Sutton & Davidson, 1997; Tomarken, Davidson, Wheeler, & Doss, 1992). Of interest, dispositional anger correlated significantly with the anterior asymmetry even without selecting extreme groups in

the present research. Moreover, in recent research, dispositional approach motivation tendencies correlated significantly with the anterior asymmetry even though extreme groups were not selected (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997). These results suggest that the anterior asymmetry in cortical activity may more clearly tap motivational direction than affective valence.

Of interest, the present results demonstrate that dispositional anger is positively associated with left-anterior cortical activity but negatively associated with right-anterior cortical activity. These results suggest that individuals with high dispositional anger have increased approach motivation and decreased withdrawal motivation. In line with the present results, Izard (1991) has suggested that anger may occasionally have adaptive functions, among these are counteracting fear (which would impel flight), supplying energy and determination, and preventing the occurrence of depression. Individuals have reported that anger causes subjectively high levels of activity that are clearly focused and directed (Izard, 1972). Moreover, fear is lower in anger-causing situations than in other negative-affect situations (Izard, 1972), which suggests that anger inhibits fear. Anger has also been found to be associated with high levels of self-assurance, physical strength, and bravery. Thus, anger may mobilize energy for action and induce a sense of self-confidence and vigor, which may make individuals more capable of defending themselves. These heightened approach and lowered withdrawal tendencies associated with anger may be useful in coping with challenges and dangers.

Viewing anger as an emotion with heightened approach and lowered withdrawal motivational tendencies could inspire several future research directions. For example, as Berkowitz (1993) proposed, and consistent with the present research, negative affects that have approach tendencies, such as anger, may be more likely to activate the anger–aggression network, which prompts associated physiological, motor, and cognitive responses. Future research could also examine the extent to which responding with anger to challenges prevents depression and facilitates learning, as suggested by the research of Lewis et al. (1992) and Izard (1972, 1991).

In addition to occasionally serving adaptive functions and occasionally producing negative social consequences (e.g., aggression), anger may cause adverse health effects. For instance, research has suggested that high levels of dispositional anger predict adverse health outcomes including hypertension, coro-

<sup>5</sup> The adolescents from the inpatient unit were compared to the adolescents from the middle schools on the anterior asymmetry, anger, positive affect, and negative affect. Significant differences did not emerge on negative affect ( $p > .25$ ) or the anterior asymmetry ( $p > .35$ ). However, the adolescents from the inpatient unit did differ from the adolescents from the middle school on positive affect, inpatient  $M = 29.67, SD = 11.67$ ; middle school  $M = 37.84, SD = 6.74$ ;  $F(1, 24) = 4.68, p < .05$ , and anger, inpatient  $M = 25.29, SD = 5.12$ ; middle school  $M = 19.21, SD = 4.04$ ;  $F(1, 25) = 10.01, p < .01$ .

<sup>6</sup> The effects of age were partialled out of the relation between the anterior-alpha asymmetry and trait anger using a partial correlational analysis. The partial correlation of the anterior alpha asymmetry and anger remained significant;  $r = .52, p < .01$ .

nary heart disease, and all-cause mortality (e.g., Barefoot, Dodge, Peterson, Dahlstrom, & Williams, 1989). Moreover, laboratory research has suggested that high levels of trait anger are associated with exaggerated cardiovascular responses to interpersonal stressors (e.g., Suls & Wan, 1993). Research aimed at examining the relation of the EEG anterior asymmetry to cardiovascular reactivity among persons high in dispositional anger might be especially fruitful in increasing our understanding of the relationships between these variables (Lane & Jennings, 1995). Moreover, research could be conducted in which the EEG anterior asymmetry is manipulated (e.g., by use of biofeedback as in Rosenfeld, Cha, Blair, & Gotlib, 1995), and the effects of this manipulation on psychological and cardiovascular reactions to interpersonal provocations could be examined.

Anger may be functional as well as dysfunctional. Whether it becomes functional or dysfunctional may depend, in part, on its regulation and on the situation. Another potential factor that influences whether anger is functional may be its duration (i.e., whether it is increased temporarily or for a long period of time). If anger persists for long durations, it may assist in overcoming obstacles, but at the same time it may have adverse health effects. In any event, the present research provides support for the idea that motivational direction rather than affective valence underlies the anterior EEG asymmetry. Moreover, the present research suggests that the motivational implications of emotions need to be considered in attempts to understand emotion.

References

Allen, J. J., Iacono, W. G., Depue, R. A., & Arbisi, P. (1993). Regional electroencephalographic asymmetries in bipolar seasonal affective disorder before and after exposure to bright light. *Biological Psychiatry*, *33*, 642-646.

Barefoot, J. C., Dodge, K. A., Peterson, B. L., Dahlstrom, W. G., & Williams, R. B. (1989). The Cook-Medley Hostility Scale: Item content and ability to predict survival. *Psychosomatic Medicine*, *51*, 46-57.

Berkowitz, L. (1993). Towards a general theory of anger and emotional aggression: Implications of the cognitive-neoassociationistic perspective for the analysis of anger and other emotions. In R. S. Wyer & T. K. Srull (Eds.), *Perspectives on anger and emotion: Advances in social cognition* (Vol. 6). Hillsdale, NJ: Erlbaum.

Buss, A. H., & Perry, M. (1992). The aggression questionnaire. *Journal of Personality and Social Psychology*, *63*, 452-459.

Chapman, L. J., & Chapman, J. P. (1987). The measurement of handedness. *Brain and Cognition*, *6*, 175-183.

Darwin, C. (1965). *The expression of the emotions in man and animals*. Chicago: University of Chicago Press. (Original work published 1872)

Davidson, R. J. (1992). Anterior cerebral asymmetry and the nature of emotion. *Brain and Cognition*, *20*, 125-151.

Davidson, R. J. (1995). Cerebral asymmetry, emotion, and affective style. In R. J. Davidson & K. Hugdahl (Eds.), *Brain asymmetry* (pp. 361-387). Cambridge, MA: Massachusetts Institute of Technology.

Davidson, R. J., Chapman, J. P., Chapman, L. J., & Henriques, J. B. (1990). Asymmetrical brain electrical activity discriminates between psychometrically-matched verbal and spatial cognitive tasks. *Psychophysiology*, *27*, 528-543.

Dawson, G., Panagiotides, H., Klinger, L. G., & Hill, D. (1992). The role of frontal lobe functioning in the development of infant self-regulatory behavior. *Brain and Cognition*, *20*, 152-175.

Ekman, P., & Friesen, W. V. (1975). *Unmasking the face: A guide to recognizing emotions from facial clues*. Englewood Cliffs, NJ: Prentice-Hall.

Fox, N. A. (1991). If it's not left, it's right. *American Psychologist*, *46*, 863-872.

Fox, N. A., & Davidson, R. J. (1988). Patterns of brain electrical activity during facial signs of emotion in 10-month-old infants. *Developmental Psychology*, *24*, 230-236.

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

Heller, W. (1990). The neuropsychology of emotion: Developmental patterns and implications for psychopathology. In N. L. Stein, B. Leventhal, & T. Trabasso (Eds.), *Psychological and biological approaches to emotion* (pp. 167-211). Hillsdale, NJ: Erlbaum.

Henriques, J. B., & Davidson, R. J. (1990). Regional brain electrical asymmetries discriminate between previously depressed and healthy control subjects. *Journal of Abnormal Psychology*, *99*, 22-31.

Henriques, J. B., & Davidson, R. J. (1991). Left frontal hypoactivation in depression. *Journal of Abnormal Psychology*, *100*, 535-545.

Homer. (1963). *The Iliad of Homer* (E. Rees, Trans.). Indianapolis, IN: Bobbs-Merrill.

Izard, C. E. (1972). *Patterns of emotions: A new analysis of anxiety and depression*. New York: Academic Press.

Izard, C. E. (1991). *The psychology of emotions*. New York: Plenum Press.

Jasper, H. (1958). Report on the committee on methods of clinical examination in electroencephalography. *Electroencephalography and Clinical Neurophysiology*, *10*, 370-375.

Lane, R. D., & Jennings, J. R. (1995). Hemispheric asymmetry, autonomic asymmetry, and the problem of sudden cardiac death. In R. J. Davidson & K. Hugdahl (Eds.), *Brain asymmetry* (pp. 271-304). Cambridge, MA: Massachusetts Institute of Technology.

Laurent, J., Potter, K., & Catanzaro, S. J. (1994, March). *Assessing positive and negative affect in children: The development of the PANAS-C*. Paper presented at the 26th annual convention of the National Association of School Psychologists, Seattle, WA.

Lewis, M., Sullivan, M. W., Ramsay, D. S., & Alessandri, S. M. (1992). Individual differences in anger and sad expressions during extinction: Antecedents and consequences. *Infant Behavior and Development*, *15*, 443-452.

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

Plutchik, R. (1980). *Emotion: A psychoevolutionary synthesis*. New York: Harper & Row.

Robinson, R. G., & Downhill, J. E. (1995). Lateralization of psychopathology in response to focal brain injury. In R. J. Davidson & K. Hugdahl (Eds.), *Brain asymmetry* (pp. 693-711). Cambridge, MA: Massachusetts Institute of Technology.

Rosenfeld, J. P., Cha, G., Blair, T., & Gotlib, I. H. (1995). Operant (biofeedback) control of left-right frontal alpha power differences: Potential neurotherapy for affective disorders. *Biofeedback and Self-Regulation*, *20*, 241-258.

Schaffer, C. E., Davidson, R. J., & Saron, C. (1983). Frontal and parietal electroencephalogram asymmetry in depressed and nondepressed subjects. *Biological Psychiatry*, *18*, 753-762.

Silberman, E. K., & Weingartner, H. (1986). Hemispheric lateralization of functions related to emotion. *Brain & Cognition*, *5*, 322-353.

Suls, J., & Wan, C. K. (1993). The relationship between trait hostility

- and cardiovascular reactivity: A quantitative review and analysis. *Psychophysiology*, 30, 615-626.
- Sutton, S. K., & Davidson, R. J. (1997). Prefrontal brain asymmetry: A biological substrate of the behavioral approach and inhibition systems. *Psychological Science*, 8, 204-210.
- Tomarken, A. J., Davidson, R. J., Wheeler, R. E., & Kinney, L. (1992). Individual differences in anterior brain asymmetry and fundamental dimensions of emotion. *Journal of Personality and Social Psychology*, 62, 676-687.
- Tomarken, A. J., Davidson, R. J., Wheeler, R. E., & Doss, R. (1992). Psychometric properties of resting anterior EEG asymmetry: Temporal stability and internal consistency. *Psychophysiology*, 29, 576-592.
- Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, 54, 1063-1070.
- Wheeler, R. E., Davidson, R. J., & Tomarken, A. J. (1993). Frontal brain asymmetry and emotional reactivity: A biological substrate of affective style. *Psychophysiology*, 30, 82-89.

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