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Behavioral Activation Sensitivity and Resting Frontal EEG Asymmetry: Covariation of Putative Indicators Related to Risk for Mood Disorders

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Dispositional tendencies toward appetitive motivation have been hypothesized to be related to the development of psychopathology. Moreover, decreased left-frontal cortical activity has been reported in depression and has been related to low-trait positive affect and high-trait negative affect. The present study tested the hypothesis that relatively greater left- than right-frontal cortical activity would be related to heightened approach-related dispositional tendencies. Resting frontal cortical asymmetrical activity, as measured by electroencephalographic activity in the alpha band, was examined in relation to the motivational response tendencies of a behavioral activation system (BAS) and a behavioral inhibition system (BIS), as measured by C. S. Carver and T. L. White's (1994) BIS–BAS self-report questionnaire. Results supported the hypothesis.

To understand the causes of depression and to identify individuals most vulnerable to depression, researchers have increasingly attempted to identify factors related to risk for depression. A promising indicator of risk for depression is resting asymmetrical electroencephalographic (EEG) activity over the frontal cortex. Asymmetrical resting frontal EEG not only distinguishes currently depressed individuals from nondepressed individuals (Allen, Iacono, Depue, & Arbisi, 1993; Henriques & Davidson, 1991), it distinguishes previously depressed euthymic individuals from individuals without a history of depression (Allen et al., 1993; Henriques & Davidson, 1990), and it is stable across phases of depression (Hitt, Allen, & Duke, 1995). The EEG asymmetry is characterized by an increase in alpha-band activity (8–13 Hz) in the left-frontal region compared with the homologous right-frontal region. Because increased alpha is seen during periods of greater cortical quiescence (Lindsley & Wicke, 1974), the asymmetry suggests that individuals with a history of depression, independent of current clinical state, have decreased left-frontal cortical activity compared with never-depressed individuals. This interpretation is consistent with data indicating that individuals with left-frontal lesions demonstrate greater depressive symptoms than those with comparable right-frontal lesions (Robinson, Kubos, Starr, Rao, & Price, 1984). This pattern of frontal asymmetry may predict vulnerability to depression, as evidenced by research that has found that the pattern is more likely to occur in children of mothers with a history of major depression than in children of mothers without such a history (Tomarken, Simien, & Garber, 1994).

Frontal EEG Asymmetry, Temperament, and Emotion

Resting frontal EEG asymmetry has been hypothesized to relate to appetitive (approach-related) and aversive (withdrawal-related) motivation and emotion, with heightened approach tendencies reflected in relative left-frontal activity and heightened withdrawal tendencies reflected in relative right-frontal activity (Davidson, 1992). For example, individuals with relatively less left- than right-frontal activity exhibit larger negative affective responses to negative films and smaller positive affective responses to positive films (Wheeler, Davidson, & Tomarken, 1993). These findings suggest that resting frontal EEG asymmetry taps a diathesis to respond to emotionally evocative events with depressive emotional responses. Moreover, the asymmetry is present at a very young age (Davidson & Fox, 1989), suggesting that the asymmetry taps a fundamental dimension of temperament related to depression.

Emotion-Related Temperament and Psychopathology

Several writers have emphasized the role that temperament plays in influencing emotional responses and in the development of psychopathology (Depue & Iacono, 1989; Fowles, 1987, 1988, 1994). These writers have described biobehavioral models similar to Gray's (1972, 1987) model, which proposes three fundamental systems: the behavioral activation system (BAS), the behavioral inhibition system (BIS), and the fight–flight system. Abnormal sensitivity of any one of the systems is posited to reflect greater proneness to psychopathology, given appropriate

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Table 1
Means, Standard Deviations, and Cronbach's Alphas of BAS and BIS Scales

Scale	*M*	*SD*	α
BIS	22.14 (19.99)	2.85 (3.79)	.73
BAS reward responsiveness	17.89 (17.59)	2.04 (2.14)	.78
BAS drive	12.22 (12.05)	2.26 (2.36)	.86
BAS fun seeking	12.78 (12.43)	2.16 (2.26)	.76

Note. Possible ranges for each scale are the following: for BIS, 7–28; for BAS Reward, 5–20; for BAS Drive, 4–16; and for BAS Fun Seeking, 4–16. Means and standard deviations for BAS and BIS scales not in parentheses and the alpha coefficients are from the present sample of women. Those displayed in parentheses are from Carver and White (1994), and they are based on both men and women. Carver and White found that men scored lower on the BIS (M = 18.84) and on the BAS reward responsiveness (M = 17.27) scales than did women (Ms = 21.09 and 17.90, respectively). BAS = behavioral activation system; BIS = behavioral inhibition system.

situational cues. The BIS and BAS have been the most thoroughly researched.

The BIS is sensitive to signals of conditioned punishment, nonreward, novelty, and innate fear stimuli. The BIS inhibits behavior, increases arousal, prepares for vigorous behavior, and increases attention to aversive stimuli. High levels of BIS sensitivity are posited to predispose individuals toward anxiety disorders.

The BAS is sensitive to signals of conditioned reward, nonpunishment, and escape from punishment, and its activation causes movement toward goals. Low levels of BAS sensitivity are posited to predispose individuals toward certain types of depression.

The Present Study

On the basis of the preceding overview, we predicted that resting frontal EEG asymmetry would be related to measures of BAS sensitivity. Specifically, individuals with relatively greater left-frontal activity (i.e., less alpha) should possess greater levels of BAS sensitivity (i.e., heightened approach motivation). No prediction was advanced concerning the relation of frontal EEG asymmetry and BIS sensitivity.

Method

Participants

Participants were prescreened as part of a larger study examining emotional processing among women who were high or low in social anxiety (Harmon-Jones & Allen, 1996). At prescreening sessions, 152 women from introductory psychology classes completed the Social Avoidance and Distress Scale (SAD; Watson & Friend, 1969) and a handedness scale (Chapman & Chapman, 1987). Only those women who were strongly right-handed (with scores between 35 and 39) and scored in the upper or lower third of the distribution of social anxiety scores were invited to the experiment. Only right-handed women were invited to participate because the EEG asymmetry has been examined most often in right-handed women (e.g., Tomarken, Davidson, Wheeler, & Kinney, 1992). Thirty-seven women participated in exchange for course credit. EEG data were discarded from one participant because of high impedance.

Procedure

The experimenter informed participants that the session would consist of two experiments, one that assessed the relation between brainwaves and personality characteristics and one that assessed brainwaves during the processing of visual information (Harmon-Jones & Allen, 1996). After participants provided informed consent, electrodes were affixed to their face and scalp to record muscle and EEG activity, respectively. Electromyographic activity was recorded for purposes of the second experiment. Participants were then seated alone in a dimly lit, sound-attenuated room, and were asked to complete the Positive and Negative Affect Schedule—State Version (Watson, Clark, & Tellegen, 1988), the SAD (Watson & Friend, 1969), and the BIS/BAS Scales (Carver & White, 1994). The experimenters were unaware of the participants' scores on these questionnaires. After participants had completed the questionnaires, resting EEG was recorded for 4 min, 2 min with eyes open (O) and 2 min with eyes closed (C), in one of two randomly assigned counterbalanced orders (O, C, O, C or C, O, C, O).

Electroencephalographic Assessment

To assess frontal asymmetries in EEG activity, we placed tin electrodes in a stretch-Lycra cap (Electro-Cap International; Eaton, OH) on the participant's head, using Electro-Gel (Electro-Cap International) as the electrode paste. EEG was recorded at sites F3, F4, P3, and P4, and referenced on-line to Cz. Cz was used as the reference because previous research has compared Cz with averaged ears and found similar effects for each (Tomarken, Davidson, Wheeler, & Kinney, 1992). Interelectrode impedances for EEG electrodes were reduced to less than 5 Ω. All sites were amplified by a factor of 20,000 with AC differential amplifiers (bandpass of 0.1 and 100 Hz) and digitized continuously at 2048 Hz. To monitor eye blinks with electrooculography (EOG), we affixed tin electrodes to the outer canthus and superior orbit (amplification = 5 K, bandpass of 0.1 to 100 Hz).

Data Analyses

EEG was first screened for eye-movement and muscle artifacts, and data containing artifacts were rejected. Data were then epoched into two-second epochs overlapping by 75%. The power spectra were derived by means of the fast Fourier transform method with a Hamming window (applied to the distal 10% at each end of the epoch) for each two-second epoch and then 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 two-second epochs (SD = 65.85) comprised the eyes-open data, and an average of 201.25 two-second epochs (SD = 53.49) comprised the eyes-closed data. Number of accepted epochs did not correlate significantly with BAS or BIS scores.

For consistency with previous research (Wheeler et al., 1993), the alpha band was used to quantify activity, the power density values were log transformed to normalize the distributions, and a frontal asymmetry index (log right minus log left alpha power) was computed. Because alpha power is inversely related to activity (Lindsley & Wicke, 1974), higher scores on the index indicate greater relative left hemisphere activity. Relations between BAS scores and (a) eyes-open, (b) eyes-closed, and (c) the average of eyes-open and eyes-closed frontal EEG asymmetries were computed. The average of eyes-open and eyes-closed periods was computed because previous research in this area has used this index (e.g., Tomarken, Davidson, Wheeler, & Doss, 1992).

Table 2
Correlations Among Alpha Asymmetry Indexes, Affect Levels, and Motivation Levels

Measure	1	2	3	4	5	6	7	8	9
1. FAC	—								
2. FAO	.41**	—							
3. FAM	.85***	.66***	—						
4. SA	.07	.05	.07	—					
5. PA	.00	.19	.11	−.01	—				
6. NA	.07	−.27	.11	.14	−.23	—			
7. BAS	.45***	.15	.38*	−.46***	.34*	−.13	—		
8. BIS	.03	−.12	−.05	.32*	.07	.33*	−.30	—	
9. PAM	.03	.10	.08	.19	−.22	−.09	.04	−.18	—

Note. FAC = frontal asymmetry, eyes closed; FAO = frontal asymmetry, eyes open; FAM = frontal asymmetry, mean of eyes closed and eyes open; SA = social anxiety; PA = positive affect; NA = negative affect; BAS = behavioral activation system; BIS = behavioral inhibition system; PAM = parietal asymmetry, mean of eyes closed and eyes open.
$^{*}p < .05$. $^{**}p < .02$. $^{***}p < .01$.

Results

The BAS subscales were highly intercorrelated ($rs > .45$), and each subscale correlated similarly with the other measures of interest. Therefore, instead of reporting results for each subscale, we report the results for the combined BAS subscales. As shown in Table 1, the means and standard deviations of the BAS and BIS scales were almost identical to those reported in Carver and White (1994).

As predicted, baseline frontal asymmetry related to BAS (see Table 2).[1] These correlations indicate that individuals with higher levels of BAS manifest higher levels of left-frontal cortical activity, suggesting that the BAS and the frontal EEG asymmetry are tapping part of the same approach motivation system.[2] To ensure that the asymmetry effects were specific to the frontal sites, a parietal asymmetry index (log right minus log left alpha power) was computed. It did not correlate significantly with BAS or with BIS (see Table 2).

Previous research has found the frontal EEG asymmetry to be consistently important in affective phenomena, and the present research converges with this past research. Relations between levels of overall frontal alpha activity and affective phenomena have been less consistent, so our primary interest was in the frontal asymmetry rather than the overall level of frontal alpha activity. However, in the present study, overall level of frontal alpha activity was found to relate to BAS, with both right-frontal ($r = -.43$ for eyes closed) and left-frontal ($r = -.45$ for eyes closed) activity correlating negatively with BAS scores. These results are consistent with research that has found that depressed individuals exhibit elevated alpha (i.e., less cortical activity; Pollock & Schneider, 1990). In the present study, individuals putatively at lowest risk for depression (high BAS) evidenced a pattern opposite to that for depressed individuals, with lower alpha power in the frontal regions. Because overall frontal alpha (log right + log left) power was related to BAS ($r = -.44$, eyes closed), we explored whether the frontal alpha asymmetry–BAS relationship was artifactually influenced by the total frontal alpha power (see Chapman & Chapman, 1988, for a discussion of this issue). In a regression analysis on the eyes-closed data, total frontal alpha power was forced as the first entry, and it significantly predicted BAS scores ($R^2 = .19$, $p < .01$, $\beta = -.44$). The frontal asymmetry, however, when entered as the second step, significantly increased the variance accounted for in BAS scores ($\Delta R^2 = .11$, $p < .05$, $\beta = .35$).[3] Thus, the BAS–frontal asymmetry relationship is not merely a consequence of the BAS–total frontal activity relationship.

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[1] These relationships were somewhat stronger for eyes-closed than for eyes-open baseline periods, $t(33) = 1.78$, $p < .10$. To assess whether this difference between correlations resulted from the rejection of EEG during ocular artifact in the eyes-open periods, instead of rejecting EEG data co-occurring with ocular (EOG) artifact, we reduced ocular artifact off-line using a linear regression approach (Semlitsch, Anderer, Schuster, & Presslich, 1986). This approach calculates the extent to which ocular movements propagate to each EEG site. We computed regression weights after averaging the EOG and EEG time-locked to blink onset. These weights were then applied to the raw data to correct the EEG data for contributions from the EOG channel. The correlations between BAS and the three asymmetry indices were: (a) eyes-open frontal asymmetry, $r = .22$, $p = .19$; (b) eyes-closed frontal asymmetry, $r = .48$, $p < .01$; and (c) the mean of eyes-open and eyes-closed frontal asymmetries, $r = .38$, $p < .05$. These correlations were not significantly different from the correlations computed with blink-rejected EEG data.

[2] To better localize the source of the effect of BAS on the frontal asymmetry, we conducted a 2 (level of BAS: bottom 33% vs. top 33% of scores) between-participants × 2 (hemisphere: left vs. right) within-participant analysis of variance on log alpha power. Main effects for hemisphere, $F(1, 21) = 35.10$, $p < .001$, and BAS level, $F(1, 21) = 4.97$, $p < .05$, emerged. A hemisphere × BAS Level interaction also emerged, $F(1, 21) = 9.59$, $p < .01$. It indicated that individuals with high levels of BAS had much greater right alpha power ($M = 1.99$ μV; $SD = 0.83$) than left alpha power ($M = 1.87$; $SD = 0.86$), $F(1, 21) = 42.54$, $p < .001$, whereas individuals with low levels of BAS did not ($Ms = 2.77$ and 2.73; $SDs = 0.93$ and 0.93), $F(1, 21) = 3.83$, $p = .06$.

[3] This regression analysis was also performed for the eyes-open and the average of the eyes-closed and eyes-open EEG data. The results were similar but only approached significance for the average data ($\Delta R^2 = .08$ $p < .075$, $\beta = .29$) and were not significant for the eyes-open data ($\Delta R^2 = .01$, $p > .30$, $\beta = .09$).

Finally, the BAS correlated positively with state positive affect, and the BIS correlated positively with state negative affect. BAS correlated negatively with social anxiety, whereas BIS correlated positively with social anxiety. Consistent with previous research, resting frontal EEG asymmetry was not related to unprovoked self-reported state affect.

Discussion

The findings are consistent with the idea that resting frontal EEG asymmetry taps a fundamental biobehavioral dimension of approach-related motivation and emotion. Moreover, the present study provides direct support for this idea by showing that resting frontal EEG asymmetry relates to a direct measure of dispositional tendencies toward approach motivation. These results suggest that resting frontal EEG asymmetry may hold prognostic value for identifying those at risk for psychopathology characterized by a deficiency in approach motivation (e.g., depression).

BIS sensitivity did not relate to resting frontal EEG asymmetry, suggesting that BIS (as measured by Carver & White's, 1994, scale) is not related to the withdrawal motivation system posited by Davidson (1992). This withdrawal system, putatively involving relative right-frontal activity, has been found to be involved in impelling movement away from aversive stimuli (disgust), inhibiting movement toward aversive stimuli (fear), and impelling movement toward stimuli so as to actively avoid punishment (for a review, see Davidson, 1992). In contrast, Gray (1987) posited that three systems deal with aversive stimuli, depending on the nature of the stimulus and response. According to Gray, the fight–flight system responds to unconditioned aversive stimuli with unconditioned defensive aggression or escape behavior. The BIS responds to conditioned punishment, nonreward, innate fear stimuli, or novelty with inhibition of behavior, increased attention and arousal, and preparation for vigorous action. The BAS is involved in active avoidance of punishment, because "avoidance responding is more controlled by the positively reinforcing properties of safety cues—the stimuli signaling that threatened punishment is no longer likely to occur—and with these cues are the functional equivalent of cues for reward" (Fowles, 1987, p. 419). Thus, the overlap between the withdrawal system of Davidson (1992) and the systems of Gray (1987) is not obvious and thus requires further delineation.

A potential limitation of the present results is that only women were examined, and only those scoring in the upper and lower thirds of the distribution of social anxiety scores participated in the study. The exclusion of women who scored in the midrange in social anxiety (SAD) may have inflated the correlation between BAS and frontal EEG asymmetry if the SAD is correlated with BAS. Although SAD correlated with BAS in the present study, SAD did not correlate with BAS among 216 women from the same college as the present sample ($r = -.08$, $p > .20$) who were not selected for being high or low in social anxiety (Harmon-Jones, 1996). In addition, the BAS means and standard deviations of the present sample are almost identical with those obtained from Carver and White's (1994) sample of 732 college students (see Table 1). These results suggest (a) that our sample was representative of the population of college students on BIS–BAS scores and (b) that exclusion of midrange SAD scores in the present study may have inflated the correlation between SAD and BAS but did not inflate the correlation between BAS and frontal EEG asymmetry.

Because only 4 min of resting EEG data were collected, the present correlations involving the EEG asymmetry may be somewhat attenuated relative to those that might be obtained with longer samples of EEG. Some researchers (e.g., Tomarken, Davidson, Wheeler, & Kinney, 1992) have recommended sampling for at least 6 min, although others have found reliable estimates of EEG spectra with samples as short as 20 s (Gasser, Bacher, & Steinberg, 1985). Moreover, the reliability of EEG asymmetry from 4 min of sampling was apparently adequate to statistically establish that BAS and frontal EEG asymmetry are related.

The present results suggest that resting frontal EEG asymmetry and BAS tap a common dimension that may predict the development of mood disorders. Prospective studies are needed to test this hypothesis.

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