
Abnormality of EEG Alpha Asymmetry in Female Adolescent Suicide Attempters

Flemming Graae, Craig Tenke, Gerard Bruder, Mary-Jane Rotheram, John Piacentini, David Castro-Blanco, Paul Leite, and James Towey

Abnormal electroencephalographic (EEG) activity has been associated with various psychiatric disorders and behaviors, including depression, suicide, and aggression. We examined quantitative resting EEG in Hispanic female adolescent suicide attempters and matched normal controls. Computerized EEG measures were recorded at 11 scalp sites during eyes open and eyes closed periods from 16 suicide attempters and 22 normal controls. Suicide attempters differed from normal controls in alpha asymmetry. Normal adolescents had greater alpha (less activation) over right than left hemisphere, whereas suicidal adolescents had a nonsignificant asymmetry in the opposite direction. Nondepressed attempters were distinguished from depressed attempters in that they accounted for the preponderance of abnormal asymmetry, particularly in posterior regions. Alpha asymmetry over posterior regions was related to ratings of suicidal intent, but not depression severity. The alpha asymmetry in suicidal adolescents resembled that seen for depressed adults in its abnormal direction, but not in its regional distribution. Findings for suicidal adolescents are discussed in terms of a hypothesis of reduced left posterior activation, which is not related to depression but to suicidal or aggressive behavior.

Key Words: Electroencephalogram, suicide, depression, adolescents, hemispheric asymmetry

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Introduction

Since the pioneering electroencephalic (EEG) work of Berger (1929), the alpha rhythm has been viewed as a characteristic "resting" EEG state. The posterior distribution of alpha and its enhancement with eyes closed are also classic properties of alpha rhythm. Conversely, alpha

desynchronization has been viewed as a sign of cortical activation. Studies have explored the regional and functional specificity of hemispheric activation as measured by alpha reduction, and have determined in what ways it is associated with affective and behavioral parameters (Davidson et al 1985, 1989; Davidson, 1992). Studies have reported consistent differences between depressed adults and controls in quantitative measures of EEG alpha asymmetry (Davidson et al 1985; Henriques and Davidson 1990, 1991; Tucker et al 1981). Henriques and Davidson (1991) found that depressed adults showed relatively less left- than right-sided activation (i.e., more alpha power) in the midfrontal region, whereas normal subjects showed the

From the Department of Child and Adolescent Psychiatry (FG, M-JR, JP, DC-B) and the Department of Biopsychology (CT, GB, PL, JT), Columbia University College of Physicians and Surgeons and New York State Psychiatric Institute, New York, New York.

Address reprint requests to Flemming Graae, MD, New York Hospital-Westchester Division, 21 Bloomingdale Rd, White Plains, NY 10605.

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opposite alpha asymmetry. This reversal of normal asymmetry was also found for individuals who recovered from past depression (Henriques and Davidson 1990). EEG alpha asymmetry has also been associated with emotional responses to maternal separation in infants (Davidson and Fox 1989). Left-sided hypoactivation in the midfrontal region predicted whether an infant would show excessive distress and behavioral inhibition during brief maternal separation.

Davidson (1992) proposed that abnormal alpha asymmetry in the frontal region is a trait marker of vulnerability for affective disorders or behaviors associated with decreased approach-related positive affect. Although this model implies a developmental continuum, no work has been done with adolescents that would provide a link between the infant and adult studies.

The present study is the first effort to examine EEG alpha asymmetry among high-risk adolescents. The sample for this study consisted of inner-city female adolescents who attempted suicide. Suicidal girls often exhibit depressive symptoms, anxiety, and impulsivity. We hypothesized that these youths would differ from demographically matched normal controls in their resting EEG alpha asymmetry and would be more likely to show the abnormal EEG pattern seen in other age groups at risk for affective disturbance.

Methods and Materials

Subjects

The suicide attempters were 16 English-speaking Hispanic females presenting for treatment at the Child and Adolescent Suicide Disorders Clinic of Columbia Presbyterian Medical Center (CPMC). Since almost all attempters in our patient population are female, we excluded male attempters from our sample so as to maximize its homogeneity. A matched sample of 22 normal Hispanic adolescent girls was recruited from local high schools through classroom presentations describing the study. The average age for both groups was 14, with a range from 12–17 years old. Suicide attempters and controls attended the same schools within the same inner-city catchment area. All had lower-range socioeconomic status (SES). The subjects in the two groups were therefore of similar age, SES, cultural background, and locale.

Exclusionary criteria for both groups included a history of neurological pathology or mental retardation. For normal controls, a psychiatric interview by a child psychiatrist (F.G.) excluded current or recent psychiatric pathology, including depression or suicidal ideation in the past 6 months, and lifetime suicide attempts.

Current and past substance abuse was assessed for both

suicide attempters and normal controls at the initial interview. None reported significant current or past substance use. Three patients reported some alcohol use during their suicide attempt, one reported occasional alcohol use in the recent past, while the rest reported no alcohol or drug use within the 3 months prior to their attempt. Thirteen of the 16 attempters took medications of various kinds during their attempts, one cut her wrists, and two attempted to jump off a roof or out of a window. Only one attempter needed a medical admission because of her attempt (with iron pills), and another was psychiatrically admitted. None had medical or neurological sequelae as a result of the attempt. The EEG testing occurred between 2 and 28 weeks postattempt (mean = 7 weeks, SD = 3.2). At the time the EEG was done, none of the attempters had current medical problems or history of any neurological problem, and none was on psychotropic medication. Thus, EEG data were not likely to have been affected by drug status or medical complications of the suicide attempt.

Measures of suicidal ideation (Harkavy, Asnis Suicide Scale [HASS]; Harkavy et al 1987), suicidal intent (Pierce Suicide Intent Scale 1977), and depressive symptomatology (Beck Depression Inventory; Beck et al 1961) were obtained from each attempter. In addition, all of the suicide attempters were interviewed using the child version of the Diagnostic Interview Schedule for Children, Version 2.3 (DISC-C), and a parent was interviewed using the parent version (DISC-P; Shaffer et al 1989). Diagnostic algorithms were used that incorporate information from both the DISC-C and the DISC-P, so as to yield "combined diagnoses" (Piacentini et al 1992). The following six diagnostic modules from the DISC-C were administered: Major Depressive Disorder (MDD); Dysthymia (DD); Overanxious Disorder (OAD); Separation Anxiety Disorder (SAD); Agoraphobia (AG); Panic Disorder (PA); Conduct Disorder (CD); and Oppositional-Defiant Disorder (ODD). The diagnostic frequencies for the 16 index cases receiving the DISC were as follows: MDD ($n = 9$, 56%); DD ($n = 5$, 31%); OAD ($n = 5$, 31%); SAD ($n = 6$, 38%); AG ($n = 3$, 19%); PA ($n = 1$, 6%); CD ($n = 6$, 38%); and ODD ($n = 6$, 38%). Information for SAD was missing for one subject. Five attempters did not meet criteria for any of the six disorders assessed. Psychiatric characteristics of the index group are summarized in Table 1. Five of the attempters endorsed a prior history of physical abuse ($n = 1$), sexual abuse ($n = 2$) or both ($n = 2$). Although abuse history itself may be associated with hemispheric abnormalities (Teicher et al 1995; Schiffer et al 1993), EEG alpha asymmetries for these five subjects were not distinguishable from the other attempters; therefore, history of abuse was not included as a variable in this study.

All subjects were right-handed, as measured by the

Table 1. Description of Index Group

Subject	Age	Suicidal Intent ^a	DISC Diagnoses
1	13	2	MDD, OAD, SAD, AG, ODD
2	14	1	MDD, SAD, ODD, CD, DD
3	12	0	MDD, SAD, CD, DD
4	17	2	AG, CD
5	12	1	No Diagnosis
6	14	1	MDD, ODD, CD
7	14	2	OAD
8	14	0	MDD, OAD, SAD, PA, ODD, CD, DD
9	15	2	OAD, ODD, CD
10	16	2	No Diagnosis
11	15	2	MDD, OAD, SAD, AG, ODD, DD
12	15	1	MDD
13	17	— ^b	SAD
14	15	— ^b	— ^b
15	14	— ^b	MDD, DD
16	16	1	MDD

^aPierce suicide intent: 0,1 = none or unsure; 2 = intended or expected death.

^bMissing data.

DISC = Diagnostic Interview Schedule for Children.

MDD = Major Depressive Disorder; OAD = Overanxious Disorder; SAD = Separation Anxiety Disorder; AG = Agoraphobia; ODD = Oppositional-Defiant Disorder; CD = Conduct Disorder; DD = dysthymia.

Edinburgh Handedness Inventory (Oldfield 1971). Subjects were volunteers and were paid \$20 for their participation. Each subject had an escort who accompanied her through the entire laboratory procedure and assisted her with any scheduling and/or transportation problems. The procedure from time of recruitment through the testing was identical for both groups, and all participants appeared to tolerate the procedure well.

Electrophysiological Methods

Computerized EEG measures were recorded during two 3-minute resting periods (eyes open and eyes closed) from 11 scalp electrode sites (F8; F7; F4; F3; C4; C3; T6; T5; P4; P3; Oz) located according to standard 10-20 EEG nomenclature. Electrode locations were selected to provide symmetrical coverage of the scalp, with an emphasis on anterior sites (to sample frontal asymmetries) and posterior sites (the location of maximum alpha in resting subjects). All EEGs were recorded using an electrode cap (Electro Cap International) with a nose reference. Electrodes at supra- and infraorbital sites surrounding the right eye were used to monitor eyeblinks and vertical eye movements (bipolar), and electrodes at right and left outer canthi monitored horizontal eye movements (bipolar). To ensure compatibility with the cap, the EEG reference electrode was composed of tin. All other electrodes were standard Beckman Ag/AgCl electrodes. All electrode impedances were below 5 K. EEGs were recorded through a Grass Neurodata acquisition system at a gain of 10 K (2 K for eye channels), with a bandpass of 0.01–30 Hz.

Subjects were instructed to inhibit blinks or eye movements during each recording period. During the eyes open condition, subjects fixated on a central fixation mark. A PC-based EEG acquisition system (NeuroScan) acquired and digitized data continuously at 200 samples/sec over each 3-min recording period. This recording period was chosen based on previous studies, which have shown that total recording periods as brief as 1–2 minutes were adequate to produce stable estimates of alpha power in normal or depressed subjects, and a period less than 2.5 min was sufficient for schizophrenic subjects (Henriques and Davidson 1991; Lund et al 1995).

Data were subsequently segmented into consecutive 1.28-sec epochs. Epochs contaminated by blinks, eye movements, and movement-related artifacts were excluded from analysis using a rejection criterion of $\pm 100 \mu\text{V}$ on any channel. These criteria produced artifact-free data, as verified by direct visual inspection of the raw data. Each epoch was then baseline corrected and tapered over the entire 1.28 sec using a Hanning window. EEG data were subjected to an off-line Power Spectrum analysis using a Fast Fourier Transform. At each electrode, alpha power was averaged for artifact-free epochs spanning the 3-min recording period for each subject and subsequently integrated over 8–13 Hz. Logarithms of alpha power were computed to normalize the data.

The total number of recording epochs entering into each average ranged from 62–227 (1.3–4.8 min) and did not differ for the two groups (Attempters: $M = 159.2$, $SD = 40.1$; Controls: $M = 163.3$, $SD = 50.6$, $t(36) = 0.26$, $p > 0.5$). This number of epochs was found to be sufficient to produce stable spectral estimates even in severely disturbed psychiatric patients (Lund et al 1995). Although the reduction in data due to artifact rejection reduced the statistical power of subtle comparisons across hemispheres, the amount of data matched or exceeded that reported in a prior study of depressed adults (e.g., Henriques and Davidson 1991).

A nose reference is appropriate for the study of asymmetries in the EEG by virtue of its midline location and was used in all analyses except where explicitly indicated; however, some previous studies have used a central (Cz) reference (e.g., Henriques and Davidson 1991). While this difference is unlikely to have any effect on hemispheric asymmetries, it is still important to account for the possible contribution of the reference electrode to alpha topography. We addressed this issue by also reporting the results of analyses computed using waveforms which had been digitally referenced to a central recording site (average of C3 and C4). In all cases, results using a central reference were used as a confirmation of findings for a nose reference.

Statistical Comparisons

Previous work has indicated the importance of anterior vs. posterior alpha asymmetry in distinguishing between groups of depressed and nondepressed subject (Henriques and Davidson 1991). To directly examine these regional differences, data were pooled across electrode sites within anterior (Right = F8/4; Left = F7/3) and posterior (Right = T6, P4; Left = T5, P3) regions. Differences in log alpha power were evaluated using a repeated measures analysis of variance (ANOVA) with the following variables: Group (patient vs. control); Hemisphere (left vs. right); Region (anterior vs. posterior); and Condition (Eyes Open vs. Eyes Closed). All analyses and figures reflect this design. Data were collapsed across Condition whenever the interactions with Condition were not statistically significant.

Results

Overall Alpha Power Levels

A well-defined alpha peak was seen at posterior electrodes for all subjects in both groups for the eyes closed condition (Figure 1). Alpha blocking was evident in the reduction of power in the eyes open condition, which was also maximal at posterior sites. The desynchronization of alpha (disruption of alpha waves by low voltage, fast activity) with eyes open is indicative of greater cortical activation when compared to the recording period with eyes closed. The above results were confirmed in an ANOVA of power within the alpha band. Alpha power was greater at posterior as compared to anterior sites for both groups (Region: $F(1,36) = 395.92, p < 0.0001$), and it was attenuated in the eyes open condition (Condition: $F(1,36) = 124.42; p < 0.0001$), particularly at posterior sites (Condition \times Region interaction: $F(1,36) = 100.9; p < 0.0001$). There was no significant difference between the suicide attempters and normal controls in overall alpha power, and alpha blocking was equally present for both groups. There was also no significant difference between groups in overall power for the other frequency bands.

Alpha Asymmetry

Suicide attempters and normal controls were significantly different from each other in EEG alpha asymmetry (Figure 2). Normal controls had overall greater alpha power (less activation) over right than left hemisphere, whereas suicide attempters had a nonsignificant asymmetry in the opposite direction (Group \times Hemisphere interaction: $F(1,36) = 6.21; p < 0.02$). Further analysis showed that the difference in alpha power over the left and right hemispheres was statistically significant in controls ($F(1,21) = 5.76; p < 0.05$), but not in suicide attempters

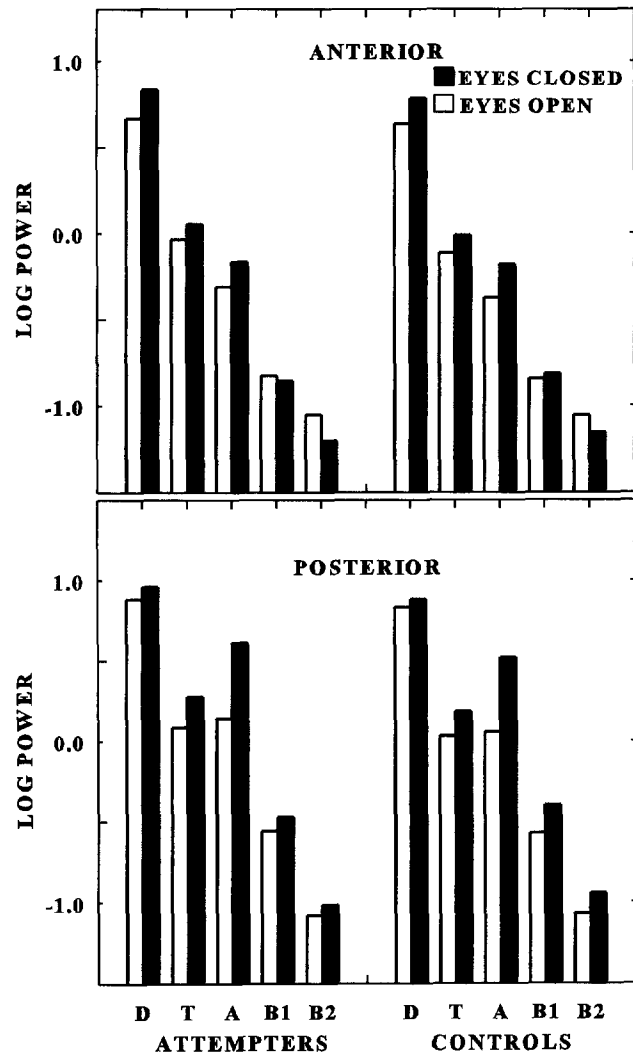


Figure 1. Bar graph of mean log power for each frequency band. Delta (D), theta (T), alpha (A), beta-1 (B1), beta-2 (B2) for both eyes open (white bars) and eyes closed (filled bars) conditions in each group at anterior and posterior electrodes.

($F(1,15) = 1.53; NS$). These quantitative group differences were also reflected in the alpha asymmetry for individual subjects. Sixty eight percent of the controls had greater alpha power over the right than left hemisphere, whereas only 44% of the suicide attempters showed this asymmetry. Confirmatory analyses using a central reference (average of C3 and C4) supported the Group \times Hemisphere interaction ($F(1,36) = 8.01; p < 0.01$). Controls had generally greater alpha power over right than left hemisphere (Hemisphere: $F(1,21) = 10.89; p < 0.005$), while suicide attempters did not (Hemisphere: $F(1,15) = 0.90; NS$).

There was also a trend toward regional differentiation of the alpha asymmetry difference between groups. As can be seen in Figure 2, the group differences in alpha asymmetry

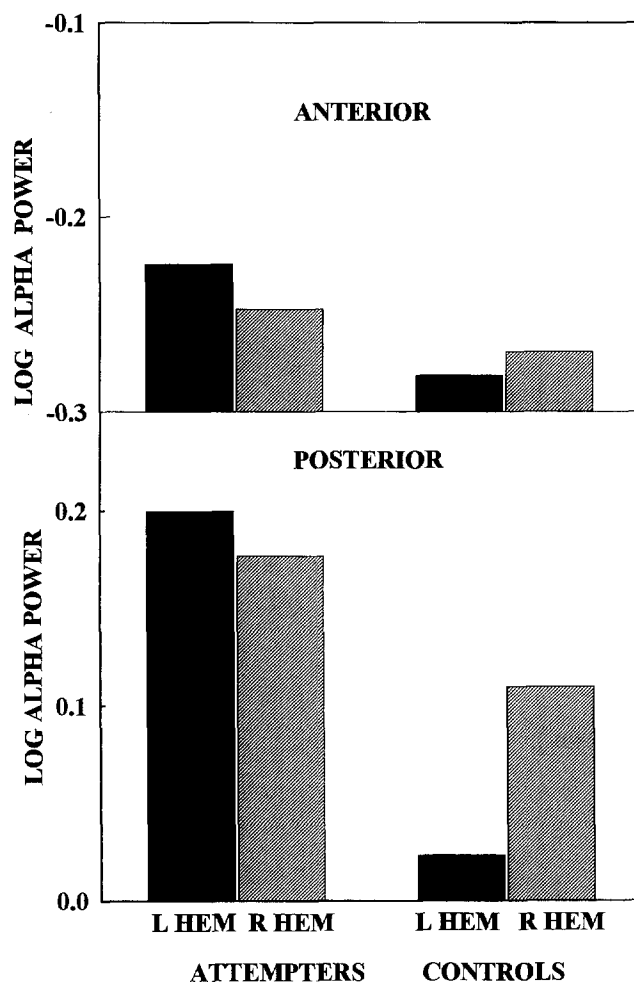


Figure 2. Mean log alpha power for attempters and controls over left and right hemisphere sites at anterior and posterior regions.

tended to be larger at posterior sites (Group \times Hemisphere \times Region: $F(1,36) = 1.16$; NS). This trend attained statistical significance for the centrally referenced data (Group \times Hemisphere \times Region: $F(1,36) = 4.05$; $p = 0.05$). The Group difference in asymmetry was unique to alpha activity, as it was not seen for theta, beta1, or beta2 activity. A Group \times Hemisphere interaction detected in the delta band ($F(1,36) = 5.50$; $p < 0.025$), was not supported using a central reference ($F(1,36) = 1.44$; $p > 0.2$).

Given prior findings of differences between depressed and control adults at midfrontal and parietal electrodes, separate analyses were conducted for these and other homologous electrode pairs (i.e., F4,3; F8,7; T6,5; P4,3). Significant group differences in asymmetry were found at posterior sites (Group \times Hemisphere interactions for T6,5 sites: $F(1,36) = 6.95$, $p = 0.01$; and for P4,3 sites: $F(1,36) = 3.86$, $p = 0.06$), but not at either of the frontal sites.

Correlational analysis of data for attempters did not find

significant correlations between alpha asymmetry and severity of depression (BDI; $r = 0.27$; NS) or suicidal ideation (HASS; $r = 0.31$; NS).

Alpha Asymmetry, Diagnosis of Depression, and Suicide Intent

Suicide attempters were further divided as to the presence or absence of a diagnosis of depression; nine attempters had MDD and five attempters had a nondepressive disorder (SAD, OAD, AG, ODD, CD; $n = 4$) or no diagnosis ($n = 2$). Attempters without a depressive disorder had the abnormal direction of alpha asymmetry, i.e., greater alpha over the left hemisphere, at posterior sites (Figure 3), whereas attempters having MDD did not (Region \times Hemisphere \times Subgroup: $F(1,13) = 7.37$, $p < 0.025$).

Further, suicide intent, as measured by Pierce Scale questions about whether the attempter intended to die or not, was more evident among attempters without a diagnosis of MDD. Among the 13 attempters for whom Pierce data were available, only two of eight attempters with MDD indicated lethal intent, but four of five non-MDD attempters indicated lethal intent. A repeated measures ANOVA of attempters grouped according to intent showed a significant Intent \times Region \times Hemisphere interaction ($F[1,11] = 5.66$; $p < 0.05$), where only the group indicating suicidal intent showed the abnormal posterior asymmetry. A Spearman correlation between overall hemispheric asymmetry and the intentionality item (0,1 = no intent or unsure versus 2 = suicide intent) was significant for posterior regions ($\rho = -0.5107$; $p < 0.05$), but not anterior regions ($\rho = 0.3345$; $p > 0.1$). Thus, the finding of a trend for greater alpha (less activation) over the left posterior hemisphere was related to suicidality and not to a diagnosis of depression.

Discussion

The main finding, which was evident for both nose and central references, was a difference in alpha asymmetry between female adolescent suicide attempters and normal controls. Normal controls showed greater alpha (less activation) over the right hemisphere, whereas suicidal adolescents showed a trend in the opposite direction.

Normative EEG data for a large sample of men (Wieneke et al 1980) and women (Tomarken et al 1992) indicate considerable individual differences in alpha asymmetry. Wieneke et al found greater alpha on the right than left side in the anterior temporal (T4-T3) and more posterior sites (T6-T5, P4-P3, O2-O1), and Tomarken et al reported a mean alpha asymmetry in this same direction at midfrontal (F4-F3) and anterior temporal (T4-T3) regions with an average ears reference. Our findings for normal

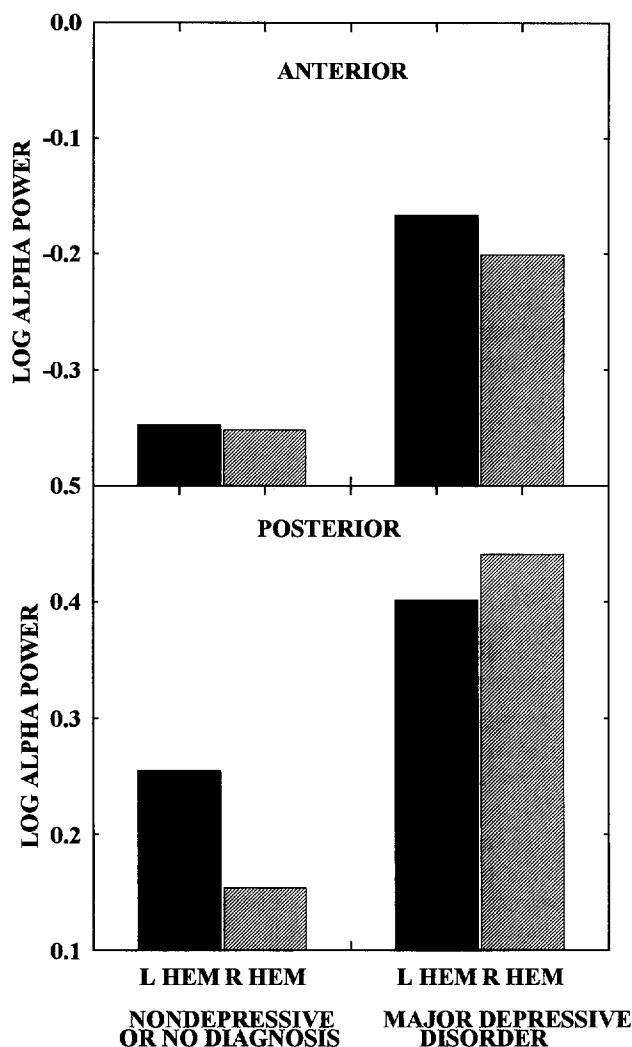


Figure 3. Mean log alpha power for depressed attempters and nondepressed attempters over left (black bars) and right (hatched bars) hemisphere sites at anterior and posterior regions.

female adolescents are consistent with these normative data. In contrast, the suicidal adolescents in the present study did not show the normal alpha asymmetry.

Clinical EEG abnormalities (paroxysmal dysrhythmias) have been associated with suicidal behavior (Struve et al 1972). Our study screened out subjects with significant neurological history, and most (or all) paroxysmal activity would have been artifacted out by our procedures. For this reason, we cannot draw conclusions about the relation of abnormalities of alpha asymmetry in suicidal adolescents to findings of clinical EEG abnormalities in suicidal adults.

In previous studies, depressed adults were found to show the opposite alpha asymmetry compared to normal controls at midfrontal sites (Davidson et al 1985; Hen-

riques and Davidson 1990, 1991). While our subsample of attempters with a diagnosis of major depression tended to show this abnormal direction of alpha asymmetry at the anterior sites, the nondepressed subgroup of attempters showed an abnormal direction of alpha asymmetry at posterior sites, where the amplitude of alpha is maximal. Nondepressed suicide attempters were further distinguished from depressed suicide attempters in that the posterior alpha asymmetry correlated with suicide intent, not with a diagnosis of depression. The EEG asymmetry distinction between the depressed and the nondepressed attempters may suggest a behavioral and physiologic separation of the two subgroups of suicide attempters.

The trend for relatively greater alpha power (less activation) over left posterior sites in suicide attempts was related to lethality of their attempts and not to the level of their depression. One possibility is that this EEG pattern may be related to the serotonin abnormalities that have been found in suicide victims and in aggressive behavior disorders. People attempting suicide and those committing acts of aggression may share a common disorder involving lower than normal levels of serotonin (Kreusi and Rapaport 1990; Linnoila et al 1983; Plizka et al 1988). It is also of interest that Arato et al (1991) has suggested a linkage between abnormal serotonin function in suicide and abnormal laterality. They present evidence that suicide victims have the reverse pattern of serotonin laterality as seen in normal adults; however, others (e.g., Arora and Meltzer 1991) have failed to find evidence of serotonin asymmetry.

In electrophysiological studies, both adolescent and adult psychopaths have been found to have reduced left hemisphere lateralization on verbal dichotic listening tests (Hare and McPherson 1984; Raine and O'Brien 1990). Moreover, a recent EEG study by Davidson and Hugdahl (in press) indicates that ear advantages on a verbal dichotic test were related most closely to EEG alpha levels in the left posterior region. If suicidal adolescents can be conceptualized as displaying inwardly directed aggression, they might be expected to resemble adolescent or adult psychopaths in showing both reduced left hemisphere advantage for verbal dichotic listening and also evidence of reduced left posterior activation on EEG alpha measures. This would be consistent with the view that abnormal posterior asymmetry in suicidal adolescents is related not to depression, but rather to the suicidal or aggressive behavior itself. Severity of depression (BDI) was not significantly correlated with suicidal ideation (Harkavy) in this group of subjects, and there was also no correlation between severity of depression and alpha asymmetry. The BDI was, however, done closer to the time of the suicide attempt than the EEG, which was administered weeks afterward, and it is not clear whether or not the abnormal

asymmetry in attempters could be due to depression at the time of the EEG measurement. It should also be noted that the adolescent suicide attempters we studied were a diagnostically heterogeneous group with anxiety and other behavioral problems, as well as depressive symptoms.

This study was not designed to examine the question of state versus trait causation of EEG abnormalities in suicide attempters. Adult studies have indicated stability of baseline EEG over time (Tomarken et al 1990; Wheeler et al 1993) and have found abnormal alpha asymmetry in remitted depressives (Henriques 1990). While the abnormality of alpha asymmetry in suicide attempters may

reflect a trait effect and suggest a vulnerability marker, our findings are not directly comparable to those found in depressed adults. Although other studies have found an association between history of childhood abuse and lateralized electrophysiologic abnormalities (Ito et al 1993; Schiffer et al 1995), our sample did not have sufficient numbers of adolescents with a history of abuse to adequately address this issue. Further studies of EEG alpha asymmetry in children and adolescents are needed to assess EEG stability, and to specify the relationship of EEG abnormalities to depression and other behavioral and affective disorders.

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