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Effects of Lateralized Presentations of Faces on Self-Reports of Emotion and EEG Asymmetry in Depressed and Non-Depressed Subjects

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ABSTRACT

Recent data suggest that individuals with affective disorders show anomolies on various measures of cerebral lateralization and hemispheric activation. In this study, EEG was recorded from left and right frontal and parietal scalp regions during left and right visual field and foveal presentations of happy, sad and neutral faces in 10 depressed and 10 non-depressed subjects. The sample was selected from a student population on the basis of scores on the Beck Depression Inventory. Faces were presented for 8 seconds and EOG was used to exclude trials associated with eye movements. Alpha activity from each of the leads during the middle 6 seconds of each trial was extracted for analysis. In addition, subjects were asked to rate each face on the degree to which it depicted various emotions, as well as the degree to which they experienced various emotions in response to each presentation. The results indicated that non-depressed subjects report more happiness in response to RVF compared with LVF presentations of the identical faces while depressed subjects show the opposite pattern. Frontal EEG alpha asymmetry paralleled the subjective ratings of happiness for both groups and accounted for more than 50% of the variance in self-reports of this emotion. Parietal asymmetry showed little relationship to subjective reports of emotion but did show systematic differences as a function of stimulus location, primarily due to changes in right parietal alpha. Finally, depressed subjects showed reciprocal relationships between frontal and parietal asymmetry while non-depressed subjects showed a positive relationship between asymmetry in these regions. The implications of these data for cognitive dysfunction in depression are discussed.

DESCRIPTORS: Cerebral asymmetry, EEG, Emotion, Depression, Subjective experience.

A growing body of literature indicates that at least certain regions of the two cerebral hemispheres are differentially lateralized for the processing of positive and negative affective stimuli in normals (see reviews by Davidson, 1984a and 1984b). Studies utilizing behavioral measures have demonstrated that right-handed subjects report more negative affect in response to information presented initially to the right hemisphere (i.e., left visual field) compared with responses to the identical stimuli when presented initially to the left hemisphere (right visual field) (e.g. Dimond, Farrington, & Johnson, 1976; Davidson, Mednick, Moss, Saron, & Schaffer, 1985). Data are also available which indicate that subjects respond more quickly to positive affective stimuli when they are presented to the RVF, compared with presentations of the identical stimuli to the LVF. In response to negative affective stimuli, precisely the opposite result was obtained (Reuter-Lorenz & Davidson, 1981). These latter findings have recently been replicated in an independent sample of subjects (Reuter-Lorenz, Givis, & Moscovitch, 1983).

Studies of EEG asymmetries in response to affective stimuli indicate that differential activation asymmetries in response to positive versus negative affective events are observed predominantly in the frontal region (e.g., Davidson, Schwartz, Saron, Bennett, & Goleman, 1979; Tucker, Stenslie, Roth, & Shearer, 1981). Recordings of EEG activation

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asymmetry from posterior scalp regions at coincidental points in time do not discriminate between positive and negative conditions. This frontal asymmetry for positive and negative affect is present in infants in the first year of life (Davidson & Fox, 1982).

Since depression involves, among other things, a disorder of emotion, depressed individuals might be expected to display a pattern of behavioral and electrophysiological asymmetries which differs from non-depressed subjects. Recent evidence using a variety of methodological approaches has indeed uncovered a different pattern of asymmetry in depressed compared with non-depressed subjects. These group differences in asymmetry have been observed during rest as well as in response to cognitive and affective tasks. For example, in studies using both dichotic listening tasks (Moscovitch, Strauss, & Olds, 1981; Wexler & Heninger, 1979; Yozawitz et al., 1979) and sodium amytal (Hommes & Panhuysen, 1971), depressed subjects displayed a negative relationship between left hemisphere dominance for language functions and severity of symptoms. Symptom remission was associated with increased lateral asymmetry. A number of investigators have reported that depressed subjects exhibit specific deficits on spatial cognitive tasks which presumably depend upon posterior right hemisphere involvement (Flor-Henry, Fromm-Auch, & Schopflocher, 1983; Taylor, Redfield, & Abrams, 1981). Group differences were much less pronounced or non-existent on verbal tasks which presumably require left hemisphere involvement.

Using electrophysiological measures, a number of investigators have reported that depressed subjects show differences in patterns of resting activation asymmetry compared with controls (e.g., Abrams & Taylor, 1979; Flor-Henry, Koles, Howarth, & Burton, 1979; Perris & Monakhov, 1979; Schaffer, Davidson, & Saron, 1983). For example, Flor-Henry and his colleagues (Flor-Henry et al., 1979) compared the EEG of psychotically depressed patients to normal controls. The depressed patients, relative to controls, showed a bilateral increase in temporal power in the 13–20 Hz (beta) band while at rest with eyes closed. The energy distribution was lateralized to the right hemisphere, indicated by a larger increase in right compared to left temporal beta power relative to controls. Other investigators have also observed a greater proportion of right versus left sided EEG abnormalities among depressed patients (e.g., Abrams & Taylor, 1979). Perris and Monakhov (1979) have recently found positive correlations between right pre-central activation and ratings of depressive mood, although other components of depressive symptomatology were correlated with left-sided activation. We (Schaffer et al., 1983) have recently studied resting frontal and parietal EEG asymmetry in a group of depressed and non-depressed students. EEG was recorded during both eyes open and eyes closed resting conditions. The results revealed a significant group difference during the eyes closed period, with depressed subjects showing greater right frontal activation (relatively less right frontal alpha) compared with non-depressed subjects. No group differences were found on a measure of parietal activation asymmetry recorded at the same points in time.

Very little data exist on differences between depressed versus non-depressed subjects in activation asymmetries in response to tasks. Flor-Henry et al. (1979) report differences in asymmetric hemispheric activation between depressed and non-depressed subjects in response to verbal and spatial cognitive challenges. The major difference they uncovered was increased relative left-sided temporal activation in response to a spatial task in depressed subjects compared with non- depressed subjects. To the best of our knowledge, no data on EEG asymmetry differences between these groups in response to affective tasks have been reported.

The purpose of this study was to examine both behavioral and electrophysiological responses obtained simultaneously to affective and neutral stimuli which were presented laterally as well as foveally. The paradigm we used in this study was modelled after another recent behavioral experiment of ours (Davidson et al., 1985). In that experiment, affective and neutral faces were exposed to the LVF and RVF. Following each stimulus exposure, subjects were required to rate the degree to which they experienced various emotions in response to the stimulus. In addition to obtaining ratings on traditional emotion categories, we also requested the subjects to rate the extent to which the face elicited the desire to approach as well as to not approach. These questions were included for theoretical reasons. In several recent publications, we (e.g., Davidson, 1984a, 1984b; Fox & Davidson, 1984) have speculated that the essential distinction underlying asymmetries for affect is approach/avoidance. Recent findings from animal (e.g., Denenberg, Hofmann, Rosen, & Yutzey, 1984) and developmental (Fox & Davidson, 1984) research support this formulation.

The stimuli were presented for long durations (8 seconds) since subjects reported that it was difficult to make the type of judgment for which we asked on the basis of shorter exposures. Because of this unorthodox stimulus presentation procedure, we recorded EOG and excluded all trials associated with an eye movement. The data from this study (Davidson et al., 1985) revealed, among other things, that subjects reliably reported more happiness in response to RVF compared with LVF presentations of the identical faces.

The present study utilizes the identical stimulus presentation paradigm. In addition to obtaining behavioral ratings, we recorded EEG from the left and right frontal and parietal regions during stimulus exposures. Based upon the previously reported findings we predicted that depressed subjects would show a different pattern of both behavioral and EEG asymmetry in this task. In light of earlier findings relating frontal EEG to affect, we expected the group difference to be localized to the frontal region. On the behavioral ratings, we predicted that the depressed subjects would report both more sadness and less happiness compared with non-depressed subjects, particularly in response to LVF presentations. We hypothesized that the frontal EEG data would parallel the behavioral data and would reveal greater right frontal activation in depressed compared with non-depressed subjects, particularly in response to LVF presentations.

Methods

Subjects

In order to select groups of depressed and non-depressed subjects, 415 undergraduates were administered the Beck Depression Inventory (BDI) (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) in trait form. Those scoring in the top 9% (20 or above; N = 38) were considered eligible as potential depressed subjects. After elimination of those whom we were unable to contact, were uninterested, left-handed, recently pregnant or used medication, 17 students came to the laboratory and prior to the experiment filled out the BDI again, on this occasion in *both* trait and state forms. Eleven subjects met an additional requirement of scoring 14 or above on the second administration of the trait form and completed the experimental tasks. Based upon the EEG findings, we eliminated one depressed subject (prior to data analysis) on the basis of abnormal electrophysiological data which suggested possible neurological disease. The remaining 10 subjects' responses were analyzed for the purpose of the present study. These subjects had a mean score of 28.6 (SD = 7.23) on the initial trait BDI[1], 21.7 (SD = 8.12) on the second trait administration (given just prior to the experiment), and 15.5 (SD = 6.29) on the state scale, also administered just prior to the experimental session. This sample consisted of 7 females and 3 males.[2] The mean age of the depressed sample was 20.4 yrs (SD = 1.84; range: 18–23 yrs). Seven of the 10 depressed subjects had sought psychological or psychiatric help at some point in their past. Five depressed subjects were under treatment for depression at the time they participated in this research. None of the depressed subjects were receiving medication.

The non-depressed subjects were selected to be matched to the depressed subjects on sex, age and marital status. Individuals were required to score 6 or below (N = 211) on the BDI. In addition, the Marlowe-Crowne Scale of Social Desirability (MC) (Crowne & Marlowe, 1964) was administered along with the BDI, for the purpose of assessing defensiveness in self-reports of individuals reporting low ratings of depression. In other words, individuals who report low depression but score highly on the Marlowe-Crowne are assumed to be defensively reporting little depression. These low BDI scorers may in fact be different from those individuals who score comparably on the BDI but who also score low on the Marlowe-Crowne. We therefore wished to exclude subjects who were high in defensiveness from our subject sample. Subjects scoring 11 or below (N = 177) on the MC met the criterion for non-repression. To be eligible for inclusion in the non-depressed group, scores of 6 or below on the initial BDI and 11 or below on the MC were necessary as well as meeting criteria such as age, sex, marital status, medication, etc. Fifteen subjects meeting these criteria came to the laboratory and prior to the experiment, again filled out the BDI in trait and state forms. In order to participate further, subjects were required to score 8 or below on this second administration of the scale in trait form. One individual

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[1]In order to examine "vegetative signs" in the depresssed and non-depressed groups, the scores on the final 6 items of the BDI (items 16 through 21) were separately tabulated. These items specifically relate to vegetative symptomatology. The depressed group had a mean of 7.1 (SD = 2.47) on these items while the non-depressed group had a mean of 1.8 (SD = 1.48) ($t(18) = 5.82$, $p<.00002$). Thus, subjects in the depressed group presented with unambiguous vegetative signs.

[2]Most previous investigators who have used the BDI to select subclinical depressed and non-depressed subjects did not specify whether the questionnaire was administered in trait or state form (e.g., Smolen, 1978; Rizley, 1978). We decided to use the trait form as our criterion measure since we were interested in differences between depressed and non-depressed subjects and not simply in dysphoric and euphoric mood states. The cut-offs which we adopted were based upon Beck's suggestion (Beck, 1967) that scores of 13 or 14 were clinically significant. It should be noted that most studies (e.g. McNitt & Thornton, 1978; Teasdale, 1978; Willis & Blaney, 1978) of depression in college students used a BDI cutoff of 9. On the state form of the questionnaire, administered just prior to the experiment, 2 of the depressed subjects had scores below 9. While these 2 subjects would not be considered to be currently in a dysphoric mood state, they did score 14 or more on the BDI trait form. In light of this discrepancy between trait and state reports of depression, the low scores on the state form might be best interpreted as a phasic attenuation of the overriding depression, likely to be a function of the experimental context.

was excluded on this basis. The remaining 14 subjects completed the experimental procedures. One subject was excluded prior to analysis because it was determined that he was left-handed in childhood. An additional 3 subjects who were run in the experiment were excluded prior to analysis in order to match the final groups on age and sex. The remaining 10 subjects, with a mean score of 4.4 (SD = 1.43) on the initial trait BDI, 5.0 (SD = 2.11) on the second trait administration, and 4.4 (SD = 2.22) on the state form, were analyzed for the present study. The mean age of the non-depressed group was 19.1 yrs (SD = 1.10; range: 18–21 yrs). Two individuals in this group had sought psychological or psychiatric help. No subject in the non-depressed group was receiving medication of any kind.[3] On the MC, the non-depressed group had a mean score of 8.7 (SD = 2.63) while the depressed group had a mean score of 11.0 (SD = 2.45). All subjects were right-handed as assessed by the Edinburgh Handedness Questionnaire (Oldfield, 1971). Specifically all subjects wrote with their right hands and had 7 or more responses in the right-handed direction.[4] To rule out any transient mood fluctuations that could result from phasic neuroendocrine activity (Wiener & Elmadjian, 1962; Janowsky, Gorney, & Kelley, 1966), women participating in the study were scheduled during the middle two weeks of their menstrual cycle. The experimenter was not blind to the group status of the subject.[5] On a question requesting them to report any unusual stress or major disruption in their daily life during the last year, 7 depressed and 5 non-depressed subjects answered affirmatively. This observation suggests that the groups did not differ in recent life stress.

[3]The subjects tested in this experiment included all of the 9 non-depressed and the 6 depressed subjects whose baseline EEG asymmetry data have been reported elsewhere (Schaffer, Davidson, & Saron, 1983).

[4]The mean score on the Edinburgh Questionnaire for depressed subjects was 9.5 (SD = 1.6) while for non-depressed subjects it was 11.2 (SD = 1.3). While these differences were significant ($t(18) = 2.61$, $p = .02$), correlations between the Edinburgh (number of items performed with the right hand) and all of the major dependent measures indicate that these slight differences in handedness do not account for very much variance in either the behavioral or EEG measures. For example, the mean correlation between self-ratings of happiness and handedness was .26 (SD = .095). Of the 18 correlations which comprised this mean, none were significant. The mean correlation between the mean EEG laterality ratio score and handedness was −.217. None of the correlations which comprised this mean were significant.

[5]Because of the number of personnel who were involved in running this study, experimenter blindness was not possible to achieve. Most of the depressed subjects inferred that they were selected on the basis of their high ratings on the BDI. The lack of experimenter blindness may have accentuated some of our group differences although the magnitude of such effects is unknown in our data and needs to be established in future research.

Stimuli

Faces displaying happy, sad and neutral expressions from the Ekman and Friesen (1976) set were used as stimuli. In this set, there are 13 posers who each are pictured with the three desired expressions. These 39 slides were presented to 60 students (in a general psychology course at SUNY Purchase) who rated each one on a scale of 1–7 assessing how happy, sad and neutral each was. The mean ratings of each emotion were obtained for each slide.

Each happy slide was given a relative happiness score by subtracting the mean rating of sadness from the mean rating of happiness for that particular face (H−S). Each sad slide was given a relative sadness score by subtracting the mean rating of happiness from the mean rating of sadness for that face (S−H). Each neutral slide was given a relative neutrality score by subtracting its mean sadness rating from its mean neutrality rating and adding this number to its mean happiness rating subtracted from its mean neutrality rating and then dividing this sum by two: (N−S)+(N−H)/2. Since we desired to choose slides in which the poser was consistent in his/her intensity of expression of the three emotions, the happiness score, sadness score, and neutrality score were compared for each poser. The smallest of these scores was subtracted from the largest and the slides of the 4 posers who yielded the smallest differences were chosen as stimuli. Table 1 presents the ratings of the intensity of the target emotion for the slides used as stimuli. Of the 4 posers, 2 are male and 2 are female. Three of them have closed-mouth happy expressions.

Stimulus Presentation Procedure

Each slide was presented twice to each visual field (LVF and RVF) and foveally. On one occasion, the slide was presented in a normal orientation and on a second occasion, the slide was mirror reversed. The purpose of including stimulus orientation as a variable was to evaluate the potential contributions of facial

Table 1

Mean ratings of the relative intensity of the target emotion for each of the 4 happy, sad, and neutral slides which were used

Posers	Mean Ratings[a] Happy Slide	Sad Slide	Neutral Slide	Most Intense Minus Least Intense Rating[b]
1	4.24	3.77	3.77	.47
2	3.62	4.21	3.97	.59
3	3.56	4.47	3.61	.91
4	3.11	4.26	3.63	1.15

[a]The ratings for the happy slides consist of the happy rating minus the sad rating. The ratings for the sad slides consist of the sad rating minus the happy rating. The ratings for the neutral slides consist of the following ratio: ((neutral rating − sad rating) + (neutral rating − happy rating))/2. Means are based on an N of 60.

[b]The relative intensity difference between the most and least intensely rated slide per poser.

asymmetry in the stimuli to EEG asymmetry. A number of authors have suggested that the two sides of the face are sometimes perceived differently and show asymmetries in the intensity of expressed emotion (Sackeim, Gur, & Saucy, 1978; Borad & Koff, 1984), particularly posed facial expressions (Ekman, 1980; Ekman, Hager, & Friesen, 1981). In the Ekman and Friesen stimulus set from which the faces used in the present study were obtained, all but the happy faces were posed. The slides were counterbalanced for emotion and then randomized for visual field, poser, and orientation. The 72 trials were preceded by 3 practice trials.

Preceding each stimulus presentation, a fixation point was presented foveally for 5 s. As the projectors advanced, the screen was blank for 1.5 s and then the face was presented for an 8-s duration. On all hemifield trials, the fixation point was presented foveally throughout the 8-s stimulus presentation. During foveal trials the subjects were told to focus on the center of the face. We chose this duration based upon previous research which indicated that subjects were not able to confidently make the types of judgments asked of them with durations that were shorter (Davidson et al., 1985).

Following each stimulus presentation, subjects filled out a brief one-page questionnaire which contained a series of 7-point rating scales. The subjects were required to rate their responses to the following six questions using this scale:

1. How happy was the face you just saw?
2. How sad was the face you just saw?
3. How happy did that face make you feel?
4. How sad did that face make you feel?
5. How much did that face invite you to become involved with and approach that person?
6. How much did that face make you *not* want to become involved with and approach that person?

The subjects were given 15 s to rate their answers following each slide. We chose to use independent happy and sad rating scales because of the widespread belief among emotion researchers (e.g., Ekman, 1972; Izard, 1977) that happiness and sadness are not endpoints of the same continuum but rather, are two qualitatively different emotions.

The subjects were instructed that they would see each face more than one time and they should feel free to rate it similarly or differently from trial to trial. After the 35th trial as well as whenever requested, subjects were given a break. In addition, when the experimenter noticed a decline in the subject's ability to fixate, a break was suggested.

Subjects were seated in a room situated between the projection room and the control room. Nasion to screen distance was 104 cm. The distance from the bottom of the screen to the floor was 95 cm.

Slides were presented using a modified 3-field projecting tachistoscope. The center field was used to project the fixation point as well as foveal presentations. The projection system used 3 Kodak Carousel projectors, Model AF-3, set on low intensity with a Sylvania ELH 300 watt projector lamp. Ten percent transmittance neutral density filters were mounted on Gerbands shutters which were attached to 4″ focal length lenses on each of the three projectors. Coulbourn digital logic was used to control stimulus presentations. Slides were projected onto a 24″ × 36″ 3M Polacoat rear projector screen mounted ½″ in front of plate glass identical in size to the projection screen. The purpose of the plate glass was for shutter sound attenuation. The horizontal angle from the fixation point to the nasion edge of each stimulus was 5.5 degrees. The horizontal angle of the projected stimuli themselves was 10 degrees. Communication with the subject was established through two-way intercom.

Apparatus and Electrophysiological Recording Procedure

EEG was recorded with a lycra electrode cap (Electro-cap, Inc.). The electroencephalogram was monitored with a Grass Model 7B, 8-channel polygraph. EEG was recorded from left and right frontal sites (F_3 and F_4) and left and right parietal sites (P_3 and P_4). All placements were referenced to C_Z (Jasper, 1958). Electrode impedances were all under 5,000 ohms. EEG was filtered for the presence of narrow band alpha activity (9–12 Hz) with Rockland bandpass filters (roll-off 48dB per octave) and passed into four Coulbourn contour-following integrators. The outputs of the integrators were multiplexed and sent into a voltage-controlled oscillator whose output was quantified. The recording system was calibrated to yield μV-seconds of alpha activity by inputting a 25 μV 10 Hz signal prior to every subject and then scaling the raw data to this known voltage. Alpha values were obtained for the middle 6 seconds of each stimulus presentation. The data from the first and last second of each stimulus presentation were excluded. In order to eliminate those trials confounded by eye movements, EOG was recorded through an AC preamp using Beckman miniature electrodes attached to the external canthus of each eye. The EOG channel was calibrated so that an eye movement of 1 degree could be easily resolved. The output of this channel was led into two Schmidt triggers which detected eye movements of 1 degree or more in either direction. Digital logic was programmed to produce a tone in the subject room whenever the eyes deviated by more than 1 degree from central fixation. Prior to the practice trials, subjects received training in keeping their eyes still with the help of the feedback apparatus. Subjects were given the additional incentive of a monetary reward for their keeping their eye movements to a minimum. Prior to data analysis, all trials associated with eye movements were eliminated.

Results

The rating data will be presented first, followed by the EEG results. The final section of the results will contain analyses related to relationships between the ratings and EEG.

Rating Data

We first examined the number of usable trials (unconfounded by eye movement artifact) for each group (out of a total of 72 per subject). The depressed group had a mean of 52.5 usable trials (SD = 13.0) while the non-depressed group had a mean of 61.2 usable trials (SD = 5.29). This difference was not significant ($t(18) = 1.96$). Both the rating and EEG data were based upon within subject averages computed for each condition combination.

The rating data were first examined by computing an analysis of variance (ANOVA) with Group (depressed/non-depressed), Emotion of stimuli (happy/sad/neutral), Orientation (straight/mirrored), Visual Field (LVF/RVF/Foveal), and Question (Questions 1–6) as factors.[6] Main effects and interactions across Question were not interpretable since the meaning of ratings collapsed across different affect rating scales is ambiguous. Therefore, only effects which interacted with Question will be reported. A highly significant Emotion × Question interaction was obtained ($F(10/180) = 91.74$). This interaction was simply a function of subjects giving higher ratings to stimuli belonging in the category which was being rated.

A significant Visual Field × Question interaction was obtained ($F(10/180) = 2.65, p = .05$). This interaction must be qualified in light of the significant Group × Visual Field × Question interaction ($F(10/180) = 3.16, p = .002$). In order to decompose this interaction, separate ANOVAs were computed on data derived from each question. These ANOVAs were computed in two ways. In the first method, Visual Field was a three-level factor and included RVF, LVF, and foveal trials. In the second method, Visual Field included only RVF and LVF trials. This procedure was followed since our previous experiment (Davidson et al., 1985) utilized only hemifield presentations and we wanted to compare the present data with the previous findings.

No group differences were found in response to questions 1 or 2, i.e., those in which the subjects rated their perception of emotion in the stimuli.

On question 3, the subjects were asked to rate their own experience of happiness in response to the stimuli. The Group × Visual Field interaction did not reach significance when foveal trials were included ($F(2/36) = 2.27, p = .12$). When the ANOVA was performed without the foveal condition, a significant Group × VF interaction emerged ($F(1/18) = 5.99, p = .03$) (see Figure 1). Depressed subjects reported more happiness in response to LVF versus RVF presentations while non-depressed subjects showed the opposite effect. Six of the 10 depressed subjects reported more happiness in response to LVF versus RVF presentations while only 3 of the non-depressed subjects showed this effect. The direction of asymmetry for the non-depressed subjects is consistent with our recent findings (Davidson et al., 1985). Contrary to our expectation, depressed subjects did not report significantly less happiness compared with non-depressed subjects.

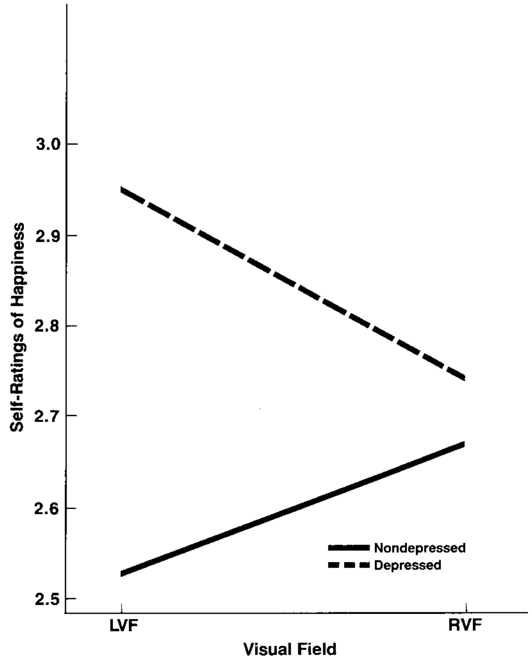

Figure 1. Mean self-ratings of happiness (on a 7-point scale) in response to the identical faces presented to the left visual field (LVF) and right visual field (RVF), split by Group. N = 10 per group.

On question 4, the subjects were asked to rate their own experience of sadness. In the ANOVA including foveal trials, a non-significant Group × VF interaction was obtained ($F(2/36) = 3.31, p = .07$). Depressed and non-depressed subjects showed equivalent sadness ratings in response to foveal presentations. However, the depressed subjects showed lower sadness ratings compared with non-depressed subjects in response to both LVF and RVF trials. The lack of significant Group × VF interaction in the absence of the foveal condition indicated that the groups did not differ in the pattern of sadness ratings as a function of lateralizing the stimulus presentation to the left or right visual field.

On question 5, the subjects were asked how much the face invited them to approach. A significant

[6]The probability values associated with all repeated measures ANOVAs with factors containing more than two levels have been corrected with the Greenhouse-Geisser correction procedure.

Group × VF ($F(2/36) = 4.17$, $p = .03$) interaction was obtained when the foveal condition was included. This effect was a function of higher approach ratings given by depressed versus non-depressed subjects in response to foveal presentations. No group difference on this question was obtained in response to hemifield presentations and the Group × VF interaction in the absence of the foveal condition was not significant.

On question 6, the subjects were asked to rate each face on the extent to which it evoked feelings of not approaching. A significant Group × VF interaction ($F(2/36) = 6.57$, $p = .01$) was obtained when foveal trials were included as well as when they were excluded ($F(1/18) = 4.54$, $p = .05$). While the non-depressed subjects did not differ in their ratings of RVF versus LVF trials, the depressed group gave significantly ($p = .037$) higher ratings of not-approach to RVF compared to LVF trials (Figure 2).

EEG Data

The EEG data were first evaluated by examining laterality ratio scores (R−L/R+L alpha). Higher numbers on these scores are indicative of the greater relative left-sided activation. An overall ANOVA was computed on the ratio scores with Group (depressed and non-depressed) as a between-groups factor and Emotion (happy, sad, and neutral face), Orientation (straight and mirrored), Visual Field (LVF, RVF, and foveal), and Region (frontal and parietal) as repeated measures factors. Since Emotion and Orientation did not show significant main effects nor interact with any other variable, the data were collapsed across these conditions and ANOVAs were computed with only Group, Visual Field, and Region as factors. A marginally significant main effect for Visual Field was obtained ($F(2/31) = 3.39$, $p < .07$). In addition, a significant main effect for Region was obtained ($F(1/18) = 5.57$, $p = .03$). A main effect for Group was not found.

The main effects for Visual Field and Region must be qualified in light of the significant interaction which was obtained between these variables. Figure 3 illustrates a significant Visual Field × Region interaction ($F(2/31) = 7.01$, $p = .02$). As can be seen from this Figure, the hemifield to which stimuli were presented dramatically affected parietal asymmetry, with right-sided parietal activation obtained in response to stimuli initially presented to the right hemisphere (LVF) and left-sided parietal activation seen in response to left hemisphere presentations (RVF). Little visual field difference was obtained for the frontal leads.

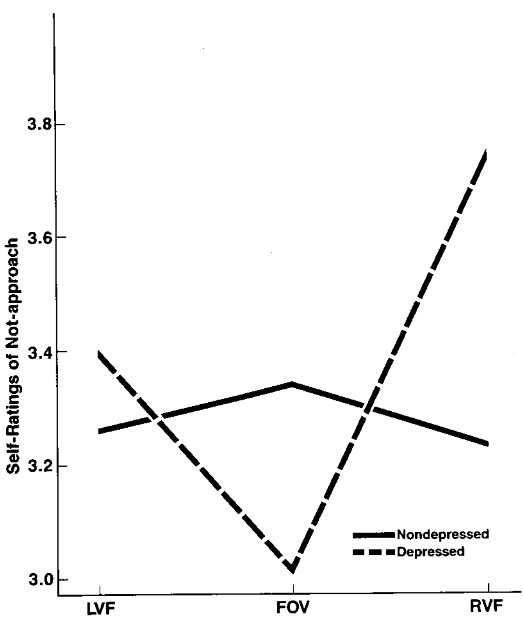

Figure 2. Mean self-ratings of not-approach (on a 7-point scale) in response to the identical faces presented to the LVF, RVF and foveally, split by Group. N = 10 per group.

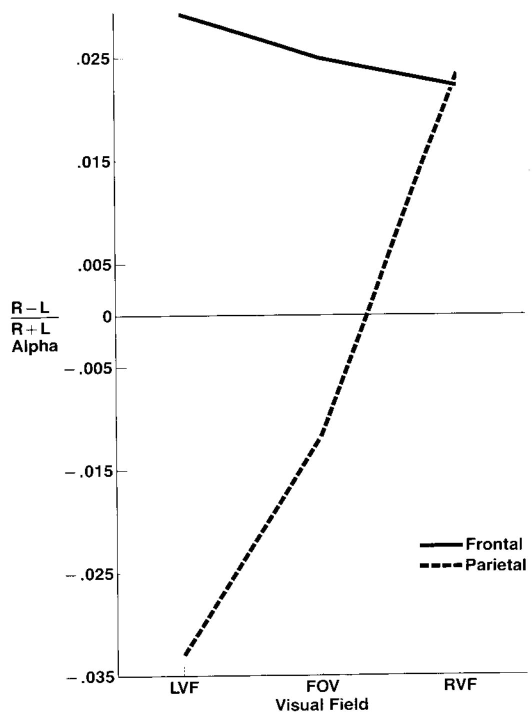

Figure 3. Laterality ratio scores (R−L/R+L alpha—higher numbers on this ratio are indicative of greater relative left-sided activation) for frontal and parietal scalp leads across Group, split by Visual Field. LVF = left visual field; RVF = right visual field; FOV = foveal. N = 20.

These effects were expressed differently in the depressed versus non-depressed subjects as indicated by a significant Group × Visual Field × Region interaction ($F(2/13) = 3.77$, $p = .05$). This interaction is illustrated in Figures 4 and 5. Separate ANOVAs for each Region were performed to decompose the triple-order interaction. As can be seen from Figure 4, the two groups showed a similar pattern of parietal asymmetry among the three visual field conditions: parietal activation contralateral to the field stimulated. The similar pattern of asymmetry for each group is supported by the absence of a significant Group × VF interaction for the parietal leads ($F(2/31) = 1.90$). However, as expected, a significant main effect for Visual Field was obtained ($F(2/13) = 5.38$, $p = .04$).

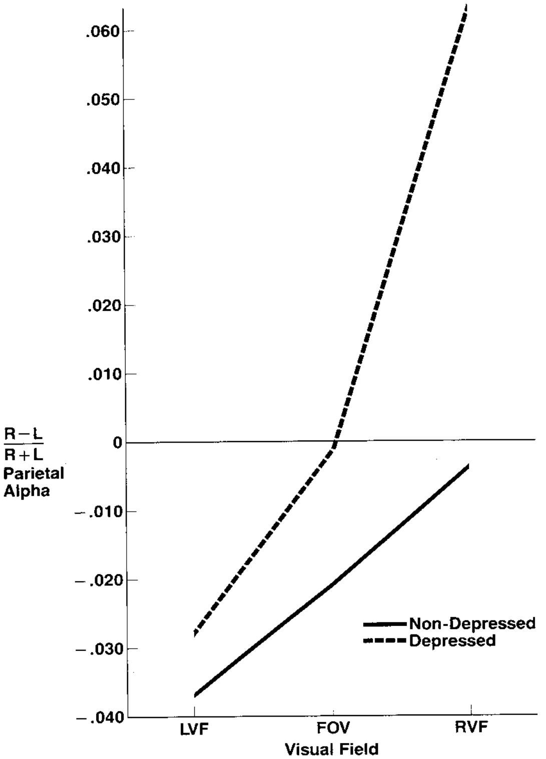

Figure 4. Parietal laterality ratio scores split by Group and Visual Field. N = 10 per group.

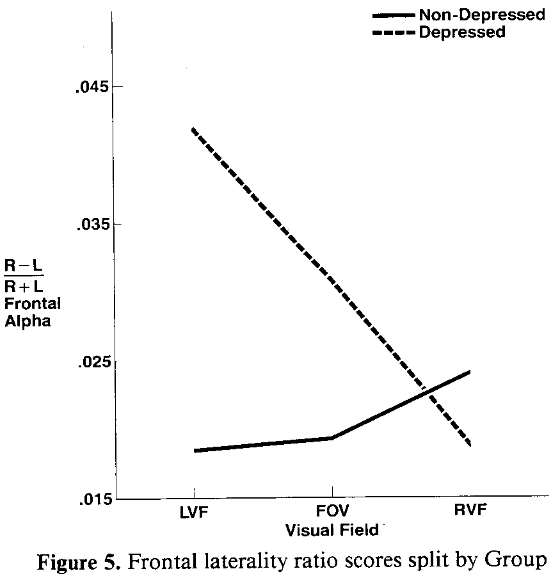

Figure 5. Frontal laterality ratio scores split by Group and Visual Field. N = 10 per group.

Frontal EEG asymmetry showed a different pattern of results among the visual fields for the two groups. This is supported by a significant Group × VF interaction on the frontal ratio score ($F(2/13) = 4.45$, $p = .05$). As is illustrated in Figure 5, depressed subjects showed more left-sided frontal activation in response to stimuli presented initially to the right hemisphere (LVF) compared with identical stimuli presented to the left hemisphere (RVF) ($p<.001$). Non-depressed subjects showed little difference in frontal activation asymmetry among the three visual fields. One additional feature of this interaction was noteworthy. The non-depressed subjects showed a comparable pattern of asymmetry across the visual fields in the frontal and parietal regions. When separate ANOVAs for each Group were performed, these subjects did not show a Visual Field × Region interaction ($F(2/18) = 1.36$). However, the significant VF × Region interaction for the depressed group ($F(2/13) = 5.93$, $p = .03$) indicated that the pattern of asymmetry among the visual fields was different for each Region in this group. In the parietal region, they showed increasing left-sided activation in response to foveal compared with LVF stimuli and in response to RVF compared with foveal stimuli. This was the same pattern as was displayed by non-depressed subjects. In the frontal region, the opposite effect was observed.

In order to decompose the laterality ratio scores, ANOVAs were computed on the alpha data separately for each hemisphere (μV-seconds of alpha in each lead). The overall analysis included Group, Visual Field, Region, and Hemisphere (left and right) as factors. A significant main effect for Visual Field was found ($F(2/31) = 4.35$, $p = .05$). Foveal trials elicited the least amount of alpha ($\overline{X} = 5.01$, SD = 2.20), LVF trials were intermediate ($\overline{X} = 5.30$, SD = 2.64), and RVF trials elicited the largest amount ($\overline{X} = 5.53$, SD = 2.66).

A highly significant main effect for Region was also obtained ($F(1/18) = 49.14$, $p<.0001$). Less alpha was present in the frontal ($\overline{X} = 4.39$, SD = 2.21) compared with the parietal leads ($\overline{X} = 6.15$, SD = 2.47).

The significant Visual Field × Hemisphere interaction ($F(2/31) = 3.35$, $p = .05$) illustrated that: a) the two hemispheres produced comparable amounts of alpha during the foveal condition, and b) the difference between the two visual fields in overall EEG asymmetry was a function of differences in right hemisphere alpha only ($p < .08$). This pattern was different however, for each Region as indicated by a significant Visual Field × Hemisphere × Region interaction ($F(2/31) = 5.09$, $p = .03$). ANOVAs performed separately on each Region revealed a significant Visual Field × Hemisphere interaction only for the parietal leads ($F(2/31) = 4.36$, $p = .05$) (see Figure 6). It is only the right parietal lead which showed reliable differences in alpha activity between LVF and RVF presentations ($p = .002$), with LVF presentations eliciting less alpha compared with RVF presentations. Although the left parietal lead showed the opposite pattern, the difference was not significant.

As predicted, based upon the ratio score findings, a significant Group × VF × Region × Hemisphere interaction was obtained on the raw alpha data ($F(2/31) = 4.54$, $p = .04$). Separate ANOVAs were performed for frontal and parietal data to decompose this complex interaction. A non-significant Group × VF × Hemisphere interaction was obtained on the frontal data ($F(2/31) = 2.96$, $p = .10$). This interaction for the parietal data was also non-significant ($F(2/31) = 3.38$, $p = .07$). In general, the interactions showed that visual field differences in EEG asymmetry for both groups were more a function of changes in amount of right hemisphere compared with left hemisphere alpha. Table 2 presents the means and standard deviations of alpha activity, separately by Group, split by Visual Field, Region, and Hemisphere.

It is apparent when comparing Figures 4 and 5 that depressed subjects showed opposite patterns of frontal and parietal EEG asymmetry across the visual field conditions. In order to explore this phenomenon in more detail, we computed within subject correlations between frontal and parietal EEG laterality ratio scores. The correlations were based upon all condition combinations (total of 18 per subject—3 emotions × 2 orientations × 3 visual fields). We then examined the correlations separately for each subject and determined whether they were positive or negative in sign. An inverse correlation indicates that frontal and parietal asymmetry patterns move in opposite directions across condition. Seven out of 10 depressed subjects exhibited negative frontal/parietal correlations while only one non-depressed subject showed this effect ($p < .01$ by Fisher's Exact Test).

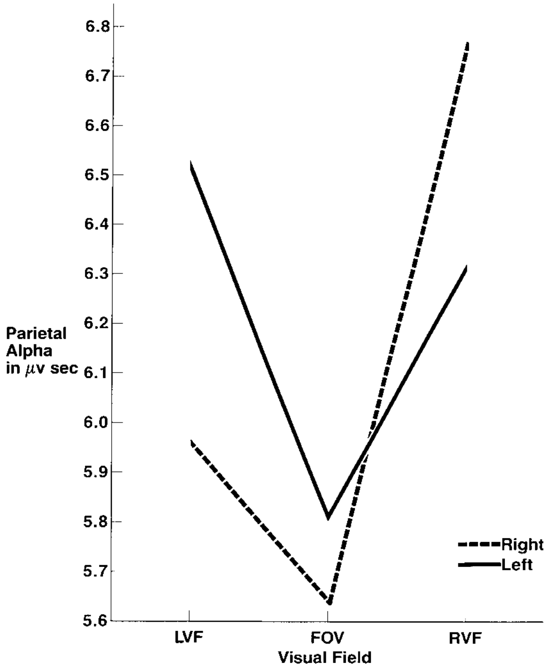

Figure 6. Left and right-sided parietal alpha (in μV-seconds) across Group, split by Visual Field. N = 20.

Table 2

Means and standard deviations of alpha activity for non-depressed (Non Dep) and depressed (Dep) subjects, split by visual field, region, and hemisphere

Groups (N=10)	Mean Alpha Activity (μV seconds) (SDs below each mean)											
	Left Visual Field				Foveal				Right Visual Field			
	Frontal		Parietal		Frontal		Parietal		Frontal		Parietal	
	L	R	L	R	L	R	L	R	L	R	L	R
Non	3.63	3.77	5.77	5.36	3.63	3.78	5.29	5.05	3.70	3.90	5.84	5.71
Dep	.79	.91	1.70	1.66	.84	.90	1.70	1.52	.94	1.09	1.99	1.76
Dep	4.94	5.26	7.34	6.64	4.89	5.09	6.38	6.24	5.49	5.60	6.99	8.24
	3.32	3.20	3.87	2.73	2.86	2.76	2.78	2.50	3.36	3.22	2.75	3.82

Self-Report/EEG Relationships

In order to explore relationships between changes in EEG activation asymmetry and changes in the self-report of emotion, we computed correlations between measures of EEG activation asymmetry and ratings of emotional experience for those rating categories which showed a significant interaction between LVF and RVF ratings and Group. We therefore examined relationships between ratings on Question 3 ("How happy did that face make you feel"?) and Question 6 ("How much did that face make you *not* want to become involved with and approach that person?") and both frontal and parietal EEG alpha laterality ratio scores. A comparison of Figures 1 and 5 reveals that self-ratings of happiness and frontal EEG asymmetry appear to parallel one another for each group. The correlation between the change in happiness rating from LVF to RVF conditions and the change in frontal asymmetry between the same conditions across groups was .74 ($df = 18$). The correlation between change in self-ratings of happiness and parietal asymmetry across the same conditions was .32.

Correlations between frontal and parietal activation asymmetry and self-ratings of not-approach were low and insignificant. The correlation between change in the frontal laterality ratio score and change in self-ratings of not-approach was .11. The correlation between change in parietal ratio score and change in self-ratings with the same conditions was .31.

Discussion

The data from this study indicate that depressed subjects show different patterns of behavioral and electrophysiological response to lateralized presentations of faces compared with non-depressed subjects. The non-depressed subjects reported slightly more happiness in response to RVF compared with LVF presentations of the identical faces, a pattern which is consistent with our previous findings (Davidson et al., 1985). Depressed subjects showed the opposite pattern with higher ratings of happiness in response to LVF compared with RVF presentations. The direction of this finding was not as predicted. We expected depressed subjects to show a pattern similar to non-depressed subjects, but more extreme with less happiness and more sadness reported in response to LVF compared with RVF presentations.

The frontal EEG data parallel the findings on self-ratings for happiness. Increased intensity of happiness was associated with greater left frontal activation. This relationship held across groups. This finding indicates that changes in frontal activation asymmetry account for a substantial amount of variance in changes in self-reports of particular affects. The magnitude of this correlation is noteworthy (.74) since it is higher than any previously reported relationship between brain activity and subjective experience known to the authors.

The fact that depressed subjects showed greater left frontal activation than the non-depressed subjects in response to LVF presentations was contrary to our initial expectation. It may be that presenting a stimulus directly to the right hemisphere (LVF) activates the right parietal region, which in depressed subjects, results in reciprocal inhibition of the ipsilateral frontal region, i.e., right frontal inhibition or relative left-sided frontal activation. In light of the fact that the increased relative left frontal activation in depressed subjects is associated with higher ratings of happiness, these data suggest that tasks which directly activate right hemisphere posterior regions (as a function of being presented directly to the right hemisphere) may at least temporarily attenuate depression or dysphoric mood by inhibiting right frontal activation. Needless to say, these suggestions require formal testing in future research.

Parietal EEG asymmetry showed little relationship with self-reports of happiness. The difference in the magnitude of correlation between frontal versus parietal asymmetry and self-report highlights the specific role of the frontal cortex in affective behavior.

Group differences were also observed on ratings of "Not Approach." Depressed subjects reported feeling more "not-approach" in response to RVF versus LVF presentations while non-depressed subjects showed no visual field difference. In addition, in response to foveal presentations, depressed subjects reported less intense feelings of "not-approach" compared with the non-depressed subjects. The fact that the correlations between EEG asymmetry and self-reports of "not-approach" were low and insignificant indicates that this scale was presumably tapping features of affective behavior which were independent of at least the measures of activation asymmetry which were included in this study. Additional research is needed to specify whether a scale of this type does indeed provide valid measures of approach and withdrawal and whether frontal or parietal asymmetry is related to this behavioral dimension.

It is of interest to note that both non-depressed and depressed subjects showed reliable differences in parietal asymmetry as a function of stimulus location. LVF presentations resulted in right-sided parietal activation, RVF presentations resulted in relative left-sided parietal activation, and foveal presentations elicited a pattern of asymmetry in between. While these findings were predicted on the basis of previous theorizing, to the best of our knowledge these data provide the first demonstration that lateralized input indeed produces reliable changes in posterior hemispheric activation.

In the non-depressed subjects, frontal and parietal asymmetries showed similar changes across visual fields with greater relative left-sided activation in both frontal and parietal regions observed in response to RVF compared with LVF presentations. In the depressed group, frontal and parietal activation asymmetries were reciprocally related with increases in one associated with decreases in the other. While the mechanism for this pattern is not currently known, it may help to explain the neuropsychological profile of the depressed subject which has been described in recent research (e.g., Flor-Henry, Fromm-Auch, & Schopflocher, 1983). These data indicate that depressed subjects show selective deficits on "right-hemisphere" cognitive tasks. The fact that depressed subjects show right frontal activation during rest (e.g., Schaffer et al., 1983) in conjunction with the current finding of reciprocal relationships between frontal and parietal asymmetries in this population argues for right hemisphere posterior inhibition in this group. Whether these resting EEG findings are predictive of subsequent task performance is an issue which remains to be explored. The current study did not contain any measure of right hemisphere cognitive performance and therefore precluded addressing this question. We are directly examining this issue in our current work.

Two additional minor observations deserve comment. No reliable differences in asymmetry were found as a function of the valence of the emotional faces. We do not regard this as disconfirmation of previous EEG findings which indicate differences in frontal asymmetry as a function of the valence of affective stimuli. This view is based upon the fact that the stimuli we utilized in the current study (i.e., still photographs of emotional and neutral faces) typically did not elicit strong affect in the viewer. Most of the studies which have reported EEG asymmetry changes as a function of affective valence have used stimuli which elicit much more intense emotion. In future research on EEG asymmetries in response to affective stimuli in depression, it might be informative to include not only happy and sad stimuli, but also stimuli which are designed to elicit anger in light of theoretical models suggesting the important role of this emotion in the etiology of depression.

The orientation of the stimuli also made little difference in either the ratings or in measures of brain asymmetry. These findings suggest that whatever subtle facial asymmetry existed in the stimuli, either the direction of the asymmetry is not consistent across stimuli or the magnitude is so slight as to make little difference in terms of brain function.

In summary, depressed and non-depressed subjects show opposite patterns of self-reported happiness in response to faces presented to the two visual fields. Consistent with previous findings, non-depressed subjects report more happiness in response to RVF versus LVF presentation of the identical faces. Depressed subjects report the opposite. Frontal EEG asymmetry is highly consistent with self-ratings of happiness in both groups and accounts for more than 50% of the variance in subjective reports of this emotion. Specifically, increased relative left frontal activation is associated with higher ratings of happiness. These findings underscore the important role of frontal asymmetry in affective experience and indicate reliable differences on this measure between groups which differ in characteristic affective style.

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