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Short communication

Comparison of two EEG asymmetry indices in depressed patients vs. normal controls

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Abstract

In 11 non-depressed, age-matched controls, and in 13 depressed patients, we compared the frontal alpha asymmetry mean for a baseline session with the percentage of the time in the session when the asymmetry score > 0. It was found that the percent index was a better discriminator of the two groups than was the asymmetry score.
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1. Introduction

It has been shown several times that depressed patients show a cortical activation asymmetry pattern which differs from that of non-depressed controls (Henriques and Davidson, 1990, 1991; Gotlib et al., 1998). In these studies, the asymmetry metric has typically been $A_1 = \log R - \log L$, where R refers to EEG alpha (8–13 Hz) power or magnitude recorded from F_4, and L refers to the EEG alpha power or magnitude from F_3 (Cz is the common reference site). Other related studies (Rosenfeld et al., 1996; Baehr and Baehr, 1997; Baehr et al., 1998) used an asymmetry ratio $= A_2 = (R - L)/(R + L)$. These two indices, (A_1 and A_2) correlate very highly ($r \geq 0.98$; Ranganath, 1996), and are both expressed in microvolts (μV) or (μV^2). The *group effect* which is typically shown is that the A-scores are greater in the normal patients than in the depressed patients, suggesting (but not proving; see Rosenfeld, 1997) that there is greater right frontal activation (= less alpha) and/or less left frontal activation (= more alpha) in depressed patients than in normals.

We have recently developed a biofeedback pro-

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tocol[1], based on the findings just reviewed, in which patients are trained to alter the A_2 score (Rosenfeld et al., 1995; Baehr and Baehr, 1997; Rosenfeld, 1997; Baehr et al., 1998). It may be useful in this and in other clinical work, as well as in research, to have available a reliable, diagnostic EEG-based metric, to compliment the questionnaire-type metrics of depression in typical current use (e.g. the Beck Depression Inventory or BDI; Beck et al., 1961). A-scores do not appear to have good diagnostic promise since, on an individual basis, they do not discriminate particularly well between depressed persons and normal controls. For example, in Henriques and Davidson (1991), of 16 depressed subjects and 12 controls, only three controls (25%) and five depressed subjects (< 33%) showed A scores for the single test session which did not overlap the distributions of respective comparison groups; 20 depressed and control subjects (71%) all had comparable A scores, which varied in the range of A_1 from approximately +1.8 to −1.8 (see Henriques and Davidson, 1991, figure 2), despite the reported significant interaction ($P < 0.02$) of group by hemisphere. This overlap in asymmetry indices based on single session, mean A-scores is not unexpected; a moment or two of extremely high (or low) A-scores can significantly influence the session mean, and increase variability.

Another single session index which one could look at is the percentage (PCT) of time during the session that either A_1 or A_2 is greater than zero (or some other threshold). Such a metric is equally influenced by large and small departures from the chosen threshold (e.g. zero), and should thus be less variable than the A-score, itself. This would suggest that PCT would be a better diagnostic tool. Indeed, our clinical impression that PCT is stabler than A_1 or A_2, as a session summary metric, prompted the present study in which we systematically compare normals and depressives in both A_2 and PCT for single baseline sessions. Thus our results not only: (1) compare PCT in depressives vs. normals; and (2) compare A_2 and PCT for the first time; we also have the opportunity to replicate the studies cited earlier which compare A_1 and A_2 between patients and depressed subjects.

2. Methods

All subjects were white, middle class persons. To be classified as depressed, two criteria were imposed: (1) A BDI score of ≥ 10 (this is the Beck et al., 1961, threshold for mild depression); and (2) A DSM-IV interview resulting in a diagnosis of depression. To be classified as a non-depressed control, subjects needed to score < 9 on the BDI. In fact, the range of BDI scores in the depressed group was 11–40, with a mean of 21.92 (see Table 1) and the range of scores in the controls was 0–7, with a mean of 3.44 (see Table 1). Statistical tests comparing groups on all variables are in Table 1. Of the 11 control subjects, five were non-depressed patients seeking outpatient psychotherapy for other reasons, three were therapist colleagues, two were the personal physician and the wife of one of the present authors, and one was the mother of a patient. Depressed subjects were persons seeking outpatient psychotherapy for depression. Of the 13 depressed persons, seven had the DSM-IV diagnosis of 300.4 (dysthymia or neurotic depression).

[1] The protocol may be obtained by contacting the second author.

Table 1

	N	Age	Years ed.	BDI	PCT	A_2
Control subjects	11	44.2 ± 13.3	16.0 ± 1.8	3.44 ± 2.9	71.46 ± 10.1	9.76 ± 7.86
Depressed subjects	13	43.5 ± 6.99	17.2 ± 2.6	21.92 ± 9.2	44.61 ± 14.3	−1.16 ± 7.82
t-test		$P < 0.8$(ns)	$P > 0.2$(ns)	$P < 0.001$	$P < 0.001$	$P < 0.004$

Note. *N* = number of subjects, Yrs. ed. means number of years of education, BDI, PCT, A_2 defined in text. Values are group means ± 1 S.D. The *t*-test is based on an independent groups test comparing the means of the two groups and shows probabilities (*P*) of the null hypothesis; ns means not significant.

Three had the diagnosis of 296.2 (major depression, mild). Two cases had the diagnosis of 293.83 (mood disorder secondary to chronic illness), and one had the diagnosis of 291.8 (substance-induced mood disorder). The age range of depressives was 33–61, and for controls, 25–62 (means and statistical tests in Table 1 and Results). The range of years of education was 12–20 in both depressed and control groups (see Table 1).

All subjects were seated in a comfortable lounge chair for the application of electrodes and running. After some time adapting to the environment, the subjects were run for a 5-min baseline EEG collection with eyes closed. Both Davidson's group and ourselves have consistently found no difference in A_1 or A_2 means during eyes closed vs. eyes open conditions.

The EEG was recorded from F_3 and F_4 referenced to Cz (so as to be consistent with previous studies) with the earlobe grounded, utilizing a commercial EEG analysis system (Lexicor Neurosearch Model 2A). The EEG was sampled at 256 Hz, after amplification at 32000. Signals between 2 and 32 Hz were passed; alpha band was defined as 8–13 Hz. The system performs Fast Fourier Transforms on artifact-free 1-s epochs, overlapping by 50%, utilizing Blackman–Harris windows (Harris, 1978). The output is an alpha asymmetry score $A_2 = (R - L)/(R + L)$, where R and L are right- and left-alpha magnitude (square root of power), respectively. Artifacts included both EEG range errors (> 90 μV) and EOG excursions > 50 μV recorded from electrodes above and below the right eye.

3. Results

Table 1 shows single session summary statistics for age, years of education, BDI-score, PCT, and A_2 score for depressed patients vs. controls. It is evident that the controls and depressed subjects differ in BDI ($t_{22} = 6.36$, $P < 0.001$); PCT ($t_{22} = 5.25$, $P < 0.001$), and A_2 ($t_{22} = 3.4$, $P < 0.004$), but not in age ($t_{22} = 0.15$, $P > 0.8$) or years of education ($t_{22} = 1.25$, $P > 0.2$). It is noted that the direction of difference between groups is consistent with previous reports showing larger A-scores in normals than in depressed subjects. The *t*-values and associated probabilities suggest (but do not robustly show) a better differentiation for PCT than for A_2 between patients and controls. Likewise, the overlap in control vs. patient distributions of A_2 scores (using means and S.D.s in Table 1) appears greater than for the comparable PCT distributions, but this too is only suggestive.

To acquire analytic support for the notion that the PCT scores better discriminate the control and patient groups than do the A_2 scores, it was first necessary to transform these scores into comparable units of measurement. We did this by conversion of A_2 and PCT scores into standard scores, using the control subjects' means and standard deviations as the conversion metrics for all subjects. Plotting these data (standardized PCT and A_2 as a function of group) would show a steeper slope for the PCT scores than for the A_2 scores. Both mean indices superimpose at zero for the contol group, but are -1.4 (A_2) and -2.77 (PCT) for the depressed group. This suggests a larger difference (better discrimination) between depressed and control subjects for PCT than for A_2. To confirm this impression, we performed a 2×2 ANOVA (2 groups, 2 standardized dependent variables), and computed a significant interaction term of $F_{1,22} = 9.73$, $P < 0.006$.

In terms of individual scores, we note that the range of A-scores in depressives was -22–8.35; in controls, the range was 1.8–27.5. Five depressives and six controls were in the overlapping range of 1.8–8.35; (46% of the sample). In contrast, the range of PCT scores in depressives was 12–59, vs. 58–94 in controls. Two depressives and two controls (17% of sample) were in the narrower overlapping PCT range of 58–59.

4. Conclusions

The major new finding here is that the percentage of the recording session (PCT) in which the A_2 asymmetry score is greater than zero, better discriminates depressed vs. control subjects (the former from outpatient clinical practices) than the A_2 score, itself, the latter being the only metric previously correlated with affective performance in earlier studies. In the introduction, we discussed why this result was expected in that the

PCT session summary is less affected by extreme phasic changes in A_2 than is the session mean A_2. PCT is thus likely to be less variable than mean A_2, and therefore, a better discriminator. This conclusion is important for obvious diagnostic reasons, but also, because a metric, such as PCT is more familiar and thus explainable to patients in asymmetry biofeedback paradigms (Rosenfeld et al., 1995; Baehr and Baehr, 1997; Baehr et al., 1998) than is A_2. Moreover it is also likely that the less variable PCT will show smoother changes with training than will A_2. We refer here only to charting and discussing a patient's progress with the patient; obviously, for moment-to-moment evaluation of asymmetry for purposes of reinforcement, the A_1 or A_2 scores must be used. It is also possible that a PCT-type metric could be developed for other biofeedback situations, e.g. the Attention Deficit Disorders (Lubar, 1991), and there may be advantages for its use in these cases also.

We also note that we here provide further confirmation of earlier reports (Henriques and Davidson, 1991; Gotlib et al., 1998) of a robust *group* effect, using asymmetry scores, in the discrimination of depressed and normal groups, with normals showing A_2 and PCT scores greater than those of depressed persons. Moreover, we obtained this group effect with shorter sampling periods (5 min) than those reported previously (8 min).

On the basis of these very preliminary results in only 24 subjects, it may be suggested that PCT < 55 suggests the presence of some depression; a score > 60 suggests no depression (see last paragraph of results). However, such a guideline would be specific to the parameters (epochs, etc.) used here, and it is probable that a longer baseline observation period would yield a different and stabler set of guidelines. This further research should be done, and on a much larger sample, before the guidelines can become less tentative and qualified.

Note

Of the 13 depressed patients, two males and two females were medicated with Prozack ($n = 2$) and Zoloft ($n = 2$) when the data reported here were collected. The data on these cases were not outlying in any way. The main point regarding the two compared asymmetry indices would not have been affected in any case, however comparisons with earlier studies might have been.

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