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EEG Coherence During Hemispheric Activation in Schizophrenics

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Summary. We studied the change of EEG alpha-band coherence between resting and motor performance ("reactivity of EEG coherence") in 18 chronic schizophrenics and 30 normal controls, examining differences between left and right hemisphere tasks. Three coherences were examined for each hemisphere. The central-parietal coherence in normals increased on the left for left hemisphere tasks, and decreased on the right for right hemisphere tasks, whereas the patients showed a decrease of both measures, more on the left side. Thus, the interhemispheric difference of central-parietal coherence reactivity was reversed for the schizophrenics ($P < 0.06$) and suggested a left-sided deviation. The lateral-precentral and precentral-central coherences showed no left-right deviations of reactivity in the patients. Since coherence increase is considered to be a sign of the coupled function between the studied regions, our findings suggest a defective coordination of left central-parietal regions during a task in schizophrenics.

Key words: EEG coherence – EEG reactivity – Schizophrenia – Hemisphericity

Introduction

Recent advances in solid-state electronics and in the capacity of small computers offer the possibility of building dedicated systems to analyse EEG signals with different methods relatively easily (Dumermuth and Molinari 1987; Fisch and Pedley 1985; John 1989; Nuwer 1988a, b). This makes possible the sophisticated analysis of large amounts of EEG data that can be obtained non-invasively.

In psychiatry, extensive literature has dealt with EEG examinations of schizophrenic patients, documenting abnormal findings of power and centroid frequency (Fisch and Pedley 1989; Furst 1976; Gevins et al. 1980; John 1989; Koukkou and Manske 1986; Maurer and Dierks 1987). These neurophysiological findings very often relate to hemispheric specialisation, and many studies reported deviant findings concerning the left hemisphere in schizophrenic conditions (Flor-Henry et al. 1984; Flor-Henry 1988; Gruzelier 1983; Guenter et al. 1986; Kemali et al. 1988; Morstyn et al. 1983).

It has been reported that performance-related changes of the EEG parameters, the so-called EEG reactivity (Autret et al. 1985; De Toffol et al. 1990; Koukkou 1982, 1983; Koukkou et al. 1983; Koukkou and Manske 1986), are particularly sensitive indicators of aberrant EEG activity in schizophrenics. In particular, the EEG reactivity measured as power or centroid frequency in the EEG alpha frequency band has been shown to be significantly reduced in schizophrenics (Koukkou and Manske 1986), a finding that substantiated earlier observations of "hyperstability of alpha waves" in schizophrenics.

Numerical estimation of the EEG coherence between recording positions has been reported to reflect finely function-related changes of cortical activation, with increased coherence associated with performance-related activation (Dumermuth and Molinari 1987; Gasser et al. 1987; Gevins et al. 1979; Shagass et al. 1982; Thatcher et al. 1986; Tucker et al. 1986), but it has not yet been much used in schizophrenia research.

In the present study we combined the above-mentioned approaches; namely we combined the "reactivity" measure with the coherence measure to gauge the degree of local cortical cooperation. Because of the reported decrease of alpha-band power reactivity in schizophrenia, we restricted the analysis to the alpha band. We formulated the specific hypothesis of left-sided deterioration of coherency reactivity in schizophrenia. We designed the study to measure EEG alpha-band coherence within the hemispheres of schizophrenic patients and normal controls during the execution of unilateral motor tasks. We tested the hypothesis that the hemispheric lateralisation of the task-induced reactivity of EEG coherence differs in schizophrenics from that in normals, showing deficits in the left hemisphere.

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Subjects and Methods

Subjects

Data from 18 chronic schizophrenics (12 men, 6 women; mean age 34.5 years, range 26–42 years, SD = 4.3) are reported in this study. Originally, recordings from 28 suitable patients had been collected, but because of incomplete recordings, patient non-compliance, and excessive artefacts, 10 subjects had to be excluded from further analysis. The patients belong to a group of chronic in-patients in a rehabilitation programme where an effort is made to maintain the same type and dosage of medication as much as possible. They were mainly under haloperidol as basic treatment, combined with chlorpromazine and/or amitriptyline in certain cases. This group was homogeneous in the sense of consisting of chronic, institutionalised schizophrenics for a mean time of 9.2 years (SD = 5.0) since the last admission and 18.2 years (SD = 12.0) since the first admission. The diagnosis was made clinically and we included only patients whose diagnosis was confirmed using the Present State Examination (Wing et al. 1974) and the CATEGO programme is a computer programme used to classify patients into basic psychiatric diagnostic categories based or data obtained from the Present State Examination (Wing et al. 1974). The inter-rater reliability of the diagnosis was better than 0.90. The severity of psychopathology was also estimated as the sum of the Syndrome Check List scores (see Wing et al. 1976); their mean value was 16.9 (SD = 7.8).

The control group consisted of 20 normal students (13 men and 7 women, mean age 20.9 years, range 18–24, SD = 1.6) and 10 older healthy volunteers (6 men and 4 women, mean age 45.5 years, range 39–56 years, SD = 5.2). The mean age of the 30 controls was 29 years (SD = 12).

Methods

The EEG electrodes were placed according to the 10/20 system, and referred to connected (A1 + A2) earlobe electrodes. The patient or subject was instructed about the sequnce of the data collection.

All EEGs were recorded on paper for monitoring, and simultaneously fed into an analogue FM tape recorder (MEDILOG B.V., Nieuwkoop, The Netherlands). The time constant was 0.3, high frequency filter 70 Hz. The light and noise in the examination room were at low levels.

First, the data from the right hemisphere were recorded. The first recording was a resting condition with closed eyes for about 2 min. During the second recording, the subject had to perform certain iterative finger movements with the fingers of the left hand (with eyes closed) following instructions that were given verbally in irregular sequence by the experimenter (e.g. "make finger movements like a piano player", "move your thumb", etc.). The subject had been given instructions and some training for these finger movements before the actual recording session started. The performance condition continued for about 2 min.

The resting and performance conditions were then recorded with left hemisphere EEG leads and with finger movements of the right hand. Thus, there were four recording conditions for each subject. The EEG data were fed off-line from the analogue tape into a dedicated computer system for digitising and spectral analysis. This system included anti-aliasing analogue low-pass filters (45 Hz/3dB), an analogue-to-digital converter and a DEC-PDP 11/23 computer. The digitisation was performed with a sampling rate of 102.4 Hz/channcel (Dumermuth and Molinari 1987). Before analysis, epochs containing visible artefacts were omitted. In 18 of the original 28 patients, a total of three sections, each lasting 20 consecutive seconds, of artefact-free EEG data was available for all four recording conditions in four recording channels (F7, F3, C3, C4, and F8, F4, C4, P4). Because of artefacts, insufficient data were available in the originally recorded channels (Fp1/2 and T3/4, so that they had to be excluded from the analyses.

Fourier transformation (epochs of 2.5 s giving a spectral resolution of 0.4 Hz) was performed by FFT. After hanning of the Fourier coefficients, the raw autospectra were calculated and averaged over 8 successive epochs giving sections of 20 s. The coherence spectra were calculated between the recordings from the electrode positions F7 vs F3 ("lateral coherence"), F3 vs C3 ("precentral coherence"), and C3 vs P3 ("postcentral coherence") over the left hemisphere, and from the corresponding positions over the right hemisphere (F8 vs F4, F4 vs C4 and C4 vs P4); all referred to linked earlobes. The coherence spectra of three 20-s data sections were averaged. For each averaged coherence spectrum, the value of maximal coherence in the alpha frequency band (i.e. for the frequency band between 8.0 and 11.6 Hz) was extracted for further analysis.

t-Test statistic was used for the testing of the formulated hypothesis that the right-left difference in coherence reactivity is larger in normals, being based on left hemisphere values; the difference (between patients and normals) of the right-left difference of the coherence reactivity (three comparisons: for the lateral, precentral, and postcentral coherences).

Results

Table 1 presents the mean results over patients and normals for the six coherences in the four recording conditions, and the mean values (and SE) of the six coherence reactivities for patients and normals. The mean (and SE)

Table 1. Mean coherences ($\bar{X}$) over subjects during resting and performance in the six electrode combinations, and their difference (coherence reactivity) and SE of this difference, over subjects

	Normals		Patients		
	Left	Right	Left	Right	
Resting					
$\bar{X}$	0.701	0.708	0.680	0.650	Lateral
$\bar{X}$	0.533	0.493	0.626	0.580	Precentral
$\bar{X}$	0.501	0.561	0.522	0.546	Postcentral
Performance					
$\bar{X}$	0.681	0.691	0.632	0.606	Lateral
$\bar{X}$	0.615	0.595	0.710	0.643	Precentral
$\bar{X}$	0.529	0.535	0.500	0.538	Postcentral
Coherence reactivity (difference performance minus resting)					
$\bar{X}$ (SE)	−0.020 (0.021)	−0.017 (0.021)	−0.048 (0.032)	−0.044 (0.022)	Lateral
$\bar{X}$ (SE)	0.083 (0.023)	0.102 (0.025)	0.084 (0.026)	0.063 (0.028)	Precentral
$\bar{X}$ (SE)	0.029 (0.024)	−0.026 (0.019)	−0.022 (0.027)	−0.008 (0.024)	Postcentral

Table 2. Right-left mean differences $(\bar{X})$ of coherence reactivity (see Table 1), their SE over subjects, and t-test P for the hypothesis of smaller values in patients

	Normals	Patients	P	
$\bar{X}$ (SE)	0.0027 (0.029)	0.0033 (0.037)	NS[a]	Lateral
$\bar{X}$ (SE)	0.0193 (0.027)	−0.0217 (0.038)	NS[a]	Precentral
$\bar{X}$ (SE)	−0.0547 (0.028)	0.0144 (0.031)	0.06	Postcentral

[a] Not significant

of left-right differences of coherence reactivity for patients and for normals are shown in Table 2. Normals and patients showed reversed reactivities in the postcentral coherence measure, the normals having an increase over the left side and a decrease over the right side, whereas the patients showed a decrease over both sides, more on the left than on the right. This difference in lateralisation was in the predicted direction, and as such was associated with a chance probability at the 6% level (one-sided t-test). The two other left-right relations of coherence reactivity, the precentral and lateral values, showed no significant differences between patients and normals.

Separate examination of the postcentral left-right differences of reactivity for normals and patients (Table 1) showed a significant difference for normals at the 5% level (no significance in patients). Similarly, there was a trend (9% chance level) for a difference of the left postcentral mean value to be greater in normals than in patients (Table 1), supporting the trend of deviant values of the left postcentral coherence reactivity in the patients.

Discussion

Our results showed a strong statistical trend supporting the hypothesis that performance-induced reactivity of EEG coherence is smaller over the left than the right hemispheric EEG leads in chronic schizophrenics when compared with normal subjects. This is in agreement with many reports that implicated left hemispheric malfunctioning in schizophrenia (see Flor-Henry et al. 1984; Nasrallach 1986).

Our findings also indicate that it is the postcentral areas that show a stronger deviation in this regard. This contrasts with previous descriptions, according to which frontal and temporal regions show deviant activity in schizophrenics (e.g. Kemali et al. 1988; Morihisa and McAnulty 1985; Morstyn et al. 1983; Nasrallach 1986). Nevertheless, our findings are supported by at least three previous reports: (a) an increase of beta spectral energy in recordings obtained from postcentral areas of schizophrenics (Morstyn et al. 1983); (b) a significant reduction of alpha variability from the left centroparietal areas in schizophrenics compared with healthy controls (Etevenon et al. 1983); (c) "a striking increase in left centroparietal slow activity" during hallucinatory states (Stevens and Livermore 1982).

We emphasise that, although there was no difference between the left and right hemispheres of resting schizophrenics, such differences became obvious during performance of the motor task. This result demonstrates the sensitivity of EEG reactivity measurements, in particular those employing coherence estimates, when attempting a comparison between a condition of functional loading and a resting condition.

Our findings are potentially compromised by the fact that some of the subjects we studied were psychiatric patients treated with major neuroleptics. This is a serious problem for almost every neurophysiological study on schizophrenics. We doubt, however, that this can account for a major portion of our findings, since the effect of such medication is negligible a few weeks after the start of the treatment (Koukkou and Manske 1986; Saletu et al. 1986).

A second potential problem in the present study concerns the sequence of hemispheric activation, which was fixed. Accordingly, a sequence effect cannot be excluded. Here again, we doubt that this affects our conclusions, since the sequence was identical in both normal and schizophrenic subjects.

Overall, our findings contribute to the effort to define biological markers of schizophrenia. They implicate a decreased synchronisation of the left parietal lobe in the pathophysiology of schizophrenia, a hypothesis that deserves further testing. Furthermore, they suggest that EEG coherence reactivity could prove a useful measure of brain malfunction in other patient groups, besides schizophrenics.

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