Interaction of delta, theta and alpha activity in schizophrenics, depressives and alcoholics

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1 Introduction

Differences between EEG/MEG power spectra in different psychiatric disorders and controls have often been reported (overview Winterer and Herrmann, 1995; Tauscher, 1995). The present study examined the distribution of magnetic source activity in different frequency bands in schizophrenics, depressives, alcoholics and controls. In addition, for controls and schizophrenics correlations between minimum-norm-values over different regions and frequency bands were calculated.

2 Methods

Whole-head (148 channels) magnetoence-phalographic recordings (MAGNES® WH 2.50, 4D Neuroimaging, San Diego, USA) were obtained from 34 schizophrenics (predominantly paranoid or disorganized schizophrenia, 14 female, mean age 31.5±9.2 years, 29 right-handed, 5 left-handed, 25 medicated, 9 unmedicated), 10 depressive (7 female, mean age 47.5±7.6 years, 9 right-handed, 1 left-handed, 8 medicated, 2 unmedicated) and 12 alcoholic patients (1 female, mean age 39.7±10.9 years, 11 right-handed, 1 left-handed) and 18 healthy controls (2 female, mean age 31.7±12.4 years, all right-handed) during a resting, a mental calculation and a mental imagination condition. Subjects were asked to fixate a colored mark on the ceiling of the chamber in order to avoid eye- and head-movement. The MEG was recorded with a 678.17 Hz sampling rate, using a band-pass filter of 0.1-200 Hz. For artifact control, eye movements (EOG) were recorded from four electrodes attached to the left and right outer canthus and above and below the right eye. The electrocardiogram (ECG) was monitored via electrodes attached to the right collarbone and the lowest left rib. The generators of the magnetic slow waves were located employing multiple delta [1.5-4.0 Hz], theta [4.0-8.0 Hz] and alpha [low: 8.0-10.5 Hz; high: 10.5-13.0 Hz] sources by means of the minimum norm (MMN) estimate (L2-norm). Minimum-norm values were calculated only over prominent magnetic field patterns of a thirty second data epoch (for each subject and condition) that was low on artifacts. No patterns that correlate with a typical eye-blink pattern were included in the analysis. In addition magnetic fields with a global field power over 18000 [ft2] (artifacts) and under 3000 [ft2] (noise) were excluded.

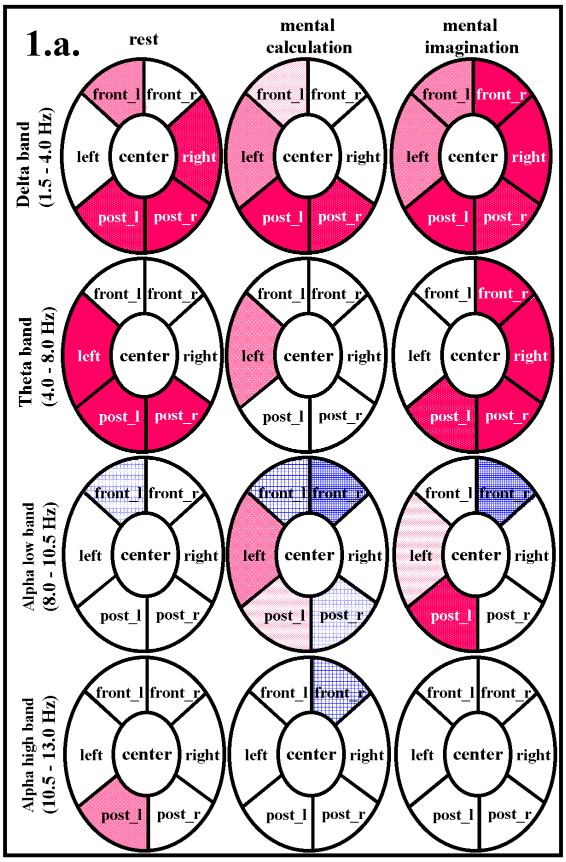
ANOVAs over the four different groups, seven regions (see fig.1 for schematic overview and results) and the three conditions were calculated for each of the four band-pass filtered frequency bands. In addition an exploratory approach was performed by correlating the minimum-norm values of the seven regions and the four frequency bands within the schizophrenic and the control group. The results of these correlations should be interpreted carefully in two respects: (1) The analysed minimum-norm values should be representative for the main activity in the examined epochs (evaluated by a separate correlational analysis, see Fehr et al., submitted manuscript) but there is no evidence for any direct phase relation between the frequency bands except for some examples (example, see fig. 2), (2) The correlation z-test values are not statistically corrected and the results should therefore be interpreted as explorative.

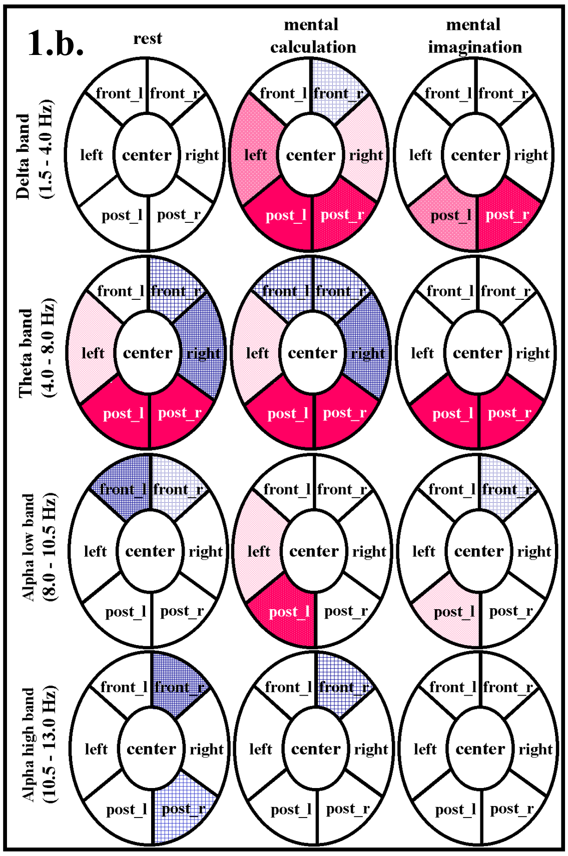
3 Results

ANOVAs showed significant GROUP x REGION interactions in all analysed frequency bands (GROUP x REGION: delta $F(18,1260)=72.69$, $p<.001$; theta $F(18,1260)=12.38$, $p<.001$, alpha low $F(18,1260)=74.83$, $p<.001$, alpha high $F(18,1620)=1.81$, $p<.05$).

Schizophrenics exhibited more delta and theta activity than controls in almost all regions but less alpha activity in frontal regions. In left and left posterior regions schizophrenics showed more alpha than controls. Depressives exhibited enhanced delta and theta in posterior but less activation in frontal regions in all analysed bands.

Alcoholic patients showed more posterior delta, less right-temporal and right-frontal theta and more central, left-temporal and left posterior alpha low. Group differences are not identical for all conditions (see fig. 1a,b,c for more details).





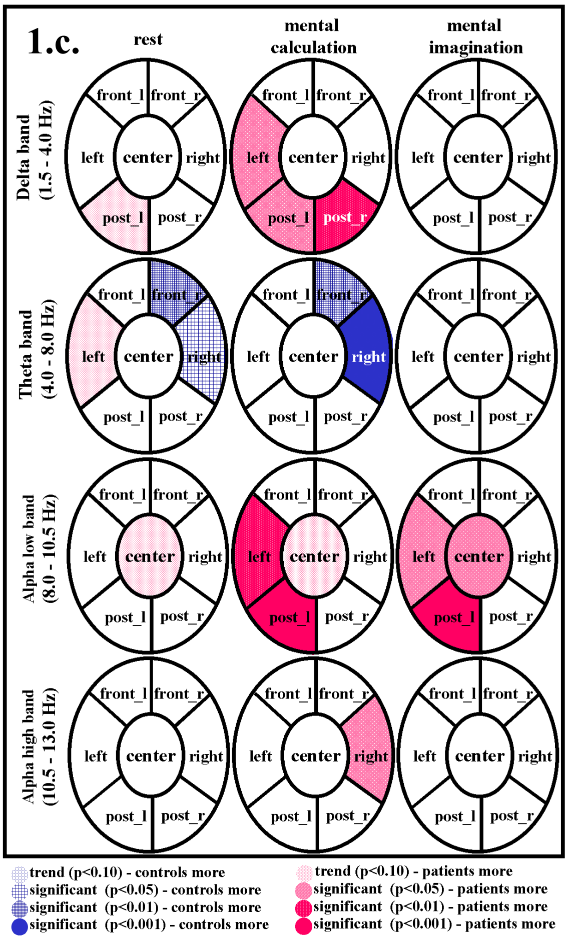


Figure 1: *Schematic illustration of the statistical differences between groups in the MMN estimate for schizophrenics vs controls (**1.a.**), depressive patients vs controls (**1.b.**) and alcohol patients vs controls (**1.c.**). Conditions are arranged in columns (rest, mental calculation and mental imagination), frequency bands in rows: delta (first row), theta (second row), alpha low (third row) and alpha high (4th row). Darker shadings indicate higher levels of significance (red indicates higher values in patients, blue indicates higher values in controls).*

Interactions (correlations and PCA) between different regions and frequency band related activities were group specific. Several differences between the correlation maps of schizophrenics and the controls are described as follows:

Rest condition: In controls most correlations were seen in right posterior, posterior and left frontal regions. In contrast to schizophrenics controls showed more correlations between central and right temporal regions whereas schizophrenics exhibited correlations between central and left temporal activity. Schizophrenics showed strong relationships within the left hemisphere and among left hemispheric and frontal regions. Left posterior and left temporal alpha correlated with frontal delta.

Mental calculation: Controls exhibited correlations between left posterior, central and left frontal delta-, theta- and low alpha activity. In addition controls showed negative relationships between corresponding left and right temporal MMN-values. Patients showed frontal and posterior interhemispheric correlations. Delta and theta activity correlates between posterior and left temporal and frontal regions. Under mental calculation the schizophrenics and controls seem to be more similar than under resting or mental imagination.

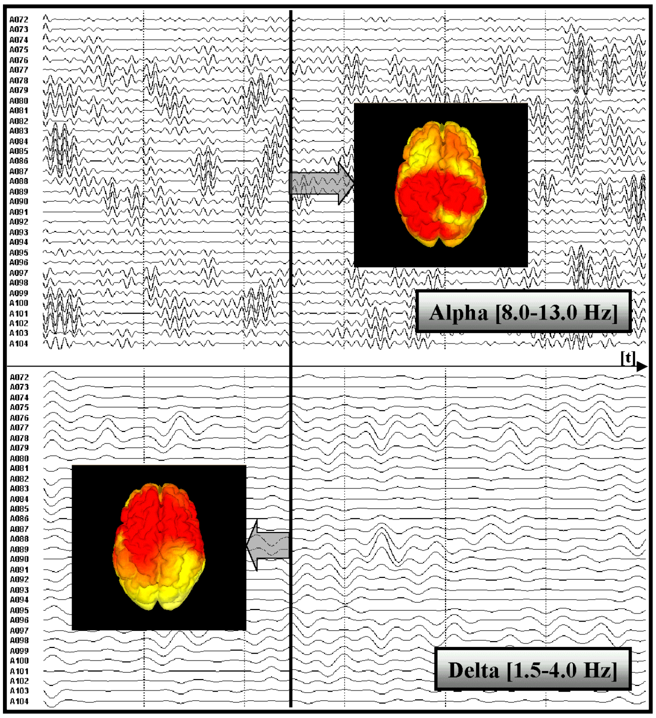


Figure 2: *Minimum-norm solution for simultanous delta [1.5-4.0 Hz, lower part] and alpha [8.0-13.0 Hz, upper part] band pass filtered magnetic activity at the same time point in the resting condition of an unmedicated schizoprenic patient.*

Mental imagination: Strong frontal and temporal interhemispheric correlations are shown by the controls. Additionally, controls exhibited relationships between right temporal delta activity and central and posterior regions. Schizophrenics showed a diffuse network of correlations. Interhemispheric correlations are prominent over frontal, temporal and posterior regions. Delta and theta activity correlate intra- and interhemispherically over the whole scalp. Right posterior alpha strongly correlates with right frontal alpha.

For all conditions controls showed more negative correlations than patients. The results for the correlational analysis were largely confirmed by principle component analysis (in detail reported elsewhere).

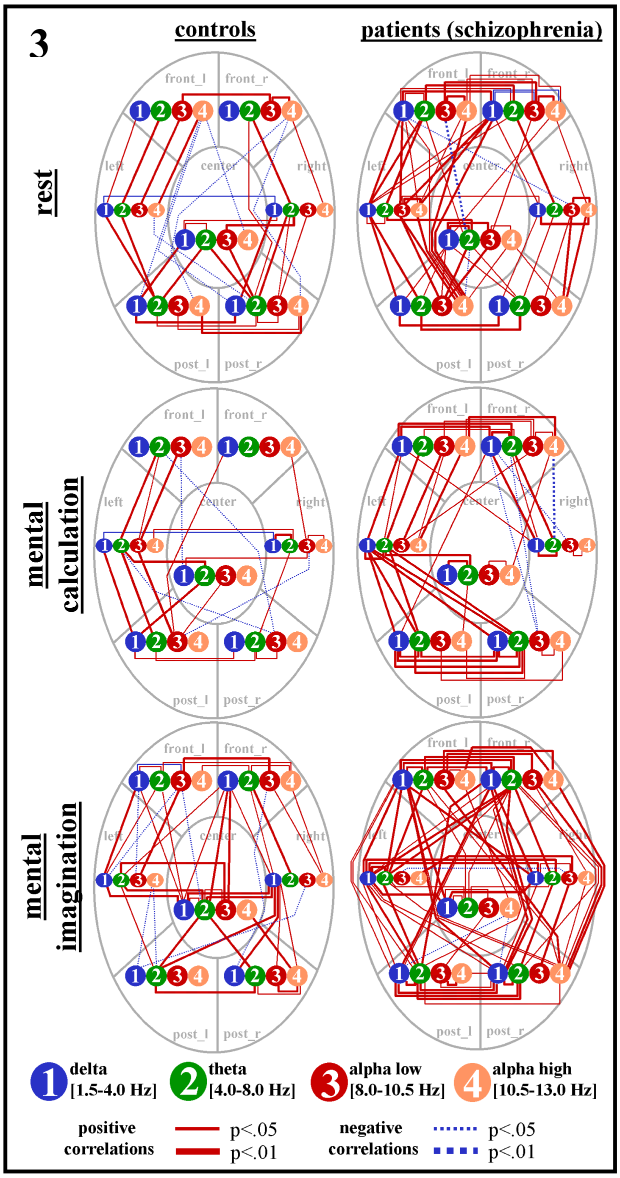


Figure 3: *Schematic illustration for the significant correlations between the minimum-norm values of seven regions and four frequency bands (see legend) within the schizophrenic and the control group (columns) seperately for three conditions (rows).*

4 Discussion

Group differences between delta, theta and alpha minimum-norm values are very strong. These differences could largely be confirmed by the dipole density method (reported elsewhere) and supported by power spectra analysis (reported elsewhere). As expected schizophrenics showed more slow wave activity in the delta and theta range and less activity in frontal alpha but more alpha in left posterior regions.

Depressive patients exhibited less slow wave activity in frontal and right temporal regions but more in posterior regions. In the alpha range they also showed reduced frontal and right posterior activity. This leads us to the conclusion that depressives possibly have a generally reduced activity in frontal brain regions. Alcoholics showed a similar pattern to depressives particularly under mental calculation that could possibly be explained by the comorbid occurrence of depressive symptoms in almost all examined alcoholics.

Correlations between minimum-norm values of different regions and frequency bands showed group and condition specific patterns. Independent of the conditions schizophrenics showed strong correlations in the left hemisphere that could possibly suggest some kind of permanent over-activation of the left hemisphere. Controls showed such left posterior correlations only under mental calculation combined with negative relationships to the right hemisphere. Harmony (1999) found a left parietal enhancement of slow wave source activity under mental arithmetic in comparison to a rest condition and a reduction of higher alpha activity. Schizophrenics exhibited an inter- and intra-hemispherical excess of correlations in the mental imagination condition. Controls also showed more interhemispheric relationships but none of the posterior-frontal correlations found in schizophrenics. In general schizophrenic patients showed different patterns of correlations under all conditions. In sum they exhibited more relationships but remarkably less negative correlations between different regions, which might be interpreted as a possible lack of regulation of different brain functions. Coherency analysis will have to show what the phase-related relationships between the activities in different frequency bands are, and how they could explain the group specific interplay of different frequency generators in detail.

References

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