Theta-power Differences in Patients with Mild Cognitive Impairment Under Rest Condition and During Haptic Tasks

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Summary: The aim of this study was to investigate spectral EEG theta-power during perceptive-cognitive demands in age-homogenous groups of subjects with mild cognitive impairment (MCI), mild dementia (MDE), and a healthy control (CO) group. The present study includes 51 subjects (23 males, 28 females). We used the scales of the CDR (clinical dementia rating) to assign the subjects to the different groups. EEG data were collected during 10 minutes rest condition with eyes closed and during haptic perception test.

The quality of the haptic reproductions differed significantly between CO and MCI, as well as between CO and MDE. The statistical comparison between EEG theta-power under rest condition and theta-power during haptic tasks revealed a significant decrease in theta-power during haptic tasks in all three groups over parieto-occipital regions. During haptic tasks, the theta-power was significantly different between CO and MDE over occipital regions and over parieto-temporal regions. A significant difference between CO and MCI was only revealed over right occipital regions (O2). Spectral theta-power during haptic tasks is a suitable measure to distinguish healthy subjects (CO) from patients with MCI respectively MDE. The results show that haptic tasks are sensitive to early perceptive-cognitive and functional deficits in patients with MCI.

Due to the high practicability of quantitative EEG data and the positive differential EEG findings concerning the theta-band in Alzheimer disease (AD) (Brenner et al. 1988; Briel et al. 1999; Jelic et al 1998; Förstl et al. 1996; Signorino et al. 1995; Soinnen et al. 1991; Schreiter-Gasser et al. 1993), differential EEG parameters were also investigated regarding its meaning for prognosis and diagnosis of mild cognitive impairment (MCI).

The differences in brain electrical activity between AD and MCI during rest condition (eyes closed) were analyzed in two studies (Jelic et al. 1996, Zappoli et al. 1995). They showed that there are clear differences in spectral power (relative power) of the theta-band (4-8 Hz) between AD patients and subjects with MCI as well as between AD patients and healthy subjects (Jelic et al. 1996). Differences between subjects with MCI and healthy controls could not be observed in this study. However, Zappoli et al. (1995) found no significant differences in theta power (4–7.5 Hz) between AD patients and patients with MCI.

Different causes could be responsible for the heterogeneity of these results. The findings of Günther et al. (1993) support the assumption that EEG measurement during an unspecific rest situation without perceptive-

cognitive demand is not sensitive enough to produce significant group differences in spectral EEG parameters. Therefore, the quantitative EEG should be obtained during perceptive-cognitive demands to measure the smallest changes in brain electric activity.

On the grounds of these findings, the aim of this study was to investigate the spectral theta-power during perceptive-cognitive demands in age-homogenous groups of subjects with MCI, mild dementia (MDE), and healthy control persons. As demands we chose haptic tasks with regard to the study of Freedmann & Oscar-Bermann (1987). The design used in this study was already introduced by ourselves in other clinical and psychophysiological studies (Grunwald et al. 1998; Grunwald et al. 1999; Grunwald et al. 2001 a,b).

As MCI and MDE are accompanied with a functional disturbance of parieto-occipital areas of the cortex (Friedland et al. 1985; Heiss et al. 1990; Huang et al. 2000; Jelic et al. 2000; Kessler et al. 1991; Small et al. 1989) we assumed, on one hand, that significant differences regarding the theta-power during haptic tasks over parieto-occipital regions (O1, O2, P3, P4) were only present between controls and patients with MCI and between controls and MDE patients. Differences between MCI patients and MDE patients are not expected due to similar functional disturbances of parieto-occipital cortical regions in these patients. On the other hand, we expected significant differences in theta-power under rest conditions only between healthy subjects and MDE patients over frontal regions (Fp1, Fp2, F7, F8).

MATERIALS AND METHODS

Our sample was drawn from the *Leipzig Longitudinal Study of the Aged, LEILA 75+* (Riedel-Heller et al. 1999 a,b), a community-based study of 1,692 randomly selected individuals aged 75 and older.

As part of LEILA 75+ a fully structured interview was administered at a home visit during the time period from January 1997 to June 1998. The core component of the interview was the SIDAM (Structured Interview for the Diagnosis of Dementia of Alzheimer type, Multi-infarct dementia and dementias of other etiology according to ICD-10 and DSM-III-R) (Zaudig et al. 1991). One part of this interview is a cognitive test battery that contains all items of the Mini-Mental-State-Examination (SIDAM-MMSE) and a number of additional items.

Subjects

A subsample of the LEILA population was subsequently invited for further clinical and paraclinical examinations which took place in the Memory Clinic of the University at the Department of Psychiatry. Inclusion criteria were: age 75 to 85, right-handedness, and a SIDAM-MMSE score above 18. Exclusion criteria were: physical and/or neurological disabilities (such as blindness, deafness, severe movement disorders, or paralysis), which would have interfered with the ability of the subject to complete neuropsychological tests or paraclinical examinations (such as computed tomography, electroencephalography or magnetic resonance imaging). Subjects were randomly selected for either CT or MR imaging with the exception of cases in which contraindications for MRI were present. To facilitate an adequate distribution along a presumed cognitive continuum, subjects were sampled in equal proportions according to their MMSE scores (group 1: MMSE 19-21, group 2: MMSE 22-27, group 3: MMSE 28-30). The present study includes 51 subjects (23 males, 28 females) who fulfilled the previously described inclusion and exclusion criteria and were assessed until June 1999. All subjects were clinically examined. Paraclinical tests included blood sampling and ambulatory blood pressure monitoring.

Methods

Clinical Assessment

All subjects were medically and neurologically examined by a trained physician and/or neurologist/psychiatrist (HW, HJG). In a neurological examination, focal neurological signs and symptoms, gait, balance, primitive reflexes and extrapyramidal signs (according to a subset of items of the Unified Parkinson's Disease Rating Scale, UPDRS) were assessed. Psychiatric assessment included the completion of the Montgomery-Asberg-Depression-Scale (MADR) (Montgomery et al. 1979) and a semistructured interview to assess cognitive and functional abilities of the subject as well as psychopathological features such as delusions and hallucinations. Scales of the CDR [Clinical Dementia Rating] (Berg 1984; Devanand et al. 1997; Frisoni et al. 1999; Jack et al. 1997; Petersen et al. 1995) were used for the assignment of the subjects to the different groups.

In cases with questionable or significant cognitive deficits, a collateral source was also interviewed. According to the available information, the cognitive state was determined using Clinical Dementia Rating (Berg 1984) in a case conference (consensus rating of three clinicians). 20 of the 51 subjects had a CDR of 0 ("normal cognition") [CO (MMSE: 28–30)], 16 had a CDR of 0.5 (questionable dementia = "mild cognitive impairment") [MCI (MMSE: 22–27)] and 15 a CDR of 1 ("mild dementia") [MDE (MMSE: 19–21)].

The clinical diagnosis is based on NINCDS-ADRDA (McKhann et al. 1984) criteria. None of the healthy sub-

jects fulfilled any criteria for dementia. Regarding the subjects with a CDR score of 0.5, thirteen subjects did not meet any dementia criteria, whereas two (one woman, one man) met dementia criteria. These two subjects fulfilled criteria of possible AD. Four of 15 subjects with a CDR score of 1 met criteria of possible AD, the remaining 11 fulfilled criteria for probable AD. We included only subjects with a late onset of the disease.

All subjects were free of neuroleptic and antidepressive drugs at least 6 weeks before the examination and during the examination itself. Demographic and neuropsychiatric characteristics of the groups are shown in Table 1. The study was approved by the local ethics committee.

EEG Recording and Parameters

EEG data were collected in a dimly lit, temperature controlled, electrically shielded room on a 19-channel EEG polygraph (Walter Graphtek, Germany) with the subject in a supine position during 10 minutes rest condition with eyes closed and during haptic perception test. All EEGs were obtained between 9 am and 12 am. Data were recorded from 19 Ag/AgCl saucer type electrodes placed according to the international 10–20 system (Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, T6, P3, Pz, P4, O1, O2; reference: linked earlobes, sampling rate: 166.6 Hz, time constant: 0.3 s, low pass filter: 70 Hz). Electrical impedance was measured manually and was kept below 5 kOhm. Horizontal and vertical eye movements were recorded from bipolar montages with the same sampling parameters. The segmentation of EEG data and subsequent calculations of the mean spectral power density were performed with an EEG analytical software package BRAIN VISION (Germany). Artifact-free segments of 1.53 seconds (256 samples/channel) of the rest period and of the haptic-task-periods were chosen by automatic artifact rejection. For the artifact rejection, an amplitude-criteria of $\pm$ 70 μV was chosen.

One hundred and fifty to 250 artifact-free EEG-segments per subject—for rest condition—and 100 to 150 artifact-free EEG-segments per subject—for haptic tasks—were used for spectral analysis. The remaining segments were submitted to a Fast Fourier Transform (FFT) analysis. The mean spectral absolute power (μV^2) was calculated as the mean amplitude of the spectral lines of the theta EEG band (theta: 3.5–7.5 Hz). The mean spectral power parameters per channel and subject were ln10-transformed before statistical analysis. Spectral power data of the theta-band (mean, SD) of the different groups are collected in Table 3a respectively. See Table 3b for rest and haptic task condition.

Haptic Tasks

The haptic task consisted of exploring five individual sunken reliefs (13 cm x 13 cm), which were presented to the participants in random order (Fig. 1). All participants were asked to palpate the haptic stimuli with both hands while keeping their eyes closed. After the haptic explorations, all participants were asked to reproduce the structure of the stimuli as closely as possible on a piece of paper with their eyes open.

Exploration time (ET) per stimulus was not limited. With the help of a strategically placed screen, the participants were prevented from gathering visual information on the stimuli. The participants were not given any feedback on the quality of their reproductions or the stimulus structure. The exploration time per stimulus was registered by means of pressure sensors (in seconds). The participants were allowed to familiarize themselves with the haptic material before the experiment by looking at one sample stimulus and practicing the haptic exploration task for a duration of 1 minute.

The reproductions were evaluated on a scale from 1 to 4 (1 = correct reproduction of stimulus; 2 = correct reproduction of stimulus with one to three mistakes; 3 = failure to reproduce stimuli adequately, correct reproduction of single elements only; 4 = failure to reproduce stimulus or single elements correctly). Two students (A,B) who where blind to the purposes of the study evaluated each single reproduction. The inter-examiner reliabilities (Douglas, 1991) amount to $k_{A/B} = 0.87$. As
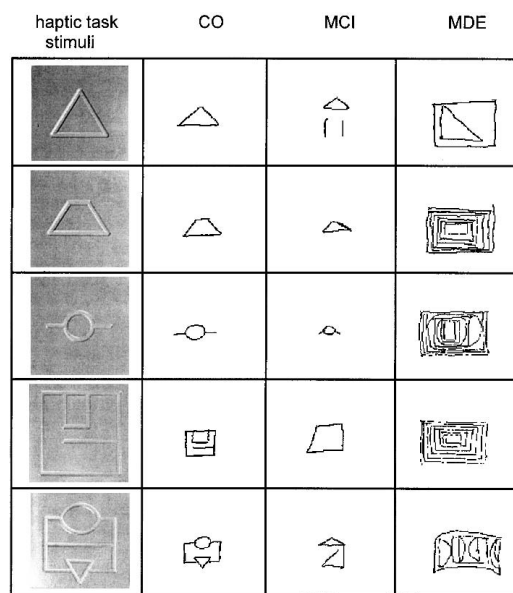

FIG. 1. Representative sample of haptic reproductions from one subject per group (controls [CO], patients with mild cognitive impairment [MCI], patients with mild dementia [MDE]).

an example, drawing reproductions of three subjects (1 CO, 1 MCI, 1 MDE) are shown in Figure 1.

Statistical Evaluation

All statistical analyses were conducted using the SPSS package for Windows (version 7.5.2). The statistical significance for age, MMSE, and exploration time (ET) were evaluated by t-test for independent groups. Statistical differences in quality of reproductions (QR) between groups were evaluated with the non-parametric Kruskal-Wallis-Test for independent groups. Tests of intergroup differences of ln10-transformed EEG data between rest and haptic tasks were performed by t-test for dependent groups. As critical alpha we used Bonferroni $\alpha' = 0.05/19 = 0.0026$. Significant differences between rest condition and haptic tasks are documented in a probability map as applied by Rappelsberger et al. (1988). A blank square indicates a significant lower respectively decrease in power (significance level $p < 0.05$ or $p < 0.01$) whereas a black square indicates a significant higher respectively increase in power (significance level $p < 0.05$ or $p < 0.01$) via the corresponding electrode in comparison to the statistical hypothesis. The size of the squares corresponds with the reached significance level. The significance level $p < 0.05$ is shown by a small square whereas the significance level $p < 0.01$ is shown by a large square. For the comparison between the state of rest and of haptic task a blank square means a significant decrease in theta-power during haptic exploration in contrast to the state of rest for the respective electrode.

Tests for statistical significance of ln10-transformed EEG data between the groups for the two measurement conditions (rest and haptic task) were performed by an MANOVA model with repeated measurements (electrodes x condition by group) followed by Gabriel post hoc analyses to reveal differences of theta-power means between groups in each channel. The Levene procedure was used to test the homogeneity of variance. The Gabriel procedure was used due to the different number of subjects in the single groups (Gabriel 1960). The critical α'-level was calculated according to Bonferroni ($\alpha' = 0.05/4 = 0.012$). The results of these tests are shown in Table 3a and 3b.

We used the nonparametric proceeding according to Spearman (two-tailed) for the calculation of the correlation coefficients between the behavioral data sets (MMSE etc.) as well as for the correlation between theta-power and behavioral data. For the correlation between theta-power and MMSE we only used those electrodes that showed group differences in the post-hoc analysis of the MANOVA. These correlations were carried out separately for theta-power during rest and for theta-power during haptic perception.

RESULTS

No significant age effects appeared between the groups $(F(2,48) = 16.31 \; p = 0.168)$. But significant group differences for the MMSE were shown $(F(2,48) = 92.49, p = 0.000)$. Regarding the mean exploration time, a clear difference between the groups was revealed $(F(2,48) = 5.01, p = 0.011)$ although a significant difference could only be observed between CO and MDE $(t_{CO-MDE} = -3.29, p = 0.006)$. The control group needed significantly less time to explore the haptic stimuli than the demented group. MCI and MDE patients needed the same exploration time on average.

The quality of reproductions (rating score) differed significantly between CO and MCI $(Chi = 17.53, p = 0.000)$ as well as between CO and MDE $(Chi = 23.23, p = 0.000)$. The difference in quality of reproductions between MCI and MDE was not significant $(Chi = 0.019, p = 0.889)$. Thus, the quality of reproductions was clearly worse in MCI and MDE patients compared with the control group.

The mean exploration time and the mean rating scores for the quality of reproductions per group are displayed in Table 1.

Comparison of Theta-power Between Rest Condition and Haptic Tasks for Each Group

The statistical comparison of theta-power under rest condition and of theta-power during haptic tasks revealed a significant decrease in theta-power during the haptic tasks in all three groups (Table 2). The decrease in theta-power was observed in all three groups over parieto-occipital, parieto-temporal and central regions. A decrease in theta-power over postfrontal regions was only seen in MCI and MDE. The topographical distribution of

TABLE 1. *Number, mean age (SD), mean MMSE-score (SD), mean exploration time (SD) for the haptic stimuli and mean rating score (SD) of the reproduction quality for each group arranged by Clinical Dementai Rating (CDR)*

	CO CDR = 0	MCI CDR = 0.5	MDE CDR = 1
Cases (male/female)	20 (11/9)	16 (6/10)	15 (6/9)
Age (m, SD)	78.35 (3.45)	79.25 (2.08)	77.20 (3.55)
MMSE (m, SD)	29.10 (0.64)	26.87 (1.31)	20.26 (3.17)
min-max	28–30	22–27	19–21
Mean time (m, SD)	54.44 (24.83)	68.79 (36.79)	91.22 (41.02)
Rating (m SD)	1.94 (0.47)	3.16 (0.75)	3.19 (0.79)

TABLE 2. *Significance level of statistical comparison per EEG channel between theta-power under rest condition and during haptic tasks*

Channel	Controls		MCI		MDE	
	T	p	T	p	T	p
C3	−2.471	0.023	−3.523	0.003	−4.443	0.001
C4	−1.553	0.137	−4.463	0.000	−4.421	0.001
Cz	−2.710	0.014	−4.385	0.001	−4.718	0.000
F3	−0.138	0.892	−2.011	0.063	−3.746	0.002
F4	0.545	0.592	−2.275	0.038	−3.930	0.002
F7	1.789	0.090	−0.160	0.875	−2.634	0.020
F8	1.659	0.114	−0.477	0.640	−1.683	0.114
Fp1	2.462	0.024	1.635	0.123	−1.240	0.236
Fp2	2.728	0.013	1.750	0.101	−1.993	0.066
Fz	−0.064	0.950	−2.957	0.010	−4.412	0.001
O1	−3.861	0.001	−3.398	0.004	−4.108	0.001
O2	−3.353	0.003	−3.130	0.007	−4.756	0.000
P3	−3.610	0.002	−4.229	0.001	−4.560	0.000
P4	−3.331	0.004	−4.129	0.001	−4.633	0.000
Pz	−2.936	0.008	−4.406	0.001	−5.134	0.000
T3	−0.549	0.589	−2.916	0.011	−3.584	0.003
T4	−0.636	0.533	−2.324	0.035	−2.739	0.016
T5	−2.960	0.008	−4.085	0.001	−4.998	0.000
T6	−2.479	0.023	−3.739	0.002	−5.268	0.000

T-test for dependent groups, two-tailed.

theta-power decrease is shown in the probability maps (Fig. 2). Moreover, an increase in theta-power over frontal regions (Fp1, Fp2) was only observed in CO ($0.05 > p > 0.01$). Concerning the statistical hypothesis, the critical α-level was reached by at least one test. Therefore, it can be stated for all three groups that theta-power decreases generally during haptic tasks over parieto-occipital regions.

Group Differences in Theta-power Under Rest Condition

Under rest condition, theta-power differed only between CO and MDE (Fp1, Fp2, F7, T3, T5, O1, O2), and it was higher in MDE than in CO (Table 3a). Regarding the statistical hypothesis, the critical α-level was reached for the electrodes Fp1 and F7 (Fig. 3b). Therefore, it can be said that CO and MDE generate a significantly different theta-power under rest condition over frontal regions.

Group Differences in Theta-power During Haptic Tasks

Theta-power differed significantly between CO and MDE over occipital regions (O1, O2) and over parieto-temporal regions (T5) (Table 3b) during haptic tasks. A significant difference between CO and MCI was only revealed over right occipital regions (O2) (Figure 3a).

Regarding the statistical hypothesis, the critical α-level was reached for the electrode O2 and thus, the hypothesis formulated at the beginning can be confirmed. Non-significant theta-power differences between MCI and MDE were shown over occipital regions. Generally, mean theta-power over occipital regions was lower in CO than in MCI and MDE.

Main Effects and Interactions of Theta-power

The main effect CONDITION [$F_{(1,48)} = 18.46$; $p = 0.000$] and ELECTRODES [$F_{(18,31)} = 37.12$; $p = 0.000$] was significant, whereas the GROUP effect was not significant [$F_{(2,48)} = 2.35$; $p = 0.105$]. Neither the interaction effect CONDITION x GROUP [$F_{(2,48)} = 2.64$, $p = 0.081$] nor the interaction ELECTRODES x GROUP [$F_{(36,64)} = 1.16$; $p = 0.296$] were significant. But the interaction CONDITION x ELECTRODES was significant [$F_{(18,31)} = 5.92$; $p = 0.000$].

Correlations

The correlation between MMSE and rating score (quality of reproduction) was $r_{MMSE-QR} = -.594$, $p =$
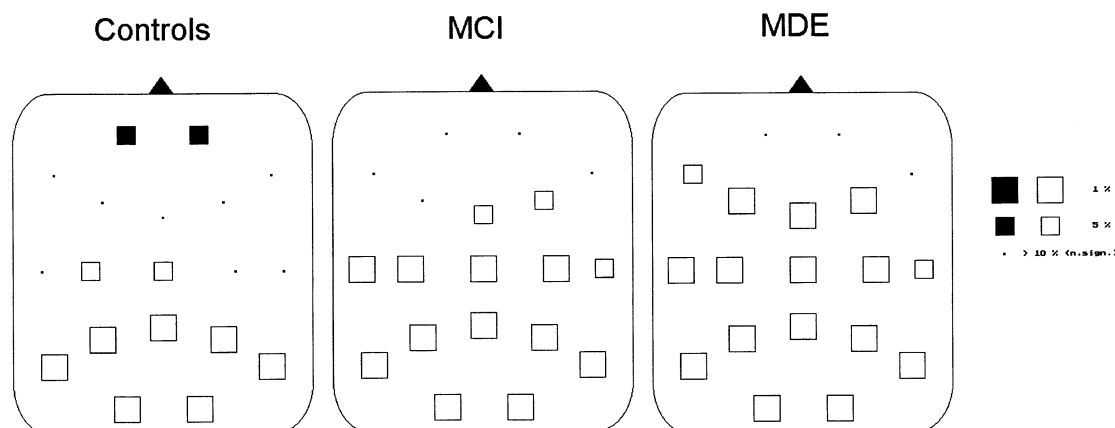

FIG. 2. Probability map. Significant differences in theta-power between the rest situation (eyes closed) and during haptic tasks in each group. The white caskets mean a significant decrease of theta-power for this electrode during haptic tasks.

TABLE 3a. *Mean theta-power (SD) for control group (CO), mild cognitive impairment (MCI) and patients with mild Dementia (MDE) under rest condition*

	CO		MCI		MDE		Hom. of variance		ANOVA		
	Mean	SD	Mean	SD	Mean	SD	Levene	Statistik	F	p	Gabriel
C3	6.43	5.22	8.61	6.04	14.85	16.97	1.455	0.244	2.414	0.100	
C4	6.44	5.44	8.53	6.15	12.18	11.68	1.454	0.244	1.514	0.230	
Cz	5.50	4.42	7.83	5.85	10.61	9.31	1.302	0.281	1.806	0.175	
F3	5.43	4.19	7.51	5.02	12.48	12.46	1.562	0.220	3.097	0.054	
F4	5.09	4.16	6.94	5.04	9.52	8.38	2.212	0.121	1.900	0.161	
F7	3.21	2.15	4.99	3.34	8.25	8.76	2.380	0.103	4.715	0.014	CO < MDE*
F8	4.06	3.54	4.59	3.45	6.42	5.53	1.390	0.259	1.014	0.371	
Fp1	4.16	2.86	5.49	3.12	8.84	6.76	2.086	0.135	5.070	0.010	CO < MDE#
Fp2	4.62	3.09	5.39	2.97	8.77	6.47	2.348	0.106	3.190	0.050	CO < MDE*
Fz	5.70	4.51	9.01	7.15	12.49	11.49	1.396	0.257	2.814	0.070	
O1	3.92	3.00	5.67	4.65	8.91	7.51	.403	0.670	3.357	0.043	CO < MDE*
O2	3.84	2.69	5.99	4.82	9.32	8.13	.425	0.656	3.718	0.032	CO < MDE*
P3	5.70	4.55	7.48	5.73	14.79	18.38	1.478	0.238	2.260	0.115	
P4	5.17	4.08	7.16	5.02	12.47	13.07	2.042	0.141	2.206	0.121	
Pz	5.08	3.85	6.85	4.96	10.74	11.25	1.065	0.353	1.819	0.173	
T3	3.08	2.26	6.63	7.48	12.25	16.63	2.823	0.069	3.944	0.026	CO < MDE*
T4	2.35	2.63	3.10	3.10	4.79	4.72	1.445	0.246	2.052	0.140	
T5	3.34	2.45	5.54	5.63	9.79	11.91	.447	0.642	3.522	0.037	CO < MDE*
T6	3.79	3.49	5.39	5.48	9.22	9.44	1.049	0.358	2.940	0.062	

Levene's test statistic of Homogenity of Variance; F-statistic of ANOVA and Gabriel statistic for intergroup comparisons.
*p < 0.05, #p < 0.010 (significance level Gabriel test).

0.000. The correlation between MMSE and exploration time was $r_{MMSE–ET} = -.466$, $p = 0.001$. The correlation between ET and QR was $r_{ET–QR} = 0.101$, $p = 0.480$. The correlations between MMSE and theta-power (O1, O2, T5) during haptic perception were $r_{MMSE–O1[haptic]} = -0.360$, $p = 0.009$; $r_{MMSE–O2[haptic]} = -0.362$, $p = 0.009$; $r_{MMSE–T5[haptic]} = -0.363$, $p = 0.009$. The correlations between MMSE and theta-power during rest condition for the single electrodes (F7, Fp1, Fp2, O1, O2, T3, T5) were $r_{MMSE–F7[rest]} = -0.326$, $p = 0.020$; $r_{MMSE–Fp1[rest]} = -0.357$, $p = 0.010$; $r_{MMSE–Fp2[rest]} = -0.255$, $p = 0.071$; $r_{MMSE–O1[rest]} = -0.315$, $p = 0.024$;

TABLE 3b. *Mean theta-power (SD) for control group (CO), mild cognitive impairment (MCI), and patients with mild Dementia (MDE) during haptic tasks*

	CO		MCI		MDE		Hom. of Variance		ANOVA		
	Mean	SD	Mean	SD	Mean	SD	Levene	Statistik	F	p	Gabriel
C3	3.97	1.97	5.32	2.98	6.17	4.58	1.167	0.320	1.383	0.261	
C4	4.19	1.76	4.85	2.86	6.27	5.21	3.112	0.054	0.314	0.732	
Cz	3.29	1.66	4.35	2.63	4.69	3.33	0.716	0.494	0.836	0.440	
F3	4.53	2.12	5.69	4.13	5.58	3.58	0.344	0.711	0.422	0.658	
F4	5.08	3.68	5.02	3.22	5.26	3.68	0.657	0.523	0.004	0.996	
F7	4.02	3.08	4.44	2.06	5.94	5.78	3.100	0.054	0.719	0.492	
F8	5.55	5.54	4.09	2.36	5.56	5.19	1.390	0.259	0.176	0.839	
Fp1	6.71	4.81	9.29	10.30	7.11	4.96	0.365	0.696	0.328	0.722	
Fp2	10.85	15.67	8.53	7.62	6.21	3.58	0.163	0.850	0.524	0.595	
Fz	4.84	2.67	5.92	4.26	5.48	3.52	0.313	0.733	0.199	0.820	
O1	2.34	1.42	3.56	2.59	4.75	3.44	1.674	0.198	4.166	0.021	CO < MDE*
O2	2.22	1.08	3.77	2.32	4.32	2.91	1.041	0.361	5.005	0.011	CO < MCI*, CO < MDE*
P3	3.04	1.61	4.36	2.64	5.70	4.75	1.276	0.288	2.059	0.139	
P4	2.89	1.43	4.07	2.34	5.27	4.24	2.934	0.063	1.800	0.176	
Pz	3.01	1.58	3.89	2.34	4.42	3.48	0.390	0.679	0.915	0.407	
T3	2.49	1.13	4.05	4.03	6.06	6.40	4.465	0.017	2.214	0.120	
T4	1.65	1.11	2.05	1.67	3.31	3.28	5.349	0.008	1.004	0.374	
T5	1.98	1.10	2.97	2.15	4.13	3.13	0.894	0.416	3.746	0.031	CO < MDE*
T6	2.11	1.13	3.20	2.57	4.09	3.23	2.566	0.087	2.245	0.117	

Levene's test statistic of Homogenity of Variance; F-statistic of ANOVA and Gabriel statistic for intergroup comparisons.
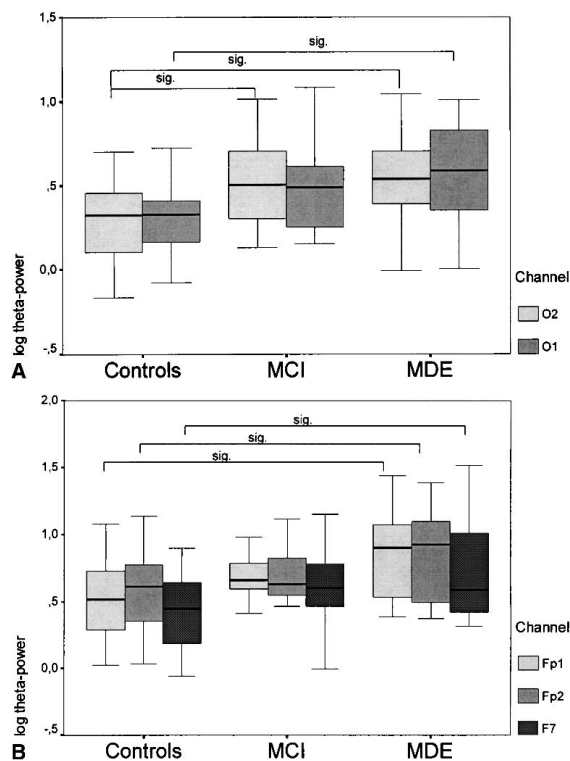*p < 0.05 (significance level Gabriel test).

FIG. 3. (A) Boxplot for the log-transformed theta-power between the groups regarding the occipital EEG electrodes O1 and O2 during haptic tasks. Significant differences are marked. (B) Boxplot for the log-transformed theta-power between the groups regarding the frontal EEG electrodes Fp1, Fp2, F7 under rest condition. Significant differences are marked.

$r_{MMSE-O2[rest]} = -0.338$, $p = 0.015$; $r_{MMSE-T3[rest]} = -0.305$, $p = 0.030$; $r_{MMSE-T5[rest]} = -0.347$, $p = 0.013$.

DISCUSSION

The analysis of the EEG data revealed distinctive group differences between CO and MCI as well as between CO and MDE over occipital cortical regions during haptic tasks. This confirms our assumption that, due to similar functional deficits in MCI and MDE, differences in theta activity over occipital regions appear only between CO and MCI, and between CO and MDE, but not between MCI and MDE. Therefore, it can be stated that spectral theta-power during haptic tasks is suitable to distinct healthy subjects from patients with MCI respectively MDE. The behavioral data (*ie*, the mean rating score of quality of reproduction) show similar relations between the groups (distinctive differences between CO and MCI, and between CO and MDE, but no differences between MCI and MDE). This congruence between behavioral data and brain electrical parameter of theta-power show that both variables depict functional deficits in MCI and MDE. This leads to the conclusion that functional and cognitive deficits in patients with MCI or MDE can be revealed by complex sensomotoric demands. In contrast to simple mental tasks (mental calculations and verbal memory tasks), complex multisensoric integration processes and sensomotoric operations are necessary to solve haptic exploration tasks. These processes and operations are functional connected particularly to parieto-occipital cortical regions. These regions are already impaired in the early stages of AD, as known from PET and SPECT studies as well as from postmortem studies of Braak (Braak et al. 1989; Braak and Braak 1990). Therefore, our results demonstrate changes in the brain electrical activity in MCI patients which are possibly based on patho-morphologic changes in these cortical areas.

No significant differences between CO and MCI were revealed under rest condition as we had expected. Concerning the frontal theta-power under rest condition, significant differences were only seen between CO and MDE, but not between MDE and MCI (Tab. 3a). Thus, our data correspond with the results of previous studies (Günther et al. 1993; Jelic et al. 1996; Watanabe et al. 1991; Zappoli et al. 1995) which revealed differences in brain electrical activity under unspecific rest condition only between healthy controls and patients with mild/moderate dementia as well as between patients with Alzheimer disease and healthy controls. Therefore, our results are further indications that differences in brain electrical activity between CO and MCI under an unspecific rest condition are not intense enough to distinguish between these groups. Although an increased theta-power in MCI compared to CO is observable on a descriptive level, this difference is not strong enough to be considered as statistically save (Table 3a).

Moreover, the results show a clearly decreased theta-power over parieto-occipital regions during the haptic tasks compared to the rest condition (Fig. 2). This confirms the assumption that complex perceptive-cognitive demands are generally accompanied with a significant decrease in theta-power. The decrease in theta-power corresponds with multisensoric integration processes and memory processing during the solution of tasks (Weiss et al. 1995; Grunwald et al. 1999; Grunwald et al. 2001b). Whereas the observed increase in theta-power over frontal regions in CO corresponds with other results revealing that memory load processing during perceptive-cognitive tasks leads to an increase in theta-power over frontal cortical regions in healthy subjects (Gevins et al. 1995; Klimesch et al. 1996). A remarkably finding of our study is the different topographical distribution of activity changes between the groups. While the decrease in

theta-power in CO concerns mainly the parieto-occipital regions, the theta-power decrease involves additional central regions in MCI, and central and post-central regions in MDE (Fig. 2). The extended topography of theta-power decrease in MCI and MDE is an indication of a "compensating" activation of other cortical areas due to the functional disturbance of parieto-occipital cortical structures, which are actually involved in the solution of perceptive-cognitive tasks. Similar findings are shown for the delta-band in patients with mild to moderate DAT during perceptive-cognitive and motor tasks (Günther et al. 1993). The extended distribution of theta-activity changes in MCI and MDE during haptic tasks indicates distinctive group differences even on a descriptive level. However, a topographical analysis is not useful for a save diagnostic classification due to the natural measurement bias (*eg*, deviation of electrode positioning). Yet, topographical analysis conveys an impression of the involvement of cortical areas in information processing and allows descriptive statements.

In contrast with other studies, our results show that distinctive differences in theta-band activity are observable between healthy subjects and patients with MCI, provided that the EEG is obtained under sufficiently complex perceptive-cognitive demands. Moreover, our results show that haptic tasks are suitable to reveal early perceptive-cognitive and functional deficits in MCI patients compared with healthy controls.

The absence of significant differences in theta-power between MCI and MDE in our as well as in comparable studies is possibly caused by the intragroup-variability respectively heterogeneity of our MCI group. In other studies we have demonstrated (Grunwald et al. 1998) that there exists a considerable variance of theta-power generated under rest condition within the MCI population. This high intragroup-variance of the theta-baseline could be the cause for the lack of differential effects between MCI and MDE. Additionally, these findings could indicate that the MCI population has to be differentiated in further subgroups. For this, however, further—particular longitudinal—studies are required.

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Errata

In the July/September 2001 issue of *Alzheimer Disease & Associated Disorders,* there was an error. On page 124 of the article by van der Steen, the sentence as written states: "In addition, 2% of NHPs indicated . . ." The correct sentence is: "In addition, **29%** of NHPs indicated . . . "

In the October/December 2001 issue of *Alzheimer Disease and Associated Disorders* there was an error. On page 174 of the article by Doraiswamy et al., the citation for Figures 1 and 2 (and therefore the figure placement) appeared in the introduction and was placed with the Rosen, Mohs, and Davis (1984) citation in error. The correct citation for Figures 1 and 2 appears in the RESULTS on page 177.