EEG during memory activation: a study of early functional brain changes in Alzheimer's disease and Huntington's disease
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EEG correlates in the spectrum of cognitive decline

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**Abstract**

To investigate relations between EEG measures and performance on tests of global cognition, memory, language and executive functioning. Twenty-two controls, 18 patients with mild cognitive impairment (MCI) and 16 with probable Alzheimer’s disease (AD) underwent neuropsychological and EEG investigations. We used the following EEG measures: theta relative power during eyes closed, alpha reactivity during memory activation (i.e. the percentual decrease in alpha power as compared to eyes closed) and alpha coherence during eyes closed and memory activation. Theta relative power was increased in AD patients as compared with controls (p<0.001) and MCI patients (p<0.01) and related to decreased performance in all cognitive domains. Alpha reactivity was decreased in AD patients as compared with controls (p<0.005) and related to decreased performance on tests of global cognition, memory and executive functioning. Alpha coherence did not differ between groups and was unrelated to cognition. EEG power measures were associated with decreased performance on tests of global cognition, memory, language and executive functioning, while coherence measures were not. The EEG yielded several power measures related to cognitive functions. These EEG power measures might prove useful in prospective studies aimed at predicting longitudinal cognitive decline and dementia.
Introduction

Alzheimer’s disease (AD) is characterized by a progressive, global loss of cognitive functions [21]. Its early diagnosis and treatment poses a major challenge in dementia research. Of special research interest are those patients who present themselves with amnestic mild cognitive impairment (MCI) and are presumed to be in a preclinical stage of AD. MCI is characterized by memory loss without impairment in other cognitive domains, such as language, perception, practical skills and executive functions [23].

The electroencephalogram (EEG) has been used for many decades as a non-invasive, cost-effective tool for exploring functional brain changes in AD. Characteristic phenomena seen in AD patients are EEG slowing and decreased coherence [1, 5, 16, 34]. Recently, cross-sectional and prospective EEG research focused on patients with MCI. It was discovered that memory activation disclosed EEG power and coherence changes in MCI patients that were not apparent in the resting EEG [17, 24, 35]. In search of markers of cognitive decline and dementia, a number of prospective and cross-sectional studies explored relations between EEG and cognition.

Several prospective studies investigated EEG correlates of global cognition, mostly using compound tests such as the Mini Mental State Examination (MMSE) [10], Global Deterioration Scale (GDS) [27] or Cambridge Cognitive Examination (CAMCOG) [30]. One qualitative EEG study noted that the pattern of cognitive decline depended on the presence of EEG abnormality in the early stage of AD. In that study, AD patients with an abnormal EEG at baseline showed a decline in praxic functions, confrontation naming and automatic speech functions after three years, while AD patients with a normal EEG did not [12]. Both groups showed similar decline in visual functions, understanding of speech, and memory functions. In a quantitative study in mildly demented AD patients slowing of the EEG, i.e. higher theta power, less beta power and lower peak frequency, were associated with subsequent cognitive decline on the CAMCOG [8]. These results were corroborated by another longitudinal study that used change in GDS score as an indicator of cognitive decline in subjects with subjective memory complaints. In that study, increases in theta power, slowing of mean frequency and changes in coherence among regions were observed at baseline in subjects who declined after 7-9 years follow-up [25].

Cross-sectional studies in elderly with different levels of cognitive impairment have reported correlations between EEG spectral parameters, i.e. higher theta activity during rest and lower alpha activity during memory activation, and decreased MMSE or GDS scores [7, 17, ...
22, 26]. One recent study investigated specific cognitive domains; in subjects with subjective memory complaints higher alpha power was related to a decline in verbal memory performance, maze performance and working memory reaction time. Higher alpha power was positively correlated with performance in reverse digit span [2]. Although relations have been described between longitudinal cognitive decline and EEG coherence [25], cross-sectional studies did not discover similar associations using MMSE scores [1, 17, 19]. EEG coherence might however be associated with specific cognitive domains.

Aforementioned studies explored limited cognitive domains and were mostly confined to a particular diagnostic group. The current exploratory study therefore investigated a wide range of cognitive functions in the entire spectrum of cognitive decline, ranging from elderly without cognitive complaints to AD. We tested whether EEG power and coherence measures were related to performance in specific cognitive domains, including global cognition, memory, language and executive functioning. Cognitive domains were selected because of their relevance in the diagnostic work-up of dementia. We chose EEG measures sensitive to abnormalities in MCI and AD, such as slowing and decreased coherence in the resting EEG of AD patients [1, 5, 16, 34] and decreased alpha reactivity and coherence in MCI patients during memory activation [17, 35]. It should be noted that we purposely emphasized studies yielding easily obtainable, and therefore clinically applicable, EEG parameters. Other researchers provided more refined descriptions of localized EEG and MEG changes in AD and MCI using flexible frequency bands encompassing both slow and fast frequencies [3, 4, 11, 31-33].

**Methods**

**Subjects**

Twenty-four subjects without cognitive complaints, 20 patients diagnosed with MCI [23] and 17 with probable AD [21] agreed to participate. Patients had been referred to the outpatient memory clinics of the Leiden University Medical Center, Leiden Diaconessenhuis or The Hague Leyenburg hospital. Control subjects without cognitive complaints were recruited through an advertisement in a local newspaper.

All patients and controls underwent general medical, neurological, neuropsychological and brain MRI investigations as part of the standard diagnostic work-up of dementia. Patient histories were reviewed and diagnoses reached in multidisciplinary consensus meetings. Within three months from standard diagnostic work-up patients and controls participated in an additional EEG examination. Eligible subjects had to
be free of psychotropic medication, aged 60 yrs or above, and without previous history of psychiatric and neurological disorders or substance abuse. Moreover, they had no abnormalities on MRI other than an incidental small lacunar lesion (≤ 5 mm diameter) or white matter hyperintensities conforming with age or of a non-specific nature. The study was approved by the local Medical Ethical Committee. Written informed consent was obtained from all subjects, or from close relatives or caregivers in case of dementia.

**EEG recording**

EEGs were recorded using a Nihon Kohden 2110 apparatus with 21 Ag/AgCl electrodes placed according to the 10/20 system. ECG, respiration and horizontal eye movement leads were recorded to facilitate recognition of artifacts. The EEG was band-pass filtered from 0.16-70 Hz for display and analysis, but recorded unfiltered. The sample frequency was 200 Hz and the AD precision 12 bits. The average reference montage was used, with the exclusion of electrodes Fp1, Fp2, A1 and A2. All EEGs were recorded in the afternoon. During recording subjects sat slightly reclined in a comfortable chair, approximately 1.5 m in front of a computer screen. The light in the room was dimmed. Vigilance was monitored constantly by visual inspection of the EEG and video registration. An auditory stimulus was given in case of drowsiness.

**Experimental procedure**

The EEG of each subject was registered during a rest condition and memory activation.

The rest condition comprised 10 min of being awake with eyes closed. Three artifact-free samples, 4-8 s in length, were selected visually for further analysis. It should be noted that we selected the first artifact-free samples we encountered during these 10 min. This was necessary in view of the high chance of patient’s drowsiness after several minutes of EEG registration. The use of samples selected after 2-5 min is therefore highly discouraged.

During memory activation ten pictures of common objects were shown on a computer screen using a readily available presentation tool (Microsoft Office PowerPoint 2003). Each was presented for 2 s and subjects were asked to name the objects aloud and memorize them. After the last picture, subjects had to close their eyes and memorize the objects for 15 s (‘memorization period’). They were then asked to open their eyes and name as many objects as they could. This task was performed three times using the same 10 pictures shown in the same order. From each of the three memorization periods one EEG sample, 4-8 s in length, was selected for further analysis. We noted the total number of remembered objects.
EEG analysis

The selection of EEG samples free of eye movements, blinks and muscle activity was performed blinded for diagnosis by the first author and supervised by an experienced clinical neurophysiologist (AV). Frequency analysis was performed using a Fast Fourier Transformation. For each sample, absolute power was calculated in the theta (4-8 Hz) and alpha (8-13 Hz) bands. Lower and higher frequencies were not used as these are easily contaminated with blinks, eye movements and electromyographic activity, especially in demented patients. Although artifact reduction techniques are available, we chose a more minimalist and simpler approach by excluding delta, beta and gamma bands. Subsequently, we calculated theta relative power (absolute theta power as a percentage of total power in the 4-13 Hz band). Furthermore, alpha reactivity was calculated during memory activation, which is defined as the percentile decrease in absolute alpha power during the memorization period as compared to the eyes closed condition. EEG power measures were averaged over all electrode positions.

EEG coherence was calculated by the Fast Fourier Transformation method. Coherence between two waveforms x and y was calculated spectrally as $C_{xy}(f) = |P_{xy}(f)|^2 / P_{xx}(f)P_{yy}(f)$, where $P_{xy}$ is the cross-power spectral density of x and y and $P_{xx}$ and $P_{yy}$ are the power spectral densities of x and y. All signal processing was performed using MATLAB (The MathWorks, Natick, USA). The coherence between one electrode and each of the other 16 electrodes was computed for each electrode, in the alpha frequency band. These values were averaged to result in an overall coherence measure. Coherence values range from 0 to 1 and indicate the amount of covariation between two EEG signals in the frequency spectrum. The average coherence can be seen as an overall measure of synchronous oscillatory activity in the cortex. EEG parameters were averaged over the three selected EEG samples available for the eyes closed and working memory periods. We used the following EEG parameters for further analysis: (1) theta relative power during eyes closed (2) alpha reactivity during memory activation (3) alpha coherence during eyes closed and (4) alpha coherence during memory activation. We selected these parameters from a clinical viewpoint, i.e. easily available, simple EEG measures with known sensitivity to dementia. The choice of global EEG parameters was based on previous research showing global EEG changes in both MCI and AD patients [17, 24, 31, 35].

EEG data of two controls and one AD patient were later excluded because of drowsiness. Data of two MCI patients were excluded because of extremely low EEG voltage on most leads (<10 μV).
Neuropsychological assessment
A standardized neuropsychological test battery was used to assess cognitive functioning. The Cambridge Cognitive Examination (CAMCOG) [30], which incorporates the Mini Mental State Examination [10], was used to assess global cognitive functioning. CAMCOG subtests provided subscores for memory and language. Memory function was further tested with the Wechsler Memory Scale (WMS) [36], the picture learning task used during EEG registration and word recall from the Alzheimer Disease Assessment Scale (ADAS) [29]. Language ability was further assessed using the Boston naming task (BNT) [18]. Tests of executive functioning included letter (FAS) and category fluency (animals) [6], the Trail Making Test consisting of a simple (trails A) and a complex version (trails B) [28] and the digit symbol subtest of the Wechsler Adult Intelligence Scale-Revised (WAIS-R) [37].

Statistical analysis
SPSS for Windows (release 12.0.1) was used for data analysis. Group differences in sex, age and years of education were assessed using parametric and nonparametric tests where appropriate. Univariate ANOVA with age as covariate was used to compare neuropsychological test scores and EEG measures between groups. Post-hoc Bonferroni tests were performed when diagnostic group effects were found. Subsequently, we used partial correlations, controlling for age, to investigate relations between EEG power and coherence measures on the one hand and neuropsychological test scores on the other. In view of the exploratory nature of the study the level of significance was set at $p \leq 0.01$, despite the relatively large number of tests.

Results
Clinical characteristics
Clinical characteristics of the study population are shown in Table 1. Sex and years of education did not differ between groups. However, AD patients were significantly older than controls ($p<0.005$). Age was therefore used as a covariate in all subsequent analyses. AD patients scored significantly lower on all neuropsychological tests compared with controls. Furthermore, AD patients had lower scores than MCI patients on tests of global cognition, memory (CAMCOG memory and picture learning), language, and executive functioning (trails A and digit symbol). MCI patients performed worse than controls on tests of global cognition, memory and category fluency. With the exception of the letter fluency task, MCI patients scored in between controls and AD patients, which confirms the concept of a spectrum of cognitive decline.
### Table 1. Clinical characteristics of the study sample

<table>
<thead>
<tr>
<th></th>
<th>Controls</th>
<th>MCI</th>
<th>AD</th>
</tr>
</thead>
<tbody>
<tr>
<td>male/ female</td>
<td>7/15</td>
<td>7/11</td>
<td>9/7</td>
</tr>
<tr>
<td>age (yrs)</td>
<td>70 (5)</td>
<td>74 (5)</td>
<td>78 (8)*</td>
</tr>
<tr>
<td>education (yrs)</td>
<td>11 (3)</td>
<td>11 (4)</td>
<td>10 (4)</td>
</tr>
</tbody>
</table>

**Neuropsychological tests**

<table>
<thead>
<tr>
<th></th>
<th>Controls</th>
<th>MCI</th>
<th>AD</th>
</tr>
</thead>
<tbody>
<tr>
<td>global MMSE (/30)</td>
<td>28 (1)</td>
<td>24 (3)**</td>
<td>21 (4)** ^^</td>
</tr>
<tr>
<td>global CAMCOG (/106)</td>
<td>96 (4)</td>
<td>83 (6)**</td>
<td>68 (9)** ^^</td>
</tr>
<tr>
<td>memory WMS (Memory Quotient)</td>
<td>121 (11)</td>
<td>94 (8)**</td>
<td>88 (13)**</td>
</tr>
<tr>
<td>memory CAMCOG memory (/27)</td>
<td>23 (2)</td>
<td>15 (4)**</td>
<td>12 (4)** ^</td>
</tr>
<tr>
<td>memory ADAS (/30)</td>
<td>19 (3)</td>
<td>12 (2)**</td>
<td>9 (3)**</td>
</tr>
<tr>
<td>memory Picture learning (/30)</td>
<td>25 (2)</td>
<td>16 (3)**</td>
<td>10 (4)** ^^</td>
</tr>
<tr>
<td>language Boston (/30)</td>
<td>26 (3)</td>
<td>24 (3)</td>
<td>19 (5)** ^</td>
</tr>
<tr>
<td>language CAMCOG language (/38)</td>
<td>34 (2)</td>
<td>32 (3)</td>
<td>27 (5)** ^^</td>
</tr>
<tr>
<td>executive letter fluency</td>
<td>33 (9)</td>
<td>33 (10)</td>
<td>23 (7)*</td>
</tr>
<tr>
<td>executive category fluency</td>
<td>21 (5)</td>
<td>15 (4)*</td>
<td>12 (5)**</td>
</tr>
<tr>
<td>executive trails A (s)</td>
<td>42 (12)</td>
<td>55 (17)</td>
<td>108 (72)** ^^</td>
</tr>
<tr>
<td>executive trails B (s)</td>
<td>96 (32)</td>
<td>162 (87)</td>
<td>248 (76)**</td>
</tr>
<tr>
<td>executive digit symbol</td>
<td>43 (8)</td>
<td>37 (9)</td>
<td>17 (12)** ^^</td>
</tr>
</tbody>
</table>

Values in the table are means with SD in parentheses. Age corrected p-values are noted. * differs from controls (p<0.01); ** differs from controls (p<0.001); ^ differs from MCI patients (p<0.01); ^^ differs from MCI patients (p<0.001). aχ²-test was used to assess group differences. bTests were administered in a smaller number of AD patients (letter fluency: N=11 and trails B: N=7). cLog transformed values were used for data analysis. CAMCOG=Cambridge Cognitive Examination; WMS=Wechsler Memory Scale; ADAS=Alzheimer Disease Assessment Scale.

### EEG

EEG data are summarized in Table 2 and illustrated in Fig 1. We found that theta relative power during eyes closed differed significantly between diagnostic groups (F(2,52)=7.6, p<0.001). The covariate age also showed a significant effect (F(1,52)=5.3, p<0.05). Bonferroni post-hoc tests indicated that theta relative power was increased in AD patients as compared with controls (p<0.001) and MCI patients (p<0.01). MCI patients scored in between controls and AD patients. As theta relative power was based on theta and alpha absolute power, we investigated group differences in absolute power as well. We found that absolute theta power was increased in AD patients as compared with controls (F(2,52)=3.5, p<0.05) without differences in absolute alpha power.

Furthermore, we discovered that the amount of alpha reactivity during memory activation was significantly different between groups (F(2,51)=6.4, p<0.005). Post-hoc tests indicated that alpha reactivity was decreased in AD patients as compared with controls (p<0.005).
Again, MCI patients scored intermediate of controls and AD patients. The covariate age was not significant (F (1,51)=0.49, p=0.49). The coherence parameters did not differ significantly between groups during either eyes closed (F(2,52)=1.2, p=0.30) or memory activation (F(2,51)=0.1, p=0.90).

Table 2. EEG differences between AD, MCI and controls

<table>
<thead>
<tr>
<th></th>
<th>Controls</th>
<th>MCI</th>
<th>AD</th>
</tr>
</thead>
<tbody>
<tr>
<td>eyes closed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>theta relative power (%)</td>
<td>25 (11)</td>
<td>33 (17)</td>
<td>51 (19)**^</td>
</tr>
<tr>
<td>alpha coherence</td>
<td>0.72 (0.8)</td>
<td>0.69 (0.7)</td>
<td>0.66 (0.4)</td>
</tr>
<tr>
<td>memory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>alpha reactivity (%)</td>
<td>38 (29)</td>
<td>16 (33)</td>
<td>0.2 (36)*</td>
</tr>
<tr>
<td>alpha coherence</td>
<td>0.67 (0.8)</td>
<td>0.67 (0.7)</td>
<td>0.65 (0.4)</td>
</tr>
</tbody>
</table>

Values in the table are means with SD in parentheses. Age corrected p-values are noted. * differs from controls (p<0.01); ** differs from controls (p<0.001); ^ differs from MCI patients (p<0.01).

Correlations between EEG and neuropsychological measures

Correlations are displayed in Table 3 and illustrated in Fig 2. Significant correlations were observed between theta relative power during eyes closed and tests of global cognition (CAMCOG), memory (WMS, ADAS and picture learning), language (CAMCOG language) and executive functioning (category fluency, trails B and digit symbol). In all cases, decreased performance was related to higher theta relative power, i.e. a slowing of the EEG.

Fig 1. Grand average power and coherence spectra
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Alpha reactivity during memory activation was correlated with tests of global cognition (CAMCOG), memory (WMS, ADAS and picture learning) and executive functioning (category fluency, trails A and B and digit symbol). In all cases, decreased performance indicated decreased alpha reactivity during memory activation.

Alpha coherence during either eyes closed or memory activation was not related to neuropsychological test performance.

Table 3. Correlations between EEG and neuropsychological measures

<table>
<thead>
<tr>
<th></th>
<th>eyes closed</th>
<th>memory activation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>theta</td>
<td>alpha reactivity</td>
</tr>
<tr>
<td></td>
<td>relative</td>
<td></td>
</tr>
<tr>
<td>power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neuropsychological tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>global</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMSE</td>
<td>-0.30</td>
<td>0.20</td>
</tr>
<tr>
<td>CAMCOG</td>
<td>-0.43***</td>
<td>0.35*</td>
</tr>
<tr>
<td>memory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WMS</td>
<td>-0.41**</td>
<td>0.40**</td>
</tr>
<tr>
<td>CAMCOG memory</td>
<td>-0.29</td>
<td>0.29</td>
</tr>
<tr>
<td>ADAS</td>
<td>-0.45***</td>
<td>0.44***</td>
</tr>
<tr>
<td>Picture learning</td>
<td>-0.49***</td>
<td>0.55***</td>
</tr>
<tr>
<td>language</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boston</td>
<td>-0.29</td>
<td>0.33</td>
</tr>
<tr>
<td>CAMCOG language</td>
<td>-0.49***</td>
<td>0.24</td>
</tr>
<tr>
<td>executive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>letter fluency</td>
<td>-0.29</td>
<td>0.38</td>
</tr>
<tr>
<td>functioning</td>
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<td></td>
</tr>
<tr>
<td>category fluency</td>
<td>-0.37*</td>
<td>0.43**</td>
</tr>
<tr>
<td>trails A³</td>
<td>0.32</td>
<td>-0.38**</td>
</tr>
<tr>
<td>trails B</td>
<td>0.13</td>
<td>-0.29</td>
</tr>
<tr>
<td>digit symbol</td>
<td>-0.39*</td>
<td>0.48***</td>
</tr>
</tbody>
</table>

Values in the table are partial correlation coefficients (controlled for age). * p<0.01; ** p<0.005; *** p<0.001. Significant correlations are printed in bold. A³log transformed values were used for data analysis.
Discussion

The current study examined EEG power and coherence in elderly with different levels of cognitive functioning, ranging from controls without cognitive complaints to AD. EEG was registered during both eyes closed and memory activation. Furthermore, an extensive neuropsychological test battery was used to assess cognitive functioning. We observed significant correlations between EEG power and cognitive functioning in several domains, including global cognition, memory, language and psychomotor speed. Overall alpha coherence was however not correlated with performance on any neuropsychological test.

EEG power

As in earlier studies, we observed a slowing of the rest EEG in AD patients, reflected in higher absolute and relative theta power. An increase in theta power is considered one of the earliest changes in AD, whereas alpha activity decreases later during the course of the disease [9, 16]. As the AD patients in our study were only mildly impaired, our findings are compatible with these.

Alpha reactivity during memory activation was significantly decreased in AD patients only. In previous research decreased lower and upper alpha reactivity has been linked with worse memory performance and is thought to reflect attentional abilities and semantic memory processes [20]. Consequently, in view of their memory impairment, we expected to find decreased alpha reactivity in MCI patients as well. This was indeed found in a previous study by our research group, particularly in the lower alpha band [35]. In the current study we decided not to split the alpha band for several reasons. Firstly, the use of lower and upper alpha bands is not consistently used in EEG research in memory clinic populations, limiting the generalizability of our findings [2, 5, 14, 15, 25, 25]. Secondly, we did not expect any additional results as the lower and upper alpha bands respond similarly to memory activation. In fact, when comparing only MCI patients and controls, we did find decreased alpha reactivity during memory activation in MCI patients. Finally, we aimed to restrict the number of EEG parameters in the study as much as possible.

Correlations between EEG power and cognitive performance

Increased theta relative power and decreased alpha reactivity indicated worse neuropsychological test performance in several cognitive domains. Our findings confirm earlier reports on relations between increased theta activity and lower scores on the GDS or MMSE [7, 26]. In addition to relations with global cognition, theta relative power was associated with memory performance and executive functioning in a
negative manner. Furthermore, it was the only EEG measure related to language performance in a similar negative manner. Theta power during rest has been found to increase with dementia and decreasing cognitive performance in general [20]. Apparently, theta power during rest is correlated with global cognitive functioning and cannot be linked to any cognitive domain in particular.

Previous studies discovered similar relations between decreased alpha (re)activity and worse performance on memory tasks [20, 35]. In addition, the current study revealed pronounced positive relations between alpha reactivity and performance on executive tests. In a lesser degree, alpha reactivity was positively associated with global cognition. Reactivity of the lower alpha band has been linked with general task demands and attentional abilities [20]. As our time-limited, executive tasks required high attentional resources, the pronounced relation between alpha reactivity and tests of executive functioning (i.e. category fluency, trails and digit symbol) seems plausible.

As both EEG power measures complement each other in their relations to cognitive functioning, their combination might prove useful in predicting longitudinal cognitive decline or subsequent dementia in MCI patients. Longitudinal studies are needed in this respect.

**EEG coherence**

We did not find any group differences in alpha coherence during eyes closed or memory activation. These results contradict earlier research. An overall finding in AD is decreased alpha coherence during either rest or memory activation, which has been observed in several electrode pairs [1, 13, 16]. In MCI, alpha coherence was found to be increased in several inter-hemispheric electrode pairs, but only during memory activation [17]. However, the methodologies of the above mentioned studies vary widely and coherence effects were found in varying locations. The absence of a group effect in the current study might be due to several factors including the use of a global coherence measure, the correction for age or differences in disease severity. At present we cannot distinguish between these possibilities.

**Correlations between EEG coherence and cognitive performance**

Previous cross-sectional studies did not discover any associations between intra- and interhemispheric coherences in several frequency bands and cognitive performance [1, 17, 19]. As most of these studies used only MMSE scores as measure of cognitive performance, we attempted to look into relations with a more diverse range of neuropsychological tests. However, the current study did not reveal any associations between alpha coherence and cognitive performance either.
As EEG power was correlated with performance in multiple cognitive domains, we conclude that measures of EEG power are superior over coherence in their relations to cognition and are possibly more suitable for studies of longitudinal cognitive decline and the prediction of dementia.

Advantages of the current study include the use of an extensive neuropsychological test battery, which enabled us to correlate EEG measures with performance in several cognitive domains. EEG was registered during both eyes closed and memory activation. Furthermore, we attempted to limit the number of parameters in the correlation analysis by choosing four global EEG parameters. This approach is justified by previous studies that have observed global EEG changes in both MCI and AD patients [17, 24, 31, 35]. The emphasis on possible clinical utility lies at the basis of the choices we made, and explains a preference for a small set of evidence-based EEG parameters that cannot be affected overly by recording problems, and are therefore suitable for clinical practice. This approach has its limitations as we were unable to look into location effects or examine a wider frequency range. Previous research using a more refined and detailed approach have unraveled interesting EEG and MEG abnormalities in MCI and AD [3, 4, 11, 31-33]. However, we have from the outset chosen a different approach, based on the fear that the detailed approach may certainly be valuable from a scientific point of view, but runs the risk of losing the ultimate goal of all medical research from sight, and that is to be clinically useful.

In conclusion, power measures reflecting slowing and decreased reactivity of the EEG, but not coherence measures, are associated with decreased performance in multiple cognitive domains. These EEG power measures might prove useful in prospective studies aimed at predicting longitudinal cognitive decline and dementia. Furthermore, they are potentially valuable for evaluating the efficiency of cognitive enhancement therapies. EEG during alternative cognitive paradigms targeting language or executive functioning might also be useful in this respect.
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Fig 2. Scatterplots of the strongest correlations per cognitive domain

A. Global cognition and theta relative power

B. Memory and alpha reactivity

C. Language and theta relative power

D. Executive functioning and alpha reactivity
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References


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