EEG during memory activation: a study of early functional brain changes in Alzheimer's disease and Huntington's disease
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EEG and MRI correlates of mild cognitive impairment and Alzheimer’s disease

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Abstract

To investigate whether cognitive function in the spectrum of normal aging to Alzheimer’s disease is better reflected in MRI or EEG measures, or a combination of both. Cognitive functions were tested in 33 elderly subjects: 10 with probable Alzheimer’s disease, 11 with mild cognitive impairment and 12 controls. Structural brain parameters were derived from conventional MRI and a quantitative MR technique called Magnetization Transfer Imaging. The EEG provided measures of brain function. We performed multiple linear regression analyses to relate EEG and MRI parameters to global cognition, memory, language and psychomotor speed. The model showed EEG alpha reactivity during eyes open to be the primary factor associated with global cognition, memory and language skills. Brain atrophy was the primary factor associated with psychomotor speed. Furthermore, EEG alpha reactivity during eyes open explained significant additional variability in psychomotor speed. EEG and MRI are each associated with different aspects of cognitive function and complement each other in their relations to psychomotor speed.
Introduction

Probable Alzheimer's disease (AD), the most common cause of dementia in elderly, is a progressive neurodegenerative disorder which gradually impairs cognitive functioning [3]. In mild cognitive impairment (MCI) a yearly conversion to AD of 1-25% has been reported [14]. MCI is characterized by isolated memory impairment that does not interfere with activities of daily living. A challenging aspect of MCI is its heterogeneity; some patients develop AD, others another type of dementia and yet others reverse to their premorbid level of functioning.

Measures of brain structure and function are potentially valuable in understanding MCI and AD, as they can provide insight in early disease processes and may facilitate early diagnosis [28]. Using conventional MRI, structural brain changes have been found in patients with MCI, including hippocampal and entorhinal cortex atrophy [12, 28]. Magnetization Transfer Imaging (MTI), a quantitative MR-technique which is highly sensitive to structural brain damage, has demonstrated more widespread brain damage in MCI and AD patients [23]. Looking into specific tissue types, structural brain damage was found in both the gray and white matter even before patients were clinically demented [23, 24].

EEG studies have explored electrophysiological changes in MCI and AD. In conventional resting state EEG, high theta power, low beta power, slowed mean frequency and spatial aspects of alpha frequency have been found to predict future development of AD in MCI [5, 6]. However, in cross-sectional EEG studies no differences were found between cognitively unimpaired controls and MCI patients, unless (memory) activation paradigms were used [13, 15, 25].

Both EEG and MRI parameters have been related to cognition. Poor test performance on psychometric tests, such as the Mini Mental State Examination and Alzheimer Disease Assessment Scale, has been linked with a decrease in EEG mean frequency, peak frequency and beta-1 activity [2]. In a study with a large group of elderly subjects with different levels of cognitive impairment, the authors found theta activity to increase with increasing deterioration on the Global Deterioration Scale [16]. Furthermore, theta and upper alpha oscillations directly reflect memory processes, such as the encoding of new information and search and retrieval processes in long-term memory [9]. Limited studies have focused on the relation between MTI measures and cognition in patients with memory complaints. In one recent study on this subject, it was demonstrated that cognitive decline in MCI and AD is associated with widespread structural brain damage [24]. In patients with multiple
sclerosis strong correlations between volumetric MTI and cognitive functioning have been found as well [21].

To our knowledge, few researchers have used combined MRI and EEG measures to develop a model of cognitive impairment in patients with memory complaints. MRI and EEG techniques might be complementary in the (early) diagnosis of dementia [7, 20]. The current study aims to investigate, in a cross-sectional design, whether cognitive function in the spectrum of normal aging to Alzheimer’s disease is better reflected in MRI measures of brain structure, EEG measures of brain function, or a combination of both.

**Methods**

**Subjects**

Forty-one elderly subjects with different levels of cognitive functioning were recruited; results of eight could not be used (see below). Fifteen patients diagnosed with MCI [14] and eleven patients diagnosed with probable AD [10], who had been consecutively referred to the outpatient memory clinic of the Leiden University Medical Center, participated in the study. Fifteen control subjects without cognitive impairment 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. Furthermore, patients and controls were asked to participate in an additional EEG examination within three months from standard diagnostic work-up. All patient histories were reviewed and diagnoses reached in multidisciplinary consensus meetings. 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 white matter hyper intensities or an incidental small lacunar lesion (≤ 5 mm diameter). 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.

**Neuropsychological assessment**

A standardized neuropsychological test battery was used to assess cognitive functions. We selected four cognitive tests covering the most important cognitive domains. The Cambridge Cognitive Examination (CAMCOG) was used to assess global cognitive functioning [18]. Memory function was tested with the Wechsler Memory Scale (WMS) [27]. The Trail Making Test was used to measure psychomotor speed, including a
simple (Trails A) and a complex condition (Trails B) [17]. Language ability was assessed with the Boston Naming Task (BNT) [8].

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 before display and analysis, but recorded unfiltered. Sample frequency was 200 Hz and A-D precision 12 bits. We used the average reference montage. All EEGs were recorded in the afternoon in a room with dimmed lights. During recording subjects sat slightly reclined in a comfortable chair, approximately 1.5 m in front of a computer screen. Vigilance was monitored constantly using video registration and EEG recordings. An auditory stimulus was given in case of drowsiness.

Experimental procedure
The EEG was registered during two conventional EEG conditions and a working memory condition. The first conventional EEG condition concerned a 10-min period where subjects had to close their eyes while remaining awake, and the second a 3-min period with eyes open. The working memory condition concerned picture memory. Subjects were consecutively shown 10 pictures of common objects on a computer screen. Each picture was presented for 2 s and subjects were asked to name the shown objects aloud. After presentation of the pictures, subjects had to close their eyes and memorize the pictures for 15 s. Afterwards, subjects were asked to open their eyes and name as many pictures they could remember. The number of remembered pictures was noted. This task was performed three times using the same 10 pictures. From each of the three memorization periods one EEG sample, 4-8 s in length, was selected for further analysis.

EEG analysis
As eye movements, blinks and muscle activity may contaminate the EEG, samples free of such effects had to be selected by visual inspection. Sample selection was performed by the first author and corroborated by an experienced clinical neurophysiologist (AV). Both were blind to clinical diagnosis. Samples had to be 4-8 s in length and were selected during conventional eyes closed and eyes open, and the working memory condition. Frequency analysis was performed using a Fast Fourier Transformation (Focus- EEG imaging and review software, MEGIS software GmdH, München, Germany). We calculated absolute power in theta (4-8 Hz) and alpha (8-13 Hz) frequency bands. Lower and higher frequencies were not used as these are easily contaminated with blinks, eye movements and electromyographic activity in
cognitively impaired subjects. Four additional parameters were calculated per condition: (1) mean frequency in the 4-13 Hz spectrum during eyes closed (2) theta relative power during eyes closed (3) alpha reactivity during eyes open and (4) alpha reactivity during working memory. Alpha reactivity is defined as the percentile decrease in absolute alpha power as compared to the eyes closed condition. EEG parameters were averaged over all electrodes, and over the three selected EEG samples available for each of the eyes closed, eyes open and working memory conditions.

Data of five subjects were excluded, three because of drowsiness (two controls and one AD patient) and two because of extremely low EEG voltage on most leads (<10 μV; two MCI patients).

**MRI data acquisition**

MRI was performed on a 1.5 T MR system (Philips Medical Systems, Best, the Netherlands). Conventional proton density (PD) and T2-weighted dual spin-echo [48 axial slices, slice thickness=3 mm; no gap; TR/TE (ms) 3000/27(PD)/120; flip angle=90°; field of view=220 mm; matrix 256x256] and fluid attenuated inversion recovery (FLAIR) scans [48 axial slices; slice thickness=3 mm; no gap; TR/TE/TI (ms) 8000/100/2000; flip angle=90°, field of view=220 mm; matrix 256x256] were obtained. The line through the inferior border of the genu and splenium of the corpus callosum defined the direction of scanning. In addition to conventional MRI, MTI of the brain was performed with a gradient-echo pulse sequence [28 contiguous axial slices; slice thickness=5 mm; repetition time/echo time (ms)=106/6; flip angle=12°; field of view=220 mm; rectangular field of view=70%; matrix=256x256; a sinc-shaped saturation pulse 1100 Hz below the frequency of water was added]. These scanning parameters were chosen to minimize T1 and T2 weighting, resulting in a proton-density contrast in the absence of MT saturation pulses. Two consecutive sets of images were acquired; the first was performed in combination with an MT saturation pulse, and the second without.

Data of three subjects (two MCI patients and one control) were excluded because of insufficient scan quality due to motion artifacts. Ultimately, results of 10 AD patients, 11 MCI patients and 12 control subjects were submitted to statistical analysis.

**Image post-processing**

Images were analyzed using Software for Neuro-Image Processing in Experimental Research (SNIPER), an in-house developed program for image processing [22]. For an extensive description of MTI post-processing we refer to earlier studies by our research group [23, 26]. Briefly, post-processing included the following steps. First, the PD image was used to create an intracranial mask. The PD and T2-weighted
images were then combined to generate segmentations of cortical gray and white matter. Magnetization Transfer Ratio (MTR) values were calculated for each voxel and their frequency distributions were displayed as MTR histograms. From each histogram, the MTR peak height was derived and normalized for brain size and atrophy by dividing the number of voxels at the peak height by the total number of segmented parenchymal voxels. The normalized MTR peak height thus obtained is a measure reflecting the amount of remaining normal brain tissue in the gray and white matter independent of atrophy. Finally, using MTR values for all intracranial voxels, we calculated a measure of global brain atrophy by dividing the number of voxels representing cerebrospinal fluid (MTR<20%) by the total number of segmented intracranial voxels [1].

**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 non-parametric tests when appropriate. As age differed between groups, univariate ANOVA (ANCOVA) with age as covariate was used to compare neuropsychological test scores, EEG and MRI parameters between diagnostic groups. Post-hoc Bonferroni tests were used when diagnostic group effects were found. Furthermore, Pearson’s correlation analysis and linear regression analyses were performed to create models of cognitive impairment using both EEG and MRI parameters. Neuropsychological test scores were used as dependent variables. The level of significance was set at $p \leq 0.05$.

**Results**

**Clinical characteristics**
Clinical characteristics are shown in Table 1. Sex ratios and duration of education did not differ between groups. AD patients were significantly older than controls ($p<0.05$). Furthermore, we found a significant diagnostic effect for all neuropsychological tests. On all tests, AD patients had significantly lower scores than controls (all $p$-values $<0.001$) and MCI patients (all $p$ values $<0.05$), with the exception of the BNT where performance only differed between AD patients and controls ($p<0.05$). MCI patients had intermediate scores between AD patients and controls on all neuropsychological tests and scored significantly lower than controls on the CAMCOG and WMS ($p<0.001$). The covariate, age, did not have an effect on any of the test scores.

**EEG differences between diagnostic groups**
Data are shown in Table 2. We found a significant diagnostic effect for mean frequency scores ($F(2,29)=10.88$, $p<0.001$), theta relative power
(F(2,29)=7.19, p<0.01) and alpha reactivity during eyes open (F(2,29)=3.33, p<0.05) and working memory (F(2,29)=3.41, p<0.05).

Post-hoc tests revealed that AD patients had a significantly lower mean frequency than controls (p<0.01) and MCI patients (p<0.001). Similar mean frequency values were found for controls and MCI patients. Furthermore, the EEG spectrum of AD patients showed a larger percentage of theta activity as compared to controls (p<0.05) and MCI patients (p<0.01). Again, controls and MCI patients had similar values. Finally, we discovered that AD patients had lower alpha reactivity during eyes open (p<0.05) and working memory (p<0.05) as compared to healthy controls. In fact, on average, AD patients showed an increase in alpha power during working memory, while healthy elderly showed a decrease. For both alpha reactivity during eyes open and working memory, values of MCI patients were in between those of AD patients and controls. The covariate, age, was not significantly related to any of the EEG variables.

**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>4/8</td>
<td>5/6</td>
<td>5/5</td>
</tr>
<tr>
<td>age (yrs)</td>
<td>70 (6)</td>
<td>73 (4)</td>
<td>78 (8)*</td>
</tr>
<tr>
<td>education (yrs)</td>
<td>10 (3)</td>
<td>10 (4)</td>
<td>10 (4)</td>
</tr>
<tr>
<td>CAMCOG (/106)</td>
<td>96 (4)</td>
<td>83 (8)***</td>
<td>67 (10)***^^^</td>
</tr>
<tr>
<td>WMS (Memory Quotient)</td>
<td>121 (11)</td>
<td>93 (8)***</td>
<td>83 (9)***^</td>
</tr>
<tr>
<td>Trails A (s)*</td>
<td>39 (13)</td>
<td>52 (17)</td>
<td>142 (76)***^^</td>
</tr>
<tr>
<td>Trails B (s)</td>
<td>101 (35)</td>
<td>153 (100)</td>
<td>279 (66)***^^</td>
</tr>
<tr>
<td>BNT (/30)</td>
<td>26 (4)</td>
<td>23 (3)</td>
<td>19 (6)*</td>
</tr>
</tbody>
</table>

Values in the table are means with SD in parentheses. Age corrected p-values are noted for cognitive test scores. * differs from controls (p<0.05); ** differs from controls (p<0.01); *** differs from controls (p<0.001); ^ differs from MCI patients (p<0.05); ^^ differs from MCI patients (p<0.01); ^^^ differs from MCI patients (p<0.001).
CAMCOG=Cambridge Cognitive Examination; WMS=Wechsler Memory Scale; BNT=Boston Naming Task; *Trails A scores were log transformed.
**Table 2. EEG and MRI data of the study sample**

<table>
<thead>
<tr>
<th></th>
<th>Controls</th>
<th>MCI</th>
<th>AD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean frequency (Hz)</td>
<td>8.6 (0.4)</td>
<td>8.8 (0.3)</td>
<td>7.8 (0.7)**^^^</td>
</tr>
<tr>
<td>Theta relative power (%)</td>
<td>32 (10)</td>
<td>30 (10)</td>
<td>54 (18)*^^</td>
</tr>
<tr>
<td>Alpha reactivity eyes open (%)^a</td>
<td>47 (13)</td>
<td>36 (20)</td>
<td>20 (20)*</td>
</tr>
<tr>
<td>Alpha reactivity working memory (%)^a</td>
<td>19 (21)</td>
<td>2 (55)</td>
<td>-20 (28)*</td>
</tr>
<tr>
<td>MTR peak height gray matter^b</td>
<td>98 (16)</td>
<td>78 (14)*</td>
<td>80 (17)</td>
</tr>
<tr>
<td>MTR peak height white matter^b</td>
<td>176 (24)</td>
<td>154 (20)</td>
<td>155 (25)</td>
</tr>
<tr>
<td>Brain atrophy (%)</td>
<td>21 (7)</td>
<td>22 (5)</td>
<td>32 (7) *^^</td>
</tr>
</tbody>
</table>

Values in the table are means with SD in parentheses. Age corrected p-values are noted, except for brain atrophy (see text). * differs from controls (p<0.05); ** differs from controls (p<0.01); ^^ differs from MCI patients (p<0.01); ^^^ differs from MCI patients (p<0.001); ^Alpha reactivity; values represent the percentile decrease in absolute alpha power during eyes open or working memory as compared to eyes closed. ^bNormalized MTR peak height; values represent the number of voxels at the peak of the MTR histogram divided by the total number of segmented voxels (x 1000).

**MRI differences between diagnostic groups**

We found a significant diagnostic effect for gray matter MTR peak height (F(2,29)=4.04, p<0.05) and atrophy (F(2,30)=10.86, p<0.01). The white matter MTR peak height did not differ between groups. The covariate, age, was not significantly related to gray matter MTR peak height and atrophy. However, age was significantly related to white matter MTR peak height (F(1,29)=4.09, p<0.05) in that older subjects had a smaller white matter MTR peak height. Post-hoc tests revealed that the gray matter MTR peak height was significantly smaller in MCI patients as compared to controls (p<0.05). Furthermore, the brains of AD patients showed more atrophy than the brains of controls (p<0.001) and MCI patients (p<0.01).

It should be noted that the statistical assumption ‘homogeneity of regression slopes’ was not tenable in the ANCOVA with atrophy as dependent variable. Therefore we decided to report ANOVA results, supported by the fact that age itself was not significantly related to atrophy.

**Regression analyses of cognition**

In order to limit the number of independent variables in the regression analyses beforehand, we used Pearson’s correlation analysis and selected three parameters with the highest correlations with cognitive parameters (Table 3). This lead to the following parameters: theta relative power, alpha reactivity during eyes open and brain atrophy. Multiple linear regression models were performed to investigate relations between EEG and MRI variables on the one hand, and cognitive function...
on the other (Table 4 and Fig 1). Alpha reactivity was the primary factor associated with scores on the CAMCOG (p<0.01), WMS (p<0.05) and BNT (p<0.05). We found that higher alpha reactivity indicated better performance, reflected in higher scores on CAMCOG, WMS and BNT.

The model showed brain atrophy to be the primary factor associated with Trails A (p<0.05) and Trails B (p<0.01). More atrophy indicated more time on Trails A and B. Furthermore, alpha reactivity during eyes open explained significant additional variability in Trails B scores (p<0.05) in that more alpha reactivity indicated less time on Trails B.

**Table 3.** Correlations between cognitive test scores and EEG and MRI parameters

<table>
<thead>
<tr>
<th></th>
<th>CAMCOG</th>
<th>WMS</th>
<th>BNT</th>
<th>Trails A*</th>
<th>Trails B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean frequency</td>
<td>0.51**</td>
<td>0.43*</td>
<td>0.36*</td>
<td>-0.41*</td>
<td>-0.35</td>
</tr>
<tr>
<td>Theta relative power</td>
<td>-0.56***</td>
<td>-0.49**</td>
<td>-0.41*</td>
<td>0.37*</td>
<td>0.37*</td>
</tr>
<tr>
<td>Alpha reactivity eo</td>
<td>0.69***</td>
<td>0.61***</td>
<td>0.53**</td>
<td>-0.45**</td>
<td>-0.54**</td>
</tr>
<tr>
<td>Alpha reactivity wm</td>
<td>0.19</td>
<td>0.36*</td>
<td>-0.001</td>
<td>-0.19</td>
<td>-0.29</td>
</tr>
<tr>
<td>MTR peak height gm</td>
<td>0.31</td>
<td>0.42*</td>
<td>0.06</td>
<td>-0.07</td>
<td>-0.31</td>
</tr>
<tr>
<td>MTR peak height wm</td>
<td>0.21</td>
<td>0.33</td>
<td>0.06</td>
<td>0.06</td>
<td>-0.22</td>
</tr>
<tr>
<td>Brain atrophy</td>
<td>-0.56***</td>
<td>-0.44**</td>
<td>-0.45*</td>
<td>0.49**</td>
<td>0.56***</td>
</tr>
</tbody>
</table>

Values are Pearson’s correlation coefficients. * p<0.05; ** p<0.01; *** p<0.001. CAMCOG=Cambridge Cognitive Examination; WMS=Wechsler Memory Scale; BNT=Boston Naming Task; eo=eyes open; wm=working memory; gm=gray matter; wm=white matter; Trails A scores were log-transformed.

**Discussion**

This study shows that cognitive function in the spectrum of normal aging to AD is reflected in both EEG and MRI parameters. Each parameter has specific cognitive correlates, but EEG and MRI also complement each other in modeling psychomotor speed. EEG alpha reactivity best reflected global cognition, memory and language ability. MRI brain atrophy was the primary factor associated with psychomotor speed on the Trail Making Test. Interestingly, we found that the EEG, reflecting brain function, was associated with a wider range of cognitive functions.
Table 4. Regression models of cognitive tests

<table>
<thead>
<tr>
<th></th>
<th>Theta relative power</th>
<th>Alpha reactivity eyes open</th>
<th>Brain atrophy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R²</td>
<td>β</td>
<td>B (SE)</td>
</tr>
<tr>
<td>CAMCOG</td>
<td>0.55</td>
<td>0.09</td>
<td>8(18)</td>
</tr>
<tr>
<td>WMS</td>
<td>0.40</td>
<td>0.05</td>
<td>5.4(28)</td>
</tr>
<tr>
<td>Trails A*</td>
<td>0.31</td>
<td>-0.15</td>
<td>-0.27(0.5)</td>
</tr>
<tr>
<td>Trails B</td>
<td>0.46</td>
<td>-0.34</td>
<td>-219(144)</td>
</tr>
<tr>
<td>BNT</td>
<td>0.33</td>
<td>0.14</td>
<td>4.2(7.8)</td>
</tr>
</tbody>
</table>

Linear regression analyses were performed with cognitive tests as dependent variables, and theta relative power, alpha reactivity during eyes open and brain atrophy as independent variables. Standardized regression coefficients (β) were noted to enable direct comparison of the effects on cognitive tests. The unstandardized coefficients (B) and standard errors (SE) are displayed on the right.* p<0.05; ** p<0.01. CAMCOG=Cambridge Cognitive Examination; WMS=Wechsler Memory Scale; BNT=Boston Naming Task; *Trails A scores were log transformed.

In the current study we encountered several well-known EEG abnormalities in AD patients, such as decreased mean frequency, increased relative theta power and decreased alpha reactivity during eyes open [7]. Earlier research has shown that alpha reactivity or suppression during eyes opening tends to decrease in several neurological disorders such as dementia. Furthermore, oscillations in the alpha band have been linked to IQ, memory and cognition in general [9]. Apparently, alpha reactivity is associated with a wide range of cognitive functions, rather than specific areas of cognition. Physiologically, alpha reactivity can be seen as an aspect of EEG slowing, which has been linked to dysfunctioning of cholinergic and monoaminergic systems [7].

In a previous study we discovered that working memory activation enhanced EEG abnormality in MCI. As compared to controls, EEG alpha reactivity during working memory was decreased in MCI patients [25]. The current study did reveal abnormal EEG reactivity during working memory in AD, but not in MCI patients. The absence of an MCI effect might be related to the use of a smaller number of patients and the large variability in alpha reactivity in response to working memory demands, which seems illustrative of the heterogeneity in the MCI group.

Few studies explored the cognitive correlates of structural brain damage measured with MTI in a memory clinic population. Global brain damage, as reflected by MTI parameters, has been related to decline in several cognitive domains [24]. On the other hand, a more recent study found
little evidence for correlations between white matter integrity, as measured with MTI, and cognitive ability in elderly subjects without dementia [4]. The current study corroborates these findings and did not reveal any significant relations between MTR peak height and cognitive test scores.

Brain atrophy, on the other hand, was independently associated with psychomotor speed. The Framingham offspring study discovered similar relations between brain atrophy and decreased performance on the Trail Making Test in a cohort of dementia- and stroke-free middle-aged subjects [19]. Another study, investigating neuropsychological profiles in relation to regional brain atrophy in Alzheimer patients, also found an inverse association between whole brain atrophy and psychomotor speed [11].

When looking into specific gray and white matter differences between diagnostic groups, only the gray matter MTR peak height was decreased in MCI patients as compared with controls. In comparison, an earlier study by our research group discovered brain changes in both the gray and white matter of AD and MCI patients [26]. The inclusion of a smaller number of subjects and our stringent statistical procedure correcting for age might explain the absence of a more extensive group effect.

Based on previous findings in MCI and AD, the current study addressed global instead of regional EEG and MRI parameters [23]. We did, however, briefly check whether diagnostic group differences in our study population were pronounced in frontal, temporal, parietal or occipital regions by applying a statistical repeated measures design with region as within subject variable. As expected, no regional effects could be detected. Hence, the use of global EEG and MRI parameters seems to have potential value for clinical routine as they provide valid and less labor-intensive measures.

Strengths of the current study include blinding and largely automated segmentation methods for MRI and EEG data. Furthermore, we studied the full spectrum of cognitive function in the elderly. To our knowledge this is the first study looking into the relation between cognition on the one hand, and both EEG and MRI on the other. Potential limitations include the small sample size. Furthermore, by purposely seeking out EEG epochs without blinks, eye movements and electromyographic activity, our selection may be biased -as in most EEG research- towards those samples with the largest amount of alpha activity. Moreover, a prospective study design would provide additional information concerning EEG and MRI associations with future cognitive impairment and conversion to dementia.
In conclusion, global changes in brain function, as measured with EEG, and brain atrophy, as measured with MRI, are each associated with different aspects of cognitive aging and complement each other in modeling psychomotor speed. We discovered that two relatively simple and global measures are most useful; EEG alpha reactivity is best associated with tests of global cognition, memory and language ability, while MRI brain atrophy is best correlated with a test of psychomotor speed. Interestingly, EEG as measure of brain function is correlated with a wider range of cognitive domains. As EEG and MRI each have specific cognitive correlates, it seems worthwhile to further study the combination of both techniques in predicting future cognitive impairment and dementia.
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Fig 1. Single associations between cognitive test scores and alpha reactivity during eyes open, and between cognitive test scores and brain atrophy (N=33).
References


[11] Pantel J, Schonknecht P, Essig M, Schröder J. Distribution of cerebral atrophy assessed by magnetic resonance imaging reflects patterns of


