Differences in quantitative electroencephalogram and voxel based volumetry between encoding and retrieval amnestic Mild Cognitive Impairment

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INTRODUCTION

amnestic mild cognitive impairment (MCI) is hypothesized to be the prodromal stage of dementia due to AD. Approximately 80% of patients with amnestic MCI progress to AD dementia within 6 years.

According to memory impairment patterns, amnestic MCI can be divided into two subtypes that show either encoding or retrieval failure. Encoding failure (EF) is a problem of both storing and recalling of information, while retrieval failure (RF) is a problem of recalling only, with intact storing processes in long-term memory. It has been suggested that EF originates from hippocampal dysfunctions such as those observed in AD, and that RF is rather caused by frontal or subcortical dysfunctions.

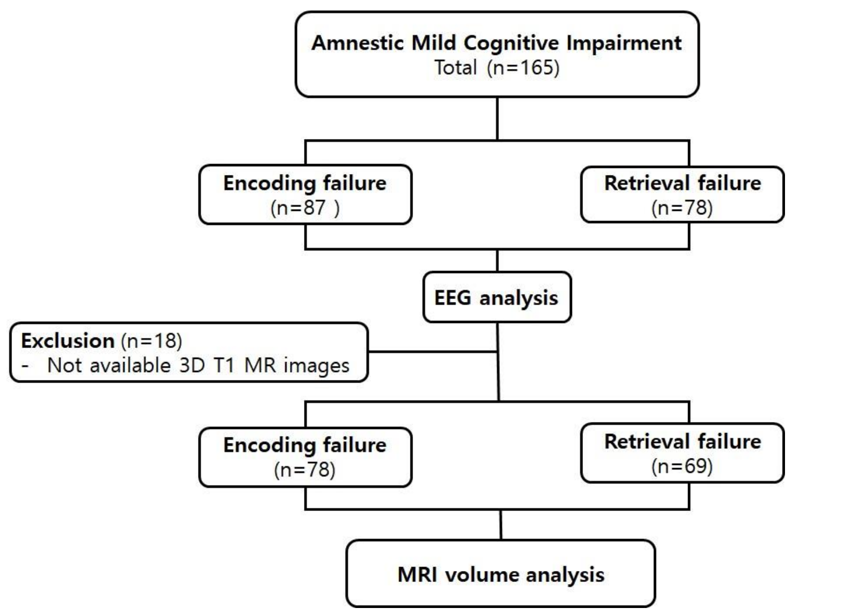
In this study, we thus aimed to explore functional and structural differences between EF and RF using quantitative electroencephalopathy (qEEG) and magnetic resonance imaging (MRI) volumetry.

METHODS

Subjects, EEG acquisition and Preprocessing

Subjects

Participants were aged 55 years or older, underwent 3D T1 MRI and qEEG within 2 weeks, and met the single-domain amnestic MCI criteria. The criteria were as follows: (1) presence of memory complaints; (2) intact performance of activities of daily living; (3) objective verbal memory impairments on the Seoul Neuropsychological Screening Battery (at least 1.0 SD below age- and education-adjusted norms); (4) Clinical Dementia Rating of 0.5 (1); and (5) not demented according to the Diagnostic and Statistical Manual of Mental Disorders (DSM)-IV criteria. Subjects were divided into an EF MCI and an RF MCI group. EF was defined as both delayed recall and recognition scores on a verbal learning test below 1.0 SD; RF was defined as only a delayed recall score below 1.0 SD. Resting-state EEG data were obtained from all 165 patients with amnestic MCI comprising 87 with EF and 78 with RF. 3D T1 MRI data were available for brain volume analysis for 147 of all subjects with amnestic MCI (for 78 with EF and 69 with RF) because of problems in the preprocessing of images (Figure 1).



Age-matched normal control (NC) subjects . The 3D T1 MRI imaging data of 71 NC were selected from the repository. The inclusion criteria for NCs were as follows: (1) from a community-based population; (2) no abnormalities based on a health screening questionnaire; (3) absence of memory complaints; (4) a Korean Dementia Screening Questionnaire score ≤ 6; (5) a Mini-Mental State Examination (MMSE) score > 26; (6) intact activities of daily living (K-IADL ≤ 0.42); (7) no history of thyroid dysfunction, vitamin B12 deficiency, or folate deficiency; and (8) at least 6 years of education.

qEEG analysis of EF vs RF

EEG acquisition

- EEG were recorded with a digital 19-channel scalp EEG device, using the International 10–20 system (Fp1/2, F7/8, F3/4, T7/8, C3/4, P3/4, P7/8, O1/2, Fz, Cz, Pz) (Comet AS40 amplifier EEG GRASS; Telefactor, USA).

EEG analysis

- EEG noise preprocessing and group analyses were conducted using iSyncBrain™ (iMediSync, Inc., Korea) (https://isyncbrain.com/), a cloud-based, artificial intelligence EEG analysis platform. All preprocessing steps, denoizing using an advanced mixture independent component analysis (amICA), and qEEG feature extraction were performed on iSyncBrain™.

qEEG features were obtained at the sensor and at the source level. At the sensor level, relative power at eight frequency bands (delta [1–4 Hz], theta [4–8 Hz], alpha1 [8–10 Hz], alpha2 [10–12 Hz], beta1 [12–15 Hz], beta2 [15–20 Hz], beta3 [20–30 Hz], and gamma [30–45 Hz]) was calculated using a power spectrum analysis. In addition, power ratios (TBR2: theta/beta2) according to frequency bands were calculated. In the source level analysis, the current distribution across the brain was assessed using the standardized low resolution brain electromagnetic tomography technique to compare relative power values in 68 regions of interests (ROIs) and connectivity (the imaginary part of coherency) between ROIs. EEG coherence has been studied as a measure of brain connectivity and the imaginary part of coherency (iCoh) has been introduced to avoid volume conduction artifacts

MRI volumetry of EF and RF

We compared gray matter (GM) volume differences between 78 participants with EF and 69 with RF and between participants with MCI and 71 controls. we conducted voxel-based morphometry (VBM) on MRI scans acquired on 3-T scanners manufactured by Philips (Achieva, Amsterdam, the Netherlands). The data were analyzed using the Computational Anatomy Toolbox (CAT12) running on Statistical Parametric Mapping software (SPM12).

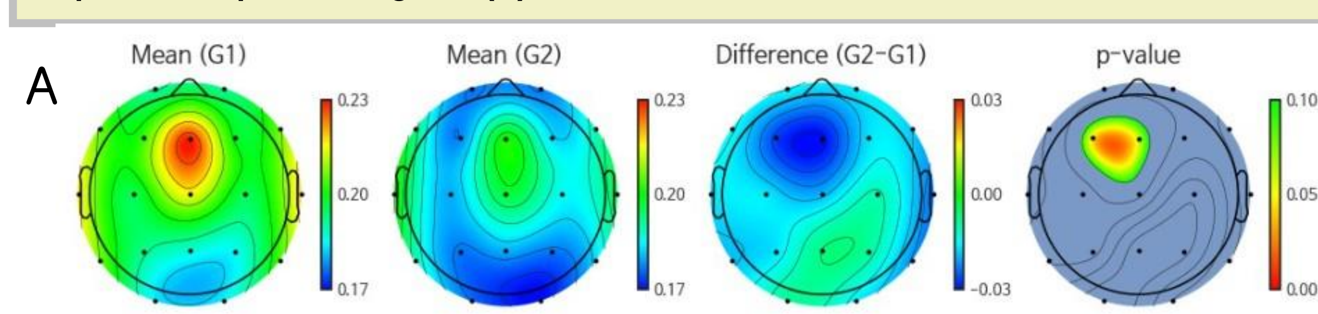
Statistical analysis

1. The obtained qEEG features were analyzed according to statistically significant differences between the EF and RF groups using iSyncBrain ™ ($p < 0.05$), and results at the sensor and the source level are presented separately.

2. To demonstrate GM volume changes underlying EF and RF in amnestic MCI, we conducted a comparison with processed MR images of cognitively normal subjects using Student's t-tests. Age and total intracranial volume (TIV), that is, the sum of the GM, WM, and CSF volumes, were classified as nuisance covariates in the GM volume comparisons between the groups.

RESULTS

In the sensor level analysis, the EF group showed significantly higher frontal theta power than the RF group (A). A higher average of theta power values across all channels was also observed in the EF group, as well as lower beta2 power in the frontal, central, temporal, and parietal regions (B).



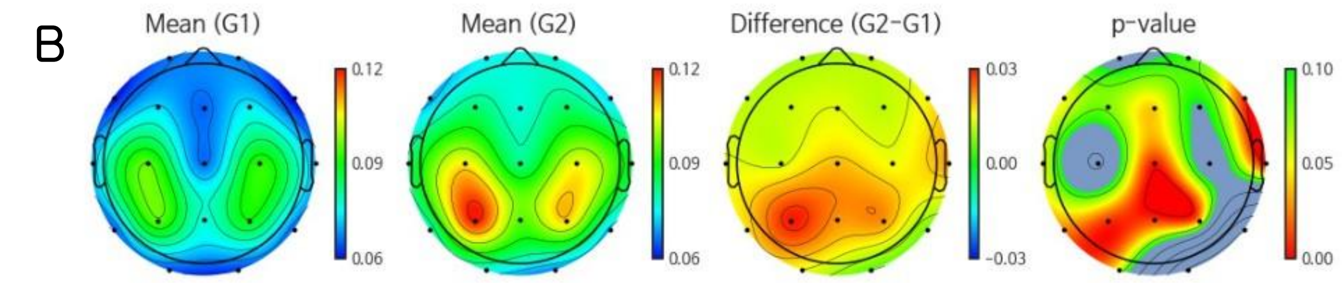
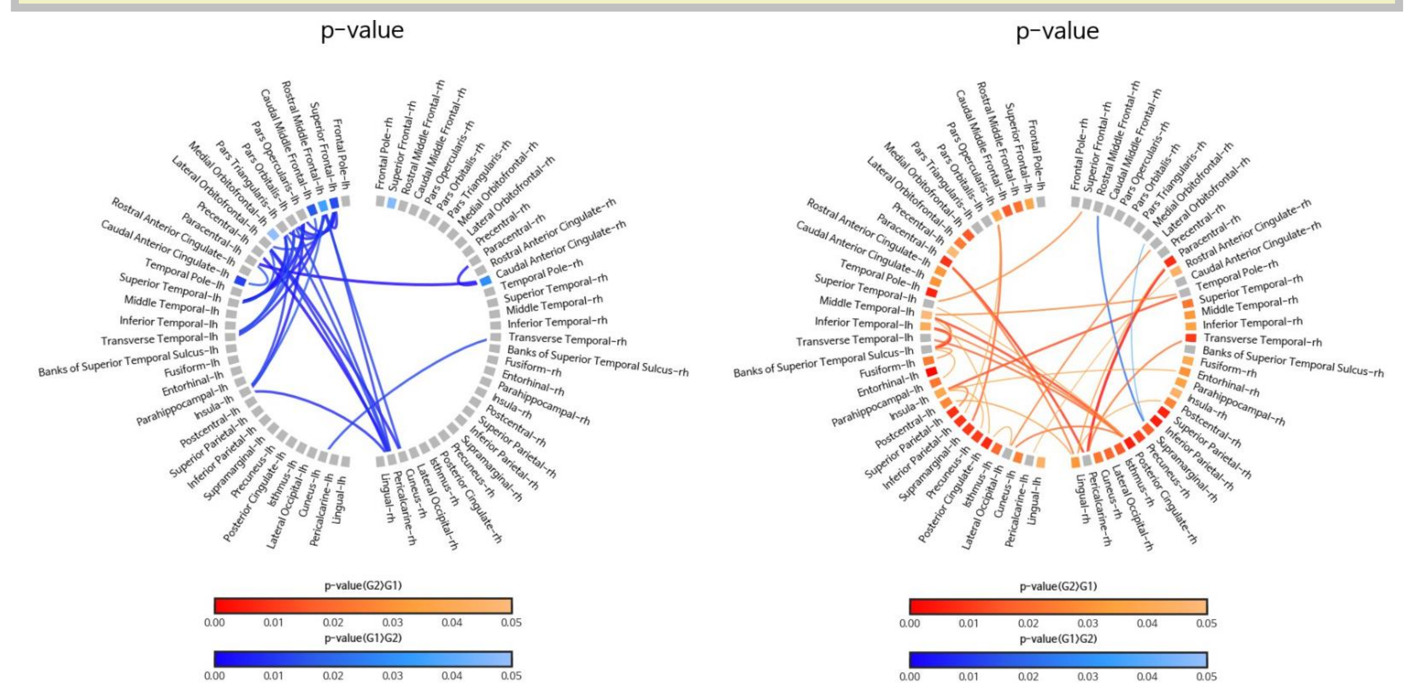
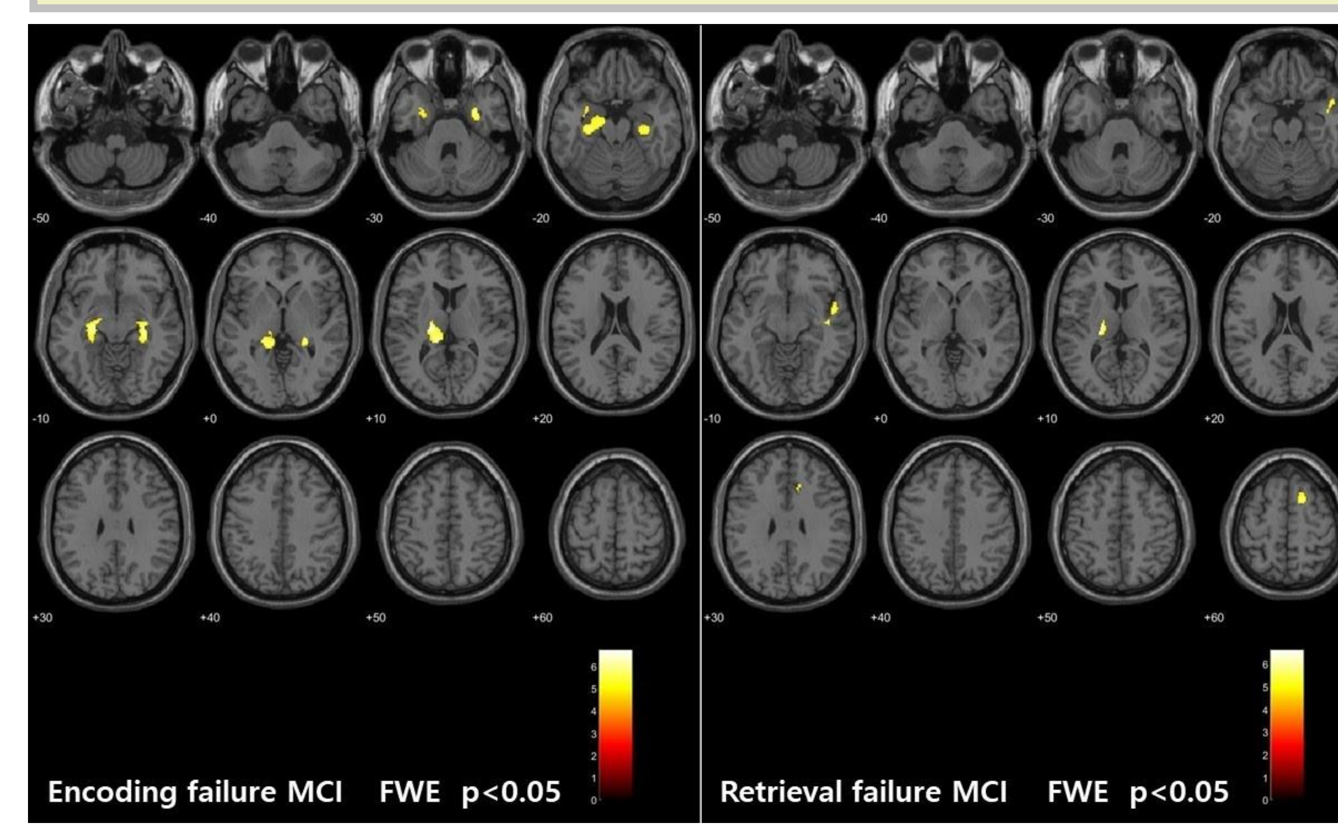


Figure shows the statistically significant difference between the EF and RF groups for the source power of 68 ROIs and the connectivity between the ROIs in the theta and beta2 bands. The theta band power in seven ROIs (bilateral superior frontal, left rostral middle frontal, left caudal middle frontal, left medial orbitofrontal, and bilateral caudal anterior cingulate regions) was significantly higher in the EF group.



The GM volume reductions underlying EF were located in the left thalamus and the bilateral hippocampi, while those underlying RF were located in the left thalamus, right superior frontal lobe, right superior temporal lobe, and right middle cingulum



CONCLUSIONS

By integrating power spectral analysis, EEG coherence analysis, and MRI volumetry analysis, we found that patients with EF due to amnestic MCI show a pattern that is more consistent with the prodromal stage of AD than the pattern observed in patients with RF.