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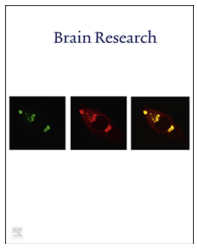

Research Report

The visual cognitive network, but not the visual sensory network, is affected in amnestic mild cognitive impairment: A study of brain oscillatory responses ☆

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ABSTRACT

Mild Cognitive Impairment (MCI) is considered in many as prodromal stage of Alzheimer's disease (AD). Event-related oscillations (ERO) reflect cognitive responses of brain whereas sensory-evoked oscillations (SEO) inform about sensory responses. For this study, we compared visual SEO and ERO responses in MCI to explore brain dynamics (Background). Forty-three patients with MCI (mean age=74.0 year) and 41 age- and education-matched healthy-elderly controls (HC) (mean age=71.1 year) participated in the study. The maximum peak-to-peak amplitudes for each subject's averaged delta response (0.5–3.0 Hz) were measured from two conditions (simple visual stimulation and classical visual oddball paradigm target stimulation) (Method). Overall, amplitudes of target ERO responses were higher than SEO amplitudes. The preferential location for maximum amplitude values was frontal lobe for ERO and occipital lobe for SEO. The ANOVA for delta responses showed significant results for the group Xparadigm. Post-hoc tests indicated that (1) the difference between groups were significant for target delta responses, but not for SEO, (2) ERO elicited higher responses for HC than MCI patients, and (3) females had higher target ERO than males and this difference was pronounced in the control group (Results). Overall, cognitive responses display almost double the amplitudes of sensory responses over frontal regions. The topography of oscillatory responses differs depending on stimuli: visualsensory responses

Abbreviations: SEO, sensory-evoked oscillatory responses; ERO, event-related oscillatory responses; AD, Alzheimer's disease; MCI, mild cognitive impairment; HC, healthy controls

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are highest over occipitals and -cognitive responses over frontal regions. A group effect is observed in MCI indicating that visual sensory and cognitive circuits behave differently indicating preserved visual sensory responses, but decreased cognitive responses (Conclusion).

1. Introduction

Recently, the increasing prevalence of Alzheimer's disease (AD) has caused an increase in the amount of investigators researching conditions of pre-dementia. The majority of patients with amnestic mild cognitive impairment (MCI) are believed to be in the symptomatic pre-dementia phase of AD. Individuals with MCI often have mild problems performing complex functional activities, but they do not lose their independence in daily life (Albert et al., 2011).

For many years, isolated brain regions were considered to be related to certain cognitive domains. However, the latest evidence indicates that the dynamic interactions of several widely distributed brain areas operating in large-scale networks results in cognition (Bressler and Menon, 2010). These networks can be assessed in several ways, including neurophysiological methods, which have an advantage of having higher resolution time (Başar, 2011). The brain consists of functional network dynamics and connectivity, both of which are crucial for normal functioning. Recent research on functional network disruption, which was assessed with electroencephalography or related methods, has shown that network abnormalities are somewhat specific to pre-dementia conditions (Pievani et al., 2011; Yener and Başar, 2013a). Oscillatory brain activity is a hallmark of neuronal network function and can accurately determine normal and abnormal brain functions. Brain oscillatory responses provide non-invasive analyses of cortico-cortical connectivity, local neuronal synchronization of firing, and coherence of rhythmic oscillations at various frequencies (Rossini et al., 2013a, 2013b). Event-related potentials (Papaliagkas et al., 2011) and oscillations (ERO) can be used as tools for detecting subtle abnormalities in cognitive processes, especially in dementia or related disorders. Here, the expression "event-related" is used to describe a potential elicited upon the application of a classical visual oddball paradigm. The term "sensory-evoked" is used when the potential is elicited by simple visual sensory stimulation, such as a simple light. Oscillatory responses transmit rhythms over distinct time durations, and they are elicited following Fourier transformation in post-stimulus time domain (Başar, 1980). In our previous work, we studied the ERO of AD (Yener et al., 2007; 2008; 2012) and MCI subjects (Yener et al., 2013; Güntekin et al., 2013). In addition, we also studied the sensory-evoked oscillations (SEO) (Yener et al., 2009) and evoked- and event-related coherences of AD (Güntekin et al., 2008, Yener and Başar, 2013b). Results of these previous studies indicate that group differences in paradigms using cognitive tasks (ERO or ER coherences) were much more prominent and widespread over the cortex than were those seen in SEO or SEO-coherences in patients with AD (Başar et al., 2010). In addition to diminished frontal theta (Yener et al., 2007, Caravaglios et al., 2010), we also reported reduced central, frontal and parietal delta responses upon cognitive stimulation (Polikar et al., 2007; Caravaglios et al., 2008; Yener et al., 2008; 2012) in AD. On the contrary, simple visual sensory stimulation evoked increased theta parieto-occipital oscillatory responses (Yener and Başar, 2010) in AD patients. We believe that these results indicate that there are fewer reactive heteromodal associations between cortices during cognitive processes and that there are possibly disinhibited visual cortices during simple sensory processes in AD patients (Yener and Başar, 2013a). Results of our previous studies supported the notion that sensory and cognitive circuits are activated differentially in AD patients. Comparing two paradigms in the same group of subjects can be used to determine the separation of sensory and cognition-related neural circuits. Our recently published studies focused on the reduced frontal-central-parietal target delta oscillatory responses (Yener et al., 2013) and diminished beta event-related power spectra in amnestic MCI patients (Güntekin et al., 2013). In the present study, we aimed to explore the behavior of neural networks related to cognitive and sensory processes by comparing visual target ERO and SEO responses in patients with MCI. To our knowledge, this is the first report comparing SEO and ERO responses in patients with MCI. Previous studies imply that connectivity between heteromodal cortices is disrupted (Pievani et al., 2010) and sensory cortices are spared at the clinical stage of MCI (Kantarci et al., 2010). These results indicate that electrophysiological investigations may provide insight into the basic fundamentals of visual sensory and cognitive networks. Such analyses could provide useful information related to the existence of and separation of sensory and cognitive neural networks in patients with MCI.

2. Results

The ANOVA on the delta responses revealed that there were no direct differences between the groups. However, the group × paradigm was significantly different between the groups [$F(1.79)=5.046$; $p<0.03$]. Post-hoc analysis indicated that there were significant differences between groups for delta responses upon presentation of the target stimulation, but not for the visual sensory stimulation. Post-hoc analysis indicated that the target stimulation elicited a higher delta response for the healthy subjects than it did for the MCI patients ($p<0.00001$). ANOVA for delta responses revealed significant results for paradigm [$F(1.81)=62.98$; $p<0.00001$], which indicated higher delta responses upon presentation of the target stimulation in comparison with the presentation of visual sensory stimulation ($p<0.00001$) (Fig. 1). Furthermore, significant differences were found for the following: anteriorposterior [$F(3.243)=3.776$; $p<0.02$]; coronal [$F(2.162)=24.792$; $p<0.00001$]; anteriorposterior × coronal [$F(6.486)=$