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Effects of alcohol on spontaneous neuronal oscillations: A combined magnetoencephalography and electroencephalography study

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Abstract

Electroencephalography (EEG) and magnetoencephalography (MEG) can detect different aspects of alcohol effects on auditory processing measured with event-related potentials and magnetic fields. The present study aimed to detect alcohol-induced changes in spontaneous neuronal oscillations with combined EEG and MEG techniques. The effects of alcohol on spontaneous neuronal rhythms were studied in 12 healthy subjects after 0.8 g/kg alcohol or juice in a double-blind, placebo-controlled, cross-over design using simultaneous high-resolution MEG and EEG in eyes-open and eyes-closed conditions. The data were analyzed with a power spectral density analysis. MEG recording showed that alcohol significantly increased the relative power of alpha rhythm (8–10 Hz) and reduced the relative power of beta activity (17–25 Hz) in both left and right hemispheres, but only in the eyes-closed condition. These effects did not depend on gender. No analogous statistically significant changes were observed in EEG rhythms. However, the power of alpha and beta rhythms was positively correlated in MEG and EEG recordings, indicating that MEG and EEG reflect similar processes. A distinct sensitivity of MEG and EEG to the sources of cortical oscillations, a better signal-to-noise ratio of MEG, as well as strong spatial blurring of potentials in EEG are most likely the reasons for the observed differences in the effects of alcohol on spontaneous oscillations as detected with two methods.

Keywords: Alcohol; Alpha rhythm; Beta rhythm; Electroencephalography (EEG); Magnetoencephalography (MEG)

1. Introduction

The changes in the brain spontaneous activity produced by alcohol have been widely investigated by electroencephalography (EEG). Most studies have shown an increase of alpha oscillations (10 Hz) after a moderate dose of alcohol ingestion (Ehlers et al., 1989; Ilan and Gevins, 2001; Noldy and Carlen, 1990). Biphasic changes in brain oscillations following alcohol administration have been observed: an initial increase in alpha and similarly in beta activity during the absorption phase followed by a decrease of those oscillations after 1 h (Schwarz et al., 1981). Apart from having an acute effect on neuronal oscillations, alcohol was shown to have pronounced effect on the resting EEG in subjects with predisposition to alcohol. According to some studies, alcoholics have increased power of beta oscillations in EEG recordings (Costa and Bauer, 1997; Winterer et al., 1998; Rangaswamy et al., 2002), and children of alcoholics also tend to have higher power of beta oscillations and lower power of alpha oscillations (Finn et al., 1999). In addition, low-voltage alpha in rest condition without alcohol consumption is regarded as an indicator of alcohol use disorders (Enoch et al., 1999). Alcohol-related changes in the central

Abbreviations: BAC, blood ethanol concentration; EEG, electroencephalography; fMRI, functional magnetic resonance imaging; MEG, magnetoencephalography; MMN, mismatch negativity.

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nervous system are thought to be mediated through the unbalance of excitation–inhibition with GABAergic activity being predominantly affected by alcohol (Wallner et al., 2003; Wei et al., 2004).

Magnetoencephalography (MEG) has better spatial resolution compared to EEG allowing a more focal investigation of activity originating from central and occipital areas of the brain. The advantage of MEG over EEG in source localization results from the skull and other extracerebral tissues being practically transparent to the magnetic field. EEG recordings, however, are impaired by distortions created by the conductivity of the scalp as well as inhomogeneous tissue conductivity. The magnetic recordings are also reference-free, whereas the electric brain maps may depend on the location of the reference electrode. However, EEG is capable of detecting both radially and tangentially oriented sources, while MEG is sensitive only to tangentially oriented sources. MEG has been shown to be an important tool in the investigation of brain dynamics after administration of CNS drugs (Kähkönen and Ahveninen, 2002). In these studies, the effects of drugs were investigated on the basis of event-related magnetic fields, which are time-locked changes due to external stimuli (Hari and Lounasmaa, 1989; Näätänen et al., 1994). Recently, we studied alcohol effects on auditory processing using mismatch negativity (MMN) and P3a responses with simultaneous MEG and EEG (Kähkönen and Marttinen Rossi, 2005). In this study, MMN amplitudes were reduced both in MEG and EEG similarly in both hemispheres. However, P3a amplitudes were decreased in EEG, but not in MEG. This study indicates that MEG and EEG are capable of detecting different aspects of alcohol effects on brain function.

Recently, the advantages of MEG and EEG have been extensively discussed with respect to the their ability to detect and localize epileptiform activity (Barkley, 2004; Baumgartner, 2004). Similar comparisons were made with respect to detection of coherence (Schack et al., 1999) and event-related responses (Komssi et al., 2004; Okada et al., 1999). To the best of our knowledge, there are no studies describing drug effects on spontaneous neuronal oscillations using simultaneous EEG and MEG recordings. Here, using whole-head MEG and EEG techniques, the effects of alcohol on spontaneous neuronal oscillations were studied. Our aim was to investigate whether these methods differ in their ability to detect alcohol-induced changes in neuronal oscillations. Since EEG and MEG measure the same neuronal processes, we hypothesized that there should be a correlation (between EEG and MEG data) of the effects caused by alcohol.

2. Materials and methods

2.1. Subjects

Twelve right-handed, non-smoking healthy subjects (aged 20–35 years, 7 females) took part in the study after a medical examination and mental-problem screening by a Symptom Check List (SCL-90; Derogatis et al., 1973). The institutional ethical committee approved the study and written consent was obtained from every subject. The subjects reported having used no caffeine for 12 h before the recording and no drugs other than the contraceptive pills during 2 weeks preceding the study. They were committed to refrain from consuming alcohol for 48 h and food for 3 h prior to experimental session.

2.2. Drug administration and study design

On the day of the experiment, subjects were given half an hour to drink 0.8 g/kg ethanol (10% v/v with orange juice) or orange juice in a double-blind, placebo-controlled, cross-over study design. The experiment started at about 1 h after alcohol ingestion was commenced. The blood ethanol concentration (BAC) was estimated using the SD-2 breath analyzer (Lion laboratories, Barry, UK) prior to and after 30 min of ethanol ingestion. The alcohol and placebo sessions were separated by approximately 1 week.

2.3. Assessment instruments

MEG was recorded with 306-channel system, consisting of 204 planar gradiometers and 102 magnetometers (Vectorview, Neuromag TM). Only gradiometers were used for the following analysis. EEG activity was recorded with 60-channel Ag/AgCl electrode cap (nose reference), a special amplifier was used for simultaneous EEG and MEG measurements (Virtanen et al., 1996, 1997). Before the measurements, the locations of four head position indicator coils were determined digitally in relation to the nasion and pre-auricular points. The head position relative to the coordinate system of the magnetometer was then calculated from the magnetic fields produced by the four coils. During the acquisition, the signals were digitized at the rate of 600 Hz and band-pass filtered at 0.03–100 Hz. Vertical and horizontal electro-oculograms were used for artifact rejection.

2.4. Data analysis

The recording session lasted 10 min during which the subjects kept their eyes open for 5 min and then closed for another 5 min. Spectral analysis was performed using the following procedure. Each MEG and EEG signal was divided into 2-s segments, each of which was detrended, then windowed using the Hanning function. Following this, the fast Fourier transform was applied to each segment. The magnitude of the Fourier-transformed signals was squared and averaged across all segments in order to obtain a power estimate. For MEG and EEG data, spectral characteristics were calculated for the right and left parieto-occipital and central regions. For MEG and EEG, the spectrums of four channels in the left and right central areas in both