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Suppression of early evoked gamma band response in male alcoholics during a visual oddball task

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Abstract

We investigated the early evoked gamma frequency band activity in alcoholics ($n=122$) and normal controls ($n=72$) during a visual oddball task. A time–frequency representation method was applied to EEG data in order to obtain phase-locked gamma band activity (29–45 Hz) and was analyzed within a 0–150 ms time window range. Significant reduction of the gamma band response in the frontal region during target stimulus processing was observed in alcoholic compared to control subjects. In contrast, significantly higher gamma band response for the non-target stimulus was observed in alcoholics compared to controls. It is suggested that the reduction in early evoked frontal gamma band response to targets may be associated with frontal lobe dysfunction commonly observed in alcoholics. This perhaps can be characterized by a deficient top-down processing mechanism.

Keywords: Gamma activity; EEG; Event-related oscillations; Alcoholism; Visual oddball task

1. Introduction

Gamma rhythms are important functional building blocks of brain electrical activity (Basar-Eroglu et al., 1996b). Oscillatory activities in the gamma range form a group of signals with common frequency characteristics but that are functionally related to diverse brain processes (Schurmann et al., 1995, 1997; Sannita et al., 2001). In humans, gamma activity has been observed in a variety of cognitive tasks involving selective attention, mental arithmetic, multistable visual perception, mental rotation, music perception, somatosensory perception, visuo-motor coordination, associative learning, semantic processing, short-term memory, conscious recollection, object representation and induced visual illusions (Desmedt and Tomberg, 1994; Basar-Eroglu et al., 1996a; Tallon-Baudry et al., 1996, 1999; Miltner et al., 1999; Tallon-Baudry and Bertrand, 1999; Bhattacharya et al., 2001a,b, 2002; Burgess and Ali, 2002; Schack et al., 2002; Chen et al., 2003; Fell et al., 2003; Umeno et al., 2003). Event related oscillations (EROs) in the gamma range can be found as phase-locked (evoked) or non-phase locked (induced) to the onset of the experimental stimuli (Tallon-Baudry et al., 1996).

Evoked gamma activity has been observed following auditory (Marshall et al., 1996; Yordanova et al., 1997a,b; Karakas and Basar, 1998; Haig et al., 1999, 2000a,b; Gurtubay et al., 2001; Kaiser and Lutzenberger, 2001; Muller et al., 2001; Palva et al., 2002; Debener et al., 2003; Karakas et al., 2003), visual (Tallon-Baudry et al., 1996; Herrmann et al., 1999; Herrmann and Mecklinger, 2000b; Braeutigam et al., 2001; Bottger et al., 2002; Senkowski and Herrmann, 2002; Watanabe et al., 2002) or somatosensory stimuli (Desmedt and Tomberg, 1994; Salenius et al., 1996). It has been observed at early (0–150 ms) and later (200–300 ms)

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time intervals (Herrmann et al., 1999). The functional significance of the early evoked gamma activity has been attributed to sensory processing (Karakas and Basar, 1998; Sannita et al., 1999) and is considered to be influenced by bottom-up as well as top-down information processing (Karakas et al., 2001, 2003). However, some researchers have associated this gamma activity to early stimulus selection and attentional processing (Tiitinen et al., 1993, 1997; Debener et al., 2003; Fell et al., 2003).

Abnormalities in gamma band activity have been observed in patients with psychiatric disorders (Lee et al., 2003). Studies in schizophrenic patients have shown abnormalities in amplitude, latency, topography and phase coherence of gamma band responses (Haig et al., 2000a; Green et al., 2003; Spencer et al., 2003). Investigations of other psychiatric disorders have been few in number. However, studies of patients with attention deficit hyperactivity disorder (ADHD), autism, Alzheimer's dementia and epilepsy patients with psychiatric symptoms have revealed aberrations in gamma band responses (Loring et al., 1985; Le Van Quyen et al., 1997; Grice et al., 2001; Yordanova et al., 2001; Green et al., 2003; Spencer et al., 2003).

Although there is a large literature showing the impact of alcoholism on several components of the event related potential (ERP), studies of event related oscillations (EROs) in alcoholics are few. The most commonly reported ERP deficit in alcoholics is the reduced amplitude of P300 for the task relevant target stimuli during oddball tasks (for review, see Porjesz and Begleiter, 1996). It has been suggested that ERP components are the end products of specific superpositions of oscillations in various frequency bands, and P300 consists primarily of delta and theta oscillations (Basar-Eroglu et al., 1992; Yordanova and Kolev, 1996; Basar et al., 1999; Karakas et al., 2000). A significant reduction of evoked delta and theta power has been observed in alcoholics while processing the target stimuli in a visual oddball paradigm, indicating that the reduced P300 amplitudes reported in alcoholics are caused by deficits in theta and delta oscillations that underlie P300 (Porjesz and Begleiter, 2003; Jones et al., in preparation). In a recent study, EROs were investigated using a Go/No-Go paradigm in alcohol dependent individuals (Kamarajan et al., 2004). A significant reduction in delta and theta bands was observed in the frontal region of alcoholics, suggestive of deficient inhibitory control and information processing mechanisms. In another study conducted in our laboratory, a reduction in frontal midline theta activity was observed in alcoholics during a mental arithmetic task (Suresh et al., in preparation).

Acute alcohol administration in normal individuals and investigations of heavy social drinkers has shown that EROs are sensitive to the short-term effects of alcohol. Krause et al. (2002) investigated the effect of alcohol on event related synchronization (ERS) and desynchronization (ERD) of theta and alpha bands during an auditory memory task; administration of alcohol decreased the early-appearing ERS responses during auditory encoding and increased the later-appearing ERD responses during retrieval in the theta and lower alpha frequency ranges indicating that alcohol has disorganizing effects on brain electric oscillatory systems during cognitive processing. In another study, Jaaskelainen et al. (2000) investigated the dose-related impact of alcohol on auditory transient evoked 40-Hz responses during a selective attention task. They found that higher doses of alcohol significantly suppressed the early evoked gamma responses in both attended and non-attended conditions. As gamma band responses have been associated with several cognitive functions, the authors concluded that this result indicates an alcohol-induced cognitive deficit. This study demonstrated that cognitive processing associated with gamma band activity is affected by alcohol administration. In a recent study, increased EEG synchronization in theta and gamma bands was observed in heavy social drinkers; this finding was similar across the brain areas for resting EEG, as well as during a mental rehearsal task (De Bruin et al., 2004).

Although there are numerous studies showing electrophysiological aberrations in alcoholism, event related gamma band oscillations have not been investigated. It has been demonstrated that gamma oscillations can be generated by GABAergic interneuronal activity (Whittington et al., 2000b). GABAergic receptors have been implicated in mediating the effects of alcohol in the central nervous system (Davies, 2003), suggesting a potential role for gamma oscillations in the electrophysiological processes of the alcoholic brain. Hence, in the present study we examined the early evoked gamma band activity in alcoholics during a visual oddball task, one of the most frequently used methods in ERP research. This task was chosen based on: 1) the consistent electrophysiological findings in alcoholics during visual oddball tasks, and 2) increased early evoked gamma band activity observed during target stimulus processing in visual oddball tasks in healthy individuals (Stefanics et al., 2004). Based on the evidence of electrophysiological deficits observed during target stimulus processing in alcoholics during visual oddball tasks, we hypothesized that the early evoked gamma activity to the target stimuli would be suppressed in alcoholics when compared to controls.

2. Materials and methods

2.1. Subjects

The participants were 194 adult males ranging from 19 to 40 years of age. The demographic and clinical characteristics of the sample are presented in Table 1. The alcoholic subjects ($n=122$; mean age=32.33 years; S.D.=4.28) were recruited from individuals undergoing treatment in the Short Term Alcohol Treatment Unit, Addictive Disease Hospital,