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Evoked gamma band response in male adolescent subjects at high risk for alcoholism during a visual oddball task

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Abstract

This study investigates early evoked gamma band activity in male adolescent subjects at high risk for alcoholism (HR; $n=68$) and normal controls (LR; $n=27$) during a visual oddball task. A time–frequency representation method was applied to EEG data in order to obtain stimulus related early evoked (phase-locked) gamma band activity (29–45 Hz) and was analyzed within a 0–150 ms time window range. Significant reduction of the early evoked gamma band response in the frontal and parietal regions during target stimulus processing was observed in HR subjects compared to LR subjects. Additionally, the HR group showed less differentiation between target and non-target stimuli in both frontal and parietal regions compared to the LR group, indicating difficulty in early stimulus processing, probably due to a dysfunctional frontoparietal attentional network. The results indicate that the deficient early evoked gamma band response may precede the development of alcoholism and could be a potential endophenotypic marker of alcoholism risk.

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

1. Introduction

Alcoholism is a multifactorial disease which has polygenic influence among biological relatives of alcoholics. A positive family history of alcoholism has been recognized as a consistent predictor of alcoholism risk. A detailed review of family studies indicates that alcoholics are 4 to 6 times more likely to have a parent who is alcohol dependent than are non-alcoholic controls (Cotton, 1979). Children of alcoholics (COAs) are 2 to 10 times more likely to develop alcoholism than non-COAs (Lieberman, 2000). A comprehensive review of the literature on the epidemiology of alcoholism concluded that genetic factors predispose sons of alcoholic fathers to alcoholism (Hesselbrock, 1995).

Electrophysiological abnormalities are one of the most extensively studied markers of high risk for alcoholism. Studies of alcohol naïve offspring of alcoholics at high risk (HR) indicate that the anomalous electrophysiological characteristics observed in alcoholics are already apparent prior to prolonged alcohol exposure (for review, see Porjesz et al., 2005). Several electrophysiological abnormalities have been reported in studies of offspring of alcoholics using electroencephalogram (EEG),

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event-related potentials (ERP) and event-related oscillations (EROs) methods. Reductions in EEG alpha and increases in beta power in male and female offspring of alcoholics have been reported by Finn and Justus (1999). Several studies have shown increased beta power in children of alcoholics (Gabrielli et al., 1982; Bauer and Hesselbrock, 1993; Pollock et al., 1995). In a recent investigation, Rangaswamy et al. (2004b) reported increased beta power in the resting EEG of a large sample of offspring of male alcoholics. In this study, male high risk offspring of alcoholics had elevated slow beta power (12–16 Hz) and female high risk offspring of alcoholics had increased faster beta power (16–28 Hz) when compared to low risk offspring of non-alcoholics. ERP deficits, particularly the reduced P300 component in children of alcoholics have been the most consistent finding in the investigations for a phenotypic marker for alcoholism. Begleiter et al. (1984) reported that male children of alcoholic fathers manifested significantly lower P3 voltages prior to any exposure to alcohol compared with matched males coming from low risk families without first or second degree alcoholic relatives. This finding has been replicated in younger and older male and female offspring of alcoholics (Begleiter et al., 1987; Benegal et al., 1995; Berman et al., 1993; Cohen et al., 1997; Ehlers et al., 2001, 2003; Hesselbrock et al., 1993; Hill and Steinhauer, 1993; Hill et al., 1995; O'Connor et al., 1986, 1987; Porjesz and Begleiter, 1990; Ramachandran et al., 1996; Ratsma et al., 2001; Rodriguez Holguin et al., 1999; van der Stelt et al., 1998; Whipple et al., 1991). In a comprehensive meta analysis, Polich et al. (1994) found that the strongest P300 group differences were obtained in young male offspring with relatively difficult visual tasks and concluded that low voltage P300 may have predictive value as an index of vulnerability for alcoholism.

Several studies have demonstrated that numerous ERP features arise from oscillatory changes due to sensory or cognitive processes which influence the dynamics of ongoing EEG rhythms of different frequency bands (Basar-Eroglu and Basar, 1991; Karakas et al., 2000a,b; Basar et al., 2001; Demiralp et al., 2001). It has been suggested that the P300 component of the ERP consists of superimposed event-related oscillations (EROs) of delta and theta bands (Basar-Eroglu et al., 1992; Yordanova and Kolev, 1996; Schurmann et al., 2001). Similar to the reduced P300 amplitudes observed in alcoholics, deficits in evoked delta and theta ERO amplitudes underlying P300 have been observed in alcoholics while processing the target stimuli during a visual oddball paradigm (Porjesz and Begleiter, 2003; Jones et al., in press). A recent investigation examined high risk children of alcoholics using the same visual oddball paradigm in order to determine whether these deficits in theta and delta oscillations antecede the development of alcoholism (Rangaswamy et al., in preparation). It was found that the 14–17 year old children of alcoholics have reduced delta and theta band ERO amplitude while processing the target stimuli compared to controls. Significant changes in EROs of higher frequency bands have also been observed in alcoholics during visual oddball tasks. In a recent study, significant reductions in early evoked gamma band activity were reported during target stimulus processing in alcoholics in a visual oddball paradigm (Padmanabhapillai et al., 2006).

Event related oscillations in gamma frequency band have been associated with several complex cognitive processes (Basar-Eroglu et al., 1996; Tallon-Baudry and Bertrand, 1999; Schack et al., 2002; Chen et al., 2003; Fell et al., 2003). A recent study that investigated the gamma band activity during multiple cognitive tasks concluded that task complexity augments gamma band power (Fitzgibbon et al., 2004). Event related gamma oscillations 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 band activity has been observed following auditory, visual and somatosensory stimuli (Desmedt and Tomberg, 1994; Marshall et al., 1996; Salenius et al., 1996; Tallon-Baudry et al., 1996; Yordanova et al., 1997; Haig et al., 1999; Herrmann and Mecklinger, 2000; Watanabe et al., 2002). It has been observed at early (0–150 ms) and later (200–300 ms) time intervals (Herrmann et al., 1999). The early evoked gamma was found to be insensitive to the stimulus type and was suggested to reflect sensory processing (Karakas and Basar, 1998; Sannita et al., 1999). However, some experiments have shown increased early gamma band activity during target stimulus processing indicating early stimulus selection and attentional processing (Tiitinen et al., 1993, 1997; Debener et al., 2003; Fell et al., 2003). In addition, early evoked gamma band response has been found to be correlated with neuropsychological functions such as attention, learning, memory and executive functions, suggesting that early gamma band response reflects basic sensory (bottom-up) as well as top-down information processing (Karakas et al., 2001, 2003).

The aim of the present study was to investigate early evoked gamma band response in subjects at high risk to develop alcoholism and to determine whether the reduction in gamma band activity observed in alcoholics is a consequence of chronic alcohol abuse or a predisposing factor. Since many of the electrophysiological abnormalities observed in alcoholics have also been observed in high risk subjects, in the present study we investigated the early phase locked gamma band activity in the children of alcoholics using the same task as we had used in alcoholics. For this purpose, early evoked gamma band response elicited during a visual oddball task, in male children of alcoholic parents, was compared to the response in age matched male children of non-alcoholic parents. A similar pattern of deficits in high risk children would indicate that these deficits precede the development of alcoholism; the present study aimed to examine early evoked gamma band response as a potential phenotypic marker for the development of alcoholism.

2. Materials and method

2.1. Subjects

Subjects included in this study were participants in the Collaborative Study on the Genetics of Alcoholism (COGA), a large multi-center study investigating the genetic predisposition to develop alcohol dependence and related disorders. The six participating centers are located at: SUNY-Downstate Medical Center, University of Connecticut Health Center, Washington University School of Medicine in St. Louis, University of California at San Diego, University of Iowa and Indiana University