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ABSTRACT

BACKGROUND: Binge Drinking (BD) typically involves heavy drinking over a short time, followed by a period of abstinence, and is common among young people, especially university students. Animal studies have demonstrated that this type of alcohol consumption causes brain damage, especially in the non-mature brain. The aim of the present study was to determine how BD affects brain functioning in male and female university students, during the performance of a visual working memory task. METHODS: Event-related potentials (ERPs) were recorded, with an extensive set of 32 scalp electrodes, in 95 first-year university students (age range 18-20 years), comprising 42 binge drinkers (BD) and 53 controls, in a visual "identical pairs" continuous performance task. Principal components analysis was used to identify and analyze the N2 (negative waveform with a latency around 200-300 ms related to attentional processes) and P3 (positive waveform with a latency around 300-600 ms related to working memory processes) components of the ERPs. RESULTS: In the matching condition of the task, the N2 component in central and parietal regions was significantly larger in the BD than in the control group. In the control group, the P3 component was larger in the matching than in the non-matching condition in the frontal, central and parietal regions, whereas the BD group did not show any significant differences between conditions in any region. CONCLUSIONS: The results of this study confirm the presence of electrophysiological differences between young university student binge drinkers and controls during the execution of a visual task with a high working memory load. The larger N2 in the BD group suggests higher levels of attentional effort required by this group to perform the task adequately. The absence of any differences in the P3 component in the different conditions (matching and non-matching stimuli) in the BD group suggests a deficiency in the electrophysiological differentiation between relevant

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and irrelevant information, which may reflect some impairment of working memory processes.

KEY WORDS: ERPs, binge drinking, university students, working memory, attention.

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INTRODUCTION

Binge Drinking (BD) is characterized by the consumption of large amounts of alcohol in a short time, followed by a period of abstinence, and is particularly common among young people, especially university students (Lange et al., 2002; Wechsler et al., 2002). The prevalence of BD in young people varies significantly (7-40%) among different countries (Hibell et al., 2004; Newes-Adeyi, et al., 2005; White et al., 2006; World Health Organization, 2004). Part of this variability may be attributed to a lack of consistent criteria for BD in non clinical samples (university students) and the use of different definitions as regards both the quantity of alcohol consumed per session and the frequency of BD episodes. However, the most frequently used and accepted definition of BD is the consumption of five or more standard alcoholic drinks (four or more for women) on one occasion (within a two hour interval, according to the National Institute on Alcohol Abuse and Alcoholism), at least once in the last two weeks (Keller et al., 2007; Presley and Pimentel, 2006; Syre et al., 1997; Wechsler et al., 1994, Wechsler and Austin, 1998; Wechsler et al., 2000; White et al., 2006) or in the last month (Griffiths et al., 2006; Jeninson, 2004; Kypry et al., 2005; McNally and Palfai, 2001; Xing et al., 2006), with periods of abstinence between episodes.

According to this definition, in a large-scale study in US universities, approximately 40% of students were classified as binge drinkers (Wechsler et al., 1995; Wechsler et al., 1998). Different studies carried out in Europe have reported a similar prevalence of BD in university students (D´Alesio et al., 2006; Gill, 2002). In a recent study by our research group in Spain (Caamaño et al, 2008), 37.1% of first-year university students (N= 2700) were found to consume large amounts of alcohol (‘risky consumption’) and 12.2% were classified as binge drinkers.

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It has been suggested that the adolescent brain is more sensitive to the neurotoxic effects of alcohol and BD than the adult brain, particularly those brain structures that mature late on in development, such as the hippocampus and the prefrontal cortex (Hunt, 1993; Monti et al., 2005; White and Swartzwelder, 2004). Animal models have shown that BD causes more brain damage in adolescent than in adult rats. Regions of the frontal association cortex are only damaged in adolescent rats (Crews et al., 2000) and inhibition of hippocampal neurogenesis is greater in adolescent than in adult rats (Crews et al., 2006). In addition, BD in adolescent rats causes learning deficits and impairment of spatial working memory that are not observed in control adolescent rats (Tokunaga et al., 2006; White et al., 2000); such impairment is greater than in adult rats with the same BD pattern (Markwiese et al., 1998; Silvers et al., 2003).

Numerous human studies with clinical samples have reported that adolescents with Alcohol Use Disorders (AUDs) show an important reduction in the volume of the hippocampus (De Bellis et al., 2000; Nagel et al., 2005) and prefrontal cortex (De Bellis et al., 2005; Medina et al., 2008), as well as deficits in visospatial abilities (Tapert and Brown, 1999), and especially in learning processes and working memory (Brown and Tapert, 2004; Tapert et al., 2002), as compared with adolescents without AUDs. Although few studies have investigated the neurobiological and neurocognitive effects of BD in non-clinical samples of adolescents and university students, it has been shown that young people who indulge in BD experience difficulty in carrying out tasks involving frontal lobe functions, such as working memory (Townshend and Duka, 2005; Weissenborn and Duka, 2003), planning, attention and decision making (Goudriaan et al., 2007; Hartley et al., 2004; Johnson et al., 2008).

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The event related potential (ERP) technique enables investigation of the brain mechanisms in attention and working memory -and the effects of alcohol on them- with high temporal resolution. This technique has been widely used to assess the neurocognitive effects of alcohol with other populations (alcoholics, abstinent chronic alcoholics, children of alcoholics) (Cadaveira.et al., 1991; Cohen et al., 1997; Cristini et al., 2003; Kamarajan et al, 2005; Miyazato and Ogura, 1993; Rodríguez Holguín et al., 1999a); two components of ERPs that are associated with attention and working memory processes, N2 and P3, have been shown to be particularly sensitive to alcohol (Easdon et al., 2005; George et al., 2004; Olbrich et al., 2000, 2002). Nevertheless, to our knowledge, only one study of BD in young people has been published: Ehlers et al. (2007) used a face recognition task and reported anomalies in the P3 component in BD young people (18-25), which they related to inhibition-related problems. However, these anomalies only appeared in BD subjects with other relevant factors such as a family history of alcoholism.

In the present study, the N2 and P3 components of the ERPs elicited in response to a visual Continuous Performance Task (CPT) were analyzed in order to assess the effects of BD on attention and working memory processes in young university students. The most complex and demanding versions of this task enable the study of executive functions such as sustained and transient attention, inhibitory processes and working memory (Borgaro et al., 2003; Kirmizi-Alsan et al., 2006; Riccio et al., 2001; Smid et al., 2006). One well known hypothesis states that the main cognitive function underlying CPT performance is a subcomponent of working memory: the ability to represent and maintain context information necessary to guide appropriate task behavior (Baddeley, 2001; Barch et al., 2001; Goldman-Rakic, 1999; Levy and Farrow, 2001).

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Thus, in the present study ERPs were recorded during the execution of a visual CPT with a high working memory load in a sample of young people (first-year university students) with and without a BD pattern of alcohol consumption: i) to establish whether ERPs differ between university student binge drinkers and corresponding control subjects, which may reveal any impairment in the process of attention and visual working memory; ii) to determine if the electrophysiological measurements associated with this task are affected differently by BD in male and female subjects.

MATERIALS AND METHODS

Participants

Ninety five first-year university students (age range 18-20 years) participated in the study; 42 of these participants (21 females) were classified as binge drinkers (BD) and 53 (26 females) as controls (see Table 1).

For sample selection, first-year students at the University of Santiago de Compostela (N=2700) were asked to complete a questionnaire during class. The initial sample used in the present study is the same as in an epidemiological study carried out by our research group (Caamaño et al., 2008). The questionnaire included the Galician validated version of the Alcohol Use Disorder Identification Test (AUDIT) (Varela et al., 2005) and other items about alcohol use (speed of consumption, frequency of BD episodes in the last two weeks and the last month, age of onset of use, etc.) and other drug use. The original AUDIT has been validated to assess alcohol-related problems or disorders (Allen et al., 1997; Babor et al., 2001; Conigrave et al., 1995), and specifically in university students (Fleming et al., 1991).

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The participants were classified as binge drinkers or controls according to the answers they gave in the questionnaire. Subjects who (1) drank six or more standard alcoholic drinks (approximately 60g of alcohol) on one occasion at least once a month, and (2) drank at a speed of consumption of at least three drinks per hour during these episodes, were classified as binge drinkers. Those who (1) drank less than six standard drinks on each occasion and (2) drank at a maximum speed of consumption of two drinks per hour, were classified as controls (see Figure 1).

The initially selected subjects were interviewed about their individual and family history of medical and psychopathological disorders. The SCL-90-R questionnaire (Derogatis, 2002) was applied in order to detect any psychopathological symptoms, and the Edinburgh test (Oldfield, 1971) to determine handedness.

The exclusionary criteria were scores > 20 in the AUDIT, no history of alcohol drinking, non-corrected sensory deficits, loss of consciousness for more than 20 minutes, history of traumatic brain injury or neurological disorder, personal or familiar history of major mental disorder, regular cannabis consumption, other drug use (except tobacco) and scores > 90 for the global severity index (GSI) or at least two symptomatic dimensions of the SCL-90-R. Alcohol abuse/dependence was assessed in all subjects, both controls and binge drinkers, by use of the AUDIT. Subjects with AUDs or alcohol dependence were excluded.

Smokers were not excluded from the study. A high correlation between alcohol and tobacco consumption in adolescents and university students has been consistently reported (Koopmans et al., 1997; Lund et al., 2008; Schmid et al., 2007; Schorling et al., 1994; McKee et al., 2004). In the same way, in the present study the percentage of smokers was significantly higher in the BD group than in the control group (see Table 1).

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The experiment was undertaken in compliance with spanish legislation and the code of ethical principles for medical research involving human subjects of the World Medical Association (Declaration of Helsinki, Williams, 2008). Participants signed an informed consent and were paid 15 euros for participating in the entire experiment.

Procedure

The participants were asked to abstain from consuming drugs and alcohol for 12 hours before the experiment. In addition, they were instructed not to smoke or drink tea or coffee for at least three hours prior to the experiment. Each subject was seated in a comfortable armchair located in a light- and sound-attenuated electrically shielded room, and a brain cap and electrodes (see below) were fitted to the subject's head. General instructions were given to avoid movements during the test and the task was explained.

A visual identical-pairs CPT was used. Identical-pairs or dual-target CPT, developed by Cornblatt et al. (1988), is a version of CPT that increase demands on working memory. In this task any stimulus in the total set is a cue, and can become a target stimulus if it appears in two successive trials. Thus, subjects must attend to each of the stimuli and maintain previous presentations of stimuli active in their working memory in order to detect a "match" and respond correctly (Cornblatt et al., 1988).

Two hundred stimuli, size 2.6 x 2.6º visual angle, were randomly presented in the centre of a computer monitor placed 100 cm in front of the subject's eyes. The stimulus duration was 50 ms and the interstimulus interval (ISI) varied between 2500 and 2800 ms. The stimuli consisted of 60 different abstract figures, which are difficult to verbalize. The subjects were instructed to press a button with the preferred hand when two consecutive identical stimuli appeared (probability 0.2) and not to respond in the

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other cases (probability 0.8). The subjects therefore had to maintain each figure present in their working memory during the ISI, and had to respond if the next figure was the same.

ERP Recording

Electroencephalogram (EEG) activity was recorded with 32 Ag-AgCl electrodes and linked-noise reference from AF3, AFz, AF4, F7, F3, Fz, F4, F8, FC3, FCz, FC4, T7, C3, Cz, C4, T8, CP3, CPz, CP4, P7, P3, Pz, P4, P8, PO7, PO3, POz, PO4, PO8, O1, Oz, O2 (according to the extended International 10-20 system). Vertical electrooculogram (EOG) was recorded bipolarly to control eye movements. Electrode impedance was kept below 5 KΩ.

The EEG was continuously recorded at a sampling rate of 500 Hz and signal was analogically filtered (0.01-100 Hz). The signal was off-line processed: firstly, the EEG was corrected for ocular artefacts by the procedure developed by Gratton et al. (1983). The EEG was then epoched from 100 ms prestimulus to 900 ms poststimulus and the signal was adjusted to a 0 μV prestimulus baseline. Trials exceeding ± 80 μV at any scalp electrode were rejected. The epochs corresponding to incorrect responses (omissions or false alarms) were also excluded. Finally, the epochs were averaged according to the type of stimuli (matching and non-matching) and digitally filtered (0.1-30 Hz). All analysis were performed with Brain Vision Analyzer software (Version 1.05)

Data Analysis

Behavioral data. Only Reaction Times (RTs) occurring between 100 and 1200 ms after the onset of a matching stimulus were considered as correct responses. Responses to the

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non-matching stimuli were scored as false alarms, and failures to respond to matching stimuli were defined as omissions. The RTs and the percentage of correct responses, false alarms and omissions were analyzed by ANOVA.

Electrophysiological data. The N2 and P3 components of ERPs were examined by Principal Components Analysis (PCA). This analysis is recommended for identifying and quantifying ERP components independently from the influences of adjacent or subjacent components (Chapman and McCrary, 1995; Dien, 1998). It also enables identification of hidden ERP components and prevents possible misinterpretations that occur with traditional visual inspection of grand averages. The parameters in which components or factors are quantified by PCA are named "factor scores". Factor scores, which may be considered as "clean amplitudes", constitute a transformation of original voltages and are basically computed by multiplying the original voltage points by the factor loadings. Factor loadings reflect the extent of the association of a particular voltage point with a particular component (Chapman and McCrary, 1995).

The components that explained most of the variance in the ERPs were identified and quantified through a covariance matrix-based temporal PCA. Nine temporal factors were selected on the basis of the scree test (Cattell, 1966) and were submitted to Promax rotation (see Figure 2). Promax rotation was used because it reduces miscalculations due to e.g. misallocation of variance. The temporal and spatial characteristics of the components indicated that factor 2 (explained variance: 15%; latency: 412ms) corresponded to the P3 component, and factor 4 (explained variance: 4%; latency: 270 ms) corresponded to the N2 component.

The N2 and P3 components are the most commonly studied ERPs in electrophysiological studies involving this type of CPT. N2 is a fronto-central negative

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component, which peaks 250-300 ms after stimulus onset, and is associated with stimulus categorization and decisions about the correct response. Its amplitude has been interpreted as reflecting the allocation of cognitive effort to salient or relevant stimuli that must be attended to (Fitzgerald and Picton, 1983; Näätänen and Picton, 1986). P3 is a centro-parietal positive component, which peaks between 300 and 600 ms post stimulus, and is related to stimulus evaluation and the allocation of working memory resources to target stimuli; its amplitude is influenced by the stimulus relevance, its probability, and the difficulty of the tasks (Regan, 1988).

Statistical analysis. The factor scores corresponding to N2 and P3 from both matching and non-matching stimuli were organized into three regions, each with six electrodes: frontal (F3, Fz, F4, FC3, FCz, FC4), central (C3, Cz, C4, CP3, CPz, CP4) and parietal (P3, Pz, P4, PO3, POz, PO4). A mixed ANOVA 2x2x2x3x6 was used for the statistical analysis, with two between-subjects factors and three within-subject factors. The between-subjects factors were Group (BD and control) and Gender (male and female) and the within-subject factors were Condition (matching and non-matching stimuli), Region (frontal, central and parietal) and Electrode (six channels).

In all tests, results were considered statistically significant at $p < 0.05$. Where appropriate, degrees of freedom were corrected by the Greenhouse-Geisser estimate for sphericity violation, and when the ANOVA revealed significant effects, post hoc multiple comparison of means tests (adjusted by Bonferroni correction) were applied. All statistical analyses were performed with SPSS software (SPSS 15.0, SPSS Inc., Chicago, IL., USA).

RESULTS

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Behavioral performance

The behavioral data for each group are summarized in Table 2. No significant differences between the control and BD group were observed for RTs, percentage of correct responses, false alarms or omissions.

ERP Measurement

The grand averages of the ERPs recorded in the two groups are shown in Figure 3. The N2 and P3 components were identified by PCA, for both matching and non-matching conditions. The latency of N2 was approximately 270 ms, and maximum factor scores were obtained at central and fronto-central locations. The latency of P3 was approximately 412 ms, and maximum factor scores were obtained at parietal and parieto-occipital locations (see Table 3).

The analysis of N2 revealed that Condition had a significant effect [$F(1,91) = 54.38$, $p < 0.001$]. The N2 factor scores were significantly larger in the matching than in the non-matching condition. N2 is a negative inflexion, thus a higher factor score indicates a larger negativity. The analysis also revealed that Region had a significant effect [$F(2,182) = 58.99$, $p < 0.001$], with higher factor scores in anterior than posterior regions (frontal>central>parietal). The Condition x Region x Group interaction showed significant effects [$F(2,182) = 4.75$, $p < 0.05$; $\varepsilon = 0.63$]. The post-hoc multiple comparisons (adjusted by Bonferroni correction) showed that N2 factor scores in the matching condition were significantly larger in the BD than in the control group in the central ($p < 0.05$) and parietal ($p < 0.01$) regions (see Figure 4). No significant differences were observed in relation to gender or interactions with other factors.

As regards P3, the analysis showed that Condition had a significant effect [$F(1,91) = 13.42$, $p < 0.001$]. The P3 factor scores were significantly higher in the

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matching than in the non-matching condition. The analysis revealed that Region had a significant effect [$F(2,182) = 256.89$, $p < 0.001$], with significantly higher factor scores in posterior than anterior regions (parietal>central>frontal). The analysis also revealed significant interactions between Condition and Group [$F(1,91) = 4.56$, $p < 0.05$]. The post-hoc multiple comparisons (adjusted by Bonferroni correction) showed that P3 factor scores in the Control group were significantly higher in the matching condition than in the non-matching condition ($p < 0.001$), whereas there were no significant differences between conditions ($p = 3.09$) in the BD group (see figure 5). As with N2, neither gender nor its interactions exerted any significant effects.

DISCUSSION

A visual working memory task (identical-pairs CPT) was used to assess the effects of BD on the electrical activity of the brain. The results show that there were no significant differences in the behavioral performance, although the N2 and P3 ERP components differed significantly between the BD and control group.

Kokavec and Crowe (1999) compared chronic and regular alcohol consumption with the BD pattern in adult population. All subjects (25-68 years old, mean age around 40 years old) consumed a minimum of 10 standard alcoholic drinks per session; those in the BD group ($n = 50$) only drank two days a week or less, whereas chronic alcoholics ($n = 50$) drank every day. The neuropsychological assessment revealed that semantic organizational ability was poorer in chronic alcoholics, but that performance of tasks associated with executive functions was similar in both groups. The results of this study highlight the relevance of the specific pattern of alcohol consumption and indicate that binge drinkers, who only drank alcohol two days a week and who consumed almost three times less alcohol than chronic alcoholics, may be as vulnerable as regular or

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chronic drinkers to specific cognitive impairments, mainly those associated with executive functioning.

In youths and adolescents with less history of alcohol consumption that adults, the behavioral effects of BD are not so clear. Weissenborn and Duka (2003) compared BD and non-BD students and found that the binge drinkers showed significantly worse performance in a test of spatial working memory. In a later study, Hartley et al. (2004) showed that, compared with a group of teetotallers, binge drinkers performed less well in tests of sustained attention, episodic memory and planning ability. However, these authors did not find any behavioral differences in working memory, although they used the same spatial working memory task as in the study by Weissenborn and Duka (2003). It is important to note that subjects in the first study were between 18 and 34 years old and the quantity of alcohol consumption per week by binge drinkers was high, while subjects in the second study were younger students (aged 18-23 years) and with a lower consumption of alcohol per week. Thus the drinking in the second group may not have reached the threshold or duration needed to show behavioral impairments in working memory. Similarly, in the present study, subjects showed no behavioral differences in performance of the visual working memory task used; however, at an electrophysiological level, abnormalities in the N2 and P3 components of the ERPs were found in the BD group.

Although no neuroimaging studies of BD have been carried out, fMRI studies have revealed that, despite adequate performance, youth and adolescents with AUDs or alcohol dependence show abnormalities in brain responses to a visospatial working memory task (Akine et al., 2007; Tapert et al., 2004). The authors suggest that subtle neuronal reorganization may occur early on in the course of AUD and that alternate neural systems may compensate for disrupted or damaged regions. However, if alcohol-

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induced disruption increases, then performance-related problems may emerge. In line with these findings, the differences in N2 and P3 components of the ERPs observed in the BD group in the present study may indicate latent deficits in attention and working memory processes.

The N2 component was larger in fronto-central regions and for matching stimuli, as expected, and differed significantly between groups. The N2 component in the matching condition was significantly larger (more negative) in the BD than in the control group in the central and parietal regions.

As stated above, the N2 amplitude has been associated with the allocation of attentional resources to relevant stimuli. In a series of oddball tasks, Fitzgerald and Picton (1983) observed changes in amplitude of N2 as a function of the difficulty in target and non target discrimination and considered these data highly suggestive of an association between N2 amplitude and the allocation of "cognitive effort", so that larger N2s were elicited by stimuli that required greater effort for processing. A similar interpretation of the fronto-central N2 has been proposed by Näätänen and Picton (1986), who argued that it partly reflects the conscious allocation of attentional resources to stimuli indicated as salient by pre-attentive processes. Several studies have reported larger N2 amplitudes in head injury patients than in controls, which were interpreted as evidence of the additional cognitive effort required (Ford and Khalil, 1996; Rugg et al., 1988; 1993).

The largest N2 observed in the BD group in the present study may therefore be indicative of the greater attentional effort required by this group to perform the task adequately. Enhancement of N2 and anomalies in information processing have also been observed in some studies of alcoholic populations in which an auditory oddball

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paradigm (Olbrich et al., 2000) or a Visual Contingent Negative Variation paradigm (Olbrich et al., 2002) was used.

As regards P3, the control group showed higher P3 factor scores in the matching than in the non-matching condition in the frontal, central and parietal regions, whereas the BD group did not show significant differences between conditions in any region.

Numerous studies have reported abnormalities in P3 amplitude associated with alcohol abuse. The decrease in P3 amplitude is the most commonly reported ERP alteration in alcoholics, both in auditory (Cohen et al., 1995; 2002; Kaseda et al., 1994; Olbrich et al., 2000; Parsons et al., 1990) and visual oddball paradigms (Bijl et al., 2005; Cohen et al., 2002; Porjesz and Begleiter, 1993), and also in more demanding tasks (Rodríguez Holguín et al., 1999b). According to the neurocognitive meaning attributed to this ERP component, the reduced P3 amplitude has been interpreted as a sign of impaired (selective) attention and diminished availability of processing resources (Rugg and Coles, 1995) and of deficits in neural inhibition systems (Cohen et al., 1997). In addition, the decreased P3 amplitude in alcoholics has been related to the deficits in working memory suffered by this population (Zhang et al., 1997a,b).

As stated above, the CPT tasks used in the present study have been proposed for assessing the subcomponent of working memory associated with the representation and maintenance of context information necessary to guide the task performance. Subjects in this study were between eighteen and twenty years old, and their drinking had not reached the threshold or duration required for development of alcoholism, and therefore they did not show the anomalies in ERP components that have been observed in alcoholic subjects (significant reduction in P3 amplitude). However, the results show anomalies in this component in comparison with the controls. The absence of differences in P3 between the two conditions (matching and non-matching stimuli) in

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the BD group would indicate that young people who indulge in BD are less capable of differentiating, at an electrophysiological level, between relevant and irrelevant information. Such people would be less efficient at distributing attentional and working memory resources between the matching and non-matching stimuli.

The assessment of possible gender differences was also of interest in the present study. In the last decade, the prevalence of BD has tended to rank equally among men and women (Eaton et al., 2006; Wechsler et al., 2002; Young et al., 2005); several neuropsychological and neuroimaging studies on alcohol consumption have reported that women are more sensitive to the neurotoxic effects of alcohol (Hommer et al., 2001; Mann et al., 2005; Medina et al., 2008), perform worse in spatial working memory tasks (Hartley et al., 2004; Townshend and Duka, 2005), and display more anomalous patterns of brain activity than BD men (Caldwell et al., 2005). In the present study both men and women binge drinkers showed the same anomalies in the N2 and P3 components, with no significant gender-related differences.

Finally, it must be noted that Control and BD groups differed in terms of tobacco consumption. However, the differences between groups are unlikely to be related to this variable (to our knowledge the pattern of ERP responses found in BD group has not been related to smoking). However, an accurate assessment of life-time history of cigarette smoking may be necessary in future studies to assess the influence of this variable.

In summary, the results of the present study confirm the presence of some electrophysiological differences between young university student binge drinkers and controls during the execution of a visual CPT with a high working memory load. The larger N2 in the BD group may suggest greater levels of attentional effort required by this group to perform the task adequately. The lack of any differences in P3 between

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conditions (matching and non-matching stimuli) in the BD group suggests a deficiency in the electrophysiological differentiation between relevant and irrelevant information, which may reflect some impairment of working memory processes, and may be associated with anomalies in neural inhibition frequently associated with alcohol abuse. No differences were found between male and female subjects, and both showed the same anomalies in the N2 and P3 ERP components in the BD groups. The results confirm the interest in characterizing the neuropsychological and psychophysiological functions of young people with a BD pattern of alcohol consumption, even when they do not meet the criteria for alcohol abuse disorder and do not manifest impairment of behavioral performance. Further research in this population is also necessary to clarify the relationship between the detected anomalies and the neurodevelopmental stage of the subjects.

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Figure 1. Mean number of drinks that the BD and Control subjects consumed on the different days of the last week and the mean speed of consumption (drinks per hour) on the days that they drink most alcohol.

Figure 2. PCA: Factor loadings of the nine temporal factors (tf) after promax rotation. Factor 2 and 4, which were associated with P3 and N2 respectively, are shown in thick lines.

Figure 3. Grand averages of event-related potentials from Control and BD groups in response to the non-matching stimuli (solid lines) and matching stimuli (dashed lines). Averages are presented for midline frontal (Fz) central (Cz) and parietal (Pz) electrode locations.

Figure 4. Factor loadings of the N2 from Control group (solid lines) and BD group (dashed lines) in response to the matching stimuli for central and parietal regions.

Figure 5. Factor loadings of the P3 from the Control and BD groups in response to the non-matching stimuli (solid lines) and matching stimuli (dashed lines) for frontal, central and parietal regions.

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