Published in final edited form as:

Exp Clin Psychopharmacol. 2008 August ; 16(4): 341–356. doi:10.1037/a0012873.

The P300 as an Electrophysiological Probe of Alcohol Expectancy

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Abstract

Language-based measures indicate that alcohol expectancies influence alcohol consumption. To relate these measures to brain actions that precede verbal output, the P300 component of the Event-related potentials (ERPs) was used to detect violations of individually held alcohol expectancies. As predicted, P300 amplitude elicited by negative alcohol expectancy stimuli was positively correlated with endorsement of positive/arousing alcohol expectancies on the language-based measure, such that the higher an individual's positive/arousing expectancies, the larger was the P300 elicited by negative alcohol expectancy stimuli. These results demonstrated concordance between language-based measures of alcohol expectancies and electrophysiological probes of expectancy. Although whether these expectancy processes are integral to decision pathways that influence consumption is unknown, these findings suggest that such processing can occur very quickly outside of conscious deliberation.

Keywords

alcohol expectancies and event-related potentials; P300 and alcohol cognitions; electrophysiological index of alcohol expectancies

Researchers from diverse domains have increasingly recognized that the brain functions as an “anticipatory machine” (Dennett, 1991) that acquires and stores expectancies of relationships among contexts, specific stimuli, behavioral outputs, and outcomes (Grossberg, 1995; Huron, 2006; Goldman, 2002; Goldman, Darkes, Reich, & Brandon, 2006; Raichle, 2006). In both animals and humans, the comparison of sensory input with learned expectations has been deemed central to virtually all psychological/ behavioral output (Grossberg, 1995), including such widely diverse phenomena as animal reward and reinforcement (Kupfermann, Kandel, & Iversen, 2000; Schultz, Dayan, & Montague, 1997; Schultz, 2004), classical and operant conditioning (Dragoi & Staddon, 1999; Kirsch, Lynn, Vigorito, & Miller, 2004; Van Hamme & Wasserman, 1994), comparative judgment (Heekeren, Marrett, Bandettini, & Ungerleider, 2004; Ritov, 2000), music appreciation (Huron, 2006; Krumhansl, 2002), perception of motion (Kerzel, 2005) and time (Correa, Lupianez, & Tudela, 2005), development of language (Colunga & Smith, 2005), interpersonal trust (King-Casas, Tomlin, & Anen, 2005), and placebo effects (Kirsch & Scoboria, 2001). Because anticipatory/expectancy processes also have been explicated in studies that relate neurophysiological activity to information

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processing/psychological variables, it is evident that this conceptual framework serves as a nexus between behavior and its underlying neural substrate (see Campos, Breznien, Bernheim, & Andersen, 2005; Cardinal & Everitt, 2004; Holland & Gallagher, 2004; Kobayashi, Lauwereyns, Koizumi, Sakagami, & Hikosaka, 2002; Matsumoto, Suzuki, & Tanaka, 2003; Phelps, 2004; Schultz et al., 1997; Tremblay & Schultz, 2000).

Parallel research on the anticipated effects of alcohol consumption (commonly referred to as alcohol expectancies) carried out over the past 25 years has identified a strong relationship among expectancies, drinking, and a number of well-established etiological factors (see Goldman, Del Boca, & Darkes, 1999; Goldman et al., 2006). This work has led some reviewers to characterize expectancy systems as one common pathway for the transmittal of important biopsychosocial antecedents to drinking outcomes (see Sher, Grekin, & Williams, 2005). In humans, language-based assessment tools have shown expectancies to appear in children before drinking begins; to change in a direction that encourages drinking as children enter adolescence (e.g., Dunn & Goldman, 1996); and to predict drinking prospectively over periods as long as nine years (e.g., Newcomb, Chou, Bentler, & Huba, 1988; Stacy, Newcomb, & Bentler, 1991). Consistent with their theoretical status as cognitive representations of prior – direct or vicarious – experience with alcohol that influence future drinking, expectancies have been shown to partially mediate the influence of personality risk factors (e.g., sensation seeking and behavioral undercontrol; Darkes, Greenbaum, & Goldman, 2004; Henderson, Goldman, Coovert, & Carnevalla, 1994; Scheier & Botvin, 1997), to partially mediate the influence of some genes (Hill, 2004; Katner, Kerr, & Weiss, 1996; McCarthy, Wall, Brown, & Carr, 2000), and possibly to mediate the influence of alcohol advertising (Fleming, Thorson, & Atkin, 2004). More direct evidence of causal influence comes from true experiments, in which manipulation of expectancies has been shown to alter actual drinking (e.g., Carter, McNair, Corbin, & Black, 1998; Darkes & Goldman, 1993, 1998; Roehrich & Goldman, 1995; Stein, Goldman, & Del Boca, 2000).

To move this line of research into the investigation of alcohol expectancy processes, multidimensional scaling methods (MDS) have been used to develop empirically-based cognitive models (Dunn & Goldman, 1996; 1998; Rather, Goldman, Roehrich, & Brannick, 1992; Rather & Goldman, 1994). These models represent hypothetical memory networks in which expectancies are treated as information nodes. Each node represents an expected effect of alcohol use based on a person's direct and vicarious experiences with alcohol as determined by individual biological characteristics and environmental exposures. The distance between these nodes indicates the potential to drink in appropriate contexts (closely located nodes are more likely to co-activate). As revealed by these models, heavy drinkers most associate positive and arousing effects with drinking, and are less likely to associate sedating and negative effects. In contrast, light drinkers most associate alcohol's sedating and negative effects. Recent studies in both children and adults using cognitive “first-associate” methodology (Dunn & Goldman, 2000; Reich & Goldman, 2005), various implicit cognitive tasks (Stroop task, hybrid cue priming, false memory task; Kramer & Goldman, 2003; Reich, Goldman, & Noll, 2004; Reich, Noll, & Goldman, 2005), and expectancy priming of actual alcohol consumption (Carter et al., 1998; Roehrich & Goldman, 1995; Sharkansky & Finn, 1998; Stein et al., 2000) have shown concordance between these statistically generated models and behavior on laboratory tasks that probe actual memory contents and processes.

To broaden the range of available probes of alcohol expectancies, and to move closer to the “nexus” studies noted earlier that relate external expectancy measures to brain actions, it would be of interest to examine electrophysiological indices of brain actions that are known as markers of expectancy-related processes. To this end, the present study used event-related potentials (ERPs) to examine the response to violations of the language-based alcohol expectancy profiles of heavier and lighter drinkers identified in previous cognitive modeling research. Because

ERP components have a temporal resolution in the range of milliseconds, electrophysiological indices of expectancy violations probe brain activity that is upstream of outputs of the verbal instruments previously used to measure alcohol expectancies. Although the extent to which ERP indices of expectancies might relate to the specific decision-making processes that ultimately determine consumption is yet unknown, the ERP waveform might reflect just how early in the course of these processes is the range of outcomes effectively narrowed.

Several ERP components are known to be elicited by events that violate an individual's expectancies (Donchin & Coles, 1988; Fabiani, Gratton, & Coles, 2000). In the present study we focused on the P300, a positive-going ERP component with a peak latency of approximately 300-600 ms after the eliciting event and maximum amplitudes measured at parietal scalp sites. It has been well established that the P300 is elicited by events that violate the individual's *subjective* expectancies (expectancy held by a particular person, whether or not it reflects objective, real world relationships; Donchin, 1981; Horst, Johnson, & Donchin, 1980). P300 amplitude in response to expectancy violation has been theorized to reflect "context updating" for that individual (Donchin, 1981); that is, P300 registers events that are unlikely given the current model of the context within which the individual is operating. Other recent work suggests that activity of the locus coeruleus-norepinephrine (LC-NE) system may be measurable at the scalp as the P300 component, and may reflect potentiation of "responses to the outcome of internal decision processes that involve motivationally significant events" (Nieuwenhuis, Aston-Jones, & Cohen, 2005, p. 526). In sum, the amplitude of the P300 may reflect, among other things, the extent to which new information is both discordant with one's expectations and motivationally significant.

In the current study, participants were presented with statements about the consequences of alcohol ingestion. The terminal word of each statement either supported, or violated, the participant's individual expectancies (as established by previous language-based expectancy research). We hypothesized that, because heavier drinkers were more likely to anticipate positive and arousing effects of alcohol, whereas lighter drinkers were more likely to anticipate sedating and negative effects, P300 amplitude elicited by the terminal word would be inversely related to each individual's profile of anticipated alcohol effects (i.e., expectancies) as revealed by language-based instruments and MDS-based information processing models. That is, we predicted that presentation of sedating, or negative, effects of alcohol would elicit larger P300s in individuals with high positive alcohol expectancies, while arousing or positive effects would elicit larger P300s in individuals with low positive alcohol expectancies, based on the violation of the subjective expectancies principle. These hypotheses were tested in a sample of typical college students, who fell within the age range that includes lifetime drinking peaks for many individuals (Schulenberg, O'Malley, Bachman, Wadsworth, & Johnston, 1996; Wechsler, Lee, Kuo, & Lee, 2000), which allowed us access to a wide range of drinking patterns and corresponding alcohol expectancies.

Because previous research has shown attenuation of the P300 amplitude in individuals with a positive family history of alcohol dependence to be associated with lifetime risk for dependence (Begleiter, Porjesz, Bihari & Kissin, 1984; Polich, Pollock, & Bloom, 1994; Porjesz et al., 1996), we ascertained family histories in each participant. In this way, we were prepared to offset possible P300 attenuation in high drinking/expectancy individuals that might operate in opposition to the hypothesized P300 effect.

Method

Participants

Thirty participants recruited from the student body at the University of South Florida were screened to ensure that they: had at least some drinking experience; were native English

speakers with normal or corrected-to-normal vision; and had no history of neurological disorder (e.g., seizure disorder or multiple sclerosis) or head injury (i.e., loss of consciousness > 5 min). To avoid the unintended priming that might occur with heavy advance assessment of anything related to alcohol use, participants were recruited in succession, within a limited time frame (to minimize the influence of systematic variations in college student drinking at certain times of the year; Del Boca, Darkes, Greenbaum, & Goldman, 2004), and without deliberate attention to drinking histories or gender balance. The resulting sample had adequate gender representation for specific consideration in most analyses. (As it turned out, the amplitude of P300 in our data appeared to be independent of gender.) Because the limited availability of psychometrically-tested alcohol expectancy stimuli (described below) restricted the number of trials per condition, stringent EEG artifact criteria were employed. As a consequence, EEG data from four participants were excluded due to excessive artifacts, leaving the final number of participants included in all analyses at 26 (16 males and 10 females).

Of the 26 subjects, 24 were Caucasian, one participant self-identified as Hispanic, and one as of mixed ethnicity. The mean age was 20.9 years ($SD = 2.8$, range 18 to 28 years). As anticipated, the participants represented a wide range of drinking patterns, ranging from light drinkers (five students reported consumption of one standard drink or less per drinking episode) to those who drank heavily by any definition (10 individuals reported consuming more than 5 drinks per drinking episode, with 4 of them consuming more than 8 drinks per episode; 4 individuals reported drinking three times per week or more). Overall alcohol consumption ranged from 1 to 179 standard drinks during the 30 days prior to participation ($M = 29.83$; $SD = 41.89$), with a mean of 5 ($SD = 4.11$) drinking occasions per month and 4.37 ($SD = 2.93$) drinks per occasion. Again as anticipated, males reported, on average, drinking slightly more drinks per occasion ($M = 5.81$, $SD = 3.33$), and having more drinking occasions per month ($M = 5.63$, $SD = 4.40$) than women ($M = 2.63$, $SD = 1.68$; $M = 4.30$, $SD = 4.22$, respectively; $ps < .01$). Eight individuals (5/8 males) reported a history of parental alcohol problems (in either or both biological parents) and 14 participants (10/14 males) reported having at least one first-degree relative (including, but not limited to, parents) with history of alcohol problems. Incidentally, five participants (3/5 males) were current smokers, eight (7/8 males) were former smokers and the rest reported never having smoked.

Measures

Experimental Task—Figure 1 presents a schematic illustration of the experimental task sequence. The data were acquired in a series of trials. Each trial began with the presentation of a statement describing a habit or an activity characteristic of college students' life-style (see Appendix for examples). The last word of each statement was withheld, e.g., “On a Friday night, alcohol makes me...” Participants initiated the display of the missing word (e.g., “happy”) by pressing a button, which first triggered a “+” symbol that served as a fixation point displayed for 500 ms, followed by the last (missing) word of the statement. This “target” word was presented for 800 ms. The EEG recording epoch began with onset of the target word and lasted 1000 ms. Following the offset of the target word the participant indicated whether she/he agreed, or disagreed, with the statement by pressing one of two buttons; this response concluded the trial. The intertrial interval was set to be at most 2000 msec, although participants could start each trial earlier, at their own pace, by pressing a button on the response box.

Stimuli consisted of 70 English sentences, of which 32 pertained to various effects of alcohol consumption. For these 32 sentences, the “target” terminal words (e.g., “happy,” “down”) were chosen from the Alcohol Expectancy Multiaxial Assessment scale (AEMax; Goldman & Darkes, 2004), a psychometrically validated instrument derived from earlier MDS “mapping” of expectancies (Rather, Goldman, Roehrich & Brannick, 1992). In total, 16 sentences related to alcohol and each repeated twice, once with a negative/sedating ending and at another time

– with a positive/arousing ending (e.g., “Alcohol makes me... happy” vs. “Alcohol makes me... sad”), were presented in a semi-random order. Additional 8 sentences adapted from the Smoking Consequences Questionnaire (SCQ; Copeland, Brandon, & Quinn, 1995) were structurally similar (e.g., “Smoking makes me...sick”), served as foils and were also repeated twice each, with either a positive or a negative ending (i.e., 16 total smoking items). Yet another 12 sentences were composed of daily activities content, such as exercising or studying (e.g., “After a workout at the gym, I always feel ...exhausted”). Together with the smoking items, these sentences served as a control condition for the ERP comparison. Finally, 10 classic N400-eliciting sentences (e.g., “I drink my coffee with sugar and...socks”) were included to control for individual participant's attention to the task. The N400 component (Kutas & Hillyard, 1980) is a negative going component of the ERP with a peak latency of approximately 400 ms after the onset of a word that is incongruent with the semantic context of the sentence (e.g., “I drink my coffee with sugar and...socks”). These 10 sentences, interspersed among the other stimuli, were expected to invariably elicit the N400 component in all participants attentive to the task.

In sum, the stimuli made up 4 experimental conditions: Alcohol/Positive-Arousing, Alcohol/Negative-Sedating, Classic Incongruent, and Other – a baseline condition, against which the remaining 3 conditions were compared (see Appendix). Stimulus delivery and the recording of overt responses were controlled by E-prime software provided by Psychology Software Tools (PST; Pittsburgh, PA), in combination with the PST serial response box.

Standard “Oddball” Task—ERPs also were recorded in a standard “oddball” task. A Bernoulli sequence of the two characters “X” and “O” was presented, with one of the characters appearing on 80% of the trials and the other, the “oddball” event, in 20% of the trials. The participants were instructed to respond (key press) each time they saw the specified letter; the rare character served as the target in all cases. The task consisted of 200 trials. Each stimulus was presented for 600 ms with an intra-stimulus-interval (ISI) of 1000 ms. The P300 elicited by the rare events served to characterize the wave shape, and latency of the P300 for each participant. Obtaining such baselines was important because amplitude and latency of the scalp-recorded P300 can be quite variable among individuals due to other than experimentally controlled variables, such as scalp thickness and shape, body temperature, ultradian/circadian cycles, and hormonal fluctuations (Fabiani, Gratton, Karis, & Donchin, 1987; Polich & Kok, 1995), or individual differences in neural circuitry of attention and mental speed of processing (Stelmack, Houlihan, & McGarry-Roberts, 1993).

In the present study, oddball responses also served as a potential index of general cognitive differences previously observed between at-risk and low-risk drinkers (Begleiter et al., 1995). That is, recording each individual's “typical” P300 elicited in a neutral, non-alcohol-laden, context allowed us to account for the possibility that individuals at risk for developing alcoholism (*CoAs*, or children of alcoholics) would manifest significantly lower P300 voltages compared with matched low-risk individuals coming from families without first- or second-degree alcoholic relatives (Begleiter et al., 1984).

Alcohol Expectancy Questionnaire (AEQ; Brown, Christiansen & Goldman, 1987)—The AEQ is designed to measure individuals' beliefs about outcomes of alcohol use, including alcohol effects in social, physical and sexual domains. Reliability and predictive validity of the AEQ are well established (Goldman, Brown, & Christiansen, 1991; Goldman, Greenbaum & Darkes, 1997); the AEQ has been consistently among the strongest predictors of alcohol use (measured by both frequency and quantity), alcohol abuse and other, non-consumptive behaviors while drinking. Because many studies have shown the Global Positive Changes and Social/Physical Pleasure scales (of the six total scales) to be the strongest

predictors of alcohol use for college student drinkers, scores on these two subscales served as independent variables.

Alcohol Expectancy Multi-Axial Assessment (AEMax; Goldman & Darkes, 2004)—An abbreviated version of the AEMax (a checklist of alcohol expectancy words) that included eight items from each of three higher-order alcohol expectancy factors: Positive/Arousing, Sedating, and Negative, was administered to each participant. The brief AEMax was included (in addition to the two AEQ scales) because it captures negative/sedating, as well as positive/arousing, expectancies (while the AEQ is limited to positive/arousing spectrum of expectancies). Hence, expectancy-ERP relationships could be assessed using a multimethod approach that included the strongest predictors of drinking and all expectancy domains. For the AEMax, participants rated the likelihood with which they expected drinking alcohol to result in each alcohol effect using a 7-point Likert scale ranging from 0 = never to 6 = always.

Recent pattern of alcohol use—Given our ultimate interest in alcohol expectancies as predictors/mediators of drinking, a 30-day Timeline Follow-Back interview (TLFB; Sobell & Sobell, 1992) was included to assess retrospective estimates of alcohol (in number of standard drinks) consumed on each day over the previous month (i.e., in the 30 days preceding the assessment day). TLFB summary data (e.g., the total 30-days score) has been shown to have good psychometric characteristics with a variety of drinker groups (Sobell & Sobell, 1995; Tonigan, Miller, & Brown, 1997) and is reasonably reliable and valid for typical drinking patterns as far back as 3 months (e.g., Sobell, Sobell, Klajner, Pavan, & Basian, 1986).

Family History Grid (FHG)—Because the P300 had previously been shown to relate to family history of alcoholism (Begleiter et al., 1995), we administered the FHG, a semi-structured interview assessing the prevalence of alcohol problems (i.e., legal, health, relationship, work or school problems), current or lifetime, among the respondent's first-degree relatives (including grandparents, parents, aunts and uncles, and siblings). Responses to these items allowed classifying participants into Family History positive (FH+) and Family History negative (FH-) categories (see Andreasen, Endicott, Spitzer, & Winokur, 1977).

Procedure

In advance of the study, potential participants were told they would be presented with statements regarding various habits, activities, and beliefs while their brainwaves were recorded. Our intent to measure alcohol expectancies was not disclosed until conclusion of the experiment.

Upon arrival, a sensor net was placed on the participant's head. The participant sat in a sound-attenuated room at a distance of 70 cm from a display monitor. The standard oddball task was administered first, followed by the main experimental task. The main task began with a practice block, during which no ERPs were recorded, to familiarize participants with the task and response options and to practice suppressing blinking while critical stimuli are being presented. Following practice, experimental stimuli were presented in one block of 70 semi-randomized sentences (no two statements from the same category – alcohol, smoking, etc. – were allowed to appear in a row; and no more than two statements of the same valence – e.g., positive alcohol expectancy – could follow each other, even if separated by filler items). All participants received the same trial list. Stimuli were presented in white letters on a black background in Courier New font, 22 dots-per-inch. All letters were lowercase, except for the first letter of each sentence.

Following the experimental task the recording equipment was removed and, in another room, the participant completed several questionnaires and interviews measuring their alcohol use

patterns and expectancy levels, in the following order: AEQ, AEMax, TLFB, and FHG. The entire session lasted approximately 60-75 minutes.

EEG Data Acquisition, Off-line Preprocessing and Component Extraction

EEG data were recorded using NetStation 4.0, an EEG recording system (Electrical Geodesics, Inc. EGI, Eugene, OR), with a 128-channel Geodesic Sensor Net (Tucker, 1993). All electrode impedances were kept at 50 k Ω or below (Ferree, Luu, Russell, & Tucker, 2001). During signal collection, each electrode was referenced to the Cz (vertex) site. Data were sampled at a rate of 250 per second, and filtered offline with a 0.1-40 Hz bandpass filter and 60 Hz notch filter.

The filtered data were segmented into epochs starting 100 ms prior to stimulus onset to 900 ms following stimulus onset. Signals were then subjected to automated artifact detection (> 70 μ V in any one of the channels), corrected for vertical and horizontal eye movements (Gratton, Coles, & Donchin, 1983), and baseline-corrected using the average of the 100-ms pre-stimulus epoch. Artifact-free trials were then averaged separately for each experimental condition, so that 4 separate average waveforms were obtained for each participant (at each of the 128 electrode sites): Alcohol/Positive-Arousing, Alcohol/Negative-Sedating, Classic Incongruent, and Other. Oddball task data were subjected to the similar sequence of processing steps, ultimately generating two separate average waveforms for rare (target) and frequent (standard) conditions for each participant. Finally, averaged data were re-referenced to a mean-mastoid reference, a 129th channel of mathematically linked reference recorded separately from the ear lobes (i.e., mastoids). All analyses reported below used the resulting 129-channel data.

The components of the ERPs were extracted using Principal Components Analysis (PCA), a formal multivariate procedure which has a number of advantages over peak and area measures (see Donchin & Heffley, 1978). First, as described by Spencer, Dien and Donchin (1999), a *spatial* PCA was applied to the matrix of covariances between any two electrodes, computed across averaged waveforms across all participants, for all experimental conditions, at each time point. Spatial PCA identifies clusters of electrodes that are highly correlated; as a result, the original 129 electrodes are replaced by a much smaller number of “spatial factors” (also referred to as “virtual electrodes”; Spencer et al., 1999), which are linear combinations of data recorded at each electrode site, weighted according to its contribution to a given factor. The data matrix for the spatial PCA consisted of the voltage readings at each of the 129 electrodes (128 plus reference) by 23,400 observations: 225 time points (with 4 ms sampling rate, for the epoch of 0-900 ms post-stimulus) $\times$ 4 conditions $\times$ 26 participants. The resulting spatial factors served as filters applied to the raw data; these “spatially-filtered” data were then subjected to a *temporal* PCA. In this step, the data matrix consisted of voltage readings at each of 225 time points by the number of the retained spatial factors $\times$ 4 conditions $\times$ 26 participants.

The resulting *spatiotemporal* factor scores (i.e., scores for a given spatial factor at a given temporal factor), reflecting the magnitude of activity at a given virtual electrode within a given temporal factor, were examined across experimental conditions and essentially served as dependent variables. The P300 was assumed to be represented by the spatial factor that was most heavily weighted in the centro-parietal channels (corresponding to the well-established scalp distribution of P300) and by the temporal factor falling in the window corresponding to the P300 latency range (i.e., 300-600 ms).

To test the hypothesis that stimuli describing alcohol effects deviant from the participant's subjective set of alcohol expectancies would elicit a large P300, correlation coefficients between the PCA-derived P300 amplitude (i.e., spatiotemporal factor score corresponding to P300) in response to either Alcohol/Positive-Arousing or Alcohol/Negative-Sedating items, and participants' scores on the verbally-based measures of alcohol expectancies (i.e., AEQ and

AEMax) were calculated (correlational analysis, rather than group variance analysis, was chosen given the continuous nature of alcohol expectancy construct).

All offline processing was performed using the EGI's Analysis Tools included in the NetStation package (EGI, Eugene, OR). PCA on the EEG data was performed using PCA Toolbox, a freely available open source toolbox (<http://people.ku.edu/~jdien/downloads.html>) running under Matlab (The Mathworks Inc., Natick, MA). All PCA decompositions were based on covariance association matrices and solutions were rotated using the Varimax procedure to maximize the amount of variance associated with the smallest number of variables (Donchin & Heffley, 1978). The number of components to be rotated was determined by the Scree test (Cattell, 1966).

Results

Relationship between Self-Report Drinking and Expectancies

To ensure that the previously found alcohol expectancy/drinking relationship replicated in the current sample, we examined the Pearson correlations between measures of alcohol expectancies and self-report measures of drinking (see Table 1). Because (as is typically found) distributions of the self-report measures revealed non-normality for most drinking variables (positively skewed, with most values concentrating at the lower end of distribution), natural log transformations were applied to all drinking measures (Tabachnick & Fidell, 2001), with a constant of 1 added to avoid taking the log of zero. Replicating previously reported data (Goldman & Darkes, 2004; Goldman et al., 1997), most of the scores on expectancy measures were strongly positively correlated with the alcohol consumption variables; e.g., total number of drinks/month was positively correlated with AEQ Global Positive Changes scale ($r(24) = .51, p < .01$) and AEQ Social and Physical Pleasure Scale ($r(24) = .59, p < .01$). No significant differences were found between males and females for any of the self-reported expectancy measures.

ERP Results

ERP: Descriptive analyses—First, visual examination of raw waveforms was carried out to evaluate (prior to component extraction and inferential analyses) whether the predicted individual differences between participants who held differential alcohol expectancies had occurred. To this end, ERPs were aggregated and averaged for individuals with high and low positive alcohol expectancies by splitting the sample in two (using median split; from now on referred to as High and Low groups) with regards to the distribution on the AEQ Social and Physical Pleasure Scale, as this measure had the highest correlation with all drinking indices (see Table 1). Median splits were used because no a priori basis was available for identifying in this sample a threshold for high (vs. low) expectancy individuals. As anticipated, the two groups indeed represented heavier and lighter drinkers: the High group had significantly higher means on Total number of drinks/month, Number of drinking occasions/month, Average number of drinks/typical drinking occasion, and Highest number of drinks/typical drinking occasion ($t(24) = -3.71, -3.40, -3.53, -2.70$, respectively, all $ps < .01$).

Figure 2 presents the ERP waveforms at three midline electrodes – frontal, central and parietal – averaged across individuals with High and Low alcohol expectancies. Visual inspection of these waveforms revealed a characteristic large positive deflection, largest at the parietal Pz electrode (where P300 is typically at its maximum), with a peak latency of about 550-600 ms after the target word, which varied as a function of different experimental conditions. Specifically, it was clear that for the High group the larger positivity was in the Alcohol/Negative-Sedating condition (i.e., in response to negative/sedating alcohol items), while for the Low group the larger positivity was in the Alcohol/Positive-Arousing condition (i.e., in

response to positive/arousing alcohol items). Consistent with the hypothesis, therefore, participants with differential alcohol expectancy networks exhibited P300 in response to opposing sets of items, each violating their particular predominant expectancies. Also in Figure 2, a clearly seen negativity with a peak latency of about 400ms post-stimulus (i.e., N400 component) is readily identified as elicited by the Classic Incongruent sentences (e.g., “Action movies are...*slow*”) in both groups, attesting to the adequate levels of attention to the task across most, if not all, participants. As can be seen, this component was not associated with (i.e., did not vary as a function of) two alcohol conditions, nor did it differ among individuals from High vs. Low groups. Visual inspection of the average waveforms is consistent, therefore, with the hypothesized relationship between P300 and violated expectancies in the alcohol domain.

ERP: Components extraction—Spatial PCA (see Methods section) was performed first, using a matrix of covariances between each pair of the 129 electrodes computed over all participants, all experimental conditions, and all time points (129 variables by $[26 \times 4 \times 225]$ observations). Using the Scree test (Cattell, 1966), 15 spatial factors, accounting for 88.7% of the total variance in the data set, were extracted and rotated. (While PCA derived scores are normally termed “components,” the term “factors” is used throughout this section when referring to PCA results to avoid confusion with ERP components.) The first five spatial factors are presented in Figure 3.A as topographic maps plotting the factor loadings (i.e., correlations between the original variables – electrode sites – and the new factors) for these factors (the remaining 10 factors were of negligible size and/or not readily interpretable).

Visual inspection of the topographic maps revealed that the first factor (Spatial Factor 1 or SF1) was heavily loaded in the central electrodes (covering the top of the scalp), with slight right asymmetry. This scalp distribution was characteristic of N400 (as described above, ten N400-eliciting sentences were included among experimental trials; given that N400 was reliably elicited in all participants, it was not surprising that a PCA factor associated with this component was the first one to be extracted). The second spatial factor (SF2) had the scalp distribution characteristic of P300, with heavy loadings in the parietal region. Of note, Spatial Factor 3 (SF3) likely represented motor activity associated with the motor response of key pressing (at least for the right-handed participants who represented 74% of the sample) associated with the task.

Each spatial factor yielded a linear combination of the voltages recorded at each electrode, so that each linear combination represented the contribution of this particular factor to the raw data. Thus, the voltages recorded at each time point, for each of the 129 electrodes, could be combined to yield a “factor score” for each of the spatial factors. These factor scores, plotted across the time points of the original dataset (i.e., 225 time points for the 0-900 ms of the recording epoch) were then subjected to a temporal PCA, using a matrix consisting of spatial factor scores associated with 225 time points as variables, and participants and experimental conditions at each of the 15 virtual electrodes ($26 \times 4 \times 15$) as observations, or cases. The Scree test suggested retention of 10 factors accounting for 94% of the variance, which were then rotated to simple structure using Varimax. Thus, the temporal PCA reduced the dimensionality of the dataset from 225 time points to 10 temporal factors, or “virtual epochs,” using the terminology of Spencer, Dien and Donchin (2001).

Figure 3.B represents factor loadings for the first five virtual epochs. Since the factor loadings signified the extent to which that factor had an influence on each time point, higher loadings indicated time points when the factor was strongly active, whereas smaller loadings indicated time points when the factor was relatively inactive. The first temporal factor (TF1), which accounted for 44% of the variance, appeared to reflect the classical Slow Wave, which typically emerges among the first factors in temporal PCAs (Spencer et al., 2001). The second factor,

TF2, loaded highly in the 450-600 ms range – the time window in which the differences between the High and Low groups emerged in the raw averaged data (see Figure 2). Thus, we considered TF2 to represent the P300 component. The third factor, TF3, which loaded highly in the 300-400 ms range of the epoch, was attributed to the N400 elicited by incongruent terminations of sentences used as one of the control conditions in this task. TF2 and TF3 accounted for 18% and 12% of the variance, respectively.

Ultimately, the two PCA steps resulted in a finite set of factors, or “virtual” components, corresponding to the ERP components visible in the average waveforms (see Figure 2). Specifically, based on the scalp distribution and the temporal variance accounted for, the primary candidate for further analyses was the scores for TF2 (at the P300 latency range) associated with SF2 (posterior virtual electrode, at which P300 amplitude is typically at its maximum). This TF2/SF2 score was considered to represent the P300 ERP component, and therefore was used in further analyses (in the interest of parsimony, we will label this and other PCA-derived spatiotemporal components by the conventional name of the ERP component to which they correspond followed by an asterisk – P300*). Similarly, an N400* component was derived based on the TF3 scores (at the N400 latency range) associated with the centrally distributed SF1 factor for use in further analysis.

ERP: Inferential analyses—Next, the means of the PCA-derived P300* were analyzed with regards to the participants' expectancies and experimental conditions. Figure 4 presents the means of the P300* factor scores for both Alcohol/Positive-Arousing and Alcohol/Negative-Sedating conditions, as a function of the participants' self-reported endorsement of positive alcohol expectancies (measured by AEMax Positive Arousing scores). From this figure, it is clear that P300* appeared to be largest in response to Alcohol/Negative-Sedating items in those participants who had High positive expectancies, as predicted; it was smaller but still positive in participants with Mid-range positive expectancies, and lower yet – in fact, in the negative range – in participants with Low positive expectancies about alcohol consumption. Analysis of variance using the non-parametric Kruskal-Wallis statistic revealed that this mean difference was significant ($p = .02$). The P300* scores, however, were less consistently distributed in the Alcohol/Positive-Arousing condition and there was no significant difference among the three levels of expectancy endorsement (see Discussion for further interpretation). For comparison, also included in this figure were the N400* component scores, which clearly did not vary as a result of either participants' expectancy levels or alcohol-associated experimental conditions. It is also evident that the N400* scores were invariably negative (as expected) in response to classic incongruent sentences, regardless of the participants' expectancy levels.

Finally, to assess the extent to which P300* varied as a function of individual's expectancies and experimental conditions, Pearson correlations between the self-report drinking and expectancy measures and the TF2/SF2 scores for the Alcohol/Positive-Arousing and Alcohol/Negative-Sedating conditions were calculated. As is evident from Table 3, P300* for Alcohol-Negative/Sedating items was positively correlated with the participants' level of expectancies, as measured by both AEQ Social and Physical Pleasure and AEMax Positive Arousing scores ($r(24) = .52, p < .01$, and $r(24) = .42, p < .05$, respectively). In other words, the higher were the individual's expectations of positive effects of alcohol, the larger were his or her P300 amplitude in response to items contradicting these beliefs. Examination of the scatterplots revealed that these correlation coefficients were not influenced by outliers, but rather reflected a real pattern in the data (see Figure 5). Consistent with the means distribution plotted in Figure 4, no significant correlations emerged between the expectancy measures and P300* in response to Alcohol/Positive-Arousing items; that is, even participants with “low” positive expectancies did not find these items deviant or incongruent (see Discussion for interpretation). Finally, no significant or meaningful (above .15) correlations were found between self-reported drinking

and expectancy measures, and the TF3/SF1 scores (i.e., N400*) for the Alcohol/Positive-Arousing and Alcohol/Negative-Sedating conditions, consistent with the lack of variation of the N400 amplitude among these two conditions seen in both Figures 2 and 4.

Given that P300* amplitude was significantly related to violations of established expectancy profiles (higher positive/arousing expectancies, higher P300* amplitude to negative alcohol items), and expectancy profiles were (as usual) related to drinking, it might be anticipated that P300* amplitudes would be related to drinking as well. As can be seen in Table 2, the P300* amplitudes were correlated (in particular) with the drinking quantity variables (dosage), although these correlations were not significant (but fell within the lower bound 95% confidence interval for significance). A non-significant relationship was not surprising given that drinking indices reflected previous drinking patterns and not drinking proximal to electrophysiological assessment. Nevertheless, because we were intrigued by the implications of a relationship between P300 amplitudes and drinking, we were led to further explore this possibility by using a bootstrap procedure to correct for variations that might have influenced tests of their covariance. The bootstrap procedure allows making inferences about a particular statistic based on an empirical distribution built from resampling the data at hand, without making the conventional assumption of a normal distribution. In this way, more precise standard errors for the observed variables become available for analyses. In reporting these results we acknowledge that they were, at best, only suggestive given that the distributions for the P300 amplitudes and the transformed drinking variables fell within normal limits. Nevertheless, the bootstrap runs with 10,000 replications indicated that the bias-corrected covariance seen between P300 amplitude and drinking was unlikely to have occurred by chance (e.g., for P300* and Total drinks/month, covariance = .35, *SEM* = .12, 95% CI = .12 to .59), suggesting a real relationship between the amplitude of the P300 in response to expectancy violation on the one hand, and drinking on the other.

ERP: Standard oddball P300—The ERP data collected in the standard oddball task (prior to the expectancy violation task) were also subjected to PCA to extract reliable measures of ERP components. Following the sequence of steps described above and based on the scalp distribution and the temporal variance accounted for, a P300-like centro-parietal component, with the largest factor scores for target/rare stimuli, was identified (for simplicity, referred to as the standard oddball P300*). Of note, the topographic plot of the spatial distribution of this component was almost identical to that of the P300* derived from the PCA of data collected in the Expectancy Violation task, further reinforcing the idea that the ERP component that was differentially affected by the two alcohol expectancy conditions was indeed the typical P300 (similar to the P300 evoked by the standard oddball task).

Participants with and without history of alcohol problems in at least one of the parents (obtained from the Family History Grid data) were compared with regards to the magnitude of their standard oddball P300*. Consistent with previous reports, individuals with family history of alcoholism (FM+) did have smaller P300 amplitudes ($M = 1.21$, $SD = 1.40$) than individuals with negative family history of alcoholism (FM-; $M = 2.01$, $SD = .99$), but not significantly so ($t(24) = 1.72$, $p > .05$).

Next, partial correlation analysis was used to explore the relationship between P300* and participants' expectancy levels, while controlling for the standard oddball P300*. The magnitude of the partial correlations between expectancy levels and P300* remained very similar to zero-order correlations (e.g., compare $r(24) = .51$, $p < .01$ – a partial correlation between P300* and AEQ Social and Physical Pleasure scores – to their zero-order correlation: $r(24) = .52$, $p < .01$), suggesting that controlling for the standard oddball P300* magnitude had little effect on the strength of the relationship between P300* and expectancy levels measured by self-report (AEMax and AEQ).

Discussion

As predicted, P300 amplitude elicited by stimuli describing various effects of alcohol was related to participant's subjective alcohol expectancies. Specifically, a significant positive correlation was found between the amplitude of P300 elicited by Alcohol/*Negative-Sedating* items and the participants' levels of *positive* expectancies measured by language-based questionnaires; that is, the higher the individual's expectations of positive effects of alcohol based on self-report, the larger the P300 amplitude in response to items violating these subjective expectations (i.e., items denoting negative and sedating effects of alcohol). These correlations were substantial (0.42 for the AEMax Positive-Arousing factor, and 0.52 for the AEQ Social factor), showing that the P300 amplitude could serve as a psychometrically useful individual index of reward information about alcohol use stored in memory.

In contrast, correlations between expectancy measures and P300 amplitude to Alcohol/Positive-Arousing items were not significant: neither individuals whose primary expectancies were positive/arousing nor those with negative/sedating expectancies found these items particularly deviant. It would appear that, regardless of differences in their expectancy profile, all individuals were “comfortable” with the notion that alcohol has positive/arousing characteristics. This interpretation is supported by the lack of correlation found between the P300 elicited in the standard oddball task, used as a baseline measure of individual P300, and the P300 elicited by the Alcohol/Positive-Arousing items, which suggested that these items were not perceived as “oddball” by the participants in this sample. (It remains possible, however, that very low drinkers with truly negative expectancies of alcohol consumption, who were not represented in sufficient numbers in this sample, would have perceived positive items as deviant given the moderate negative [$r = -.23$] correlation between the AEQ Social factor and P300* amplitude.) Note, however, that almost all drinking variables in all conditions were positively associated with P300, with correlation coefficients ranging from $r = .27$ to $r = .35$ in six out of eight comparisons. That is, the greater the individual's level of drinking, the larger his or her P300 amplitude to *any* stimuli mentioning alcohol. Possibly, P300 amplitude in this study was associated with processing of individually salient stimuli (see Attias, Bleich, & Gilat, 1996; Blomhoff, Reinvang, & Malt, 1998; Granovsky, Sprecher, Hemli, & Yarnitsky, 1998; Pauli et al., 1997), or stimuli that were particularly salient with respect to the task at hand, in addition to the specific reaction to expectancy violations.

Note that these findings went beyond the registration of a simple semantic anomaly. As shown by Kutas and Hillyard (1980), final words in sentences containing a semantic anomaly elicit a negative, rather than positive, ERP component (the N400). In contrast, the present findings distinguished between registration of a semantic anomaly that would be apparent to any reader familiar with the English language, and processing of an idiosyncratic expectancy-based context that was based upon the significance of the final word to that individual. Despite presentation of the experimental stimuli in a classic N400 paradigm, all sentence endings were in fact semantically compatible. Yet, a less-than-one-second-long exposure to the stem “Most alcohol tastes...” apparently invoked individually-held expectancy networks related to alcohol, and the activation of these networks was reflected in the ERP component that was most influenced by the violation of these expectancies, the P300.

Because previous research has shown expectancy levels to be predictive of future drinking, these findings also suggest that, with refinement, P300 response to alcohol expectancies eventually may prove useful as an index of risk for future drinking. Although ERP amplitudes were not significantly correlated with reported drinking levels, some of the observed correlations fell within the confidence levels for significance, and bootstrap runs showed that covariances between these variables were unlikely due to chance. In the real world, actual consumption occurs much further downstream of brain actions which, on a momentary basis,

result in a P300 (in this study, consumption measures registered *previous* drinking). Future research with larger participant pools should investigate the degree to which ERP components that reflect violations of expectancy can be used to predict various drinking parameters over time in a true longitudinal design.

Relationship of Expectancy-related ERP to other Implicit Cognitive Tasks

Because the P300 can be reliably elicited by autobiographically-relevant items, even when participants are attending to an unrelated classification task (Farwell & Donchin, 1991), assessment of ERPs certainly qualifies as an implicit measure by almost any definition available (operates outside awareness, is non-effortful, is influenced by prior learning without the individual's deliberate recollection of this learning, etc.). ERPs may even be more purely implicit in that many language-based implicit tasks are recognized as having some mix of implicit/explicit characteristics (Roediger, 2003). In fact, the present findings are consistent with a recent meta-analysis of implicit expectancy studies (Reich, Below, & Goldman, unpublished manuscript) that showed a modest, but reliable, degree of overlap between implicit and explicit measures of expectancies. As in this meta-analysis, the present study found that the ERP/implicit expectancy measure was significantly correlated with the two explicit expectancy measures.

Alcohol Use Decisions

Potentially, the most important implication of the current findings, however, might pertain to the speed and automaticity of decision making related to alcohol consumption. We acknowledge that the current findings ultimately speak only to P300 as a psychophysiological probe of processes that relate to violations of verbally presented expectancies, and not to actual decision making about alcohol use. Because previous findings demonstrated that priming of verbally presented material can, however, increase actual alcohol consumption (Roehrich & Goldman, 1995; Stein et al., 2000), it may be worth considering the possibility that the P300 may serve as a probe of the processing pathways involved in the decision making regarding consumption. Within this framework, it is interesting to note that within a few hundred milliseconds of being exposed to a stimulus that denotes alcohol and its effects, the nervous system is already passing along a signal that is consistent with downstream consumption. For heavier drinkers, this signal is biased toward anticipating positive/arousing effects; negative/sedating effects are treated by these early automatic (preattentive) processes as anomalous. If the speed and automaticity of the P300 signal in some way parallels those processes that actually influence decision-making, it would be understandable why efforts to control such cascades might be so difficult. And, as noted in the introduction, the P300 itself likely represents some aspect of motivational processing via the locus coeruleus-norepinephrine system (Nieuwenhuis et al., 2005), and related research in both humans and animals has indicated the relevance of neural-circuitry that subsumes the attachment of incentive salience (Berridge & Robinson, 2003), differential rewards (Glimcher & Lau, 2005), and emotional valence (Bechara, Damasio, & Damasio, 2000) to these decisions, all possibly in the absence of deliberative thought.

Relationship to Previous Findings of Attenuated P300 in Individuals with Family History of Dependence

Although a slight indication of P300 attenuation to the presentation of standard oddball stimuli did appear in participants with a family history of alcohol dependence (see Begleiter et al., 1987; Hill et al., 1998; Carlson et al., 2002), this relationship did not impinge substantially on the current findings. In contrast to studies directed toward this relationship, participants in the present study did not receive instructions to focus attention on one category of stimuli. Instead, participants were presented with statements which (presumably) either violated or confirmed

the participants' individual sets of subjective expectancies associated with alcohol, without preconditioning these statements as “normal” or anomalous.

Acknowledgements

This research was supported by National Institute on Alcohol Abuse and Alcoholism grant R01 AA08333. The authors thank the members of the USF Alcohol and Substance Use Research Institute (ASURI) and Cognitive Psychophysiology Laboratory (CPL) for their invaluable consultations. We especially thank Paul Greenbaum for statistical assistance.

Appendix: Expectancy Violation Task Stimuli

Sentence	Target Word	Category
1. Playing video games is a lot of...	fun	Other
2. Alcohol makes me feel ...	down	Alc. Negative-Sedating
3. Smoking makes one look...	cool	Other/Smok. Positive
4. A couple of drinks make me more...	outgoing	Alc. Positive-Arousing
5. Eating fruits and vegetables is...	unhealthy	<u>Incongruent</u>
6. I like going out and...	dancing	Other
7. Alcohol drinks taste...	good	Alc. Positive-Arousing
8. When I am upset, smoking makes me feel...	better	Other/Smok. Positive
9. A couple of drinks make me...	miserable	Alc. Negative-Sedating
10. Smoking a cigarette makes me...	sick	Other/Smok. Negative
11. Drinking alcohol makes me...	horny	Alc. Positive-Arousing
12. Exercising makes me feel...	alert	Other
13. Clubbing on weekends is...	boring	<u>Incongruent</u>
14. When I'm drinking beer, I feel...	depressed	Alc. Negative-Sedating
15. Drinking coffee makes me...	awoken	Other
16. Jogging makes me feel...	exhausted	Other
17. Alcohol makes me feel...	happy	Alc. Positive-Arousing
18. If I'm feeling irritable, a smoke will help me...	relax	Other/Smok. Positive
19. After a few drinks, I feel...	sad	Alc. Negative-Sedating
20. Studying for school makes me...	sleepy	Other
21. During Spring break, I like to...	blink	<u>Incongruent</u>
22. Drinking alcohol makes me feel...	powerful	Alc. Positive-Arousing
23. Cigarettes taste...	good	Other/Smok. Positive
24. When I eat junkfood, I feel...	unhealthy	Other
25. If I have more than 2 drinks, I feel...	sick	Alc. Negative-Sedating
26. After a workout at the gym, I always feel...	tired	Other
27. Alcohol makes me feel more...	assertive	Alc. Positive-Arousing
28. Smoking makes one seem less...	attractive	Other/Smok. Negative
29. When I drink alcohol, I expect to have...	hangover	Alc. Negative-Sedating
30. Action movies are...	slow	<u>Incongruent</u>
31. After a few drinks of alcohol, I feel...	sexier	Alc. Positive-Arousing
32. Smoking makes people...	awake	Other/Smok. Positive
33. Drinking alcohol makes me feel...	depressed	Alc. Negative-Sedating
34. Eating chocolate makes me feel...	happy	Other
35. Alcohol makes me more...	outgoing	Alc. Positive-Arousing
36. When I smoke a cigarette, its taste is...	unpleasant	Other/Smok. Negative
37. I like to cook and prepare nice...	pencils	<u>Incongruent</u>
38. Drinking beer makes me feel...	cheerful	Alc. Positive-Arousing
39. When I am at school, I feel...	bored	Other
40. Alcohol makes me...	nauseous	Alc. Negative-Sedating
41. If I'm tense, a cigarette helps me to...	relax	Other/Smok. Positive
42. A couple of drinks make me more...	aroused	Alc. Positive-Arousing
43. Playing video games is...	boring	<u>Incongruent</u>
44. Drinking alcohol makes me feel...	lonely	Alc. Negative-Sedating
45. When I'm angry, smoking makes me feel...	at ease	Other/Smok. Positive
46. A drink or two can make me feel...	energetic	Alc. Positive-Arousing
47. Eating fruits and vegetables is...	healthy	Other
48. Drinking makes me feel...	unhappy	Alc. Negative-Sedating
49. Smoking a cigarette makes me...	cough	Other/Smok. Negative
50. After a long day, drinking alcohol is really...	refreshing	Alc. Positive-Arousing
51. Drinking coffee makes me...	sleepy	<u>Incongruent</u>
52. Alcohol drinks taste...	bad	Alc. Negative-Sedating
53. When I am upset, smoking makes me feel...	worse	Other/Smok. Negative
54. Alcohol makes me feel more...	sociable	Alc. Positive-Arousing
55. When I smoke a cigarette, its taste is...	pleasant	Other/Smok. Positive
56. Drinking alcohol makes me...	sad	Alc. Negative-Sedating
57. Action movies are...	fun	Other
58. When I'm drinking beer, I feel...	high	Alc. Positive-Arousing
59. I like my coffee with sugar and...	sand	<u>Incongruent</u>

Sentence	Target Word	Category
60. Jogging makes me feel...	energetic	Other
61. Alcohol makes me feel...	nauseous	Alc. Negative-Sedating
62. Clubbing on weekends is...	fun	Other
63. After a few drinks, I feel more...	social	Alc. Positive-Arousing
64. Cigarettes taste...	bad	Other/Smok. Negative
65. After a workout at the gym, I always feel...	energized	Other
66. Most alcohol tastes...	terrible	Alc. Negative-Sedating
67. The night before an important exam I feel...	calm	Incongruent
68. Drinking alcohol makes me feel...	energized	Alc. Positive-Arousing
69. Smoking makes people...	stink	Other/Smok. Negative
70. When I drink alcohol, I expect to have...	fun	Alc. Positive-Arousing

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Figure 1.
Experimental sequence for the Expectancy Violation Task.

Figure 2. Midline electrodes waveforms averaged for individuals with high and low positive/arousing alcohol expectancies. Black vertical lines mark stimulus onset. Positive voltages are plotted as downward deflections.

Figure 3.

A. Topographic maps of the factor loadings for the spatial factors (a.k.a., “virtual electrodes”) for Expectancy Violation task. The percentage of variance accounted for by each factor after rotation is indicated. B. Factor loadings for the temporal factors (virtual epochs).

Figure 4. Means of the PCA-derived P300* and N400* components, as a function of participants' expectancy levels and experimental conditions.

Figure 5. Scatterplot of relationship between P300* amplitude in response to Alcohol/Negative-Sedating items and scores on the AEMax Positive Arousing factor.

Table 1
Zero-Order Correlations between Selected Independent Variables

Measure	1	2	3	4	5	6	7
1. AEMaxPosAr							
2. AEMaxSed	.03						
3. AEQGloPos	.42*	-.06					
4. AEQSoc	.34	.03	.66**				
5. TotalDr _{ln}	.30	-.04	.51**	.59**			
6. DrinkOcc _{ln}	.21	.00	.53**	.52**	.95***		
7. AveQuant _{ln}	.26	.15	.43*	.60***	.94***	.79***	
8. HighestDr _{ln}	.22	.10	.37*	.48**	.92***	.80***	.97***

Note. AEMaxPosAr, AEMaxSed = AEMax: Positive Arousing factor, Sedating factor, respectively; AEQGloPos, AEQSoc = AEQ: Global Positive Changes scale, Social scale, respectively; TotalDr_{ln} = Total number of standard drinks over the past 30 days, log-transformed; DrinkOcc_{ln} = Number of drinking occasions over the past 30 days, log-transformed; AveQuant_{ln} = Average number of standard drinks per drinking occasion, log-transformed; HighestDr_{ln} = Highest number of standard drinks per drinking occasion, log-transformed.

* $p < .05$
** $p < .01$
*** $p < .001$

Table 2
Zero-Order Correlations between Selected Independent Variables and TF2/SF2 (P300) scores

Measure	1	2	3	4	5	6	7	8	9
1. P300* <i>Neg</i>									
2. P300* <i>Pos</i>	.42*								
3. AEMaxPosAr	.42*	.08							
4. AEMaxSed	.07	-.08							
5. AEQGloPos	.29	.13	.14**						
6. AEQSoc	.52**	-.23	.50**	.11					
7. TotalDr ^{ln}	.16	.30	.40*	.18	.68***				
8. DrinkOcc ^{ln}	.02	.30	.36*	.03	.55***	.60***			
9. AveQuant ^{ln}	.30	.32	.34	.07	.56***	.58***	.95***		
10. HighestDr ^{ln}	.27	.35	.23	-.09	.43*	.52***	.92***	.75***	
					.38*	.52***	.92***	.80***	.96***

Note. P300**Neg*, P300**Pos* = TF2/SF2 factor scores in response to Alcohol/Negative-Sedating and Alcohol/Positive-Arousing conditions, respectively; AEMaxPosAr, AEMaxSed = AEMax: Positive Arousing factor, Sedating factor, respectively; AEQGloPos, AEQSoc = AEQ: Global Positive Changes scale, Social scale, respectively; TotalDr^{ln} = Total number of standard drinks over the past 30 days, log-transformed; DrinkOcc^{ln} = Number of drinking occasions over the past 30 days, log-transformed; AveQuant^{ln} = Average number of standard drinks per drinking occasion, log-transformed; HighestDr^{ln} = Highest number of standard drinks per drinking occasion, log-transformed.

*
 $p < .05$
**
 $p < .01$

 $p < .001$