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Priming Expectancies: Effects on Neurophysiological Indices of Expectancy Violations and Drinking Behavior

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Priming Expectancies: Effects on Neurophysiological Indices of Expectancy Violations and Drinking Behavior

by

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ABSTRACT

Investigations of the anticipated effects of alcohol indicate that cognitive frameworks are highly correlated with drinking and other variables associated with alcohol use, explaining up to 50% of the variance in drinking outcomes (Goldman, Darkes, & Del Boca, 1999; Goldman, 2002; Goldman et al., 2006; Goldman, Reich, & Darkes, 2006). Furthermore, alcohol expectancies appear to mediate the relationship between a variety of risk factors, such as sensation seeking, and alcohol outcomes (Darkes, Greenbaum, & Goldman, 2004). The current study examined the relationship of these cognitive networks with a physiological index of expectancy violation

Participants were presented with statements reflecting a wide range of alcohol outcome effects, which either violated or confirmed the participant's own set of alcohol expectancies, while the ERPs evoked by these stimuli were recorded. As predicted, the P300 amplitude elicited by negative alcohol expectancy stimuli was positively correlated with the degree of endorsement of positive/arousing expectancies on the self-report measure. That is, the higher the individual's positive/arousing expectancies, the larger the P300 elicited by stimuli asserting the negative effects of alcohol. There was no significant correlation, however, between P300 amplitude elicited by positive alcohol expectancy

stimuli and the degree of endorsement of negative/sedating expectancies on the self-report measure.

In addition, individual differences relating to alcohol expectancies were examined as well. These results were able to identify specific stimuli that violated expectancies for each individual, as well as those that tended to violate expectancies in systematic ways across subjects. These findings provide a way forward for more precise assessment and prediction based on the well developed cognitive model of Alcohol Expectancies.

In sum, variations in the amplitude of the P300 were consistent with the model of Alcohol Expectancies. Words imputing negative/sedating effects of alcohol elicited a large P300 in individuals with higher positive alcohol expectancies. By indexing the brain's electrophysiological response sensitive to expectancy violations, these findings demonstrate concordance between verbal measures of alcohol expectancies, which by their very nature are introspective, and a psychophysiological index of expectancy thought to operate automatically and to be independent of overt responding.

Introduction

Alcohol expectancies are anticipatory memory processes that affect perception, cognition, and behavior related to alcohol. Investigations of the anticipated effects of alcohol indicate that these cognitive frameworks are highly correlated with drinking and other variables associated with alcohol use, explaining up to 50% of the variance in drinking outcomes (Goldman, Darkes, & Del Boca, 1999; Goldman, 2002; Goldman et al., 2006; Goldman, Reich, & Darkes, 2006). For example, heavier drinkers tend to endorse more positive and arousing expectancies compared to light drinkers, and expectancies measured in children prior to the onset of drinking behavior are prospectively associated with drinking behavior (Goldman, 2002; Dunn & Goldman, 1998). Furthermore, alcohol expectancies appear to mediate the relationship between a variety of risk factors, such as sensation seeking, and alcohol outcomes (Darkes, Greenbaum, & Goldman, 2004). This has led some researchers to consider alcohol expectancies to be one of the primary systems that accounts for biopsychosocial risk for alcohol use and abuse (Goldman et al., 2006; Sher, Grekin, & Williams, 2005).

Alcohol expectancies have been measured via semantic associations probed through direct self-report and indirect cognitive paradigms (Goldman, Reich, & Darkes, 2006; Kramer & Goldman, 2003; Reich & Goldman, 2005). Although there is some debate over the utility of direct (explicit) versus indirect (implicit) measures, both classes of measures have explained variance in alcohol outcomes (Wiers et al., 2002, Reich, Below & Goldman, 2010). In fact, both overt and implicit manipulations of expectancies have led to changes in actual drinking behavior in several experiments (Darkes & Goldman, 1993; Roehrich & Goldman, 1995; Stein, Goldman, & Del Boca, 2000). In some respects, ascertaining expectancies via implicit measures provides insight that cannot be derived from explicit measures because implicit measures may reflect more automatic processing. Although implicit and explicit measures of alcohol expectancies index the same construct to some degree, it is clear that implicit measures add predictive value incrementally to explicit measures (Reich et al., 2010). By harnessing this variance via implicit measures, researchers may be able to better explain the anticipatory and predictive nature of expectancies in the realm of alcohol and beyond in a way that moves beyond correlational designs to studies that show the effect of expectancies on information processing and decision making at the event level.

Recently, Fishman, Goldman and Donchin (2008) developed a novel approach for implicitly measuring alcohol expectancies using event-related potentials (ERPs). They utilized an established brainwave paradigm that measures violations of expectation and created an application in which stimuli would either fit with an individual's alcohol expectations or violate one's alcohol expectations. They then showed that the individual's brain waves served as an index of the violation. This study provided evidence that expectancies predict responses to stimuli far more quickly than could be measured by language-based expectancy paradigms (i.e., within milliseconds of stimulus presentation), thus substantiating the theory that expectancies serve as anticipatory frameworks for evaluation of stimuli encountered in the environment. Furthermore, it opened the door for additional ERP investigations of alcohol expectancies at the level of individual differences.

Priming & Alcohol Expectancies

Apart from implicit measurement of alcohol expectancies, many studies have explored the implicit activation of alcohol expectancies. When activated, representations in memory trigger a host of related semantic and affective associations that can influence subsequent behavior (Bargh & Williams, 2006). As in classic priming experiments in which responses to a target are faster when a related word or concept has been primed, researchers have described numerous social and behavioral responses that result from subtle primes (e.g., Vohs, Mead, & Goode, 2006). Activation of concepts that facilitate these responses often occurs outside of one's awareness, yet this activation exerts measurable influence on subsequent behaviors. In the alcohol expectancy domain specifically, researchers have capitalized on the fact that encountering alcohol cues activates associations an individual has with those cues, which includes everything from semantic associations to behavioral outcomes, potentially increasing the likelihood of using alcohol as a behavioral option (e.g., Leigh & Stacy, 1998). While direct cuing clearly has the potential to activate associations, several studies have used indirect priming of alcohol expectancies to examine the influence of memory associations on subsequent activities.

Several studies examined the effects of activation on actual drinking behavior. For example, one study examined the effects of two types of primes on female social drinkers' behavior (Roehrich & Goldman, 1995). The primes included a video clip of a sitcom and a modified Stroop task, with a neutral condition and a positive alcohol condition for each type of prime. After viewing various combinations of alcohol and neutral primes, participants had the opportunity to consume placebo beer in an ostensibly unrelated study. Participants who viewed the alcohol video clip and completed the alcohol Stroop task consumed more placebo beer than those in the neutral or mixed prime conditions. A similar study used the same Stroop task priming paradigm, but added a negative alcohol condition in which negative or sedating alcohol expectancy words were presented (Carter et al., 1998). Results indicated that those primed with positive alcohol expectancy words consumed more beer in the taste test than those in the neutral condition and those primed with negative expectancy words consumed less than those in the neutral condition. Another study compared the relationship between positive and neutral alcohol expectancy verbal primes and positive and neutral music mood inductions with subsequent beer consumption (Stein, Goldman, & Del Boca, 2000). Those primed with positive expectancy words drank more than those in the neutral condition, and within the positive expectancy group heavier drinkers consumed more than lighter drinkers.

Several other studies examined the effects of priming on non-consumptive behaviors. For example, one study presented participants with a list of various alcohol expectancy and food words to study (Reich, Noll, & Goldman, 2005). Primes consisted of two nearly identical word lists in which the first word was altered to read “milk” in the neutral condition and “beer” in the alcohol condition. Those in the “beer” condition tended to recall a greater proportion of expectancy words. Another study utilized a modified Stroop task in which participants were primed with either neutral or alcoholic beverage words prior to the Stroop targets, which included arousing, sedating, or negative expectancy words, or neutral words (Kramer & Goldman, 2003). Results indicated that lighter drinkers demonstrated slower color naming reaction times to sedating expectancy words following alcohol beverage primes, whereas heavier drinkers demonstrated slower reaction times to arousing expectancy words following alcohol beverage primes.

Cumulatively, these studies indicate that priming alcohol expectancies results in differing responses in cognitive performance and behavior, and that the drinking status of the individual affects the results. That is, activation of alcohol expectancies via contextual and language-based priming appears to facilitate or inhibit cognitive processing and decision-making differentially, indicating that these memory networks may act as anticipatory mechanisms in subsequent stimulus evaluation and decision making, including the decision to drink alcohol. Behavioral responses are automatically facilitated by indirectly priming alcohol expectancy words and alcohol-related words, with the greatest facilitation coming from primes accompanied by a contextual cue (e.g., Roehrich & Goldman, 1995; Carter et al., 1998; Goldman, Darkes, Del Boca, 1999). These studies provide a framework within which to examine alcohol expectancies; however, each of the studies above relies on behavioral output far downstream from the purported activation of alcohol-related concepts in memory. Newer approaches, such as the ERP paradigm developed by Fishman et al., are appealing because they allow researchers to explore the processes far upstream of those previously reported. It is important to understand what ERPs are in order to understand how such a tool can contribute to the investigation of alcohol expectancies, and to understand how ERPs can build upon the strong empirical foundation of cognitive and semantic research established in the alcohol expectancy domain.

Event Related Potentials

Event-related potentials (ERPs) are components of electrical activity of the brain that are elicited by specific events. ERPs are time-locked to discrete sensory, motor, or cognitive events, and as such are manifestations of neural activities that are invoked in the course of information processing (for review see Fabiani, Gratton, & Coles, 2000). The ERP signal, which is only a few microvolts, is extracted from the electroencephgraphic (EEG) activity, which can reach 50 microvolts, by signal averaging. The ERP waveforms reflect the effects of particular information processing elicited by the event. ERP methodology provides a non-invasive tool with very fine temporal resolution (in milliseconds). ERPs have less spatial resolution to identify neural origins of electrical activity, though recent statistical techniques have allowed for source localization with greater acuity than earlier methods (Slotnick, 2004).

The ERP elicited by an event consists of a sequence of components, labeled by polarity and latency in milliseconds (e.g., N100, P300). The activity that the ERP components manifest is assumed to have a functional significance as specified in terms of the information processing role of the underlying neural action (Donchin & Coles, 1988). Early ERP components, with a latency of less than 100 ms, reflect sensory processes, while later components reflect higher cognitive processes like semantic processing and error monitoring (for a review see Key, Dove, & Maguire, 2005). To access the functional significance of ERPs, tasks must be designed to elicit specific information processing functions. For example, the P300 component is typically elicited using an "Oddball" paradigm in which participants are required to attend to a sequence of events in which are interspersed infrequent events. The P300 is elicited by these infrequent events, while a component like the N400 is elicited using semantically incongruent terminal words of sentences (e.g., "I like my coffee with sugar and *sand*"). The P300 component has been one of the most widely examined ERPs, due in part to the functional significance that is attributed to it.

Several variables affect the amplitude and latency of the P300 component (see Fabiani et al., 1987; Picton, 1992). P300 amplitude increases and decreases as a function of stimulus probability and task relevance or value (Duncan-Johnson & Donchin, 1977). Furthermore, P300 amplitude is dependent on subjective probability and relevance of an event, while the latency of the P300 is largely dependent on task complexity (Donchin & Coles, 1988; Dien, Spencer & Donchin, 2003). Thus, subjective probability and relevance are important factors for understanding the implications of the P300 in cognition. The context-updating hypothesis posits that unexpected events interrupt ongoing cognitive processes, causing the individual to revise the current model of the environment in working memory (Donchin, 1981; Donchin & Coles, 1988). Stimuli that are unexpected or that are most relevant to the individual require more significant updating and result in larger P300 responses. The functional significance of the ERP components, particularly the P300, makes ERP a very powerful tool for accessing cognitive processes including those pertaining to the evaluation of alcohol-related information and alcohol consumption.

ERPs, Alcohol, and Affect

ERPs have been utilized frequently in examinations of the cognitive effects of acute and chronic alcohol consumption. The goal of most such studies has been to identify specific cognitive deficiencies associated with various levels of alcohol use by examining the amplitude and latency of specific ERP waves. Typically, tasks are contextually neutral and measure simple information processing, such as pressing a button when rare stimuli are presented. While these tasks are valid for identifying information processing, they are non-specific because they do not have a special relationship to the phenomenon of interest: problem drinking. As will be delineated below, ERPs have the potential to access motivationally significant and emotionally relevant cognitions that provide more functionally significant aspects of perception, evaluation, and decision-making related to subjectively salient stimuli, including drug-related stimuli.

Just as priming paradigms have been used in behavioral research as mentioned above, such priming paradigms have proven effective in assessing context specific expectations and attitudes via ERPs. For example, a mismatch between a primed affective category (e.g., good or bad; happy or sad) and a stimulus word, resulted in evaluative inconsistency and elicited a “late positive ERP component” (Cacioppo, Crites, & Gardner, 1996). Upon further evaluation this late positive “component” includes the P300 component when properly parsed (Ito & Cacioppo, 2007; Spencer, Dien, & Donchin, 2001; Dien, Spencer, & Donchin, 2004). Similar results were found with affectively primed political attitudes (Morris et al., 2003). Furthermore, evidence indicates that these violations are automatic and uncontrollable, and may even conflict with reported attitudes in stereotype challenges (e.g., violations of gender stereotypes; Osterhout, Bersick, & McLaughlin, 1997). Individuals also exhibit P300 to subjectively arousing picture stimuli, and larger responses appear to reflect the level of affective arousal (Cuthbert et al., 2000). Thus, ERPs allow researchers access to affect-laden and context-specific evaluative information processing, which may or may not be readily reported by the participant in direct self-report tasks.

Alcohol- and drug-related stimuli can access associated automatic cognitions in a similar manner to non-alcohol related studies cited above, though little research has been conducted on ERP responses to alcohol stimuli. Hansenne et al. (2003) examined ten alcoholics compared to controls and found a decreased P300 latency to alcohol-related words in the alcoholics, but no differences in amplitude. These results may be confounded by the preexisting attenuation of P300 response reported in alcoholics and their offspring (Begleiter et al., 1984; Begleiter et al., 1987). In studies on drug stimuli, research has shown that drug-relevant stimuli increase ERP amplitude in those addicted to the drug (Franken et al., 2003). Therefore, context specific stimuli that were affectively salient to particular individuals elicited quicker and potentially larger ERPs.

Another set of studies examined P300 responses to alcohol cues in drinkers with varying levels of sensitivity to alcohol. They found that individuals lower in sensitivity to alcohol elicited larger P300s to alcohol cues and the P300 amplitude was correlated with self-reported drinking in the following months (Bartholow, Henry, & Lust, 2007). This same group found that ERPs elicited by alcohol cues correlated with self-reported positive evaluation of alcohol, whereas subjects' self-reported evaluation of condom use appeared to conflict with ERPs to condom cues. While these studies utilize the idea that alcohol cues are automatically evaluated, it is necessary to understand the role of alcohol-specific cognitions in stimulus evaluation and decision making to connect the ERP literature seamlessly with alcohol literature.

Fishman et al. (2008) was the first study to examine individual differences in P300 elicited by alcohol expectancy statements. Participants were presented with statements about alcohol (i.e., “alcohol makes me…”) wherein the final word in each statement either agreed or conflicted with the individual’s expectancies as indexed by a standard paper and pencil measure. Averaged waveforms indicated that individuals who primarily associated positive and arousing alcohol expectancies, which tended to be heavier drinkers, exhibited larger P300 responses to negative and sedating expectancy statements. Conversely, individuals who primarily associated negative and sedating alcohol expectancies, which were more likely to be lighter drinkers, tended to exhibit larger P300 responses to positive and sedating expectancy statements. That is, sentences that violated one’s primary expectancies elicited a larger P300 response than congruent sentences. Fishman et al. laid the groundwork for the current study to attempt to expand the ERP paradigm they developed and to test whether this index of alcohol expectancy violation may also reflect individual differences in salience or activation within an experimental task.

Study Rationale

Expectancies are assumed to be stored in memory as templates of systematic relationships between contextual cues and outcomes. They are designed to allow an individual to deal with the environment, and as such must be constantly updated to remain efficient (Goldman, 1999, 2002). As reviewed above, functional aspects of ERP research fit well into research on alcohol related cognitions. The P300 component responds to subjective probability and can be used to assess the expectations of individuals. The P300 component appears to index the level of expectancy violation (i.e., stimuli with the lowest probability appear to elicit the largest P300 in studies in which the probability of stimuli was manipulated). Research has also shown that the P300 can be elicited with context specific and affect-laden stimuli that assess specific attitudes and indicate violations of expected outcomes, and an initial study of the relationship between alcohol expectancies and ERP responses indicated that the P300 is a valid correlate of violations of alcohol expectancies.

Research on language-based assessments of alcohol expectancies has demonstrated reliable intensification through indirect priming and direct activation of alcohol memory networks that has affected memory performance, discrimination performance, and actual drinking behavior (Reich, Noll, & Goldman, 2005; Roehrich & Goldman, 1995). The P300 response observed in Fishman et al. (2008) may index alcohol expectancy violations, but it is unknown whether priming alcohol concepts prior to testing may augment such responses. Expectancy theory would predict that activation of anticipatory cognitive frameworks affects perception and categorization of stimuli, and if the P300 is sensitive to this activation of expectancy it should reflect this in increased or decreased amplitude.

In order to further assimilate these ERP findings into the alcohol expectancy framework, it is necessary to examine whether the neurophysiological indexing of expectancy violations by the P300 component also responds to experimental manipulations like other cognitive and behavioral measures of expectancy. Previous studies have purportedly increased or decreased expectancies via priming, though it is unclear whether underlying expectancies were changed or whether the effects elicited were a function of expectancy activation in a particular context-dependent state (e.g., Stein, Goldman, & Del Boca, 2000).

The current study was designed to test whether indirectly priming alcohol affected the amplitude or latency of the P300 component in an ERP paradigm, and then examined how the ERP responses related to other cognitive and behavioral measures of alcohol expectancies. This design allowed for the evaluation of potential mechanisms of action of alcohol expectancies by exploring whether the neurophysiological activity following expectancy activation correlates with drinking behavior. By exploring the effects of priming on neurophysiological measures of expectancy violation and on subsequent behavioral measures of expectancy activation, the study was designed to examine the role of perception and stimulus evaluation in expectancies' effects on behavior.

Aims & Hypotheses. The study utilized an indirect priming manipulation in order to activate alcohol expectancy memory networks prior to the presentation of stimuli in an ERP paradigm. It was expected that the neutral prime condition would replicate results obtained in an earlier investigation of ERP indices of alcohol expectancy violations (Fishman et al., 2008). That is, individuals who endorse more positive and arousing alcohol expectancies were expected to show larger P300 responses to incongruent (i.e., negative and sedating) alcohol statements.

In the alcohol prime condition ERP results were expected to be moderated by expectancies (and drinking status of the individual inasmuch as drinking and expectancies are correlated). Previous studies on expectancy activation showed effects for most college students, as activating alcohol related concepts tends to increase the salience of other alcohol associations. In this case, violations of expectancy were being examined, so individuals who endorse more positive and arousing alcohol expectancies were expected to react differently than individuals who endorse more negative and sedating expectancies. Following the alcohol prime, it was predicted that individuals with positive and arousing expectancies would exhibit a larger P300 response to negative and sedating alcohol sentences compared to those in the neutral prime group. Given the ambiguous results from the initial study in individuals with more negative and sedating expectancies, coupled with the fact that individuals with any experience with alcohol tend to have some positive alcohol expectancies (Rather et al., 1992), no hypothesis was made concerning the ERPs exhibited by individuals with more negative and sedating expectancies.

It was expected that alcohol expectancies would correlate with reported drinking levels (i.e., higher positive and arousing expectancies correlate with heavier drinking), and that heavier drinkers and individuals with greater positive and arousing expectancies would consume more during an ad lib drinking session. It was expected that the group that viewed the alcohol video prime would drinking more in the ad lib drinking session after controlling for drinking levels. In addition, it was also hypothesized that ERP responses would be associated with subsequent ad lib drinking (i.e., larger P300 to negative/sedating stimuli would correlate with greater drinking).

Method

Participants

College students aged 21 and up were recruited through the university's online research participant pool. Participants were randomly assigned to neutral and alcohol prime conditions, with equal numbers of males and females in each condition. The language-based tasks coupled with EEG recording require several restrictions to participation. Participants were screened via an online demographic survey associated with the research participant pool, in which individuals were required to endorse having consumed alcohol in the last month, being native English speakers, and having normal or corrected-to-normal vision. They were also screened for history of neurological disorder (e.g., seizure disorder or multiple sclerosis) or head injury (i.e., loss of consciousness > 5 min), which could affect the EEG quality, as well as for use of medications that might affect EEG signal (e.g., anxiolytics or neuroleptics).

Measures

Demographic form. This form provided information regarding age, gender, ethnicity, education, and health status (specifically history of head injuries, neurological disorders, and current medication).

Oddball task. A standard oddball task with X and O stimuli was used. A total of 200 trials are included with 40 “rare” targets and 160 standard stimuli. Each stimulus was presented for 600 ms and the intra-stimulus-interval (ISI) was set to 1000 ms. Participants responded to each trial by pressing one button following an X or another button following an O.

ERP expectancy sentence task. The ERP stimulus set used by Fishman, Goldman, and Donchin (2008) was utilized. This paradigm consists of 72 English statements describing various habits or activities pertinent to the college students, including studying, spending time with peers, partying, drinking, smoking, exercising, etc. Each statement was missing the last word, e.g., “On a Friday night, alcohol makes me....” and participants were instructed to press a key to move to the next screen. When the key was pressed, a fixation point appeared for 500ms followed by the last word (e.g., “happy”) for 800ms. These targets words were chosen from the Alcohol Expectancy Multiaxial Assessment scale (AEMax), which contains 132 most common alcohol expectancy words derived by various item selection procedures from a large pool of responses to the prompt “Alcohol makes one…” and subsequently normed in large college student samples, as described by Goldman and Darkes (2004). In total, 31 sentences related to alcohol: 14 with a negative/sedating ending, and 17 with a positive/arousing ending (e.g., “Alcohol makes me… happy” vs. “Alcohol makes me…sad”), in a semi-random order. Fifteen sentences were structurally similar statements, but related to smoking (e.g., “Smoking makes me…sick”), with 8 positive and 7 negative endings. These statements were borrowed from the Smoking Consequences Questionnaire (SCQ; Brandon & Baker, 1991). Another 17 sentences were composed with other, non-alcohol or non-smoking content, such as exercising or studying (e.g., “After a workout at the gym, I always feel…exhausted”). They were intended as control/neutral condition for the ERP comparison. Finally, 9 classic N400-eliciting sentences (e.g., “I drink my coffee with sugar and…socks”) were included in order to control for participants’ attention to the task.

The 72 sentences made up 6 experimental conditions: Alcohol- Positive/Arousing, Alcohol-Negative/Sedating, Smoking- Positive, Smoking- Negative, Incongruent, and Other – a baseline condition. One block of these 72 sentences was engineered so that no two statements from the same category 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. This block was presented first, followed by a block of all 72 sentences presented in random order determined by a computer that differed for each participant. The P300 amplitude elicited by Alcohol-Positive/Arousing and Alcohol-Negative/Sedating stimuli served as the main outcome measure for this task.

Alcohol Expectancy Questionnaire (AEQ; Brown, Goldman, Inn & Anderson, 1980; Brown, Christiansen & Goldman, 1987; Goldman, Greenbaum & Darkes, 1997). The measure included 68 statements in a True/False format about the various effects of alcohol, including social, physical and sedating domains. Expectancy items on the AEQ correlate with alcohol consumption, alcohol abuse and behavior while drinking, with a mean reliability of 0.84. Factor analysis revealed 6 separate subscales within this measure, including: global positive changes, sexual enhancement, physical and social pleasure, increased social assertiveness, relaxation and tension reduction, and arousal and aggression. The relative levels on each subscale were analyzed to provide further information into the type of alcohol expectancies endorsed by each participant. The AEQ was completed by participants through the online participation program prior to enrolling in the study.

Alcohol Expectancy Multi-Axial Assessment: Short Form (AEMax; Goldman & Darkes, 2004). The shortened version of this measure included 24 expectancy items, with three from each of the eight first order factors derived from the longer 132-item scale (i.e., horny; social; egotistical; attractive; sick; sleepy; woozy; and danger). These eight first order factors load onto three higher order factors: Positive-Arousing, Sedating, and Negative. Participants were asked how often they believe the item best completes the sentence “alcohol makes one…”, using a 7-point Likert Scale ranging from 0 = “never” to 6 = "always". The measure is proven both reliable and valid and is an effective measure of the positive-negative and arousing-sedating dimensions of alcohol expectancies. While many of the words overlap with those in the ERP task, this measure will give an explicit index to contrast with the ERP results.

Pattern of alcohol use. Participants were asked to report their drinking habits for the past year. This includes the frequency and quantity of their typical alcohol use, the number of occasions on which they become drunk from alcohol, as well as an item which queries how often they consumed beer. Regarding the veracity of self-reports, the relevant literature indicate that verbal reports can provide reliable and valid information when inquiries are made about sensitive personal information such as alcohol consumption, especially under circumstances in which there are no obvious incentives to under- or over-report (see Babor, Brown, & Del Boca, 1990; Del Boca & Noll, 2000).

Family Grid. Family history has been identified as an important factor in the development of alcohol used disorders as well as in responses on behavioral and psycho-physiological measures (e.g., Schuckit et al., 1992; Porjesz et al., 2005). The family grid interview measures the density of first and second degree biological relatives having in the past or currently having significant drinking problems. Problems are assessed by endorsing items in one or more major life areas including: legal problems (drunk driving violations), health problems (cirrhosis of the liver, alcohol withdrawal), relationship problems (objections about drinking from family members), work or school problems (absenteeism, poor performance due to alcohol use), and actual treatment (detox, rehab, AA meetings).

30-Day Timeline Follow-Back (TLFB; Sobell & Sobell, 1992). This calendar-based interview measures participant alcohol use (quantity and frequency) retrospectively over the month prior to assessment. Participants were asked to identify the amount of alcohol consumed per drinking day in the previous month, with special attention to drinking patterns in the previous week. At the conclusion of the interview, participants were asked whether the calendar represents a typical drinking month. If the month was not considered typical, participants were asked whether the prior month shows a heavier or lighter drinking pattern.

Taste-rating task. The drinking session of the study was purported to be a market research taste test. Protocol from previous studies was used (Roehrich & Goldman, 1995; Marlatt, Demming, & Reid, 1973). Participants were asked to participate in a taste-testing study which required tasting and rating beverages on various characteristics including taste, texture, and color. The beverages included separate brands of non-alcoholic beer to preclude the use of time consuming and costly protective measures required by NIAAA for alcohol consumption research, including pregnancy tests for females. Participants were presented with 3 glasses of beer, with 8 ounces (~236 ml) in each glass, and were given a rating form with various characteristics to be evaluated as well as an overall rating for each of the three samples. Each participant spent 7-10 minutes in the taste-rating task. The main dependent variable was the total amount of the beverage consumed.

Procedure

Individuals were recruited through the online participant pool based on the inclusion criteria detailed above. Eligible participants were invited to attend a 1.5 hour lab session in exchange for class credit. Participants were asked to refrain from alcohol or non-prescription drug use for 24 hours prior to their appointments, to eat 4-6 hours prior to their appointment, and to refrain from strenuous exercise for at least 3 hours prior to their appointment.

When participants arrived at the lab they were asked to complete an informed consent form, which provided information on confidentiality, benefits and risks of participation, and storage of the data. The title of the study was listed as “ERPs & Memory Function” and the consent form did not provide information about the specific stimuli that would be viewed during the study to prevent participants’ knowledge that the study would contain information about alcohol. Participants were also given the basic agenda of the experiment and were told that there would be a 10 minute break at one point, during which they could have the option of participating in a market research study in a separate lab in the psychology department. After completing the consent form, the participant filled out a basic demographic form to confirm eligibility and gather additional information. Upon completion of the demographic form, the EEG sensor net was placed on the participant’s head and the participant was led into an adjacent room where the EEG tasks were completed.

First, a standard “Oddball” task was administered in which participants responded by pressing a button when a target letter was presented (“X” or “O”), and pressing a different button when a non-target letter was presented. There were a total of 200 trials with targets presented 80% of the time and non-targets 20% of the time. This task served as a baseline for the participant’s individual response amplitude and latency, as well as a potential index of the general cognitive differences previously observed between at-risk and low-risk drinkers in P300 paradigms. Each ERP task began with a practice block to ensure the participant understood the instructions and was able to follow the directions. The experimenter remained in the room during this period and guided the participant through this portion of each task and left the room during the recording phase.

After completing the Oddball task, participants viewed two short video clips presented under the guise of a memory study. Participants continued to wear the EEG sensor nets, though EEG was not being recorded during the video clip presentation. Each of the clips was approximately 90 seconds long. The first video clip depicted a conversation among friends in a coffee shop (from the sitcom *Friends*) and was presented in both conditions. The second video clip differed between conditions. In the neutral condition the clip was depicts a conversation among friends in a diner (from the sitcom *Seinfeld*). In the alcohol condition, the second clip also depicted a conversation among friends, though the setting of this dialogue is a bar (from the sitcom *It's Always Sunny in Philadelphia*). The two videos that differed between conditions were matched on several variables including number of speakers, level of humor, and level of arousal, in an attempt to make the setting of the dialogue the main distinguishing feature.

After a short rest during which the experimenter ensured that the participant was comfortable and that the electrodes were still reading properly, participants completed the expectancy violation task. For the expectancy violation task, ERP recording were time-locked to the onset of the final word in each sentence and the recording epoch of each trial was 1000ms. At the offset of the target word participants were asked to perform a judgment task (Do you agree/ disagree with the statement?). They were instructed to make their response as soon as the prompt appeared on the screen and reaction times of this response were recorded. After the participant's response, there was a 2000-ms inter-trial interval before the next trial began.

Following the ERP tasks, the sensor net was removed from the participant's head and the participant was given the option of participating in a short market research study during the 10 minute break of the experiment. When participants agreed, a second experimenter took them to a lab down the hall from the EEG lab where they were told they would be participating in a taste-rating task. Participants completed a consent form and demographic form to uphold the distinction between the EEG experiment and the taste-test task. Participants were presented with three glasses of non-alcoholic beer and a glass of water to rinse their mouths between beers. They were given brief instructions then left alone with a rating form for each beverage. The experimenter running the taste-test checked in on the participant after 5 minutes, and if the participant indicated that they were done the experimenter delayed and returned to retrieve the participant 2 minutes later. If the participant was not done at 5 minutes, the experimenter returned to the room at the end of 10 minutes. Participants then filled out the pattern of alcohol use survey in the same room, with instructions that the researchers running the taste-test wanted to take into account how often people typically drink.

After completion of the taste test portion of the study, the participant was led back to the EEG lab preparation room to complete the remaining questionnaires (AEQ, and AEMax) followed by the TLFB and family history interviews with the initial experimenter. The participant was debriefed, during which knowledge of the experimental manipulation was queried and the nature of the study and the contents of the beverages were then disclosed.

Data Processing & Analysis

EEG data preprocessing. EEG data were digitally filtered with a 40-Hz lowpass filter and segmented into epochs starting 100 ms prior to stimulus onset to 1000 ms following stimulus onset for the Expectancy Sentence paradigm, and 200 ms prior to stimulus onset to 1000 ms following stimulus onset in the Oddball paradigm. These raw EEG epochs were then run through an automated artifact detection program, corrected for eye movements (Gratton, Coles, & Donchin, 1983), and baseline-corrected using the average of the respective pre-stimulus epoch. The artifact-free trials were then averaged separately for each experimental condition. In the Expectancy Sentence paradigm this yielded 6 separate average waveforms (i.e., Alcohol-Positive/Arousing, Alcohol-Negative/Sedating, Smoking- Positive, Smoking- Negative, Incongruent, and Other) for each participant. In the Oddball task this sequence of processing steps generated two separate average waveforms for each participant; one for rare “targets” and one for frequent “standard” stimuli. Finally, the averaged data were re-referenced to a mean-mastoid reference. This procedure generated a 129th channel of mathematically linked reference recorded separately from the ear lobes. Participants with fewer than 75% good trials per category were excluded (n = 7). The averaged data files were then exported to MATLAB™ (version 2008a, MathWorks, Natick, MA) for further processing.

Principal Components Analysis. In order to extract components a principal components analysis (PCA) was conducted on the observed waveforms. The extracted components were not based on peaks or troughs in the raw waveform but on the basis of experimental variation. A software package called PCA Toolbox (version 1.22; Dien, 2008), was utilized to run the PCAs in MATLAB.

The PCA procedure required several mathematical steps that are completed automatically by the software package. To begin with, correlations are calculated between each electrode pair over all the time points. The PCA procedure then forms combinations of the original measures that capture the most relevant variance. Each principal component is a weighted linear combination of all the original dependent variables. PCA is intended to describe the complex relations between the many variables in terms of a smaller number of hypothetical, unobserved, *latent* variables that do not overlap significantly. These components reflect “some essential physiological, psychological or hypothetical construct whose properties are under study” (Donchin et al., 1977, p. 10). The principal components are extracted from the data in a hierarchical fashion. The first component accounts for the largest proportion of the variance in the data, and the successive components must account for the largest portion of the residual variance. Using an orthogonal rotation (e.g., Varimax) forces each component to be uncorrelated, but when using an oblique rotation (e.g., Promax) the solution begins with the orthogonal components (i.e., simple structure solution matrix) and then rotates the solution by seeking a least squares fit so some of the components end up being correlated. For typical ERP data, this percentage of variance accounted for drops off rapidly after the first five or six components, which usually account for 90–95% of the variance in the data. The components extracted are thought to represent the variance controlled by the experimental manipulation (in the case of the P300, the degree of expectancy violation). To derive the P300 component several steps were required.

In ERP data, the variables are the microvolt readings at each electrode and at each consecutive time point. A spatial PCA was conducted for the averaged waveforms at each electrode site for all experimental conditions for each participant, to reduce the number of variables in this dimension. Spatial PCA identifies clusters of electrodes that are so highly correlated that some of the electrodes can be considered redundant (Spencer, Dien, & Donchin, 2001). The spatial PCA produce a series of "spatial factors" from the original 129 electrodes that represent highly correlated electrodes.

After reducing the dataset to a set of spatial factors, a temporal PCA was conducted to reduce the temporal dimensions. In this step, the spatial factor scores associated with the time points of the original dataset were used as the variables for the PCA, and the observations were the spatial factors. The resulting spatiotemporal factor scores (i.e., scores for a given spatial factor at a given temporal factor) then served as dependent variables for subsequent analyses. Specifically, a combination of the spatial factor accounting for the most variance in the centro-parietal channels (corresponding to the well-established scalp distribution of P300) and the temporal factor accounting for the most variance in the window corresponding to the P300 latency (300-600 ms) were sought to represent the P300 ERP component as a dependent variable.

Statistical analyses of hypotheses. Demographic and drinking data were first examined to determine whether the random assignment procedure resulted in groups that did not differ on any of the variables of interest (e.g., drinking and expectancy variables). Drinking variables (derived from quantity/frequency self-report items and the TLFB) and expectancy variables (AEQ and AEMax) were then correlated to confirm the presumed association between drinking levels and expectancy levels for further analysis. Analyses were then conducted on the amount of beer consumed in the taste-test portion of the experiment. That is, correlations between expectancy variables and the amount of beverage consumed (in milliliters) were examined in the entire sample and in each prime group separately. Beverage consumption was also compared between priming groups to explore the effect of the prime condition on subsequent drinking.

ERP data were then examined first to determine whether spatiotemporal factor scores, believed to represent the P300, reflect alcohol expectancy violation as presented by Fishman, Goldman, and Donchin (2008) in the initial study. Thus, in order to examine the hypothesis that sentences describing alcohol effects that are deviant from a participant's subjective set of alcohol expectancies will elicit a larger P300, expectancy scores were correlated with the spatiotemporal factor scores for responses to Alcohol-Positive/Arousing and Alcohol-Negative/Sedating items. This was done first for the neutral prime group. It was predicted that individuals with higher positive/arousing expectancies (i.e., heavier drinkers) would respond with a larger P300 to statements describing negative/sedating effects of alcohol consumption (i.e., a positive correlation with Alcohol-Negative/Sedating factor scores) indicating that the sentences were unexpected or less congruent with their expectancies. The converse hypothesis was also explored, though it was unclear whether individuals with higher negative/sedating expectancies (i.e., lighter drinkers) should have been expected to produce a larger P300 to positive/arousing expectancies as previous results were not significant. The extracted P300 component was then compared in the alcohol priming condition in a similar fashion.

These data were then entered into a series of regressions, using the correlation matrices as guides as to which expectancy measures and drinking variables to include. Multiple regressions were constructed using the spatiotemporal factor scores for Alcohol-

Positive/Arousing and Alcohol-Negative/Sedating as the dependent variable and an expectancy variable, priming group, and the expectancy-by-prime interaction. This allowed the examination of the hypothesized main effects or expectancy levels, as well as the potential interaction between prime and expectancy, which was exploratory in nature.

Results

Demographics

Sixty-two participants were recruited, and 55 participants comprised the final sample because data had to be excluded from seven participants due to excessive artifacts in the EEG recordings (attributed to factors such as eye or other muscle movement and difficulty in net application due to thick hair). Three additional participants refused to participate in the market research portion of the study. Their data are included in the ERP analyses, but are excluded for analyses pertaining to the beverage consumption portion of the study. Twenty-four individuals participated in the Alcohol prime condition (12 males/ 12 females), and 31 participated in the Neutral prime condition (15 males / 16 females). Seventy-five percent of the sample was aged 21-25, 18% was aged 26-29, and 7% of the sample was aged 30-41. Seventy-three percent of the sample reported being white/non-Hispanic, 9% Hispanic/Latino, 7% Asian, 6% black, and 5% reported being "other".

Expectancies and Drinking Variables

Table 1 lists the means and standard deviations of the self-report expectancy measures by prime group and sex. As expected, males reported higher expectancies than females on most subscales. There were no significant differences overall between the prime groups, and comparisons by sex between the prime conditions revealed no significant differences either.

Table 2 lists the results of drinking variables derived from the Timeline Follow-back measure as well as from the single-item quantity and frequency measure collected during the market research portion of the study. No significant differences exist between the sexes within prime condition, between prime conditions within sex, nor overall between prime conditions for the TLFB derived variables. The mean “Drinks in last month” for the males in the Alcohol prime group varies widely and is inflated due to an outlier who was greater than 3SD above the mean, but that participant’s data was left in the dataset since the means between males compared across prime condition were not statistically significantly different [$t(25) = -1.59$, $p=.12$].

For the quantity/frequency measures, males reported drinking higher quantities per occasion than females [$t(50) = 3.44$, $p<.001$]. Males also tended to endorse drinking beer more frequently than females [$t(50) = 2.12$, $p<.05$; non-significant after Bonferroni adjustment for multiple comparisons]. The Alcohol Prime group tended to report drinking beer more than the Neutral Prime group [$t(50) = -2.45$, $p<.05$], and specifically males in the Alcohol prime condition tended to report drinking beer more frequently than males in the Neutral prime condition [$t(25) = -2.25$, $p<.05$], though these effects were again only a trend when Bonferroni’s adjustment was used for multiple comparisons. These results are important to take into account when interpreting the results from the beverage consumption portion of the study detailed below.

Table 1

Expectancy Demographics by Prime Group and Sex

	Alcohol Prime Group (n = 24)		Neutral Prime Group (n = 31)	
	Males (n= 12)	Females (n= 12)	Males (n= 15)	Females (n= 16)
Alcohol Expectancy Questionnaire				
AEQ – GP	9.17 (6.0)	6.58 (5.1)	7.87 (3.9)	7.63 (5.6)
AEQ – SA	7.17 (2.1)	7.00 (1.5)	7.20 (2.5)	6.69 (3.5)
AEQ – Agg	4.75 (2.6)	5.17 (2.5)	4.20 (2.6)	4.31 (2.5)
AEQ – Sex	1.92 (1.9)	2.50 (2.2)	2.47 (2.5)	2.13 (2.2)
AEQ – SPP	7.58 (1.2)	7.50 (1.8)	7.53 (1.5)	7.19 (1.7)
AEQ - TR	5.33 (2.2)	5.50 (3.1)	5.33 (2.1)	6.25 (3.0)
AEQ – Tot	35.92 (13.6)	34.25 (12.5)	34.60 (11.2)	34.19 (15.4)
Alcohol Expectancy Multiaxial Assessment				
AEM – Horny	9.58 (4.0)	8.50 (3.7)	10.13 (2.6)	7.69 (3.7)
AEM – Ego	10.00 (3.6)	7.25 (5.2)	9.07 (3.6)	7.25 (5.3)
AEM – Sick	8.50 (3.2)	7.92 (3.3)	7.80 (2.5)	7.19 (4.4)
AEM – Woozy	8.67 (3.3)	8.58 (3.3)	9.73 (3.1)	8.13 (3.8)
AEM – Social	14.08 (2.2)	12.75 (2.7)	13.60 (2.0)	13.06 (2.9)
AEM – Attract	8.33 (3.7)	7.42 (3.5)	7.73 (3.0)	7.38 (4.6)
AEM – Sleep	10.25 (4.0)	8.75 (4.6)	9.67 (3.3)	9.06 (2.7)
AEM – Danger	7.50 (3.6)	6.17 (4.8)	5.73 (4.5)	6.13 (6.0)
AEM – Sed	27.42 (9.3)	25.25 (9.4)	27.20 (6.2)	24.38 (8.9)
AEM – Neg	17.50 (6.0)	13.42 (9.3)	14.80 (7.4)	13.38 (10.8)
AEM – PA	32.00 (7.7)	28.67 (8.8)	31.47 (5.5)	28.13 (9.4)

Note. Data are Mean (SD).
AEQ – GP = Global Positive; AEQ – SA = Social Assertion; AEQ – Agg = Aggression; AEQ – Sex = Sexual Enhancement; AEQ – SPP = Social & Physical Pleasure; AEQ – TR = Tension Reduction; AEQ – Tot = Total of all 68 items. AEM – Sed = Sedating higher order factor; AEM – Neg = Negative higher order factor; AEM – PA = Positive & Arousing higher order factor.

Table 2

Drinking Demographics by Prime Group and Sex

	Alcohol Prime Group (n = 24)		Neutral Prime Group (n = 31)	
	Males (n= 12)	Females (n= 12)	Males (n= 15)	Females (n= 16)
Timeline Follow-back Drinking Variables				
Drinks in last month	30.67 (24.8)	18.25 (15.4)	18.67 (13.8)	20.63 (21.2)
Days Drinking in last month	7.00 (4.1)	6.17 (5.6)	5.13 (3.6)	5.88 (4.7)
Drinks / Drinking Day	4.10 (1.6)	3.28 (1.7)	3.43 (1.7)	2.74 (1.4)
Drinks per Week	6.58 (5.2)	4.02 (3.2)	4.10 (3.0)	4.51 (4.7)
Quantity/Frequency Variables			(n= 15)	(n= 13)
Frequency in last year	5.17 (1.4)	5.00 (1.7)	4.73 (1.4)	4.85 (1.6)
Quantity per occasion	4.33 (1.2)	3.00 (1.1)	3.93 (1.7)	2.77 (1.1)
Drunk occasions in last year	3.92 (1.9)	3.08 (1.7)	2.93 (2.1)	2.77 (2.1)
Frequency of Beer drinking*	5.00 (1.3)	3.50 (2.5)	3.33 (2.3)	2.08 (2.1)

* Statistical trend of a difference between Alcohol Prime and Neutral Prime

Table 3 details the correlations between expectancy measures and drinking measures for the entire sample. Overall, the strongest relationships between drinking measures and expectancy measures were negative relationships between the AEMax Woozy subscale and TLFB derived drinking variables, as well as between the AEMax Sedating higher order factor and TLFB derived drinking variables. These relationships indicate that this sample is likely comprised of lighter drinkers than some other college sample studies. These relationships may also explain the lack of correlations between AEQ variables and drinking, since the AEQ indexes only positive expectancies which are apparently less predictive of drinking in this sample. A few positive relationships were present between the AEMax Attractive and three of the TLFB derived drinking variables as well as the single item Frequency measure. In addition the AEMax Positive /Arousing higher order factor exhibited a positive relationship with the single-item quantity/frequency variables and the frequency (Days drinking) from the TLFB. Most of the correlations were in the expected direction (positive and arousing expectancies would be positively related to drinking and negative expectancies would be negatively related to drinking), but were not significant. Relationships between the AEQ and AEMax were correlated as expected (not shown). Apart from the strength of negative expectancies in this sample, it is unclear why many of the AEQ variables were not significantly or positively correlated with drinking variables. A potential methodological factor contributing to this effect is that the AEQ was completed on the computer up to one month prior to completing the in-lab portion of the study so it was less proximate and had fewer controls on extraneous contextual factors that may have influenced responses.

Taste-test Beverage Consumption

Fifty-two participants completed the taste-test portion of the study (28 from Neutral Prime group; 24 from Alcohol Prime group). As expected, males (202 ml) tended to drink more than females [123 ml; $t(50) = 1.78$, $p = .08$]. In addition, several drinking variables from the TLFB and from the drinking profile were positively correlated with the amount of beverage consumed (see Table 4). There were no differences in mean consumption between the Alcohol (154 ml) and Neutral prime (173 ml) groups [$t(50) = .41$, $p = .68$]. Therefore, the alcohol prime did not appear to increase consumption directly; however, the relationships between drinking variables and beverage

Table 3

Cross-Correlations between Expectancy Measures and Drinking Measures

Expectancy measures	Drinks in last month	Days Drinking in last month	Drinks / Drinking Day	Drinks per Week	Frequency	Quantity per occasion	Drunk	Frequency of Beer drinking
AEQ – GP	.17	.31*	-.05	.18	.21	.17	.15	.39**
AEQ – SA	.10	.16	.04	.10	-.07	.22	.07	.27
AEQ – Agg	.10	.21	-.03	.13	.17	.11	.15	.25
AEQ – Sex	-.07	.08	-.25	-.05	-.16	.02	-.23	-.05
AEQ – SPP	.12	.21	-.06	.13	.05	-.05	-.15	.10
AEQ – TR	-.03	.15	-.25	-.02	-.00	-.08	-.21	.12
AEQ – Tot	.10	.26	-.12	.12	.08	.11	.00	.28*
AEM – Horny	.12	.22	-.10	.18	.24	.34*	.31*	.20
AEM – Ego	.13	.17	-.05	.14	.26	.17	.27*	.07
AEM – Sick	-.33*	-.29*	-.22	-.32*	-.15	-.01	.06	-.16
AEM – Woozy	-.50**	-.51**	-.28*	-.49**	-.36**	.03	.01	-.30*
AEM – Soc	.12	.27*	-.18	.14	.05	.04	.05	.13
AEM – Attract	.26*	.38**	-.01	.28*	.37**	.22	.11	.32*
AEM – Sleep	-.39**	-.41**	-.19	-.38**	-.26	.01	-.16	-.12
AEM – Danger	-.23	-.28*	-.08	-.21	-.13	.03	.03	-.09
AEM – Sed	-.51**	-.50**	-.28*	-.49**	-.32*	.01	-.04	-.24
AEM – Neg	-.06	-.06	-.07	-.04	.07	.10	.16	-.01
AEM – PA	.21	.36**	-.11	.25	.30*	.27*	.21	.28*

*p<.05 **p<.01

consumption were stronger in the Alcohol Prime group than in the Neutral Prime group. The relationships were all in the expected positive direction, and several variables exhibited significant relationships (Table 4). In addition to the drinking variables, several expectancy variables including AEQ Global Positive, Social and Physical Pleasure, Aggression/Arousal, and the Total score exhibited positive relationships with the amount of beverage consumed, as did the Horny scale from the AEMax (Table 5). A similar phenomenon occurred in the AEQ scores as in the drinking variables, in that the Alcohol Prime group exhibited stronger relationships with beverage consumption than the Neutral Prime group.

The differences between the Alcohol Prime group and the Neutral Prime group were examined to determine whether the prime condition moderated the effect of pre-existing expectancies and reported drinking levels on the amount of beer participants consumed in the ad lib drinking session. The beverage consumption variable was first transformed using the natural log since it was not normally distributed and a series of ANOVAs were conducted examining the main effect of Prime as well as potential interactions with drinking and AEQ variables. These models suggested that most of the variance in beverage consumption is explained directly by the expectancy and drinking variables, as none of the interactions between prime and the identified variables was significant. The current sample was dreadfully underpowered for examining differences in such relationships, so while it appears that the alcohol prime influenced responses in a way that led to stronger concordance of self reported measures of drinking and expectancy with the amount of beer consumed in the taste test, the data are not conclusive evidence of a moderating effect of the prime. Therefore, the prime conditions must be examined in the context of the ERP task to determine whether or not there was an effect of the experimental manipulation.

Table 4

Correlations between Drinking Variables and Beverage Consumption

	Beverage Consumption (ml)		
	Whole Sample	Alcohol Prime	Neutral Prime
Drinking Variables	(n=52)	(n=24)	(n=28)
Drinks in last month	.35*	.44*	.33
Days Drinking in last month	.35*	.57*	.25
Drinks / Drinking Day	.25	.15	.33
Drinks per Week	.37**	.44*	.36
Frequency	.23	.53*	.07
Quantity per occasion	.37**	.31	.42*
Frequency Drunk	.19	.42*	.10
Frequency of beer drinking	.33*	.54*	.28

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

Table 5

Correlations between Expectancy Measures and Beverage Consumption

	Beverage Consumption (ml)		
Expectancy Measures	Whole Sample (n=52)	Alcohol Prime (n=24)	Neutral Prime (n=28)
AEQ – Global Positive	.31*	.46*	.22
AEQ – Social Assertion	.18	.54*	.06
AEQ – Aggression/Arousal	.28*	.50*	.17
AEQ – Sexual Enhancement	.11	-.10	.20
AEQ – Social & Physical Pleasure	.30*	.30	.30
AEQ – Tension Reduction	.06	.24	-.04
AEQ – Total	.27*	.44*	.19
AEM – Horny	.29*	.24	.33
AEM – Ego	.11	.42*	-.07
AEM – Sick	.20	.14	.13
AEM – Woozy	-.07	.15	-.18
AEM – Soc	.05	.23	-.06
AEM – Attract	.12	.05	.16
AEM – Sleep	.13	-.01	.27
AEM – Danger	-.00	.02	-.00
AEM – Sedating	.08	.10	.08
AEM – Negative	.05	.26	-.04
AEM – Positive/Arousing	.20	.20	.22

*p<.05 **p<.01

Oddball Task

Averaged Waveforms. The oddball task served as an index of the P300 elicited by rare events or unexpected events. Infrequent Target stimuli were expected to elicit a larger positivity compared to the frequent Standard stimuli. ERPs were first examined in the averaged waveforms. Figure 1 depicts the averaged waveforms for a frontal electrode (Fz), a central electrode (Cz), and a parietal electrode (Pz) for all participants comparing responses to Target and Standard stimuli. The classic P300 is typically largest over parietal electrode sites. In Figure 1, it is apparent that a widely distributed positivity around 220 ms occurs in response to the rare Targets, but not to the frequent Standard stimuli. In the averaged waveforms at Pz a similar positive peak is observed around 220 ms that differentiates the stimuli, and this is followed by a second positive peak around 350-360 ms that also differentiates the stimuli with rare Targets eliciting a larger positivity than Standards. The early positivity is likely a component called the P3a, which responds indiscriminately to infrequent or novel targets; while the later parietal positivity is most likely the P3b (or "classic" oddball), which is associated with context updating that is pertinent to the current study (Donchin & Coles, 1988; Squires, Squires, & Hillyard, 1975; Polich, 2007). A subsequent PCA allowed for further these components to be isolated and provided values for hypothesis testing.

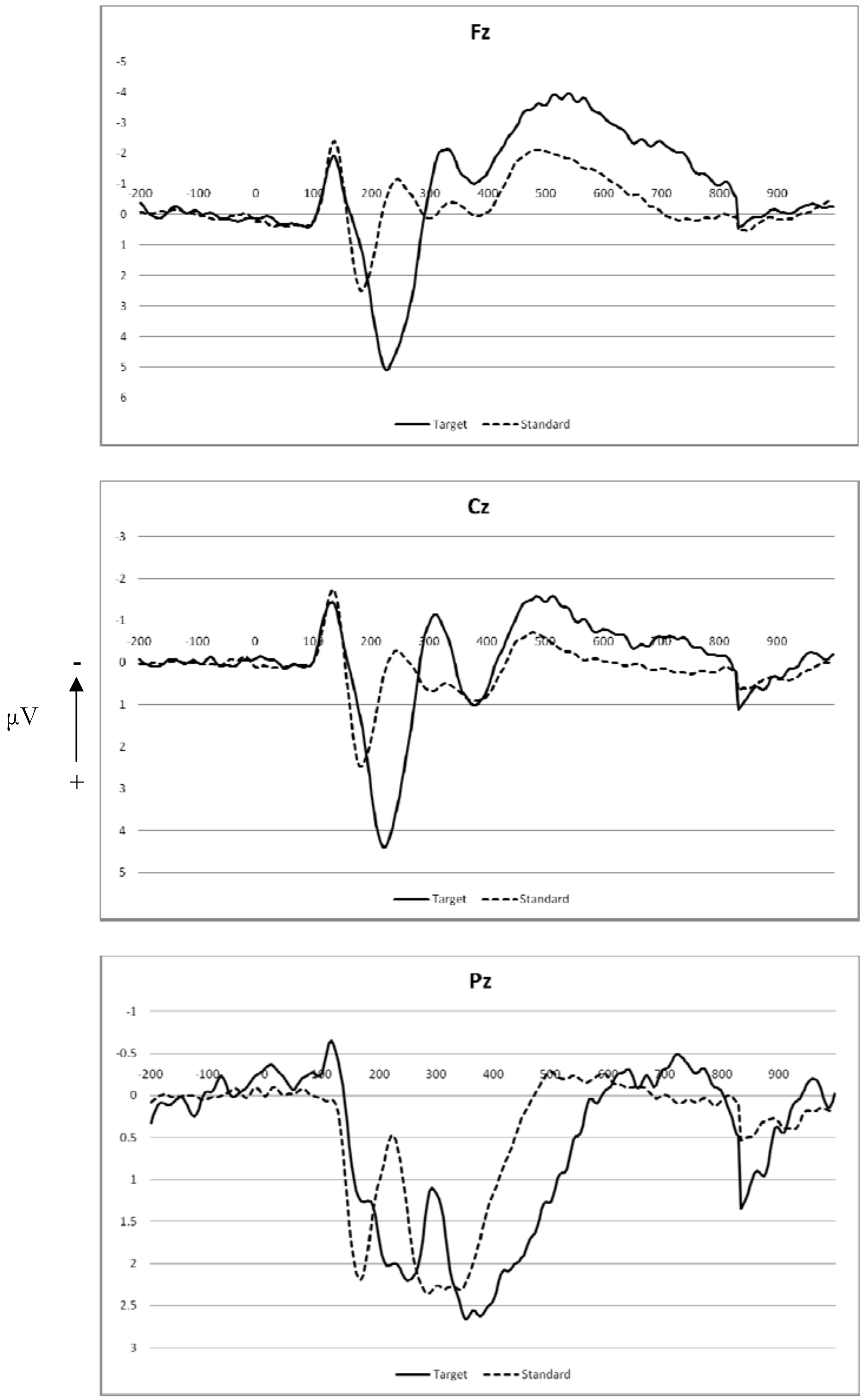

Figure 1. Oddball Averaged Waveforms at Fz, Cz, & Pz electrode sites

Spatiotemporal PCA. The spatial PCA was conducted first, to reduce the dataset from 129 channels to a smaller set of "virtual electrodes" that represent clusters of variance in the data. Fourteen spatial factors (SFs) were rotated using Varimax (orthogonal) rotation, accounting for 87% of the variance. Of the 14 SFs, only the first few yielded interpretable spatial topographies (Figure 2 depicts topography of the first 5 SFs). The first spatial factor, SF1, depicts a frontal component. SF2 exhibited the strongest loading around fronto-central, slightly right lateral electrodes, while SF3 loaded highly in the centro-parietal area typically associated with the P300 component. SF5 may be associated with response activation from the motor cortex as most participants were right handed and a response was required for each trial. The other spatial factors did not appear to capture significant variance associated with the task. As demonstrated in the literature, and confirmed in this sample by examining the averaged waveforms, it was expected that the P300 would load most highly in the centro-parietal region, so SF3 was keyed upon for further analysis though other SFs were also examined.

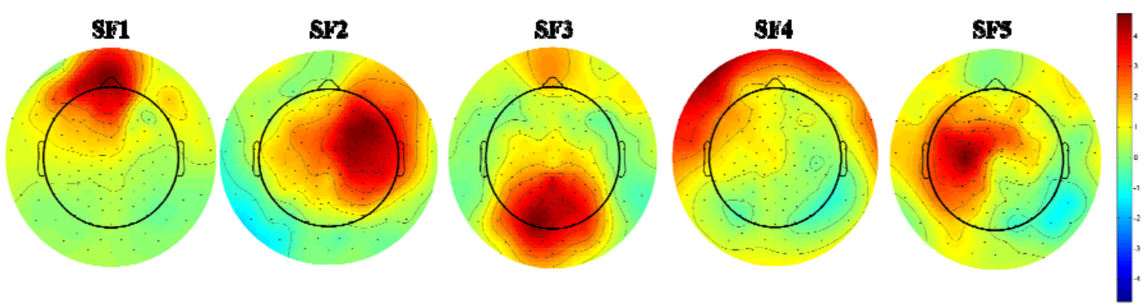

Figure 2. Spatial Factor Loadings (Virtual Electrodes) from PCA on Oddball Data

The spatial factors provided loadings for each of the 129 electrodes, so that higher loadings are more influential on the factor scores which are derived for each of the observation points (i.e., time points in the case of ERPs). Thus, factor scores for each of the spatial factors of interest become "virtual electrodes" that were plotted over time yielding "virtual ERPs" comparable to averaged waveforms. Figure 3 depicts the virtual ERPs for SF3, SF2, and SF1, which correspond roughly to the averaged waveforms presented for Pz, Cz, and Fz, respectively. In both SF2 and SF3 the waveform elicited by Target stimuli exhibited a larger positive peak than that elicited by Standard stimuli in the 300-400 ms range as expected, and in SF1 Target stimuli elicited a larger positive peak in the 200 ms range (see discussion above of the P3a).

The results of the spatial PCA were then submitted to a temporal PCA to identify particular areas across the 1200ms recording in which variance clustered. Ten factors accounting for 94% of the variance were again rotated using Varimax rotation. Figure 4 depicts the temporal factors (TFs) plotted as factors loadings across time to show the factor peaks at particular time points. Several factors overlapped with the epoch of interest identified in the averaged waveforms. Specifically, TF2 (peak around 400ms), TF4 (peak around 300ms), and TF6 (peak around 250ms) cover the range of time in which we expected to detect the P300. By extracting the factor scores where the particular SFs and TFs of interest overlap, inferential statistics can be used to test hypotheses.

It was expected that waveforms elicited by rare Target stimuli would be more positive at parietal scalp locations in the 300-400 ms range. Thus, we first tested the SF3–TF2 combination and determined that the expected results were obtained [$t(54) = -7.96$,

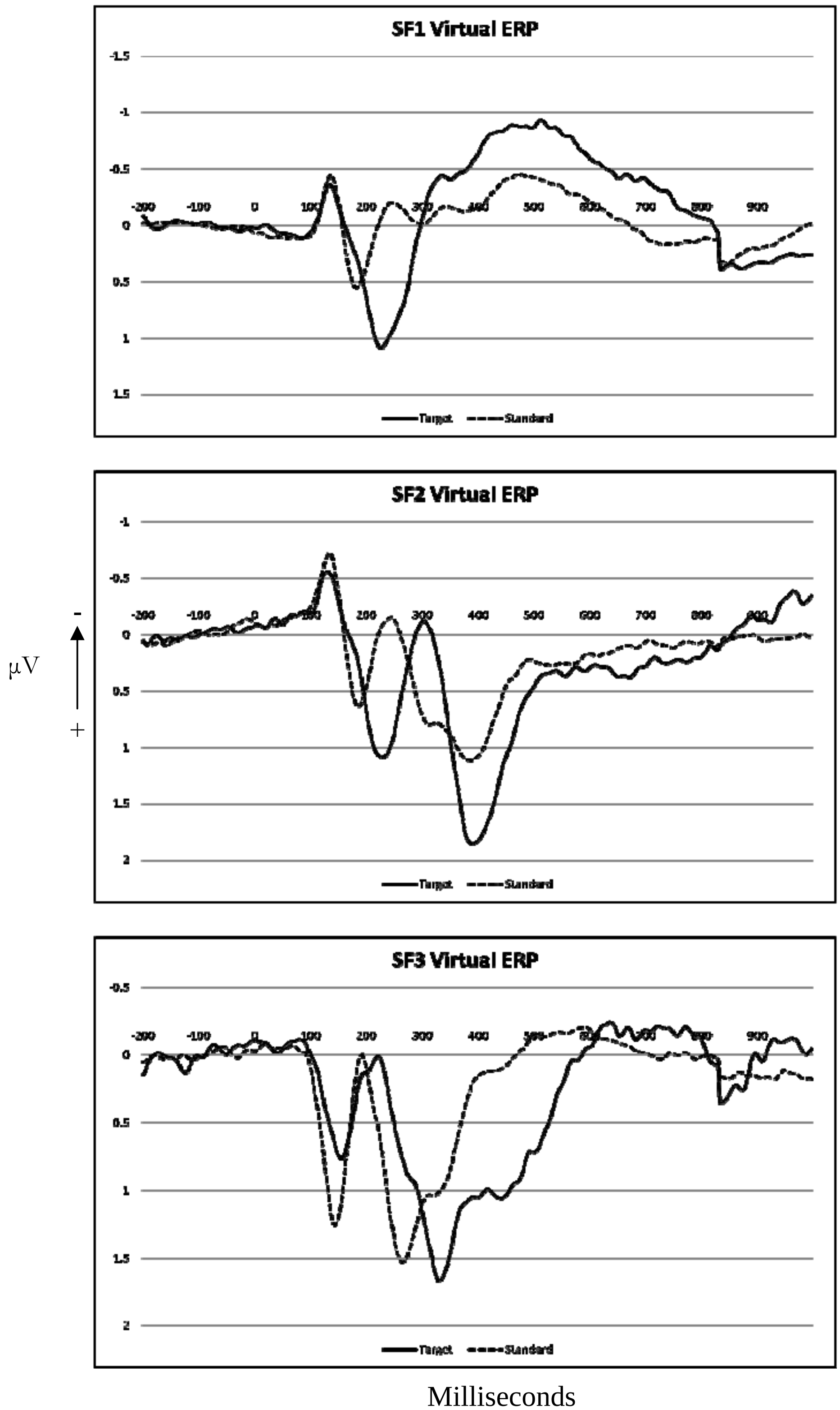

Figure 3. Virtual Electrodes for SF1, SF2 & SF3

p<.001]. Thus, the Oddball task confirmed the presence of a P300 in this sample of participants that is exhibited at parietal scalp sites between 350-400 ms following simple rare stimuli as compared to simple frequent stimuli. The waveforms following Target stimuli were also more positive in SF2–TF2 [likely an index of the same phenomenon in a slightly more frontal location; $t(54) = -4.84$, $p<.001$], as well as in SF1–TF6 [i.e., the P3a; $t(54) = -14.59$, $p<.001$]. The measure of the P300, particularly the SF3–TF2 index, provides evidence that this sample of participants exhibits a typical P300 response in rare or unexpected stimuli, thus meeting a boundary condition for subsequent analysis of the ERPs elicited by the sentence paradigm.

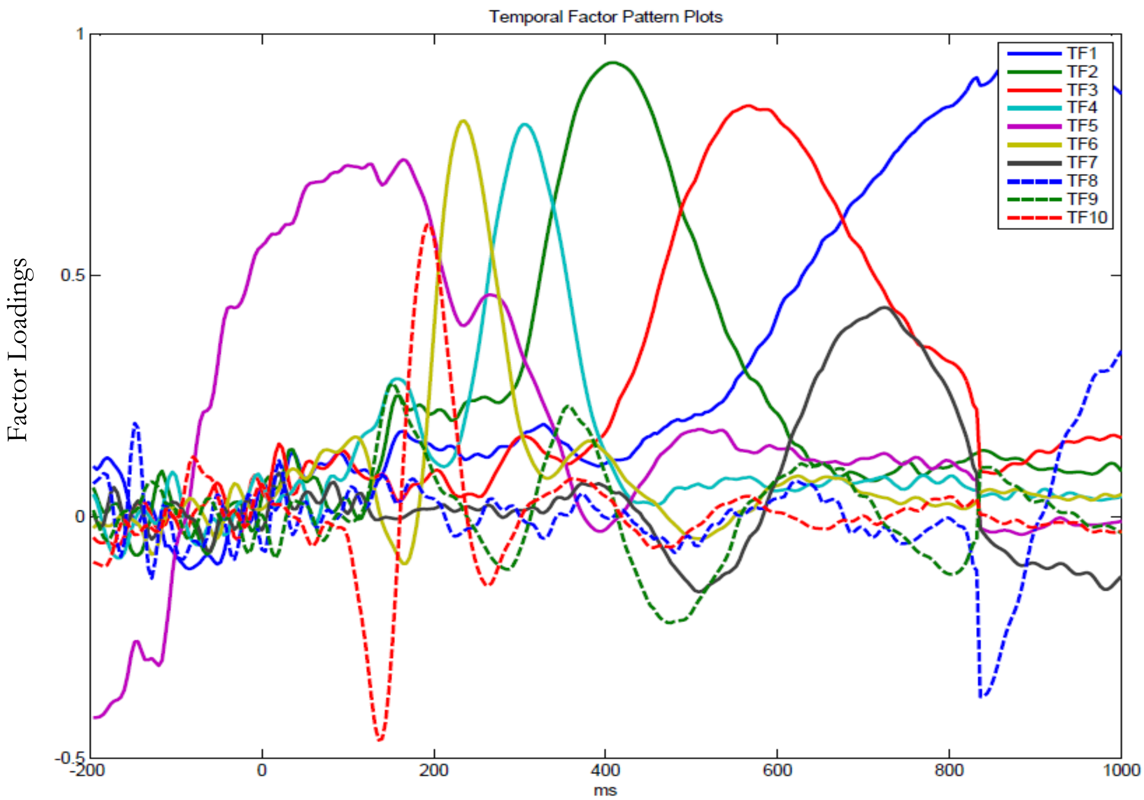

Figure 4. Temporal Factor Loadings from PCA on Oddball Data

Expectancy Sentence Task

Averaged Waveforms. ERPs were first visually examined in the averaged waveforms. This allows a cursory examination of the results and provides a frame of reference for the subsequent decomposition of the averaged waveforms. Figure 5 depicts the averaged waveforms for a frontal electrode (Fz), a central electrode (Cz), and a parietal electrode (Pz) for all participants and for the 4 sentence conditions of interest: Alcohol Positive, Alcohol Negative, Incongruent, and Other. The waveforms at Fz and Cz exhibit the typical N1/P2 complex, which indexes attentional processing. Cz and Pz are then characterized by a negative deflection in the 400-500 ms range followed by a positive deflection that continues for several hundred milliseconds. The sentence conditions appear to diverge particularly beyond 400 ms, which highlights an epoch of interest for additional analyses.

Expectancy and priming effects. Since the hypotheses of this study predict an effect of expectancy on ERP response and an interaction between prime and expectancy, the averaged waveforms were split by expectancy variables and prime for visual inspection. For the purposes of presentation, median splits were performed on the sample to create low and high expectancy groups for specific expectancy measures. The one positive and one negative expectancy measure was selected based on the correlations with variables indexing typical drinking (Table 3), because these expectancy scales best approximate the relationship between cognitive schemas related to alcohol and the outcome behavior of interest in this sample. Therefore, median splits were derived for the AEMax Woozy scale (Figure 6), and for the AEMax Attractive scale (Figure 7).

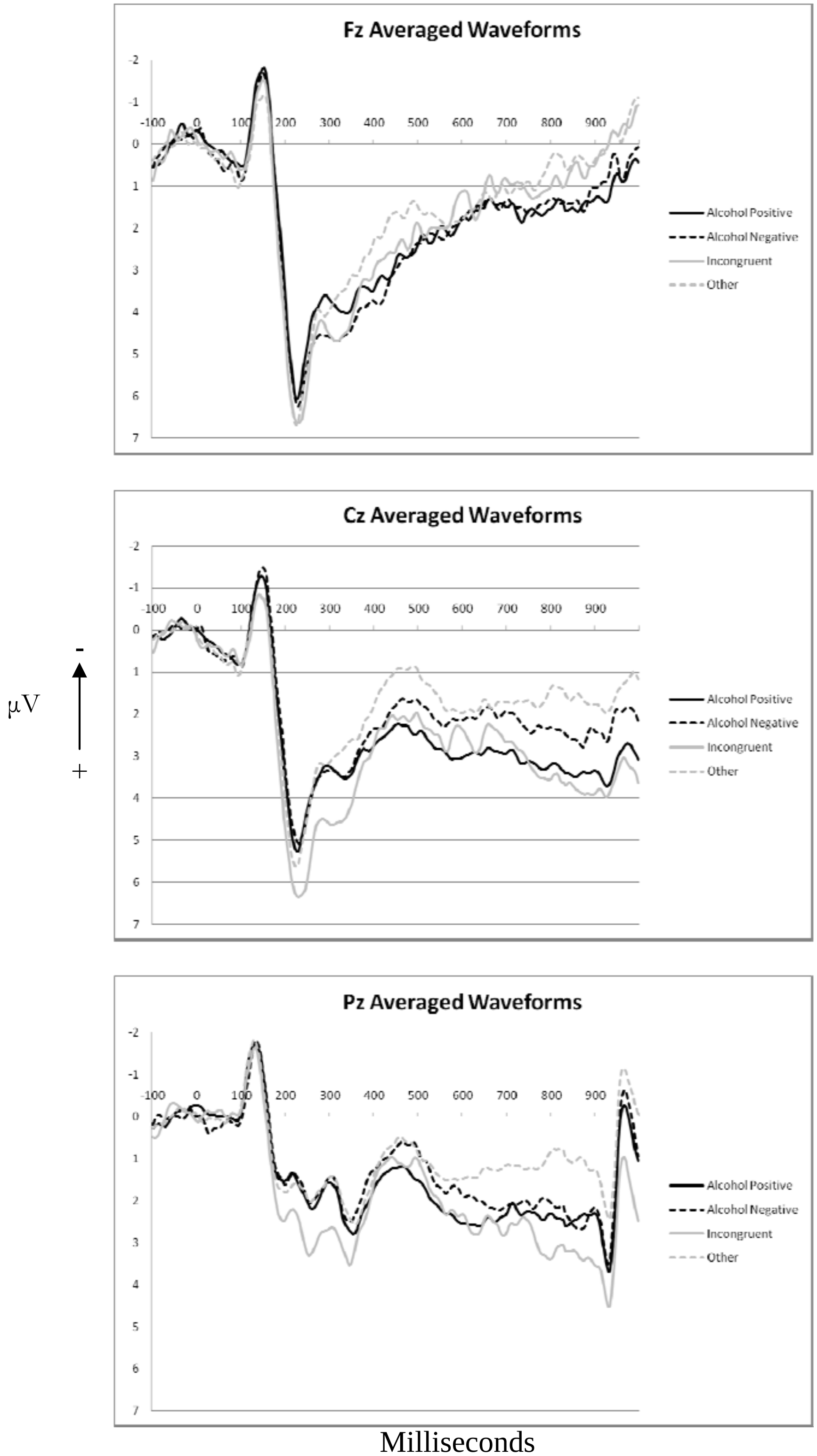

Figure 5. Average Waveforms at Fz, Cz, & Pz electrode sites for Sentence Task

Hypotheses for the High Woozy compared to the High Attractive groups would predict a different and potentially opposite effect in response to alcohol positive and negative sentence endings. Positive sentence endings were hypothesized to be more unexpected in the High Woozy group leading to a larger P300, and negative sentence endings were hypothesized to be more unexpected in the High Attractive group leading to a larger P300. The effect of the prime was hypothesized to increase responding in expectancy congruent ways for individuals with higher positive expectancies. That is, negative sentence endings were expected to elicit larger P300s in individuals with higher positive expectancies following the alcohol prime. No hypothesis was made concerning the effect of the prime on individuals with higher negative expectancies.

When split by the AEMax Woozy scale (Figure 6), there was a pronounced difference between High and Low Woozy groups in the Alcohol prime condition starting at about 600 ms and persisting to 900 ms following negative alcohol sentences that was evident at all three electrode sites (Figure 6, right column, dark lines). The High Woozy group exhibited a larger positivity compared to the Low Woozy group. A similar effect was evident following positive alcohol sentences, but only at the parietal electrode site (Figure 6, left column, dark lines). These differences were not evident in the Neutral prime group (Figure 6, grey lines); however, the High Woozy group in the Neutral prime condition did tend to exhibit a larger negativity in the 400-500 ms range at several electrode sites following both negative and positive alcohol sentences compared to the Low Woozy group (Figure 6, grey lines). While not hypothesized, these graphs may suggest that the alcohol prime enhanced the differences in responses to alcohol-related sentences between these expectancy groups.

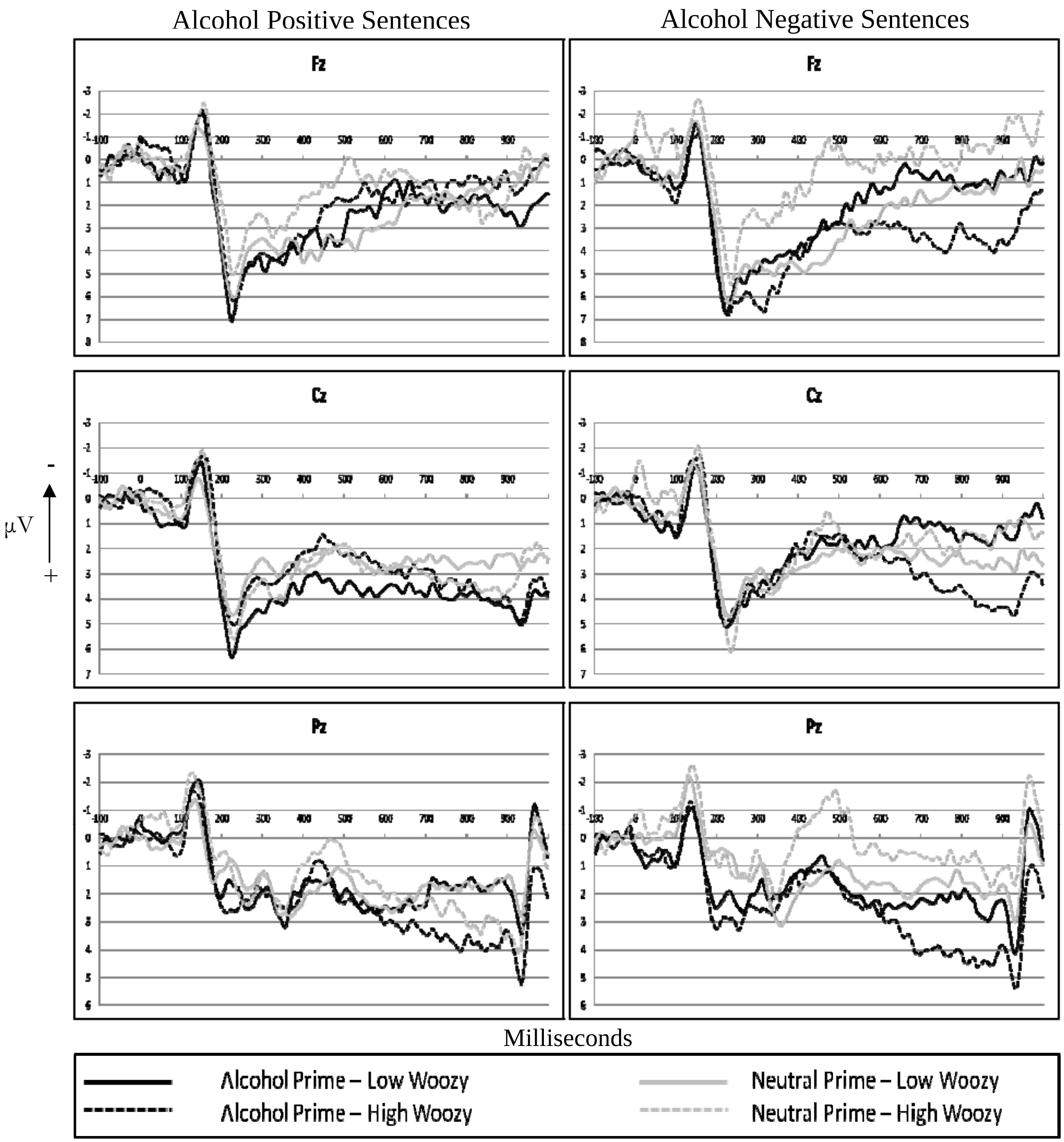

Figure 6. Prime groups compared between AEMax Woozy median split groups

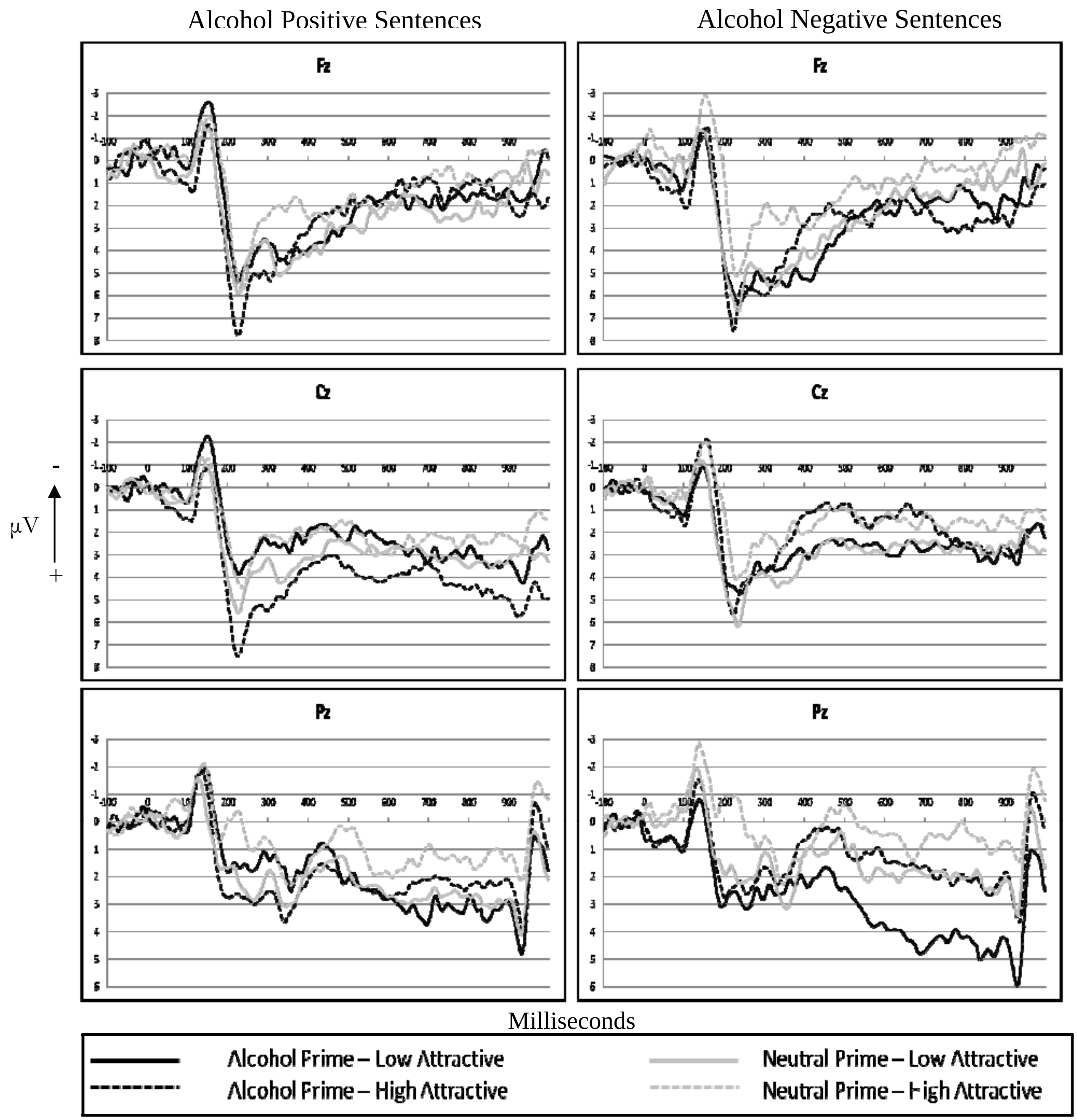

Figure 7. Prime groups compared between AEMax Attractive median split groups

The AEMax Attractive median split waveforms (Figure 9) look rather different. One notable difference was evident following negative alcohol sentence endings at Pz, where the Low Attractive group in the alcohol prime condition exhibited a large positivity from 500-900 ms compared to the High Attractive group (Figure 7, right column, bottom graph, dark lines). This effect is similar to that in the AEMax Woozy waveforms, in that sentence endings that were assumed to be more congruent with expectancies actually elicited a larger positivity for the Alcohol prime condition. These figures provide only perfunctory evidence of the phenomena occurring in the waveforms as they are crudely produced with median split groups and do not provide a way to systematically test the hypotheses. Clearly, there are differences that need to be sorted out, and additional analytical tools utilized below provide a more precise test of the hypotheses.

Spatiotemporal PCA. The spatial PCA was conducted first again, to determine virtual electrodes. Fourteen SFs were rotated using a Varimax rotation, accounting for 83% of the total variance. Of the 14 SFs, only the first few yielded interpretable spatial topographies (Figure 8 depicts topography of the first 6 SFs). The first spatial factor, SF1, appeared to be an artifact from eye movement around the left eye. Although data were processed to remove eye blinks and eye movements, the methodology is imprecise and sometimes leaves such artifacts behind. SF2 exhibited the strongest loading around electrodes that sometimes reflect the N400 component (fronto-central, slightly right lateral), while SF3 loaded highly in the centro-parietal area typically associated with the P300 component (as seen in the Oddball data above). The other spatial factors did not appear to capture significant variance associated with the task.

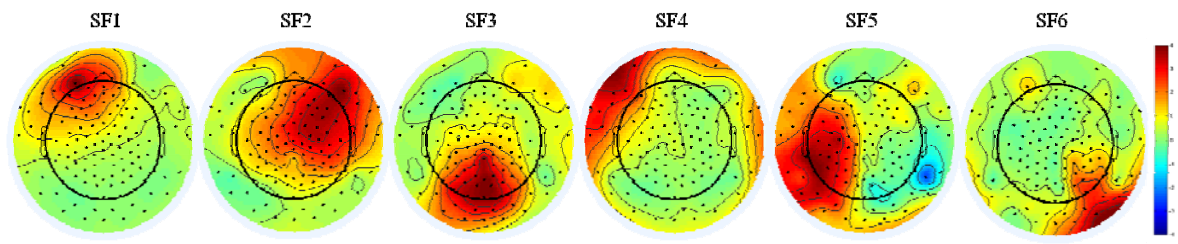

Figure 8. Spatial Factor Loadings from PCA

The virtual ERPs resulting from the SFs were then examined. As with the averaged waveforms, the sample was split along several variables of interest in order to examine the waveforms with the hypotheses in mind. Figure 9 depicts virtual ERPs SF3 with the sample split by AEMax Attractive, AEMax Woozy, and prime for the two alcohol sentence conditions. For SF3, there appear to be large differences between the expectancy groups particularly in the Alcohol prime condition from 500-900 ms. In addition, in the Neutral prime group there appear to be larger negativities in the 400-500 ms range. Overall, the differences tend to appear in the later epoch (i.e., >400 ms). In order to determine specific temporal epochs over which differences can be tested, these data need to be run through a temporal PCA.

The spatial factors were submitted to a temporal PCA to identify particular epochs across the 1100 ms recording in which variance clustered. Ten factors, accounting for 92% of the variance, were rotated using Varimax rotation. Figure 12 depicts the TFs plotted as factors loadings across time to show the factor peaks at particular time points. Several factors overlapped with the epochs of interest identified in the averaged waveforms. Specifically, TF1 (peak between 800-900 ms), TF3 (peak around 550 ms), and TF5 (peak around 450 ms) cover the time frames in which the average waveforms appeared to differ. Based on a prior study, the target temporal region for the P300

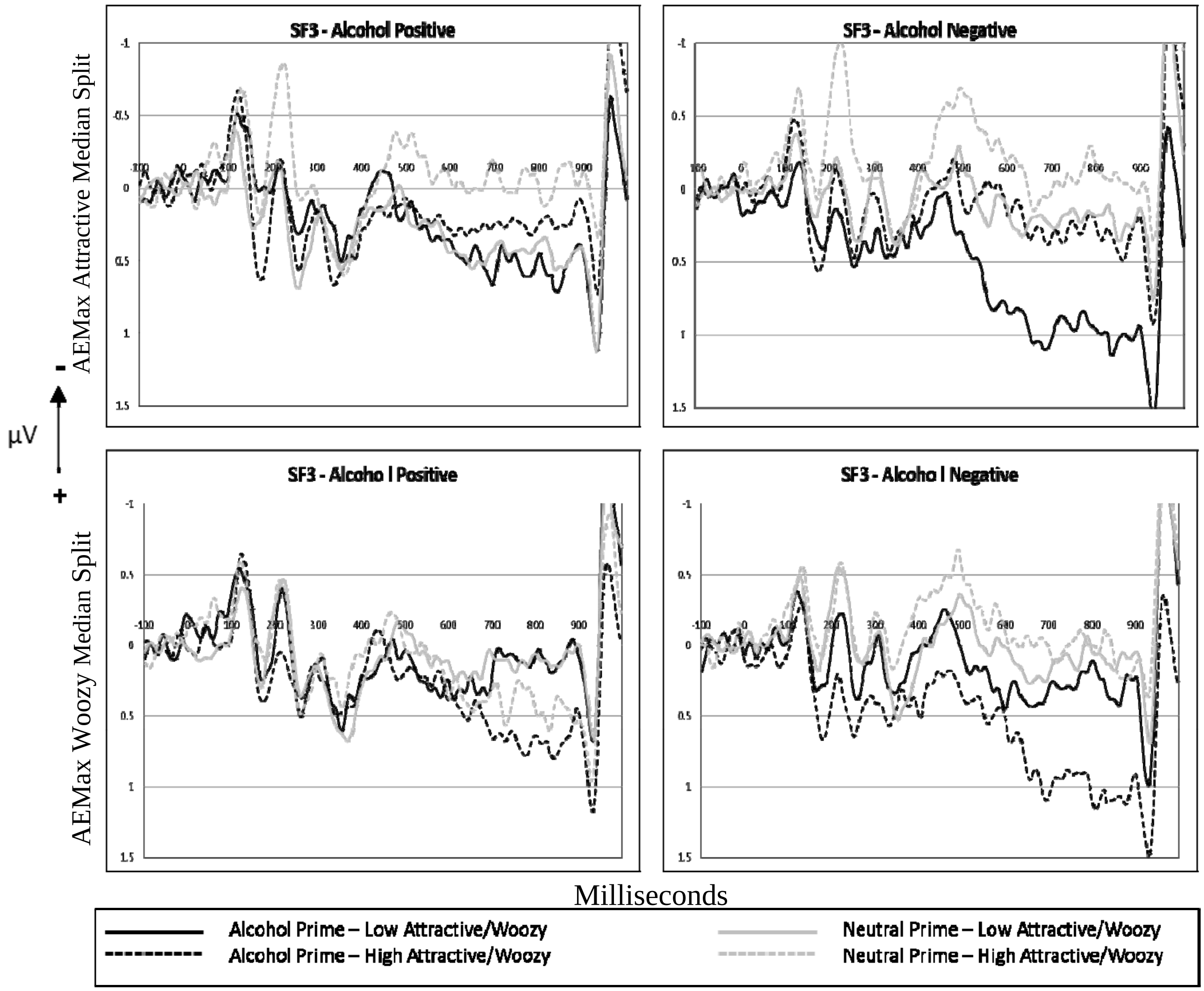

Figure 9. Virtual ERPs for SF3 (centro-parietal)

was between 300 and 600 ms, and the TF that was most similar to that reported in a previous study using this paradigm was TF3 (Fishman et al., 2008). An examination of the averaged waveforms and virtual ERPs, however, suggested that the positive peak in this study occurred later than the epoch encompassed by TF3. Therefore, the TFs surrounding TF3 were also examined covering the epochs from 300 to 900 ms.

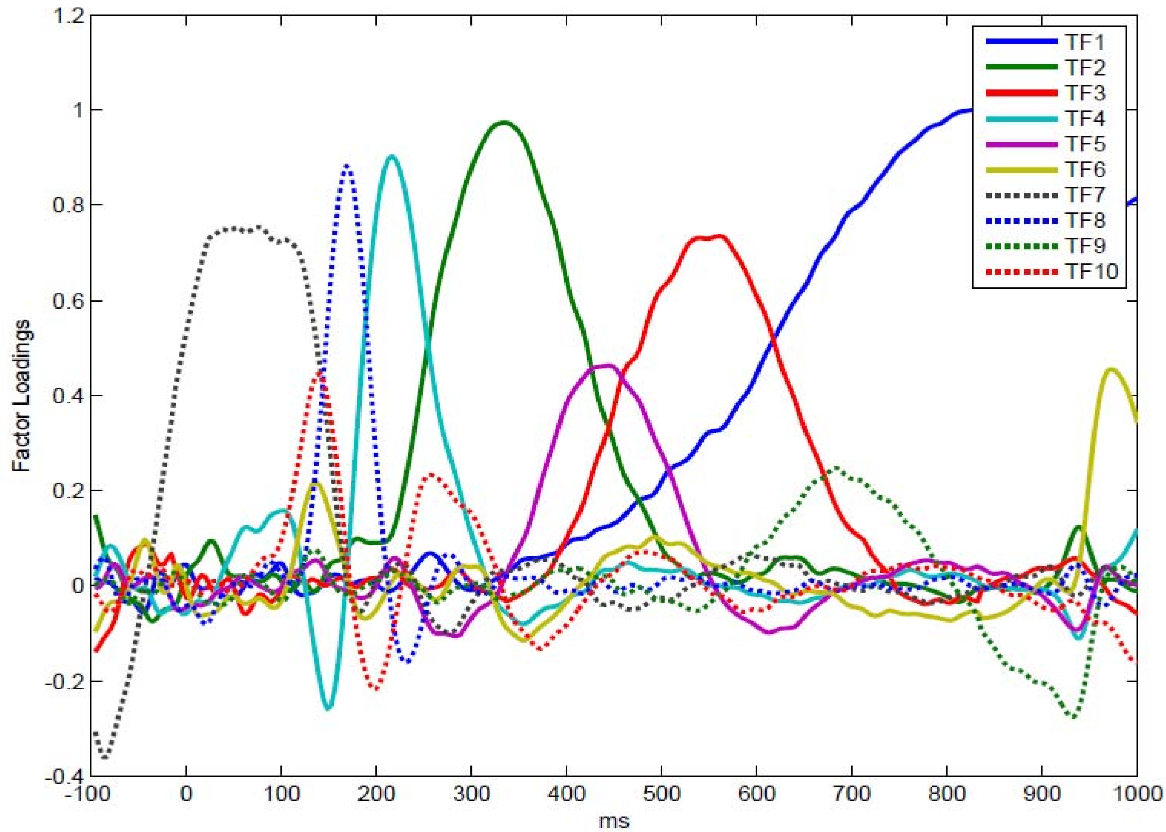

Figure 10. Temporal Factor Loadings from PCA

Analyses of SF–TF scores

SF–TF scores were examined as outcome variables in a series of regressions to test for the hypothesized effects of expectancy and priming on ERPs. Predictor variables were chosen based on the hypothesized relationships between expectancy and sentence types and on the correlations of the expectancy measures with drinking variables (Table 3). Thus, AEMax Attractive was selected as the positive expectancy scale and AEMax Woozy was selected as the negative expectancy scale. In addition, three higher-order expectancy scales, the AEMax Positive and Arousing scale, the AEMax Sedating scale, and the AEQ Global Positive scale were also selected, because these scales reflect a broader range of expectancy concepts. Prime group and an interaction variable between expectancy and prime group were entered for each of the regressions. SF3–TF3 and SF3–TF1 were examined as potential P300 components, while SF3–TF5 was examined potentially as the N400 component (based simply on the examination of the averaged waveforms and virtual ERPs). A total of 30 regressions were conducted; ten for each of three SF–TF combinations, using each of the 5 expectancy variables predicting either positive or negative alcohol sentence scores. Table 6 contains the results of regressions with significant or near significant predictors.

SF3–TF3. Based on previous research, the spatio-temporal factor scores for SF3–TF3 seemed to be a good candidate for the P300 effect; however, none of the hypothesized predictors were significant. While the averaged waveforms and the virtual ERPs showed some differences in this time epoch, the regression analyses indicate that this SF–TF score does not react to the task parameters to which the P300 was predicted to respond and should not be considered the P300 component. It appears from the virtual ERPs that this epoch does not encompass the positive peak, which occurred slightly later than the peak for TF3.

SF3–TF1. The second temporal dimension to be examined was the latest and the one with the widest temporal span. While this temporal factor covers the very latest time window in which the P300 is typically observed, the virtual ERPs (Figure 9) show positive deflections that differ by condition in the waveforms in this later section of the epoch. The regression model using AEMax Attractive to predict scores elicited by negative alcohol sentences was significant [Table 6; $F(3,51) = 3.17$, $p < .05$]. In this case, both Prime and the interaction between Prime and AEMax Attractive are significant predictors (Table 6). Overall, individuals in the alcohol prime group exhibited more positive scores on this factor (Figure 11). The interaction in this model appears to indicate that there is a slightly positive relationship between AEMax Attractive and SF3–TF1 scores in the neutral prime condition (r = .17; i.e., as AEMax increases, SF3–TF1 scores become more positive), but in the alcohol prime condition this relationship is negative (Figure 11; r = -.39, p = .06). The result from the Neutral prime group appears to replicate the relationship between expectancy and ERPs of the previous study, though the correlation is not significant. This appears to support the notion that SF3–TF1 represents the P300 in this study, and individuals in the neutral prime condition tend to exhibit the hypothesized reaction to the negative alcohol sentence endings with a larger positive deflection to stimuli that are less expected based on their self-reported alcohol expectancies. Interestingly, this relationship is reversed in the Alcohol prime condition so that the higher expectancies exhibit less positivity to these stimuli.

AEMax Attractive also exhibited a trend toward significantly predicting responses to positive alcohol sentences at this SF–TF combination. Though the total model was not significant, AEMax Attractive scores tended to predict scores in the expected direction (β = -.24, p = .08). When the underlying correlations were examined, it was evident that AEMax Attractive scores were negatively correlated with SF3–TF1 scores in the Neutral prime group (r = -.39, p <.05), but were not significantly correlated with these scores in the Alcohol prime group (r = -.12). Once again, this finding seems to replicate the prior study in the Neutral prime group. In order to further examine the differential effects of the primes, the correlations between SF3–TF1 factors and other expectancy measures were examined by prime group. The AEMax Social scale also exhibited a significant correlation in the expected direction in the Neutral prime group (r = .36, p <.05), but not in the Alcohol prime group (r = -.01). These results point toward the fact that something may have been occurring between the groups that was potentially attributable to the prime condition.

AEQ Global Positive scores also predicted SF3–TF1 scores following negative sentences in a similar manner as the AEMax Attractive scores (Table 6). That is, overall the Alcohol prime group exhibited higher scores on SF3–TF1, and an interaction occurred between AEQ Global Positive and prime condition that led to a similar inverse relationship (Figure 12). For the Neutral prime group there was a trend toward a positive relationship indicating a larger P300 to negative sentences (r = .30, p =.10), while in the Alcohol prime group the relationship was non-significant and negative (r = -.25). Also similar to the results from AEMax Attractive, the AEQ Global Positive scores exhibited a relationship with SF3–TF1 scores following positive sentences as well. The total model was not significant, but AEQ Global Positive scores predicted SF3–TF1 scores in the expected direction indicating higher expectancy scores were related to smaller P300s following positive sentence endings (β = -.29, p < .05). The underlying correlations indicated that AEQ Global Positive scores were correlated negatively with SF3–TF1 scores in both prime conditions, though these relationships did not reach significance. Thus, several expectancy scales provided support for the hypothesis that the P300 responds to expectancy violation in the Neutral prime condition; however, the results for the Alcohol prime condition were not as predicted.

SF3–TF5. Temporal Factor 5 (peaking around 450 ms), which immediately precedes TF3, was the last temporal dimension examined. Based on the virtual ERPs

(Figure 9), this epoch appears to encompass a negative peak in the waveform. So, this SF–TF combination was not considered for the P300 but it was examined for potential differences in the range of the N400. While we did not expect differences in the N400 since this component is typically elicited by semantically incongruent sentences, these analyses were conducted to explore whether the subjective incongruence based on one's alcohol expectancies may affect this negative peak in the waveform even though the sentences were semantically congruent.

One regression model significantly predicted scores for this SF–TF combination. The results for the regression predicting SF3–TF5 scores for negative alcohol sentences using AEMax Positive Arousing are presented in Table 6 [$F(3,51) = 3.4$, $p < .05$]. Neither AEMax Positive Arousing nor Prime significantly predicted scores in the model; however, there was an interaction between expectancy and Prime. It appears that there is a negative relationship between AEMax Positive Arousing and SF3–TF5 scores in the alcohol prime condition (i.e., as AEMax scores go up the ERP is more negative; Figure 13), but this relationship is slightly positive in the neutral prime condition (i.e., as AEMax scores go up the ERP is less negative). It is unclear whether this negative deflection is the N400 component, but this factor appears to be affected by priming and expectancy and it may index some cognitive process related to expectancy. In addition, since this negative deflection temporally precedes the positive deflection being examined as the P300 and is affected by factors hypothesized to affect the P300, it may significantly influence the measurement of subsequent positivity. The prior study using this paradigm did not report differences in negative peaks associated with expectancies, but it appears worth considering for future studies given the results obtained here.

Table 6

Summary of Regression Analyses for Models Predicting SF–TF Factor Scores

Outcome Variable	Predictor Variables	B	SE B	*β*	*p*
SF3–TF1 Alc. Negative*	AEMax Attractive	.03	.03	.15	.36
	Prime	1.38	.46	.92	.00
	Attractive X Prime	-.12	.05	-.71	.04
SF3–TF1 Alc. Negative*	AEQ Global Pos	.04	.03	.30	.11
	Prime	1.06	.35	.71	.00
	Positive X Prime	-.08	.04	-.55	.05
SF3–TF5 Alc. Negative*	AEMax Pos. Arousing	.01	.02	.10	.57
	Prime	1.42	.86	.83	.10
	Pos. Arouse X Prime	-.06	.03	-1.15	.03

**p*-value for model <.05

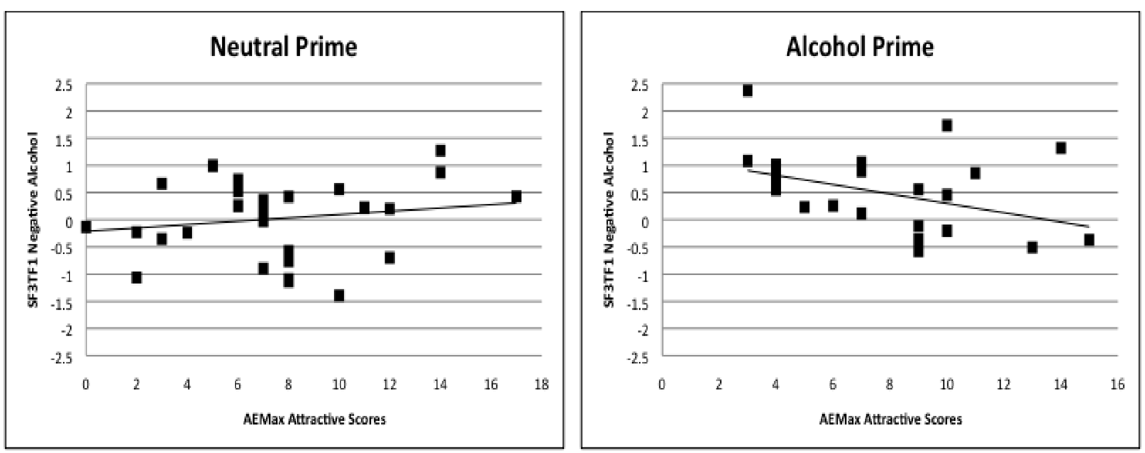

Figure 11. Scatterplot of SF3–TF1 scores for Negative Alcohol Sentences by Prime & AEMax Attractive

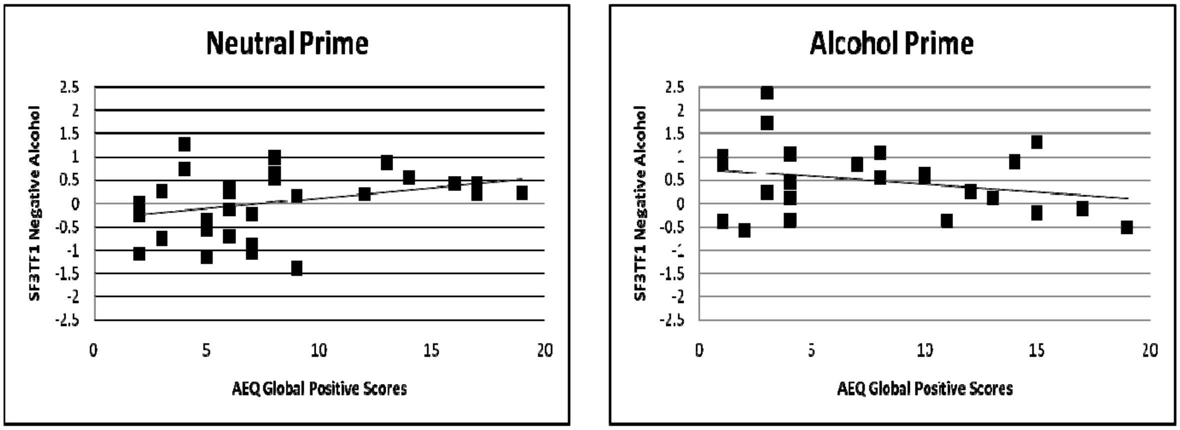

Figure 12. Scatterplot of SF3–TF1 scores for Negative Alcohol Sentences by Prime & AEQ Global Positive

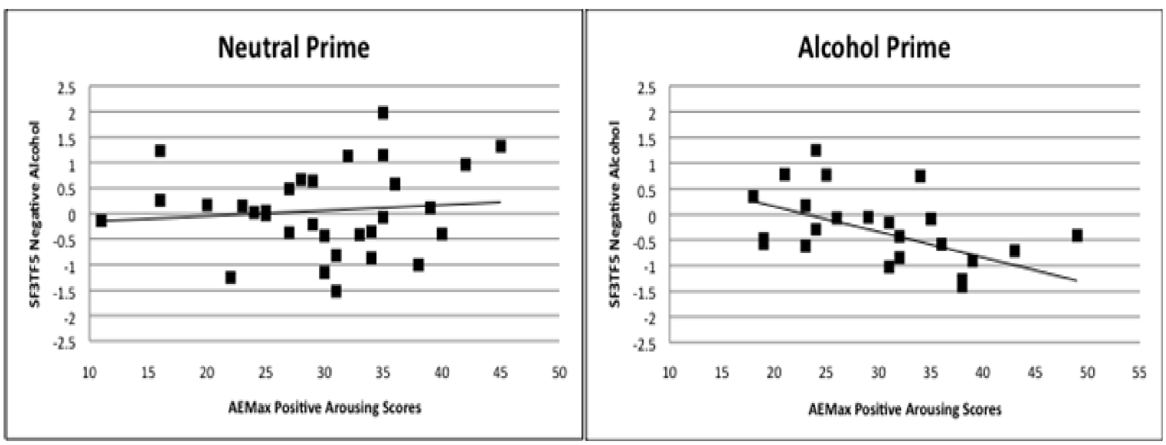

Figure 13. Scatterplot of SF3–TF5 scores for Negative Alcohol Sentences by Prime & AEMax Positive Arousing

ERPs and drinking variables. Lastly, the SF–TF scores were compared to drinking variables to examine if there were associations between drinking behavior (both self-reported and in-lab) and brainwave reactions to alcohol-related sentences. Correlations are presented in Table 7. None of the factor scores were significantly related to in-lab drinking. The single-item Frequency score was negatively correlated with ERP responses following positive alcohol sentences in the P300 (SF3–TF1). This relationship represents what was hypothesized in that people who drink more and drink more often would be more likely to find positive alcohol sentences as fitting with their expected outcomes and so would exhibit a smaller positivity compared to people who drink less frequently and who might have less positive associations with alcohol. While Frequency was the only variable to exhibit a significant relationship, it provides evidence in support of the theory connecting expectancy and drinking experience with ERP reactions to alcohol-related sentences.

Table 7

Correlations between Drinking and SF3–TF Factor Scores

	TF1		TF3		TF5	
	Alc Pos	Alc Neg	Alc Pos	Alc Neg	Alc Pos	Alc Neg
mL beverage consumed	.09	.00	.10	.05	-.11	-.14
Days Drinking in last month	-.23	-.03	-.11	-.08	-.21	-.01
Drinks / Drinking Day	-.07	-.03	.10	.08	-.04	.01
Drinks per Week	-.20	-.07	-.04	-.06	-.10	-.04
Frequency	-.29*	-.12	-.08	.04	-.21	-.05
Quantity per occasion	-.15	-.12	-.14	-.05	-.10	-.02
Frequency Drunk	-.15	.03	-.07	.12	.05	.05

*p > .05

Discussion

ERPs elicited by sentences that violate one's subjectively held expectations have been shown to elicit a P300 (Fishman et al., 2008). In this study, we sought to replicate this finding and explore whether exposing individuals to a video prime prior to an ERP task would alter the context of alcohol related sentences in such a way that the ERPs would be augmented. In the current sample we found support of the effect that was previously reported, but in a slightly different instantiation.

Prime – Expectancy Interactions Evident in ERPs

There was some support for the hypothesis that individuals with lower positive expectancies exhibit a larger P300 to negative and sedating sentence endings compared to individuals with higher positive expectancies. Similarly, there was some evidence that individuals with higher negative expectancies exhibit a larger P300 to positive and arousing sentence endings compared to individuals with lower negative expectancies. Though these trends were evident in the waveforms (particularly in the virtual ERPs), the only significant correlation between expectancy measures and P300 factor scores was for the AEQ Global Positive scale relating to the SF3–TF1 scores following positive alcohol sentences. This relationship does support the hypothesis that the more positive one's expectancies, the smaller the P300. The results point toward a slightly more complicated picture, however, when the effect of the primes was examined.

The interactions in the regression analyses indicated that the Neutral prime group exhibited the expected relationship between positive alcohol expectancies and factor scores from the negative alcohol sentence condition, replicating the prior study. The Alcohol prime group, on the other hand, exhibited higher overall P300 scores but displayed a negative relationship between expectancy and P300 amplitude. In this case, it appears that the result of the prime actually decreased the P300 to negative sentence endings for individuals with higher positive expectancies. In contrast, the Alcohol prime group displayed stronger correlations between several expectancy measures and ad lib drinking as well as between self-report drinking measures and ad lib drinking compared to the Neutral prime group. These behavioral results indicate an increase in the congruence of expectancies with the ad lib consumption perhaps reflecting an increase in the activation of the individuals' alcohol expectancies, but the prime groups did not differ in the amount of beer they consumed in the drinking session. Taken together these trends do hint toward the possibility that the pre-exposure to an alcohol context influenced both ERPs and ad lib drinking, but the effect on ad lib drinking seems to be in an expectancy congruent way and the effect on ERPs is more difficult to determine. Thus, it appears that the Alcohol prime may have activated expectancy networks, which altered the context in which the participants completed the tasks in the experiment, leading to ad lib drinking that was more congruent with self-reported expectancies. In the Neutral prime condition it is possible that the context of the experiment was not altered in a way that activated alcohol expectancies sufficiently to alter subsequent drinking. So, for individuals in the Neutral prime condition, the sentences were evaluated simply within the context of a computer task with less association to actual alcohol use. Thus, responses appear to reflect the individual's cognitive appraisal of alcohol use (i.e., their expectancies), which resulted in the P300 effect that appeared to replicate previous findings.

The Neutral prime group exhibited some of the predicted expectancy effects, but the strength of these effects were muted compared to the Fishman et al. (2008) study. The results from the Alcohol prime group are more difficult to interpret. Presumably, even in the context of a computer task, the participant's pre-existing alcohol expectancies would inform the ERP responses to alcohol-related sentences. If the current hypotheses were supported, the Alcohol prime group would have exhibited similar ERP effects as the Neutral prime group but perhaps slightly larger in magnitude (reflecting increased activation which leads to increased violation of the activated network). One potential factor that could have affected the results is that the two prime groups differed somewhat on some of the reported drinking variables. It appeared that the Alcohol prime group may have been more experience with alcohol overall since they reported more drinks in the previous month and slightly higher quantities and frequencies of drinking (Table 2). While these differences were not statistically significant nor did they manifest in differences on expectancy measures, the reported differences must be considered as they would potentially explain a muted response in the less experienced drinking group (i.e., the Neutral prime group). In addition, the current sample overall drank less than the sample reported in Fishman et al. (29.8 vs. 22.2 drinks per month), which makes it difficult to directly compare results between the two studies and may also explain some of the muted effect in the Neutral prime group in the current study. In other words, a lighter drinking sample may have had less latent expectancy "energy" to activate in the experiment potentially resulting in an asymptote level of expectancy violation.

The "P300"

The relationship between expectancy and ERPs that appears to support the hypothesis occurs rather late in the waveform (TF1). While the temporal factor that produced the trends toward significant results was rather diffuse (loading highly over a

300 ms span), previous studies have shown that components occurring at similar temporal offsets can include the P300 (e.g., Cacioppo et al., 1996). The phenomenon that has been called the “late positive complex” is a prolonged positive waveform usually 600-900 ms after a stimulus, which is essentially what was observed in this study. The late positive complex has been parsed using PCA methodology and it was determined that the P300 does make up part of this “complex” (Dien, Spencer, & Donchin, 2004). Also, the latency of the P300 in more demanding tasks like the one employed in this study may be as late as 600 ms from the stimulus as the P300 is an endogenous component reflecting internal categorization and decision making and as such occurs approximately 300 ms from the internal categorization decision *not* 300 ms from the actual stimulus (Dien, Spencer, & Donchin, 2004).

Another factor that could be influencing the ERPs is what is termed sentence wrap-up effects (Hagoort, 2003). These effects are observed when ERPs are recorded to the final word in a sentence and are thought to occur due to an overlap of local (word level) and global (sentence level) processing that culminates in a decision or categorization at the end of a sentence. They may account somewhat for the negative peak observed at central and parietal electrode sites between 300-500 ms as well as the lack of a well-defined positive peak in the 500-900 ms range (Hagoort, 2003). Sentence wrap-up effects do not eliminate the P300, but they may attenuate it or cause a flattening of the wave due to an increase in latency jitter since the sentence level processing may occur at slightly different rates across participants. Thus, the positivity observed between 500-900 ms in the parietal region of most of the waveforms is likely the P300, but it is probably obscured somewhat do to the other factors inherent to the sentence presentation paradigm.

The P300 and Decisions to Use Alcohol

The results of this study lend additional support to the theory that the P300 indexes violations of subjective expectation. The P300 response did not correlate with subsequent consumption in the ad lib drinking portion of the study, but it did correlate with some of the self-reported drinking variables. In addition, priming with an alcohol cue prior to the ERP task seemed to have some effect on the observed brainwave reaction to the alcohol related sentences, but it too did not appear to influence the amount of beer consumed in the ad lib drinking session directly. The tests of interactions between prime condition and expectancies or drinking were not highly powered enough to detect differences, but it did appear that the prime led to behavior that was more congruent with expectancies and drinking history. Thus, the results of the current study still leave many questions unanswered concerning the role of the P300 in decisions to use alcohol. It is possible that the P300 serves as a red flag to some extent that signals a violation of expectancy requiring the individual's current model to be altered to some extent given the new information (i.e., the context updating hypothesis). This study would fit with the context updating hypothesis of the P300, but it does not provide additional information as to whether the P300 feeds into the decision making process that leads to subsequent drinking.

It is well established that self-reported alcohol expectancies predict subsequent drinking, and activating alcohol expectancy semantic networks can lead to increases in expectancy congruent behavior (Reohrich & Goldman, 1995; Carter et al., 1998). One of the aims of this study was to attempt to identify the P300 in the stream of decision making from expectancy activation via the video prime to drinking behavior in the taste test drinking session. Since the study fell short of this goal, future studies should continue to explore the potential role this phenomenon plays in decision making. While it appears that ERPs occurring within a few hundred milliseconds after seeing a stimulus index violations of alcohol expectancies in some cases, it is still unknown how this ERP response affects subsequent behavioral decisions. It is possible that such effects are more specific than the current experiment allowed. For example, some expectancy scales exhibit stronger correlations with drinking than other, and these relationships differ by sample. It is possible that ERPs reflect individual differences to such an extent that responses to particular words that are salient for an individual would be more indicative of the individual's expectancies than the expectancy scale scores which average together responses to several related words. Future studies could examine responses to individual words and their relationship to subsequent decisions to drink.

A full examination of the phenomenon would need to incorporate the underlying brain function that is putatively related to the P300 to better understand the role of the P300 and how it relates to systems associated with decision making in the context of appetitive rewards. For example, the P300 has been associated with the locus coeruleus–norepinepherine system (LC–NE), which appears to play a role in stimulus evaluation and decision-making (i.e., potentiating a response to a motivationally significant stimulus; Nieuwenhuis, Aston-Jones, & Cohen, 2005). These potentiated responses may indicate that evaluation of motivationally significant stimuli (i.e., drinking related words, pictures, environments) is accomplished quickly through the function of the LC–NE, and it may implicate this system in the initiation of decision response patterns that eventually lead to drinking behavior. Clearly, the results of the current study not provide specific evidence of such brain function, but they could provide the basis for future studies to examine the underlying neural systems (e.g., Polich & Criado, 2006).

Conclusion

The current study supports the theory that the P300 reflects violations of subjective expectancy. This ERP effect was observed following a non-alcohol context prime, but in individuals who were exposed to an alcohol context prime the results were less clear. Specifically, P300 responses elicited by negative and sedating sentence endings were positively correlated with positive alcohol expectancy measures (AEQ Global Positive and AEMax Attractive) in individuals who viewed the non-alcohol prime and not in individuals who viewed the alcohol prime. Thus, viewing the alcohol prime appeared to change the relationship between self-reported expectancies and ERP responses in a way that was not expected. Rather than enhancing the incongruence of negative words completing sentences about alcohol for individuals with higher positive expectancies, this effect actually appeared to mute or even reverse the expected relationship. The limitations in sampling and experimental design may have precluded the study from addressing the larger question of the role the P300 response plays in decisions to use alcohol, but the current results encourage the continued exploration of this phenomenon.

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