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Defining semantic space and degree of association using brainwaves: An ERP investigation of alcohol expectancies

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Defining semantic space and degree of association using brainwaves:

An ERP investigation of alcohol expectancies

by

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Abstract

The current study investigated the cognitive organization of alcohol expectancies using event-related potentials (ERPs). Building on previous behavioral and ERP paradigms, the goal of the current study was to quantify the relationship among alcohol expectancies using ERP indices of salience, congruence, and cognitive distance. The ERP components being evaluated fit perfectly into the alcohol expectancy theory and research; however, implementing specific paradigms to reliably measure individual differences in alcohol expectancies using ERPs has proven to be more elusive than originally thought. This study utilized established cognitive modeling techniques coupled with ERP responses to linguistic stimuli. In essence, this study provides an implicit measure of how particular types of words, in the context of alcohol, are categorized and integrated into individuals' expectancy frameworks.

The study looked at two specific ERP components, the P300 and the N400, that have been shown to be sensitive to expectancy violations. In a sentence processing task the P300 was predicted to be related to individuals' alcohol expectancies and in a word pair task the N400 was predicted to index these expectancies. Results indicated that the P300 and N400 were both related to alcohol expectancies in the sentence task and the N400 was related to alcohol expectancies in the word pair task. While the results supported parts of the hypotheses, they were not unequivocal endorsements of the hypothesized relationships, perhaps highlighting the countervailing forces of salience and expectancy congruence. Furthermore, there were unexpected differences between males and females in the sample that interacted with the effect of expectancy on ERPs. In sum, prior research has highlighted individuals' expectations about alcohol as a mediator of biopsychosocial risk for alcohol use disorders (Goldman, 2002), and the results of this study provide a model for how ERP measures of expectancy could capture an aspect of individuals' risk based on reactions to expectancy related stimuli.

Introduction

Biobehavioral functions from the cellular level to the social and cultural level prioritize the processing of incoming stimuli in a way that permits the choice of a behavioral response that is most likely to succeed based on predicted outcomes of that response. This process depends on the storage of information in memory that can be used as templates to compare incoming stimuli in order to make more efficient and probable predictions. These mental guidelines are not so much rule-based decision processes, but rather function as heuristics. That is, "the template is not static, however, nor must a precise match occur for the system to produce the linked behavior. The stimulus configuration of the new situation must fall only within a certain confidence interval of the stored template; that is, a decision is made on the basis of some sort of fuzzy logic." (Goldman, 2002, p.740). In essence, these predictions provide a set of boundaries, and implicitly establish a goal, for future behavior. Researchers have established what follows logically from this model; namely, that an individual's predictions in specific situations can reveal how that individual is likely to act in future situations.

The following study was designed to examine an instance of such memory templates in the domain of alcohol stimulus evaluation. Utilizing neurophysiological measures combined with a well-established theory of semantic associations that provide insight into the structure of these templates (via semantic associations) and into the potency of the templates (via reactions to violations of expectations). Perhaps the most intriguing aspect of the current study is the ability of the paradigm to expose individual differences in predictions within the first few hundred milliseconds of stimulus evaluation. Relating these differences to subsequent downstream decisions that involve more deliberative processes provides insight into the influence of early perceptual biases on decision making related to alcohol use.

Alcohol expectancies

In the domain of alcohol use, these templates or predictions about outcomes are termed "expectancies", and have been researched extensively. Alcohol expectancies are anticipatory memory processes that affect perception, cognition, and behavior related to alcohol. Research has shown that expected outcomes of drinking explicitly reported by individuals are correlated with actual drinking behavior, 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). More positive expected outcomes are associated with more drinking both concurrently and prospectively. That is, individuals who report drinking more tend to endorse more positive and arousing expectancies compared to lighter drinkers (Brown et al., 1980; Goldman, 2002), and expectations about the outcomes of drinking alcohol predict subsequent alcohol use even prior to the initiation of drinking in children (Christiansen, Goldman, & Brown, 1985; 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).

One way alcohol expectancies are operationalized is as semantic associations that can be probed through direct self-report and indirect cognitive paradigms (Goldman, Reich, & Darkes, 2006; Kramer & Goldman, 2003; Reich & Goldman, 2005). As these "predictions" develop they become more ingrained and automatized, and as such are conducive to more implicit (indirect) measurement. Direct (explicit) and indirect (implicit) measures have been shown to explain unique variance in alcohol outcomes, though the direct measures typically account for more unique variance (Reich, Below & Goldman, 2010). Although implicit and explicit measures of alcohol expectancies index the same construct to a large degree, in some respects ascertaining expectancies via implicit measures provides insight that could not be derived from explicit measures because implicit measures reflect upstream automatic processing that has not been filtered through deliberative processes. Since alcohol expectancies are associations stored in memory,

characterizing the nature of the associations individuals store in memory may provide insight into the basis of an individual's decision making about alcohol. Specifically, quantifying the accessibility or strength of associations of particular concepts will shed light on how individuals assign value to stimuli and choose from among behavioral options (Montague, King-Casas, & Cohen, 2006; Hyman, Malenka, & Nestler, 2006). Previous research has made strides in attempting to quantitatively characterize alcohol expectancy associations in memory by borrowing methodology from cognitive psychology and specifically cognitive modeling.

Memory networks approach to expectancies. Cognitive modeling approaches to alcohol expectancy research naturally followed from the theory and assessment of alcohol expectancies. Although expectancy theory has posited that expectancies are dynamic memory templates that aid in organizing and interpreting incoming sensory stimuli to produce output, the assessment of expectancies has relied heavily on self-reports, which may not capture the comprehensive nature of expectancy templates. Cognitive modeling approaches allowed for associative networks to be modeled based on behavioral and self report data, which could then be tested empirically (Goldman, 1999). As a first step, Rather et al. (1992) examined expectancies using a "semantic network" model approach from the memory literature. In this approach, concepts were represented as nodes in a network that were associated with other concepts based on meaning and learning. Thus, concepts that were more closely linked were more likely to be activated when a stimulus matching one of those nodes was encountered. This model of "spreading activation" had been used in semantic and linguistic research for several decades (Collins & Loftus, 1975). As opposed to factor analysis techniques which aggregate concepts (i.e., items) based on covariance, this network model sought to derive conceptual nodes based on specific associations among items which could then be mapped in multidimensional space based on particular features of the items. Conceptualizing expectancies as semantic networks was a first step toward integrating the domain of alcohol expectancies into the larger literature of memory function, including computational and memory modeling approaches.

Rather et al. (1992), therefore, first gathered semantic data by asking individuals to generate adjectives that completed the statement "alcohol makes one _____". Since memory network approaches are built upon the assumption of "nodes" of information (consisting of images, environmental contexts, affective experiences, or the semantic representations of these concepts), the responses were pared down to the most frequent words and their synonyms. This produced 38 groups of 5 items each (190 total) that were judged to have similar meaning. In the second phase of their study, another group of participants were asked to rate each of the 190 words for how likely they were to be experienced when drinking several drinks of alcohol on a 7-point scale from 'never' to 'always'. This procedure yielded a more consistent set of 33 word groups with 4 mostly synonymous members each. These "iso-meaning word groups" formed the basis for subsequent multidimensional scaling (MDS) based on Euclidean distances derived from individuals' ratings of the likelihood of the effects being experienced. The model was best represented by a 2-dimensional array, which allowed for the words to be plotted in space with physical distances representing the relatedness of the items. The MDS model was then validated using drinking data from participants, since alcohol expectancy theory hypothesizes that individuals who drink more would hold more positive expectancies about alcohol than lighter drinkers. Indeed, a visible shift from more negative or sedating expectancies in lighter drinkers to more positive and arousing expectancies in heavier drinkers was apparent in the mapping. In other words, the organization of one's alcohol expectancies in MDS space was directly related to the amount one actually reported drinking. This may seem like an intuitive assertion, but being able to derive these associations empirically and estimate the degree to which particular associations may be related to actual behavior began a fascinating line of research in the alcohol expectancy domain.

Rather & Goldman (1994) followed with another study that sought to better define the distances between concepts using similarity judgments as opposed to indirectly derived distances based on ratings of word groups. In this study, individuals were asked to rate how likely they were to experience two effects at the same time when they consumed alcohol from 'extremely unlikely' to 'extremely likely'. These results were then mapped using MDS and examined based on individual drinking levels. This study

replicated the two dimensional model and further defined the dimensions as 'arousing–sedating' and 'positive–negative', which coincided nicely with characterizations of other affective stimuli (Goldman, 1999). Results indicated that heavier drinking individuals tended to have denser positive associations with alcohol compared to lighter drinking individuals, and also indicated that lighter drinkers more quickly associated sedating expectancies with alcohol. Thus, modeling expectancies using MDS allowed researchers to develop testable hypotheses that utilized the self-reported semantic space to predict outcome behavior.

Subsequent research using these semantic network modeling techniques revealed that semantic associations changed over the course of development with younger children associating more negative and sedating outcomes with alcohol. These associations became more positive and arousing as children entered adolescence (Dunn & Goldman, 1996, 1998). In addition, expectancies that fell on the positive and arousing quadrant of the MDS mapping were found to be the best predictors of drinking behavior, followed by expectancies on the sedating dimension (Aarons et al., 2003). These studies supported the conceptualization of expectancies as semantic memory networks that could be triggered by stimuli in the environment and spreading activation as an appropriate model for describing how associated concepts (including drinking behavior) might be discussed. In addition, manipulations of cognitive processes (e.g., context primes) have been found to influence memory associations and alcohol consumption, further validating alcohol expectancies as mediators of antecedents of risk for drinking. (Stein, Goldman, & Del Boca, 2000; Kramer & Goldman, 2003; Reich, Goldman, & Noll, 2005).

MDS techniques had the advantage of being able to connect directly to cognitive science and memory modeling techniques; however, they did not easily integrate into more traditional psychometric approaches to measuring psychological phenomena. Integrating MDS models into the experimental domain required the development of a scale that would reflect differences in association as factors. Therefore, Goldman and Darkes (2004) created the Alcohol Expectancy Multiaxial Assessment (AEMax) that utilized MDS models as a guide to creating a factor-based instrument that exhibited similar properties (i.e., semantic associations were key to creating factors). They then validated the utility of the instrument

for predicting drinking prospectively, and showed that sedating factors were related to lighter drinking and positive and arousing factors were related to heavier drinking in accord with expectancy theory. While some other measures of alcohol expectancy were shown to predict more variance in drinking (e.g., the Alcohol Expectancy Questionnaire; Brown, Christiansen & Goldman, 1987), the AEMax was a psychometrically sound instrument that mimicked the cognitive theory of expectancies. Specifically, the AEMax represented expectancies as a series of associations in memory that could be activated by particular stimuli in the environment; and in this model, more closely associated concepts were more likely to co-activate via spreading activation to influence behavior.

Cognitive structure of expectancies. The empirical evidence supporting the theory of alcohol expectancies painted an interesting picture of the way these associations were stored in memory and how they changed based on experience with alcohol. In this model, heavy drinkers could be viewed as experts in drinking behavior compared to light drinkers. Research on expertise in other domains had shown that as experts mastered a behavior, their performance of that behavior became more automatic and efficient, and this change in efficiency could be measured at the neural level (e.g., via fMRI – Chein & Schneider, 2005; via ERP – Luu, Tucker, & Stripling, 2007). That is, "performance of well-learned (habitual) behaviors in response to strong associations becomes very efficient and does not require much effort or strong involvement of neural regions implicated in control processes. The implications for verb generation and other indirect methods of word association are that they can engage either implicit or more controlled processes" (p.560, Stacy & Wiers, 2010). Thus, in the domain of alcohol expectancies it was likely that these associations changed based on one's level of expertise with drinking. Empirically, this was reflected by the denser and more accessible positive expectancies of heavier drinkers compared to lighter drinkers. Coupled with the overall endorsement of more positive expectancies among heavier drinkers, it appeared that more experienced drinkers had more broadly developed expectations about alcohol consumption that were easily and automatically accessed when a wide range of stimuli associated with alcohol were encountered. Furthermore, it was logical that the increase in breadth, accessibility, and efficiency could be measurable at the neural level, as it had been in other domains of expert behavior.

Various lines of research examining memory functioning, including working memory and learning paradigms, have utilized measures of neural function such as cerebral blood flow and scalp-recorded electrical signals resulting neuronal activity. Such studies provided evidence that individuals' experiences and expectations influenced the way those individuals preferentially processed and integrated information (e.g., Fales et al., 2008; Luijten et al., 2010). In a related line of research, a recent study in the alcohol expectancy domain showed that it was possible to measure alcohol expectancies (more specifically, violations of alcohol expectancies) using psychophysiological techniques. 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 measured 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 predicted 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 served as anticipatory frameworks for evaluation of stimuli encountered in the environment. Furthermore, this study opened the door for additional ERP investigations of alcohol expectancies at the level of individual differences.

Event-related potentials

Event-related potentials (ERPs) have been shown to be components of electrical activity of the brain that are elicited by specific events. That is, ERPs are time-locked to discrete sensory, motor, or cognitive events, and could be understood as manifestations of neural activities invoked in the course of information processing (for review see Fabiani, Gratton, & Coles, 2000). The ERP signal, of only a few microvolts, can be extracted from overall electroencephgraphic (EEG) activity, which can reach 50 microvolts, by signal averaging. The ERP waveforms are understood to 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. Several ERP components have been shown to index whether particular stimuli match or mismatch an individual's expected outcome given a specific context. For example, the medial frontal negativity indexes when a predicted outcome is less rewarding than expected (e.g., Nieuwenhuis et al., 2004), the P300 is elicited by events that are rare or unexpected in a particular context (e.g., Duncan-Johnson & Donchin, 1977), and the N400 reflects the degree to which a particular word is expected given the semantic context (Kutas & Federmeier, 2011), Kutas & Hillyard, 1980). Each of these components reflect some aspect of expectancies in the broad definition, and are a testament to the fundamental and instantaneous role that prediction of upcoming events and outcomes plays in human information processing. ERPs, therefore, 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. For the purposes of the current study, the P300 and N400 ERP components will be examined in depth.

The P300 component: An index of subjective expectancy. The P300 component, a positive-going wave that occurs 300-600 ms after an endogenous classification and is maximal over central parietal scalp locations, is traditionally elicited using an "Oddball" paradigm in which participants are required to attend to a sequence of events in which infrequent events are interspersed. In this type of task an infrequent event elicits the P300 component. Several variables affect the amplitude and latency of the

P300 component (see Fabiani et al., 1988; 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 P300 makes it a powerful tool for accessing cognitive processes pertaining to the monitoring and classification of expected and unexpected stimuli.

Several paradigms have explored the effects of violations of subjective expectancies on P300 response. 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 potential" (LPP; Cacioppo, Crites, & Gardner, 1996). Upon further evaluation, this LPP includes the P300 component when properly parsed (Ito & Cacioppo, 2007; Spencer, Dien, & Donchin, 2001; Dien, Spencer, & Donchin, 2003). Furthermore, evidence indicated that these violations were automatic and uncontrollable, and could conflict with reported expectations or attitudes (e.g., gender stereotypes – Osterhout, Bersick, & McLaughlin, 1997; condom usage – Lust & Bartholow, 2009; social actions – Bartholow et al., 2001). Individuals also exhibited P300 to subjectively arousing picture stimuli, and larger responses appeared to reflect one's level of affective arousal (Cuthbert et al., 2000). Thus, the P300 ERP component allowed researchers access to affect-laden and context-specific evaluative information processing, which may or may not have been 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 shorter-latency and potentially larger P300 activity. 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 that P300 amplitude was correlated with self-reported drinking in the following months (Bartholow, Henry, & Lust, 2007). The same group later found that ERPs elicited by alcohol cues correlated with self-reported positive evaluation of alcohol (Lust & Bartholow, 2009).

Fishman et al. (2008) was the first study to examine individual differences in P300 elicited by alcohol expectancy sentences. Participants were presented with statements about alcohol (e.g., "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. Using a similar paradigm, a follow-up study attempted to look at individual differences in the P300 effect by providing an alcohol context prime before expectancy sentences were viewed (Brumback, Donchin, & Goldman, unpublished manuscript). This study indicated that an alcohol context prime resulted in slightly larger P300 responses than a non-alcohol context prime, but the individual variation across levels of alcohol expectancy scores was muted due to the relatively light drinking sample used.

In addition to the P300, words and sentences consistently elicit the N400 component. When using word stimuli it is necessary to design one's study scrupulously so that the association and differentiation of these two components is possible, since they often overlap in time course and scalp topography (e.g., Arbel, Spencer & Donchin, 2011). This point is especially important when evaluating the role of expectations via word associations like those measured in the domain of alcohol expectancies.

The N400 component: An index of semantic expectancy. The N400 ERP component, a negative going wave that occurs about 300-500 ms after most semantic stimuli and is maximal over central or centro-parietal electrodes, was discovered and initially characterized as a unique response elicited by semantically incongruent words that completed sentences (e.g.," I like my coffee with sugar and socks"; Kutas & Hillyard, 1980). It is often slightly larger at electrode sites over the right hemisphere when elicited by visually presented word stimuli (Kutas & Hillyard, 1984; Van Petten & Luka, 2006). Extensive examination of the N400 over the last 30 years has revealed that it is elicited by nearly all potentially meaningful stimuli (particularly semantic stimuli), and the amplitude of the N400 is increased to stimuli that are less congruent or expected given the semantic or sentential context (Federmeier, 2007). The main paradigms used to elicit the N400 are priming paradigms and sentence paradigms.

In priming paradigms, a prime stimulus is used to "set the context" and a target stimulus then follows (e.g., two words presented in succession; Bentin, McCarthy, & Wood, 1985). In these paradigms, the N400 elicited by the target reflect the degree to which the two stimuli are related. The less related the stimuli are, the larger the N400 will be. A wide variety of tasks have been used in priming paradigms, and it has been shown that task demands are an important aspect of the way primes and targets are perceived. For example, when participants were asked to try to memorize word pairs, which required attention and processing of meaning, unrelated targets elicited larger N400s than related targets. On the other hand, when participants were asked to count non-words in a string of stimuli, N400s were not significantly larger for unrelated targets compared to related targets (Bentin, Kutas, & Hillyard, 1993). Participants do not necessarily have to process the meaning of the words since tasks have been shown to reliably elicit an N400 when participants were simply asked whether a particular letter appeared in the previous pair of

words (Kutas & Hillyard, 1989). Therefore, task demands that highlight the characteristic upon which participants should be evaluating the stimulus pair can manipulate the N400 component to some degree.

In sentence paradigms, words can be presented one at a time or in groups. When presented one at a time, the N400 component can be measured to each word. In congruent sentences, the N400 to each word is reduced as the sentence progresses, but when a word is presented that does not fit with the semantic context established the N400 is enhanced (Van Petten & Kutas, 1990; Kutas & Hillyard, 1980). Incongruent words can occur in the middle of sentences or, more commonly, in the sentence-final position and the N400 is elicited equally in both cases (Osterhout, 1997). The N400 is sensitive primarily to semantic association (e.g., Bentin et al., 1985) and to expectancy or cloze probability, which is the proportion of individuals who give a particular word to complete a sentence-fragment (Taylor, 1953). High cloze probability words elicit reduced N400s compared to low cloze probability words (Kutas & Hillyard, 1984). In addition, stronger semantic association as well as associations based on other stimulus features result in reduced N400 amplitude (Bentin, McCarthy, & Wood, 1985; Rhodes & Donaldson, 2007). Other factors, such as attention, have also been shown to affect the N400 amplitude in particular tasks (e.g., Kutas, Neville, & Holcomb, 1987).

In both word-pair and sentence paradigms, the N400 to the target stimulus reflects the degree of association between the context and target. In tasks using words as stimuli, the N400 is essentially a measure of semantic expectancy based on contextual factors established in the particular task. When there is minimal context provided the N400 amplitude is associated with more general features of the word such as frequency in the language and concreteness, but as more context is provided the N400 amplitude is predicted more by how well the word fits in the context (Van Petten, 1995); Kutas & Iragui, 1998). As such, the N400 provides a potentially interesting probe into semantic relatedness.

Most studies of N400 effects have focused on defining the factors that affect N400 amplitude (e.g., cloze probability), but a few studies have examined the effects of incongruity based on more specific classes of semantic associations such as gender associations (Wicha, Moreno, & Kutas, 2004; White, Crites, Taylor, & Corral, 2009). One study examined gender stereotypes using word pairs with a

gender prime (e.g., "Man" or "Woman") and a trait or occupation that is generally associated with one gender or the other as the target (White et al., 2009). In this study, the results indicated that stereotype incongruent word pairs elicited larger N400s compared to stereotype congruent word pairs. Thus, the N400 may be a viable index of the degree of association between stimuli based on appraisal of those stimuli within a particular category. It is important to point out that this study was not an examination of individual differences among participants, but rather an examination of widely held gender associations. The function of the N400 does, however, lend plausibility to the idea that the N400 could index individual differences with a large enough sample and a way of classifying high and low stereotype endorsers.

The intersection of N400 and P300 in linguistic contexts. The N400 and P300 were originally proposed as independent components (Kutas & Hillyard, 1980), and they have remained distinct in the literature though they do overlap in scalp topography and temporal dimensions (Arbel, Spence, & Donchin, 2011). A pedestrian characterization of eliciting events for these components would be that the N400 is elicited by semantic violations and the P300 by physically deviant (non-linguistic) anomalies or syntactic anomalies in the linguistic domain; however, the story is undoubtedly more complex.[1]

A Study that labeled a positive going wave at 600 ms as a P600 showed that grammatical gender violations interacted with semantic violations to yield both a larger N400 and a larger positivity (Wicha et al., 2004). This study examined the syntactic violation of gender by utilizing a language (Spanish) that marks articles with gender. They then created conditions in which the article and target matched or mismatched in the context of a sentence that was semantically congruent or incongruent. When there was a dual violation, the N400 and the following positivity were both enhanced over the respective waves in single violation conditions. Interestingly, one group of researchers proposed that the positivity peaking at 600ms (i.e., the P300 for current purposes) is elicited when participants encounter a stimulus that violates

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[1] In the linguistic literature, a wave has been commonly reported following grammatical or syntactic violations described simply by its time course and polarity as the "P600" (e.g., Hagoort, 2003). As with the LPP, there is ongoing debate about the nature of the P600 and its relation to the P300, and some argue that the P600 is, at least in part, an instance of the P300 elicited in linguistic contexts (e.g., Osterhout, 1997; Coulson, King, & Kutas, 1998; Frisch et al., 2003). For the purposes of the current study, the P600 will be considered an instance of the P300 and will be labeled as such throughout.

the context in a way that leaves the sentence's meaning in doubt and requires reanalyzing the sentence meaning (Osterhout, 1997; Osterhout & Nicol, 1999). These researchers found that a small proportion of participants exhibited an N400 to syntactic anomalies, while others exhibited the expected positivity. They proposed that individuals who exhibited an N400 to syntactic violations were categorizing those errors as semantic or content-related rather than structural. Two factors appeared to increase the percentage of individuals who exhibited the N400 in these circumstances; namely, using open-class target words (e.g., nouns, verbs, and adjective) and placing the targets at the end of sentences. Closed-class words (e.g. articles, prepositions, and pronouns) usually help communicate phrasal structure in English, whereas open-class words communicate meaning by referring to specific objects and events (Osterhout et al., 1997). Previous studies have shown that open-class words tend to elicit an N400 followed by a positive going wave (labeled as the LPP in those studies, but likely the P300), whereas closed-class words tend to elicit an N400 followed by a sustained negativity (Kutas & Van Petten, 1994). Furthermore, placing targets in the sentence final position has been hypothesized to elicit confounded ERPs that include sentence wrap-up effects, and evaluative and response processes (e.g., Osterhout, 1997). While these factors are potentially important to recognize when interpreting results, they should not be over-generalized to all sentence ERP paradigms since some paradigms are interested precisely in sentence wrap-up evaluative processes.

Overall, evidence seems to indicate that the elicitation of the N400 and P300 is not entirely independent of individual differences in sentence processing paradigms. That being the case, the P300 component has provided the most robust evidence of indexing subjective expectation varying among individuals and in paradigms using non-linguistic stimuli (Donchin & Coles, 1988; Cacioppo, Crites, & Gardner, 1996; Fishman et al., 2008; Lust & Bartholow, 2009). The P300 will, therefore, serve as the primary ERP component of interest since the N400 has been examined primarily as indices of rule-based errors. Studies that use semantically and syntactically congruent sentences are able to differentiate individuals' or groups' responses based on subjective evaluation and domain-specific individual differences. Previous ERP studies examining individual differences in domain-specific processing have

neglected or insufficiently addressed the methodological control to allow direct comparison between ERPs affected by individual differences and those that are relatively homogenous in fluent English speaking adults (e.g., Fishman et al., 2008; Brumback et al., unpublished manuscript). The current study is an effort to integrate the methodological control of many of the linguistic studies above with the innovative paradigms designed to parse out individual differences.

The Present Study

The review of the literature above indicates that alcohol expectancies are an excellent candidate to be integrated into ERP research, but implementing specific paradigms to measure individual differences has proven a formidable task. The current study was designed to increase statistical power as well as methodological control to increase the probability that the previously reported trends will be more robust and reliable. Developing an ERP measure of alcohol expectancies has several advantages over other types of measures. First of all, ERPs provide evidence of stimulus processing and categorization in a time frame that is inaccessible to almost all other behavioral measures of cognitive phenomena (Meyer, Osman, Irwin, & Yantis, 1988). As such, ERPs are less susceptible to the influences of conscious, deliberative processes and instead reflect more of the automatic associations and evaluations upon which expectancy theory is built. Cognitive modeling has been utilized in alcohol expectancy research using both explicit (e.g., ratings) and implicit (e.g. free associates) paradigms, but both types involve deliberative processes leading to a decision on the part of the participant. The ERP measures used in this study reflect processes upstream of these more deliberative behavioral measures, and as such may provide insight into early biases that influence downstream decision making.

Furthermore, ERPs provide the additional advantage of being directly associated with underlying neural activity; that is, neural activity that is not filtered through musculature or intentional, metacognitive processing. While the neural sources of many ERP components are currently unspecified, recent advances have made identifying sources of activity more plausible. Thus, developing an ERP measure of alcohol expectancies could provide data that will allow for testable hypotheses of neural activity related to expectancy functions, like those already established in other expectancy based cognitive processes (e.g., anterior cingulate and "error-related negativity" ERP component; Holroyd & Coles, 2002). While such

developments are beyond the scope of the current study, they provide an aspirational motivation for the utility of the measures presented in the current study.

This study was designed, ultimately, to better understand the decision processes that lead to the end behavior of consuming alcohol. Given the well established utility of alcohol expectancies in assessing alcohol use risk and predicting long-term outcomes (e.g., Goldman, 1999, 2002), developing a reliable measure of the neural activity associated with evaluating expectancy-related stimuli like the one presented below could potentially increase the variance in drinking variables accounted for by existing instruments (Reich et al., 2010). ERP measures reflect the early biases in individuals' expectations about alcohol and provide a measure of individual differences based on these biases.

The current study incorporated three tasks completed while EEG was continuously recorded. One task was designed to elicit a P300 to word stimuli in a classic "Oddball" paradigm. This task included words from two categories (e.g., living things and inanimate objects). One of the categories was presented 20% of the time while the other category was presented 80% of the time. This task was included to accomplish two goals: 1) to provide an exclusion criterion since anyone who did not exhibit the typical P300 may not exhibit other ERP components; and 2) to provide a robust P300 component to word stimuli which served as a comparison for ERPs from the sentence task (described next).

Another ERP task was an expansion of the task implemented in previous investigations of alcohol expectancies using sentences to elicit ERPs indexing the subjective evaluation of the sentence content (Fishman et al., 2008; Brumback et al., unpublished manuscript). This task included alcohol-related sentences with positive or negative alcohol expectancy words that are anticipated to replicate previous findings. Specifically, expectancy words that violated an individual's subjectively held expectations were expected to elicit a larger P300 compared to congruent expectancy words. Sentences are advantageous in that they provide more contextual information than single word primes, though they come with added methodological complexity. Thus, this task contained a set of semantically incongruent sentences designed to elicit a robust N400 component. By adding in this control condition, ERPs to the alcohol-

related sentences could be directly compared to the classic N400 component reported in many of the studies cited above.

The third task consisted two blocks of word pairs designed to elicit the N400. One block of word pairs mimicked those used in a previous examination of stereotypes (White et al., 2009), in which a series of alcohol-related nouns were used as the primes and alcohol expectancy words were used as the targets. The N400 elicited by the targets was expected to correlate with paper and pencil ratings of the same alcohol expectancy words. The second block of word pairs consisted of all combinations of 16 alcohol expectancy adjectives so that each word appeared with every other word in both the prime and target positions (16 x 15 = 240 iterations). Responses on this block of word-pairs served as the data for MDS modeling, in an attempt to use the N400 as a measure of semantic distance.

Hypotheses. The primary aim of the current study was to compare individuals' ERP responses to stimuli that are congruent and incongruent with self-reported alcohol expectancies in two separate ERP paradigms in order to validate ERPs as an effective measure of alcohol expectancies.

Hypothesis 1: The P300 ERP component elicited following alcohol related sentences in the sentence task was expected to reflect individuals' expectancies, replicating findings from Fishman et al. (2008). That is, individuals who endorse more positive and arousing expectancies were predicted to show larger P300 responses to sentences that violated their self-reported expectancies (i.e., negative and sedating sentences) from the paper and pencil measures of expectancies (i.e., the AEQ & AEMax). Conversely, individuals who endorse more negative and sedating expectancies were predicted to show larger P300 responses to positive and arousing sentences. These responses were predicted to be related to actual drinking behavior in as much as expectancies were related to drinking behavior in this sample.

Hypothesis 2: The N400 response elicited in the Noun-Adjective block of the word pair task were expected to be correlated with paper and pencil expectancy measures (i.e., the AEQ & AEMax). Individuals with more positive expectancies were predicted to exhibit larger N400s to negative and sedating expectancy words, and individuals with more negative expectancies were predicted to exhibit larger N400s to positive and arousing expectancy words.

Exploratory Aim: The Adjective-Adjective block of the word pair task was designed to examine the relationship of N400 measures of "relatedness" from ERP paradigms in multidimensional space.

Exploratory hypothesis 1: The MDS model derived from N400 amplitude from alcohol expectancy word pairs was predicted to qualitatively approximate the MDS model derived from self-report similarity judgments. If this first hypothesis were supported, then MDS models of the N400 amplitudes would be compared between individuals who endorse more positive and arousing expectancies and those who report fewer positive and arousing expectancies for qualitative differences.

Method

All procedures were in accordance with the Declaration of Helsinki and approved in advance by the Institutional Review Board of the University of South Florida.

Participants

Ninety-three college students aged 18-35 were recruited through the university's online research participant pool (55 females, 38 males; 61 Caucasian, 13 Hispanic/Latino, 11 African-American, 5 Asian, 3 Other). The language-based tasks coupled with EEG recording required 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: 1) consuming alcohol in the last month, 2) speaking American English as a first language, and 3) having normal or corrected-to-normal vision. In addition, participants were excluded if they endorsed a history of neurological disorder (e.g., seizure disorder or multiple sclerosis) or head injury (i.e., loss of consciousness > 5 min), as well as use of medications that might affect EEG signal (e.g., anxiolytics or neuroleptics). After meeting criteria on the online prescreening survey, answers were verified in the lab. One participant was excluded due to being under the influence of marijuana during the recording session and six participants (all females) were excluded due to reporting no drinking in the past month during the data collection session (contradicting responses on the online pre-screening survey). Three additional participants were excluded from all analyses due to software malfunction, excessive artifacts in EEG signal, and experimenter error. These exclusions left a total of 83 participants (49 females, 34 males). Any exceptions or exclusions from individual analyses are noted in the results section. See Table 1 for demographic and substance use characteristics of the sample.

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). Participants were also asked to report their typical drinking habits for the past year in two multiple-choice items, one describing the frequency of their typical drinking and one describing the typical quantity consumed per occasion.

  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. A published factor analysis revealed 6 separate subscales within this measure, including: Global Positive, Sexual Enhancement, Physical and Social Pleasure, increased Social Assertiveness, Relaxation and Tension Reduction, and Arousal and Aggression. The endorsement of each subscale was analyzed to provide further information into the type of alcohol expectancies endorsed by each participant. Due to the length of the measure, participants completed it through the online participation program prior to enrolling in the study.

  Alcohol Expectancy Multi-Axial Assessment: Short Form (AEMax; Goldman & Darkes, 2004). This short form version (derived from a longer 132-item scale) included 24 expectancy items, with three items from each of eight factors (i.e., Horny; Social; Egotistical; Attractive; Sick; Sleepy; Woozy; and Dangerous). These eight factors load onto three higher order factors: Positive-Arousing, Sedating, and Negative. The measure required participants to rate how often they believe each item 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 provided an explicit index to contrast with the ERP results.

30-Day Timeline Follow-Back (TLFB; Sobell & Sobell, 1992). This calendar-based interview measured participants' alcohol use (quantity and frequency) retrospectively over the month prior to assessment. Participants were asked to identify the amount of alcohol consumed per 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. Regarding the veracity of self-reports, the relevant literature indicate that verbal reports can provide reliable and valid information even 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).

ERP Tasks

Oddball task. A word category oddball task with stimuli from two distinct word categories (e.g., animals and furniture) was used. Categories were matched for average length, frequency and complexity. A total of 200 trials were included with 40 "rare" targets and 160 standard stimuli. Each word stimulus was preceded by a fixation cross in the middle of the screen and then the word was presented for 600 ms and the intra-stimulus-interval (ISI) was set to 1000 ms. Participants were asked to respond by pressing a button each time they saw a rare target and to do nothing when they saw a standard stimulus.

Expectancy sentence task. The task consisted of two blocks of sentences, which were presented in random order. One block of sentences consisted of alcohol-related sentences in which the final word was an alcohol expectancy word. Many of these sentences were selected from the stimulus set used by Fishman, Goldman, and Donchin (2008) and additional sentences were added. The alcohol sentences included 30 with positive/arousing endings, 16 with negative endings, and 14 with sedating endings based on previous research that organized specific alcohol-related words on these dimensions (Goldman & Darkes, 2004). In total, 60 sentences are related to alcohol in a semi-random order. In each of the alcohol sentences, the target word was an adjective describing a possible effect of alcohol (e.g., "Alcohol makes me *happy*" vs. "Alcohol makes me *sad*"). The other block of sentences consisted of 33 non-alcohol

semantically incongruent sentences and 33 non-alcohol semantically congruent sentences. These sentences were also selected from a previous paradigm (Arbel, Spencer, & Donchin, 2011). The incongruent sentences in this set have been shown to reliably elicit an N400 compared to the congruent sentences. See Appendix A for a list of the sentences used.

Each sentence was presented one word at a time, with each word appearing on the screen for 300 ms followed by a 200 ms break before the next word. The target word in all sentences occurred as the terminal word of the sentence, which appeared on the screen for 800 ms. The final words in each sentence category were matched for familiarity (Alcohol words = 6.98 Non-alcohol words = 6.97, *ns*), length (Alcohol words = 6.2, Non-alcohol words = 5.8, *ns*), and frequency (Average Standardized frequency index: Alcohol Sentences = 52.14, Non-alcohol sentences = 56.50, *ns*). After each sentence the participants were asked to rate whether they 'agree' or 'disagree' with the sentence. Participants then saw a separate screen prompting them to press a key to continue with the next sentence. Participants were told they could take breaks between sentences if necessary, and there was a mandatory break between sentence blocks.

Alcohol expectancy word pair task. This task also consisted of two blocks of trials presented in random order for each participant. For one block, adjective-adjective word pairs were created from a task previously used to map alcohol expectancy words in semantic space (see Rather & Goldman, 1994; Goldman & Darkes, 2004). Sixteen alcohol expectancy adjectives were selected from a group of adjectives often associated with alcohol consumption by college students. Each word was paired with every other word, once as the prime and once as the target yielding 240 word pairs for the task. Halfway through the task participants were given a break and allowed to continue the task at their discretion. The participants were asked to judge: "For each pair of words, consider how likely or unlikely it is that you would experience the two effects at the same time when you consume alcohol." After each word-pair trial, individuals were asked to rate their judgments on a 1 (very unlikely) to 4 (very likely) scale. For each word pair, the prime word was presented for 400 ms followed by a 300 ms fixation and then the target word was presented for 400 ms. There was then a 400 ms blank screen before the rating screen.

A separate block of stimuli consisted of 220 noun-adjective word pairs. There were four alcohol-related nouns (e.g., beer, alcohol, liquor, and wine) as primes, which were presented once each with a set of 55 alcohol expectancy adjective targets taken from the AEMax (Goldman & Darkes, 2004). Participants were asked to rate how likely they were to experience the target adjective after consuming the beverage on a 1 (very unlikely) to 4 (very likely) scale. Responses to these word pairs provided an index of the relative strength of association between alcoholic beverage words and the respective outcomes. See Appendix B for a list of the words included in both blocks and the categories into which the words were averaged. The *a priori* groups were confirmed by factoring the overall subjective likelihood ratings from the task. The only word that did not cluster as expected was 'quiet'. Therefore, 'quiet' was excluded from the group averages for both subjective ratings and ERP results.

Procedure

Individuals who were eligible after completing the pre-screen survey online and meeting the inclusion criteria detailed above were allowed to sign up for data collection sessions. Participants were invited to attend a 1.5-2 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. Upon arriving for the experiment, each participant was asked to sign an informed consent form, which provided information on confidentiality, benefits and risks of participation, and storage of the data. After completing the consent form, the participants filled out the demographic form and pattern of alcohol use form. When the forms were completed, the EEG sensor net was applied to the participant's head and the participant was led into a room where the EEG tasks were completed.

The ERP tasks were presented in varying order determined by random assignment of participant IDs prior to the beginning of recruitment to avoid sequence effects and systematic fatigue effects. Participants were given instructions for each of the tasks by the experimenter. Each ERP task began with a practice block to ensure the participant understood the instructions and was able to follow the directions. The experimenter guided the participant through this portion of each task and left the room during the

recording phase. Each task was followed by a short break during which the experimenter ensured that the participant was comfortable and that the electrodes continued reading properly. Upon completion of the ERP tasks, the participant was taken back to the net application room to remove the net. The participant was then asked to complete the remaining paper and pencil tasks (AEMax, Family Grid, & Time-line follow back). The participants were then debriefed and allowed to leave.

Data Recording and ERP analyses

Off-line EEG data preprocessing. The EEG was recorded with a 128 electrode EGI system, with the vertex electrode (Cz) used as the on-line reference site. The signal was digitized at a sampling rate of 250 Hz. Using Netstation software, all EEG data were digitally filtered with a 0.1-40-Hz wideband filter and segmented into epochs starting 200 ms prior to stimulus onset to 1000 ms following stimulus onset. These raw EEG epochs were then run through automated artifact detection procedures, and bad channels were replaced by a mathematical interpolation procedure. Data were corrected for eye blinks using an independent component analysis approach (provided in Dien's ERP toolkit, version 1.3; Dien, 2010), and baseline-corrected using the average of the 200-ms pre-stimulus epoch. ERP data were then examined trial-by-trial and remaining artifacts and bad trials that were not identified using the automated processes were manually marked. Individual trials were excluded if they contained more than 10 bad channels. The artifact-free trials were averaged separately for each task and each experimental condition. Finally, the averaged data were re-referenced to a mean-mastoid reference. This procedure generates a 129th channel of mathematically linked reference recorded separately from the ear lobes. Artifacts are a common problem in ERP data and inclusion of many trials with artifacts decreases the signal-to-noise ratio dramatically. In order to maximize the number of participants included while maintaining reliable category averages, participants were required to have at least 70% good trials per category for the Oddball and Sentence tasks. For the Word Pair task participants were required to have at least 8 good trials in each of the word group averages to be included in the analysis.

Principal components analysis: Extracting ERP components. The processing sequence described above resulted in waveforms for each averaged condition in each of the 129 electrodes. In order

to extract components, which are not based on peaks or troughs in the raw waveform but on the basis of experimental variation, a principal components analysis (PCA) was conducted on the observed waveforms from the Sentence task and Oddball task separately using scripts provided in Dien's ERP Toolkit (Dien, 2010). The PCA procedure 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. 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 account for the largest portion of the residual variance. For typical ERP data, this percentage drops off rapidly after the first four or five components, which usually account for up to 90% 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 ERP components several steps are required.

In ERP data, the variables are the microvolt readings at each electrode (the spatial PCA) or at each consecutive time point (the temporal PCA). First, a spatial PCA was conducted for the averaged waveforms at each electrode site for all experimental conditions for each participant, with the electrode sites as variables in order 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). For the spatial PCAs, Varimax rotation was used with Kaiser normalization. A scree test was conducted and the number of variables to rotate was determined by identifying the point at which the change in eigenvalues decreased (i.e., at the "elbow" of the scree plot). The spatial PCA produced 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 on the spatial factor scores was conducted to reduce the temporal dimensions. In this step, the spatial factor scores associated with the time points of the original dataset become the variables for the PCA, and the observations are the spatial factors. Varimax rotation was again used in the temporal PCAs. The resulting spatiotemporal factor scores (i.e., scores for a given spatial factor at a given temporal factor) served as dependent variables for subsequent analyses. Specifically, a combination of the spatial factor accounting for the most variance in the central midline or centro-parietal channels (corresponding to the well-established scalp distribution of N400 and P300, respectively) and the temporal factor accounting for the most variance in the window corresponding to the ERP component of interest (e.g., 300-700 for P300 & N400) were sought to represent the ERP components as dependent variables. Details of the outcome of the PCA for each task are reported below.

Hypothesis Testing

Hypothesis 1. *The P300 ERP component elicited following alcohol related sentences in the sentence task were expected to reflect individuals' expectancies, replicating findings from Fishman et al. (2008). That is, individuals who endorse more positive and arousing expectancies were predicted to show larger P300 responses to sentences that violated their self-reported expectancies (i.e., negative and sedating sentences) from the paper and pencil measures of expectancies (i.e., the AEQ & AEMax). Conversely, individuals who endorse more negative and sedating expectancies were predicted to show larger P300 responses to positive and arousing sentences. These responses were predicted to be related to actual drinking behavior in as much as expectancies were related to drinking behavior in this sample.* This hypothesis was tested by correlating individual's expectancy scores from the AEMax and AEQ scales with the P300 factor scores derived from the PCA on the sentence task. A positive correlation was predicted between the positive expectancy scales (AEMax Attractive, Social, Horny, & Positive-Arousing; and AEQ Global Positive) and P300 factor scores for negative and sedating sentences, as well as between sedating/negative expectancy scales (AEMax Sick, Sleepy, Woozy, Dangerous, Sedating, & Negative) and P300 factor scores for positive and arousing sentences. Furthermore, P300 factor scores for

sentences to which participants endorsed 'agree' within the task were compared to P300 factor scores for sentences to which participants endorsed 'disagree' in a paired-samples t-test to determine whether the P300s were indeed smaller to sentences that fit with individuals' expectancies. As a comparison, the same analyses were conducted using the ERP measure of the N400 extracted from the PCA.

Hypothesis 2. *The N400 response elicited in the Noun-Adjective block of the word pair task were expected to be correlated with paper and pencil expectancy measures (i.e., the AEQ & AEMax). Individuals with more positive expectancies were predicted to exhibit larger N400s to negative and sedating expectancy words, and individuals with more negative expectancies were predicted to exhibit larger N400s to positive and arousing expectancy words.* N400 factor scores were correlated with self-report expectancy scales as in the sentence task. N400 responses to negative and sedating words were expected to be positively correlated with positive expectancy measures (AEMax Attractive, Social, Horny, & Positive-Arousing; and AEQ Global Positive), and negatively correlated with sedating/negative expectancy measures (AEMax Sick, Sleepy, Woozy, Dangerous, Sedating, & Negative), while the reverse was hypothesized for positive and arousing words.

Exploratory hypothesis. *The MDS model derived from N400 amplitude from alcohol expectancy word pairs was predicted to qualitatively approximate the MDS model derived from self-report similarity judgments. If this were supported, then MDS models of the N400 amplitudes would be compared between individuals who endorse more positive and arousing expectancies and those who report fewer positive and arousing expectancies for qualitative differences.* In order to test this hypothesis, a series of MDS models were created using the data from participants' likelihood ratings and the N400 factor scores derived from the PCA. Averages of subjective ratings and N400 were created for each of the 240 word pairs using the data from all participants, and these data were converted into distances for entry into the MDS analyses. These models were qualitatively compared to describe similarities and differences between self-report and N400-derived models.

Significance levels were set at $p<.05$ for all analyses.

<center>**Results**</center>

Drinking and Expectancy Measures

Drinking and expectancy data for the sample are reported in Table 1. Males and females did not differ on any of the drinking variables derived from the TLFB or on single item measures of quantity and frequency. Males were significantly older than females (22 v. 20); therefore, age was entered as a covariate in analyses comparing gender. Males and females reported equivalent expectancies on all positive expectancy subscales (i.e., all AEQ scales and positive AEMax scales), while females reported significantly higher likelihoods for alcohol consumption to lead to becoming sick and tired (i.e., higher scores on the AEMax Sick and Sleepy subscales, and on the second order factor Sedating comprised of both subscales).

Drinking variables were compared with expectancy ratings. The 'Drinks per drinking day' variable from the TLFB exhibited the strongest relationships with the AEQ and was positively correlated with all six AEQ subscales (Table 2). Single item 'Typical quantity' ratings, which approximated the number of drinks consumed per occasion, were also correlated with several AEQ subscales in the expected direction (i.e., more positive expectancies about alcohol is related with more self-reported drinking). The average 'Drinks per week' derived from the TLFB was significantly positively correlated only with the Social and Physical Pleasure subscale. The number of days individuals reported drinking in the last 30 days on the TLFB was uncorrelated with the AEQ subscales, while the single item 'Typical frequency' ratings were positively correlated with most of the subscales.

For the AEMax, which indexes both positive and negative expectancies, the positive subscales were not significantly correlated with drinking variables (Table 3, columns 1-4). The negative and sedating expectancies were largely correlated with the drinking variables from the TLFB such that more negative/sedating expectancies were related to less self-reported drinking (Table 3, columns 5-11). For

the typical drinking single-items, only sedating exhibited significant relationships. Thus, self reported

drinking was related to positive and negative expectancies consistent with expectancy theory.

Table 1. Drinking and expectancy data by sex.

	Males N=34	Females N=49
Age	22.0 (4.3)*	20.1 (2.2)
Typical Frequency	2.44 (1.2)	2.24 (1.2)
Typical Quantity	3.32 (1.9)	3.15 (1.5)
TLFB (past month)		
Days Drinking	3.79 (2.6)	3.96 (2.9)
Drinks per week	4.11 (4.0)	3.64 (3.8)
Drinks per Drinking Day	4.44 (2.5)	3.54 (1.7)
AEMax (2nd order factors in italics)		
Social	14.27 (2.4)	14.73 (2.4)
Attractive	9.97 (3.8)	9.90 (3.3)
Horny	10.70 (2.5)	10.60 (3.3)
Positive Arousing	*34.93 (7.2)*	*35.22 (7.5)*
Egotistical	10.00 (2.4)	9.42 (4.1)
Dangerous	6.67 (2.9)	6.58 (4.0)
Negative	*16.67 (4.2)*	*16.00 (7.6)*
Sick	8.70 (3.1)*	10.70 (3.6)
Woozy	10.64 (2.7)	11.56 (3.6)
Sleepy	9.97 (3.2)*	11.50 (3.4)
Sedating	*29.30 (7.3)**	*33.73 (9.1)*
AEQ		
Global Positive	8.78 (6.4)	7.36 (5.7)
Social & Physical Pleasure	7.41 (1.8)	6.8 (2.0)
Sexual Enhancement	2.47 (3.0)	2.74 (2.4)
Social Assertion	6.38 (2.8)	6.21 (3.5)
Tension Reduction	6.06 (3.0)	5.51 (2.9)
Aggression Arousal	3.75 (2.3)	3.36 (2.4)

Note: * indexes $p < .05$

Table 2. Correlations between drinking (1-5) and AEQ subscales (6-11).

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Days Drinking	--	.78*	.13	.61*	-.03	.02	.16	.09	-.04	.07	.14
2. Drinks per week	.78*	--	.57*	.60*	.23*	.18	.24*	.16	.01	.20	.21
3. Drinks per Drinking Day	.13	.57*	--	.36*	.53*	.40*	.33*	.25*	.30*	.44*	.29*
4. Typical Frequency	.61*	.60*	.36*	--	.28*	.27*	.23*	.13	.11	.23*	.30*
5. Typical Quantity	-.03	.23*	.53*	.28*	--	.41*	.36*	.12	.33*	.34*	.15
6. AEQ Global Positive	.02	.18	.40*	.27*	.41*	--	.57*	.65*	.66*	.74*	.72*
7. AEQ Social & Physical Pleasure	.16	.24*	.33*	.23*	.36*	.57*	--	.48*	.64*	.56*	.52*
8. AEQ Sexual Enhancement	.09	.16	.25*	.13	.12	.65*	.48*	--	.53*	.53*	.66*
9. AEQ Social Assertion	-.04	.01	.30*	.11	.33*	.66*	.64*	.53*	--	.59*	.58*
10. AEQ Tension Reduction	.07	.20	.44*	.23*	.34*	.74*	.56*	.53*	.59*	--	.64*
11. AEQ Aggression Arousal	.14	.21	.29*	.30*	.15	.72*	.52*	.66*	.58*	.64*	--

Note: * indexes $p<.05$

Oddball Task

A PCA was conducted on the oddball task to derive the P300 component.[2] Fourteen spatial factors were rotated accounting for 90% of the variance. One spatial factor (SF2) was determined to be the spatial factor of interest as it loaded most highly at centro-parietal scalp sites as is typical of P300 elicited in Oddball tasks (cf. Figure 1A depicting the first 5 SFs). Rare stimuli clearly elicited a larger positivity than frequent stimuli in the 500-700ms range in the "Virtual ERPs" (Figure 1B). The temporal PCA in which 5 factors were rotated accounting for 87% of the variance, yielded a temporal factor (TF2) overlapping with the peak in the virtual ERP (400-800ms; See Figure 2). Factor scores extracted from this component (SF2-TF2) were examined in a paired-samples t-test, which confirmed the significant difference between rare and frequent stimuli [$t(81) = -8.51$, $p<.01$].

The P300 component factor scores were compared by age and sex as well as drinking variables. P300 factor scores were unrelated to age and drinking variables. Overall, males tended to elicit larger

[2] The data for one participant was not recorded due to software malfunction leaving 82 participants in these analyses.

Table 3. Correlations between drinking and AEMax subscales (numbered 1-11).

|	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Days Drinking	.03	.06	-.04	.02	-.09	-.22*	-.18	-.31*	-.32*	-.25*	-.35*
Drinks per week	-.07	-.04	-.12	-.09	-.27*	-.30*	-.31*	-.33*	-.37*	-.34*	-.42*
Drinks per Drinking Day	-.05	-.02	-.07	-.05	-.21	-.28*	-.28*	-.18	-.17	-.27*	-.24*
Typical Frequency	-.03	-.02	-.06	-.05	-.11	-.13	-.13	-.25*	-.28*	-.20	-.28*
Typical Quantity	.24*	.08	.15	.17	-.06	-.15	-.12	-.23*	-.18	-.12	-.21
1. Social	--	.53*	.57*	.81*	.36*	.04	.22*	-.03	.07	-.01	.01
2. Attractive	.53*	--	.49*	.85*	.26*	-.04	.12	-.11	.12	.04	-.04
3. Horny	.57*	.49*	--	.82*	.42*	.28*	.39*	.06	.12	.04	.09
4. Positive Arousing	.81*	.85*	.82*	--	.41*	.11	.28*	-.04	.13	.04	.05
5. Egotistical	.36*	.26*	.42*	.41*	--	.62*	.90*	.31*	.38*	.13	.32*
6. Dangerous	.04	-.04	.28*	.11	.62*	--	.90*	.48*	.38*	.16	.40*
7. Negative	.22*	.12	.39*	.28*	.90*	.90*	--	.44*	.42*	.16	.40*
8. Sick	-.03	-.11	.06	-.04	.31*	.48*	.44*	--	.72*	.52*	.89*
9. Woozy	.07	.12	.12	.13	.38*	.38*	.42*	.72*	--	.49*	.87*
10. Sleepy	-.01	.04	.04	.04	.13	.16	.16	.52*	.49*	--	.79*
11. Sedating	.01	-.04	.09	.05	.32*	.40*	.40*	.89*	.87*	.79*	--

Note: * indexes *p*<.05

P300s to rare trials in the Oddball task [*t*(80)= -2.7, *p*<.05], but differences on the frequent trials were not significant [*t*(80)= -1.9, *ns*; see Figure 3]. A difference score between the rare and frequent stimuli did not indicate significant differences between males (M =.96, *sd* = .84) and females (M =.64, *sd* = .79) [*t*(81)= -1.8, *ns*]. Thus, males tended to exhibit larger P300s to rare trials overall, but the size of the difference between rare and frequent trials did not differ significantly between males and females. Due to the differences in P300 to rare stimuli in this task, sex was subsequently considered in ERP analyses.

Sentence Task

Sentence ratings. Participants indicated their agreement or disagreement on each sentence presented in the task. On average, participants agreed to 19.5 of 30 (65%) positive alcohol sentences, while they agreed to only 4.9 of 16 (31%) negative alcohol sentences and 5.0 of 14 (36%) alcohol negative alcohol sentences. Males and females exhibited no differences in agreement to positive sentences
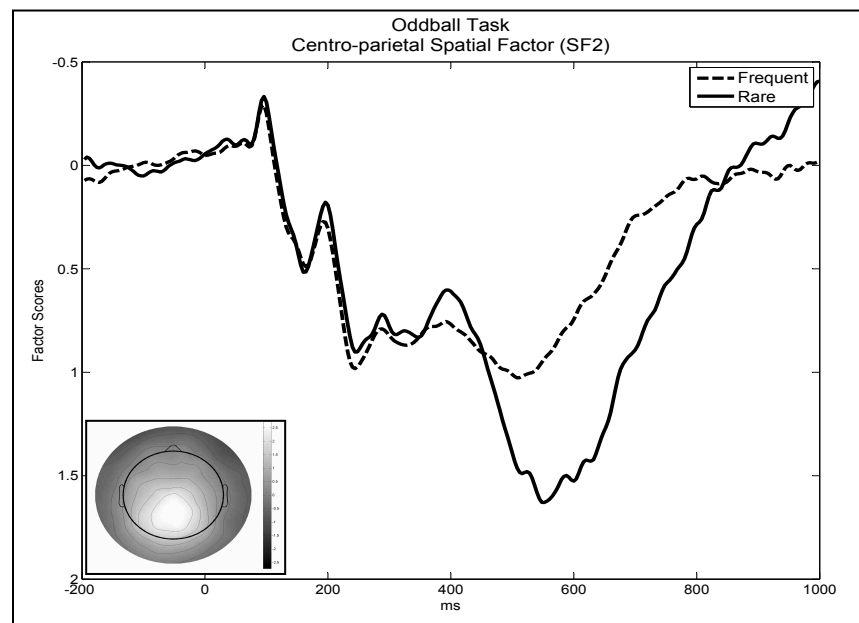
A.

SF1   SF2   SF3   SF4   SF5
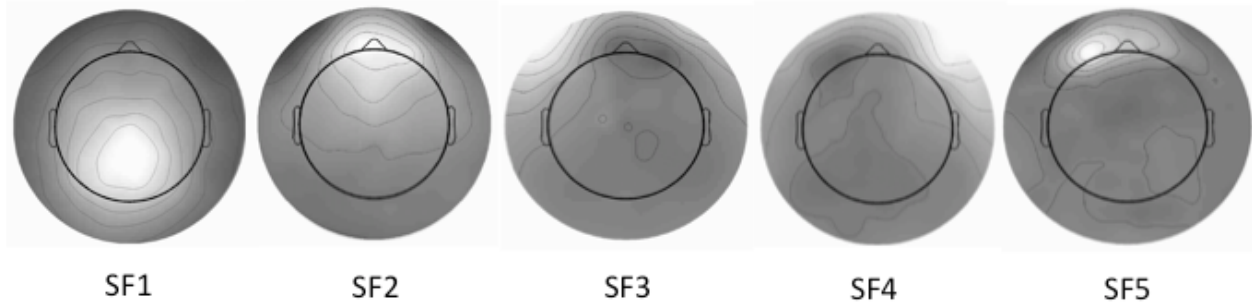
B.

Figure 1. PCA results from Oddball Task. A: Virtual Electrodes derived from spatial PCA. B: SF2 Virtual ERP depicting P300 peak for rare trials between 550-600ms.

[males = 19.3(6.3); females = 19.2(7.9)] and negative sentences [males = 3.8(2.8); females = 4.7(2.7)]; however, males agreed with fewer sedating sentences than females on average [3.7(3.0) v. 5.2(2.5); t(80) = 2.2, $p<.05$]. This difference matches self-reported expectancies as females reported greater sedating expectancies, but males and females did not differ in endorsement of positive or negative expectancies (cf. Table 1).
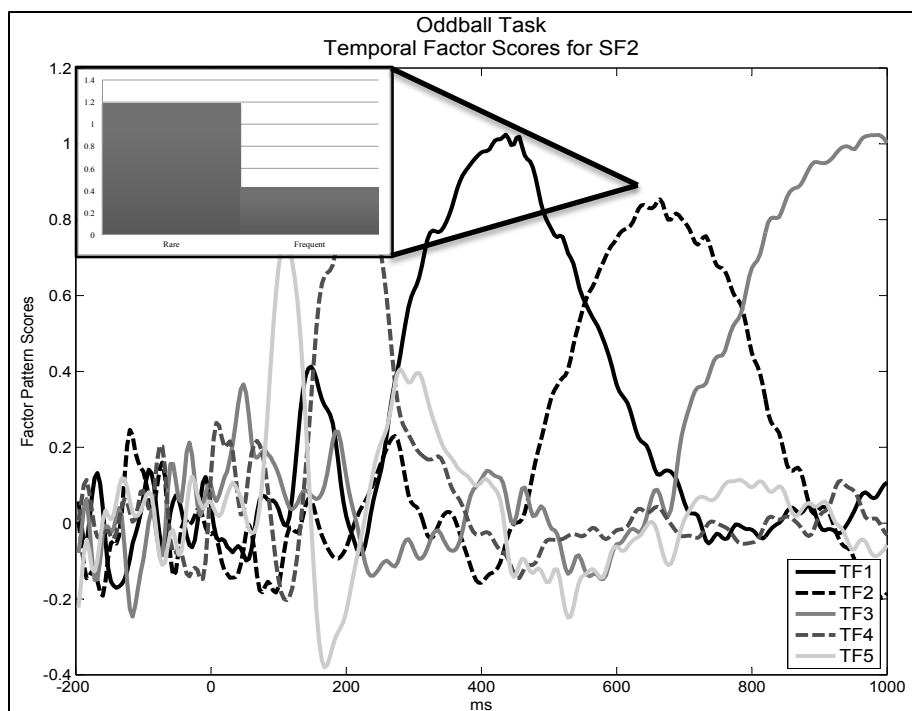
Figure 2. Factor scores from temporal PCA with bar graph inset depicting SF2-TF2 factor scores with the significant difference between Rare and Frequent Stimuli in the P300 component.
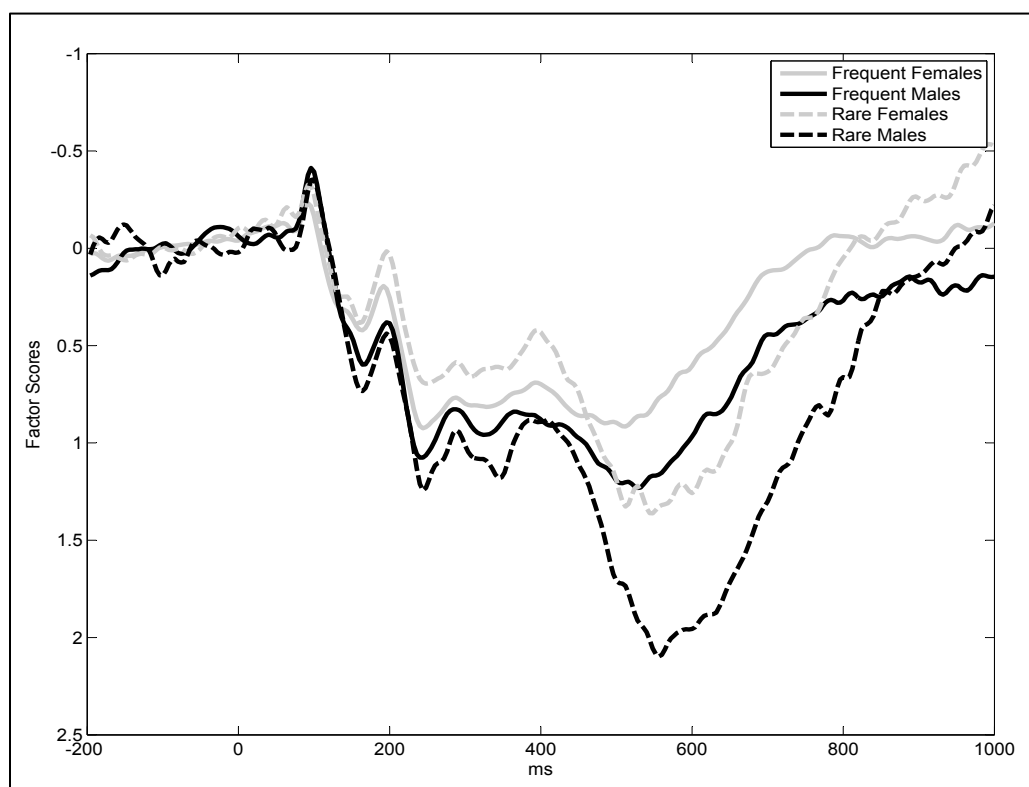

Figure 3. Oddball SF2 Virtual ERPs depicting sex differences in P300

Sentence ratings were related to drinking and expectancy measures in the expected directions. The number of positive sentences agreed to was positively correlated with all of the positive expectancy scales (AEQ scales: rs = .43 – .72; AEMax scales: rs = .41 – .60). In addition, individuals who reported higher 'Typical quantity' on the single item and higher 'Drinks per drinking day' from the TLFB endorsed more positive sentences (r = .43 and r = .26, respectively). Endorsing sedating sentences was related to sedating expectancies (AEMax Sick: r = .26; AEMax Woozy: r = .32; and AEMax Sleepy: r = .49), and social expectancies (AEMax Social: r = -.31; AEQ Social & Physical Pleasure: r = -.29). Similarly, individuals who reported higher 'Typical frequency' and 'Drinks per week' endorsed fewer sedating sentences (r = -.33 and r = -.30, respectively). Endorsing negative sentences was related to negative expectancies (rs = .25 – .32), and was also correlated with sedating expectancies (rs = .31 – .43). Unlike positive and sedating sentence endorsement, the number of negative sentences endorsed was not significantly correlated with drinking measures. Overall, these sentence-rating responses confirm that participants responded to the alcohol sentences inline with their reported expectancies.

ERPs for sentence type. ERP responses were first averaged by alcohol sentence type, recognizing that each sentence type would contain items that both matched with and violated individuals' subjective ratings. A PCA was conducted on the averages for all five sentence types: the three alcohol types (Positive, Negative, and Sedating) and the two non-alcohol types (Congruent and Incongruent). Twelve factors were rotated in the spatial PCA, accounting for 80% of the total variance. A fronto-central spatial factor (SF1) and a centro-parietal spatial factor (SF2) were identified as interpretable SFs potentially indexing variance related to the task (Figure 4).

The virtual ERPs of the data filtered through SF1 and SF2 depict differences among the sentence types (Figure 5). SF2 exhibited the expected scalp distribution for the P300 and N400 and was selected for subsequent analyses. SF2 depicted a negative peak around 400ms, which was taken to be the N400, and it also depicted a positive deflection following the N400 peaking at around 600ms, taken as the P300. Thus, the time epochs of interest for the subsequent temporal PCA were as expected in the 300-600ms range. The frontal component (SF1) was also examined to determine if the component was associated

with variables of interest, though no associations were hypothesized. For SF1, the epoch of interest appeared similar as the virtual ERPs depicted a slight positive peak in around 600ms that differentiates alcohol related sentences and non-alcohol related sentences.
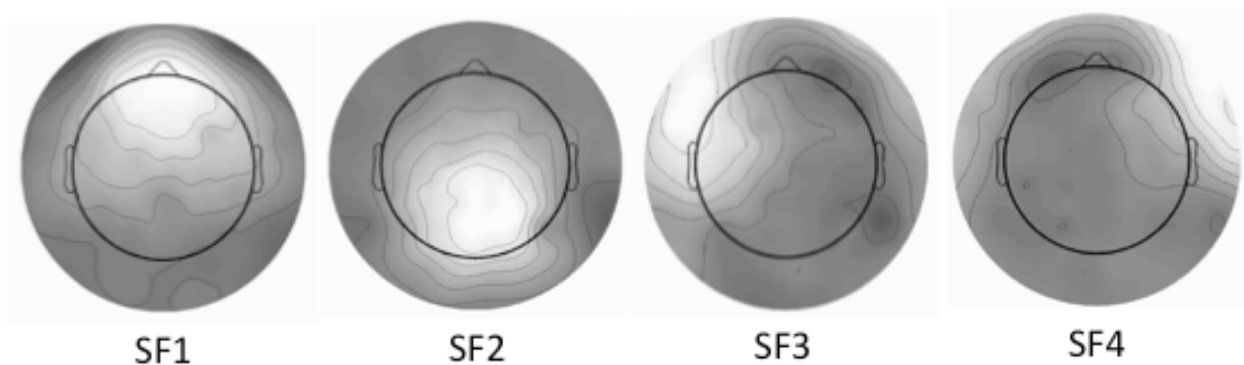

Figure 4. Virtual Electrodes from the spatial PCA for the Sentence Task.

The temporal PCA was conducted, rotating 8 factors for each spatial factor of interest (SF1 & SF2) accounting for 91% and 85% of the variance, respectively. For SF2, one temporal factor overlapped with the negative peak around 400ms (TF2) and one factor overlapped with the positive peak around 600ms (TF3; Figure 6). Therefore, SF2-TF3 factor scores were extracted as the P300 component and SF2-TF2 factor scores were extracted as the N400 component. For SF1, one temporal factor overlapped most clearly with the positive peak at which the alcohol and non-alcohol sentences differed (TF3), and this combination was extracted for further analysis.

P300 Component. A repeated measures ANOVA on the P300 component (5x2, with Sentence Type and Sex entered) revealed a main effect of Sentence Type [$F(4,78) = 16.9$, $p<.05$], and also indicated a Sentence Type x Sex interaction [$F(4,78) = 2.8$, $p<.05$]. Follow up paired comparisons showed that Alcohol Positive sentences elicited a significantly larger P300 than the Alcohol Negative or Alcohol Sedating sentences. Alcohol Positive sentences elicited significantly smaller P300s than Incongruent sentences, but did not differ significantly from Congruent sentences (cf. Figure 7, left frame). Furthermore, while the effect of sex was marginal [$F(1,81) = 3.7$, *ns*], follow up analyses indicated the
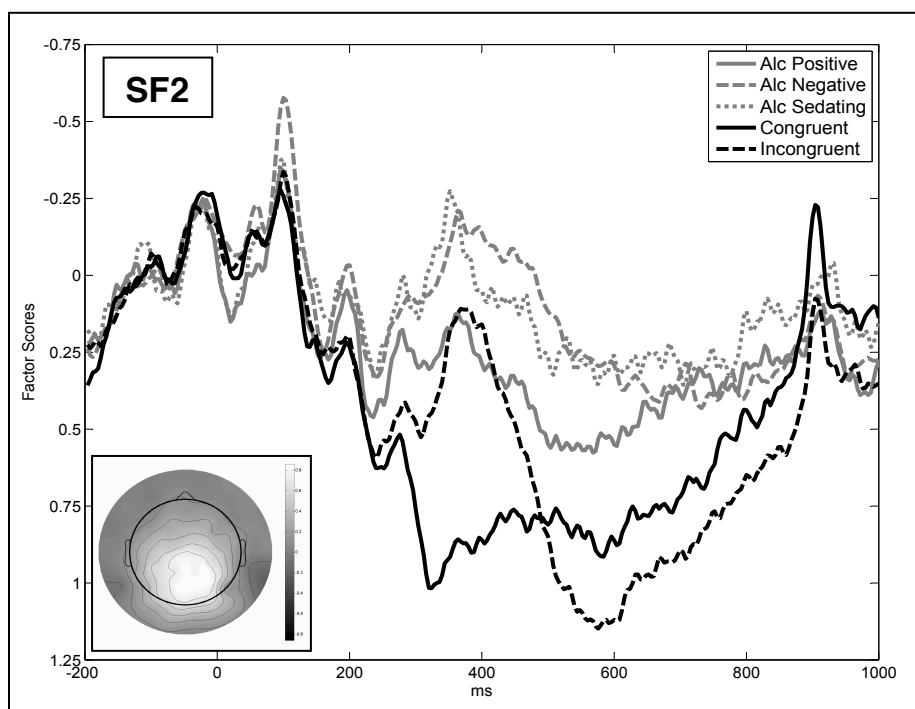
A.
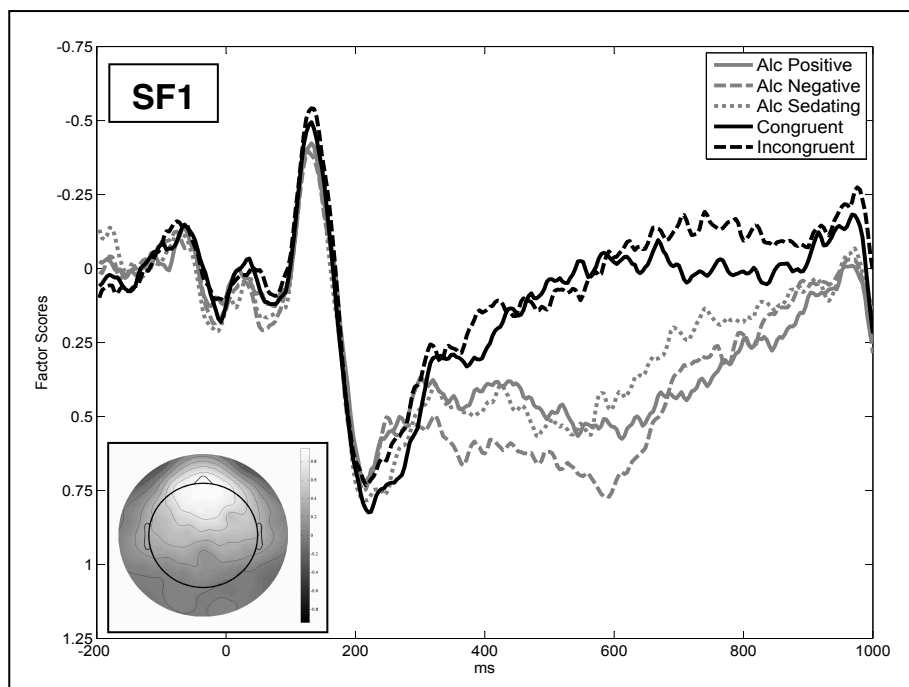
B.

Figure 5. Virtual ERPs from Alcohol Sentence Task. A: Fronto-central component (SF1). B: Centro-parietal component (SF2). *Note:* SF2 exhibited the typical scalp distribution of the P300 and N400 and is the focus of subsequent analyses.

source of the Type x Sex interaction was that males and females exhibited similar P300s to Congruent and Incongruent sentences but males exhibited significantly larger P300s following Alcohol Positive and Alcohol Sedating sentences compared to females (Figure 7, left frame). A parallel analysis of the frontal P300 component (SF1-TF3) confirmed the visible differences between the alcohol and non-alcohol sentence conditions [main effect of Sentence Type: $F(4,78) = 16.1$, $p<.05$]. Each of the alcohol sentence types was significantly different from the Congruent and Incongruent sentences, which did not differ from one another. There were no sex differences in the frontal P300 component, and it was not significantly related to any of the expectancy or drinking variables; therefore, the frontal P300 component was not considered further.

P300 and Expectancies. The P300 component was then compared with expectancy and drinking variables. The hypothesized relationship was that the P300 would be larger following sentences that violated an individual's expectancies and smaller following sentences that fit with an individual's expectancies. That is, a positive correlation was expected between contrasting expectancies and sentence type (e.g., Positive expectancy and negative sentences), and a negative correlation was expected between consistent expectancies and sentence types (e.g., Sedating expectancies and sedating sentences). The P300 following negative and sedating alcohol sentences was not significantly correlated with any of the expectancy subscales. The P300 following Alcohol Positive sentences was positively correlated with three AEQ subscales: Social & Physical Pleasure: $r=.25$; Social Assertion: $r=.25$; and Tension Reduction: $r=.24$. These relationships are in the opposite direction of the hypothesized relationships between expectancies and P300 responses. That is, individuals who endorsed higher positive expectancies on these AEQ subscales exhibited larger P300 responses following Positive alcohol sentences. One the surface, therefore, the results from the sentence task did not confirm the hypotheses.

Given the differences between males and females in ERP responses to alcohol related sentences, the correlations between P300 and expectancy and P300 and drinking variables were examined separately for males and females. Females' P300 responses were not significantly correlated with their expectancy endorsement. For males, the relationships between P300 following Alcohol Positive sentences remained
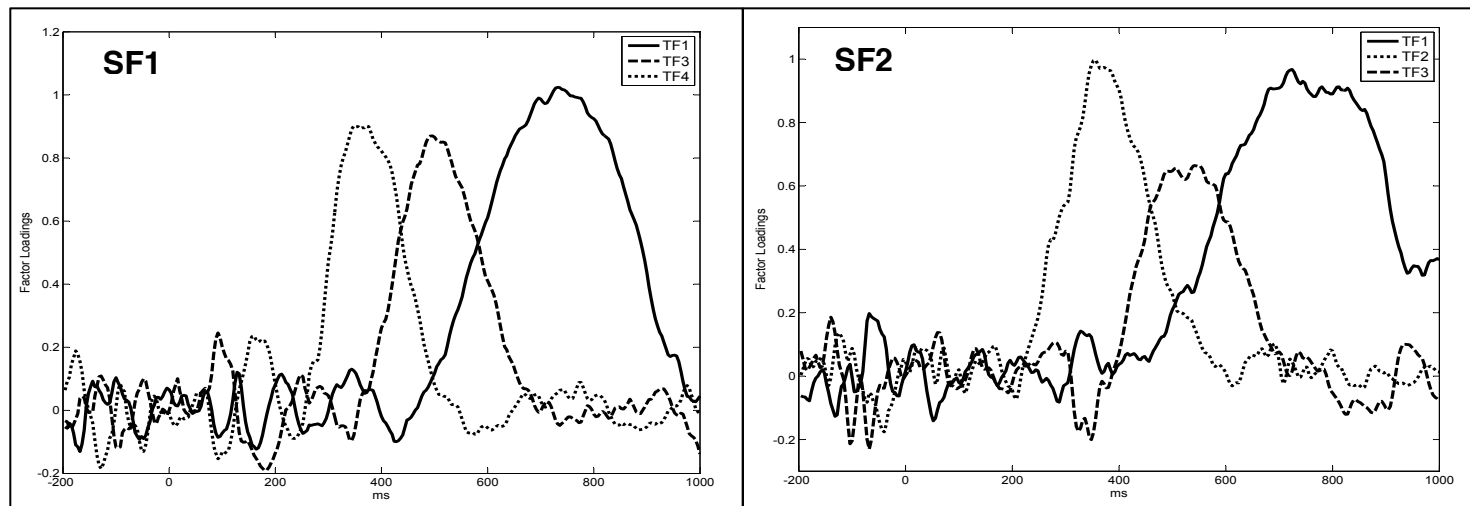
Figure 6. Factor scores from Temporal PCA for SF1 (left frame) and SF2 (right frame) with factors in epochs of interest. For SF1, TF3 was extracted as the frontal P300 component. For SF2, TF2 (N400) and TF3 (P300) were selected for subsequent analyses.
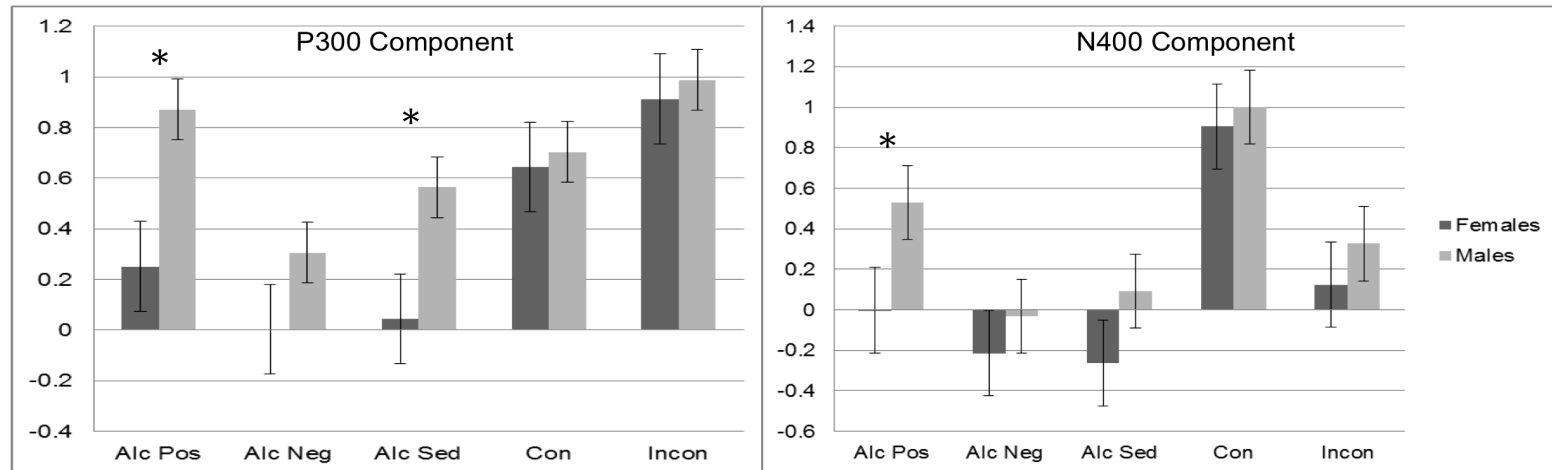

Figure 7. Factor Score comparisons by sex for P300 (SF2-TF3), left frame; and N400 (SF2-TF3), right frame.

Note: * $p<.05$

(Social & Physical Pleasure: $r=.34$; Social Assertion: $r=.37$; and Tension Reduction: $r=.48$), and the AEQ Global Positive scale was also positively correlated to the P300 ($r=.46$). As mentioned above, positive correlations between expectancies and P300 following expectancy-consistent sentences seems to be in the opposite direction of the hypothesis.

In contrast, the P300 following Alcohol Positive sentences was related to the AEMax Sleepy subscale for males ($r=.44$). Additionally, the P300 following Alcohol Negative sentences was positively correlated with each of AEQ scales (Global Positive: $r=.36$; Social & Physical Pleasure: $r=.39$; Social Assertion: $r=.36$; and Tension Reduction: $r=.47$). While the hypothesized relationship between expectancies and P300 for Alcohol Positive sentences was supported by only one expectancy subscale (and was contradicted by others), the P300 following Alcohol Negative seems to support the hypotheses in that sentences that likely violated males' expectancies elicited larger P300s.

It is worth noting that P300s across sentence types were highly correlated as is often the case in ERP measures (rs= .47-.62), and this could have contributed to positive expectancy scales being related to more than one sentence type. With that in mind, significant relationships did not exist between expectancy measures and P300s following Alcohol Sedating sentences, so the lack of independence among sentence types does not completely mitigate these results. Furthermore, it is notable that the relationships between P300 responses existed in the males but not the females in this sample.

N400 component. A repeated measures ANOVA on the N400 component also indicated a main effect of Sentence Type [$F(4,78) = 23.6$, $p<.05$]. As expected, Congruent sentences elicited the smallest N400, which was significantly smaller than all other sentence types. Follow up paired comparisons revealed that Alcohol Positive sentences elicited a smaller N400 than Alcohol Negative and Alcohol Sedating, but did not differ from Incongruent sentences. Therefore, Alcohol positive sentences elicited the smallest N400 and the largest P300 of the three alcohol sentence types, as can be seen in Figure 7. A main effect of sex [$F(1,81) = 4.1$, $p<.05$] showed that males exhibited significantly smaller N400s compared to females. Paired comparisons illustrated that males elicited smaller N400s than females only following

Alcohol Positive sentences [$t(81)$=-2.8, p<.05; Figure 7, right frame. Note that more positive values equal smaller N400s since it is a negative-going component]. No significant interactions were identified.

   N400 and expectancies. Although there were no specific hypotheses about the N400 in the sentence task, the component was also tested for relationships with drinking and expectancy variables. There were no significant relationships between the N400 and drinking variables. Among expectancy variables, the N400 following Alcohol Positive sentences was correlated with the AEQ Tension Reduction subscale such that individuals who reported higher tension reduction expectancies elicited smaller N400s to positive alcohol sentences (r = .29; again, since the N400 is a negative-going component the relationship is inverse). Similarly, N400s following Sedating alcohol sentences were smaller in individuals who endorsed higher AEMax Woozy expectancies (r = .24). The N400 following Alcohol Negative sentences was unrelated to expectancies. For the two significant relationships, therefore, individuals who were more likely to view sentences in the specific category as more congruent with their expectancies exhibited smaller N400s. While not hypothesized, these relationships would fit into a model of the N400 as an index of subjective expectancy.

   The relationships between N400s and expectancies were then examined for males and females separately. For females there were significant correlations between N400s following Alcohol Sedating sentences and AEMax Sick (r=.32), AEMax Woozy (r=.35), and AEMax Sedating (the higher order factor that includes both of subscales: r=.34). Females who endorsed more sedating expectancies exhibited smaller N400s following Alcohol Sedating sentences, which fits with the theoretical underpinnings of the hypothesized relationships in this study. It is also important to note that the AEMax Sedating scales were the only expectancy scales on which males and females differed (cf. Table 1).

   Males' N400s following Alcohol Sedating sentences, on the other hand, did not exhibit significant relationships with sedating expectancies, but rather with positive expectancies. Specifically, the N400 following Alcohol Sedating sentences was negatively correlated with the AEQ Social and Physical Pleasure scale (r=-.44). Again, though not directly hypothesized, this relationship corresponds to the theorized sensitivity of the N400 to violations of one's expectancies, as males who endorse more

positive expectancies exhibit larger N400s following Alcohol Sedating sentences. In addition, males'
N400s following Alcohol Positive sentences were positively correlated with several positive expectancy
scales from the AEQ: Social Assertion (r=.37), Tension Reduction (r=.58), and Sexual Enhancement
(r=.40). Once again, these relationships indicate that Alcohol Positive sentences elicit smaller N400s in
males who endorse more positive expectancies. As such, the significant correlations for the N400 measure
in this task may suggest a parallel process indexing subjective expectancy in the elicitation of the N400 as
that which was hypothesized for the P300.

ERPs for sentence agreement. The sentence task was also analyzed using individual's ratings of
agreement rather than the predefined alcohol expectancy sentence types. Due to the number of sentences
in each category coupled with the imbalanced number of sentences rated 'Agree' and 'Disagree' by
participants, it was not possible to split each sentence category into Agree and Disagree groups and
maintain necessary signal-to-noise ratios in the ERPs. Therefore, four sentence conditions were included
in this analysis: Alcohol Agree, Alcohol Disagree, Congruent, and Incongruent. A spatiotemporal PCA
was conducted using the same parameters as the initial Sentence Task PCA, which yielded nearly
identical spatial and temporal factors, as one would expect since essentially the same underlying data
were entered into the analysis. SF2 again loaded in the centro-parietal scalp region and was selected at the
SF of interest (Figure 8). Two temporal factors that overlapped with the peaks for the P300 (TF4) and the
N400 (TF2) were extracted.

P300 Component. A repeated measures ANOVA revealed a main effect of Sentence Type for the
P300 [SF2-TF4; $F(3,79)$=9.6, p<.05], and follow up paired comparisons indicated that Incongruent
sentences elicited a significantly larger P300 than all other conditions. There were no significant
differences among Agree, Disagree, and Congruent sentences. There was a marginal main effect of sex
[$F(1,81)$=3.85, p=.05], as males tended to exhibit larger P300s across all sentence types (Figure 9, left
frame). Once again there was a Sentence Type x Sex interaction [$F(3,79)$=3.0, p<.05], which appeared to
be a result of males exhibiting larger P300s than females following alcohol sentences based on follow-up

paired comparisons (Figure 9, left frame). No differences in P300 amplitude existed between males and females following non-alcohol sentences (i.e., Congruent and Incongruent).

Since Positive alcohol sentences elicited larger P300s and males tended to exhibit larger P300s (cf. Figures 5 & 7), additional analyses were conducted to examine the potential effects on the P300 when averaged by sentence agreement. The number of Positive sentences included in the Agree average increased the size of the P300 only marginally (r=.18, ns). In order to parse out any differences between sex and sentence type in this analysis, the ratio of sentences included in the Agree and Disagree averages were used as covariates in a series of ANOVAs using sex to predict P300. The main effect of sex remained after co-varying the number of Positive sentences included in the Disagree average, but for the Agree average the effect of sex on P300s became marginal after controlling for the number of Positive sentences included in the average [$F(1,80)$=3.5, p=.06]. It is clear, however, that the effect of sex remains a critical factor in understanding the results in this study.

N400 Component. For the N400 (SF2-TF2) there was a main effect of Sentence Type [$F(3,79)$=23.3, p<.05], which was a function of congruent sentences eliciting significantly smaller N400s than all other sentence types. Once again, sex appeared to influence the results as there was a marginal main effect of sex [$F(1,81)$=3.0, p=.09]. Paired comparisons revealed that males displayed smaller N400s following Alcohol Disagree sentences compared to females while N400 following Alcohol Agree sentences were not significantly different (Figure 9, right frame). As above with the P300, sentence type and sex influences were examined further for the N400 since Positive alcohol sentences elicited smaller N400s compared to Sedating and Negative sentences (cf. Figures 5 & 7) and males tended to exhibit smaller N400s on average.

For the Disagree average, the more Negative sentences included was related to an increase in the N400 (r = -.28), indicating that the more Negative sentences that violated individuals' expectancies led to larger N400s in the overall Disagree average. When the ratio of sentences included in the Agree and Disagree averages were entered as covariates in a series of ANOVAs using sex to predict N400 amplitude, sex maintained a significant effect on N400 amplitude for Disagree sentences [$F(1,81)$=13.0,

p<.05; males exhibit smaller N400s, Figure 9], even after accounting for the significant effect of the number of Negative sentences in the agree average [*F*(1,81)=9.8, *p*<.05; more Negative sentences in the average increased N400].

The fact that the Agree sentences elicited P300s and N400s that were similar to those elicited by Disagree sentences indicates that the straightforward hypothesis that Agree sentences are equivalent to "expected" sentences outcomes is insufficient. As shown above, the type of sentence included in the averages likely affects these components in regards to the ratio of sentences included in the Agree and Disagree average. Still, the size of neither the P300 nor the N400 is sensitive enough to agree/disagree binary decisions to separate the all sentences based on this categorization. These findings also point to the need to include larger number of trials in future paradigms to potentially examine both sentence type and sentence agreement in the same analysis more effectively.
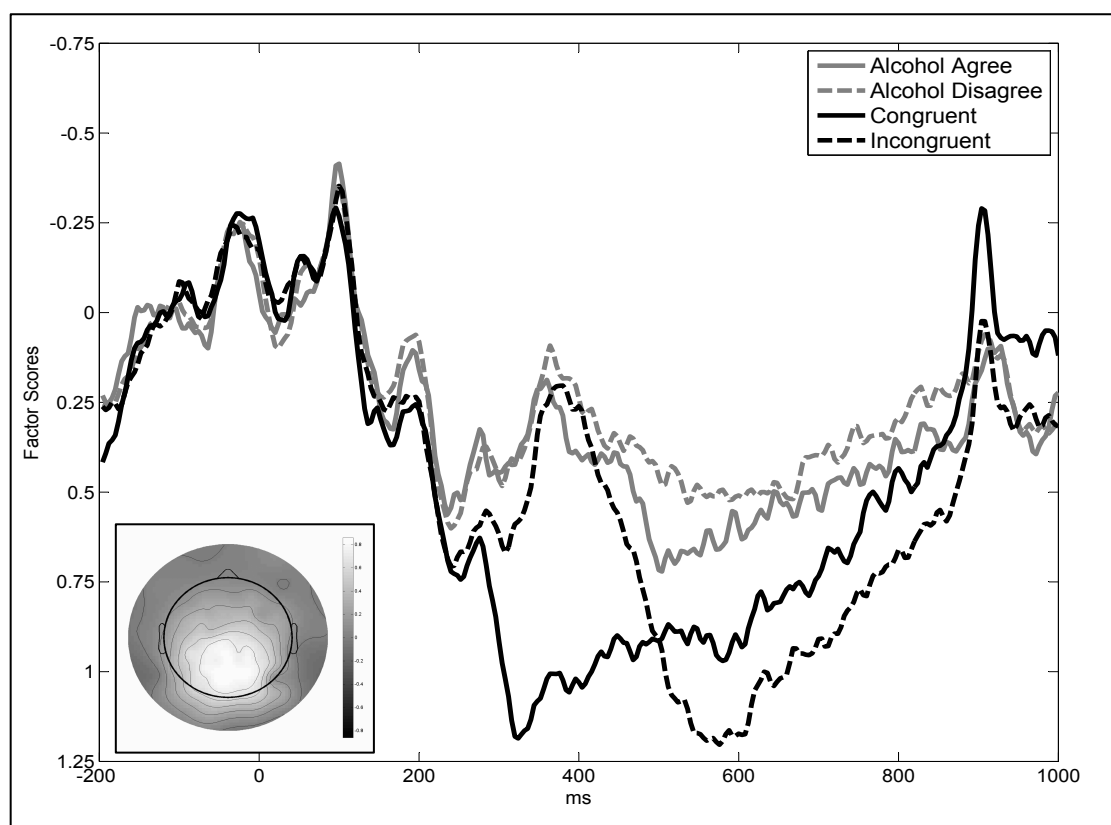

Figure 8. SF2 virtual ERPs from Sentence Task depicting average of alcohol sentences by agreement.
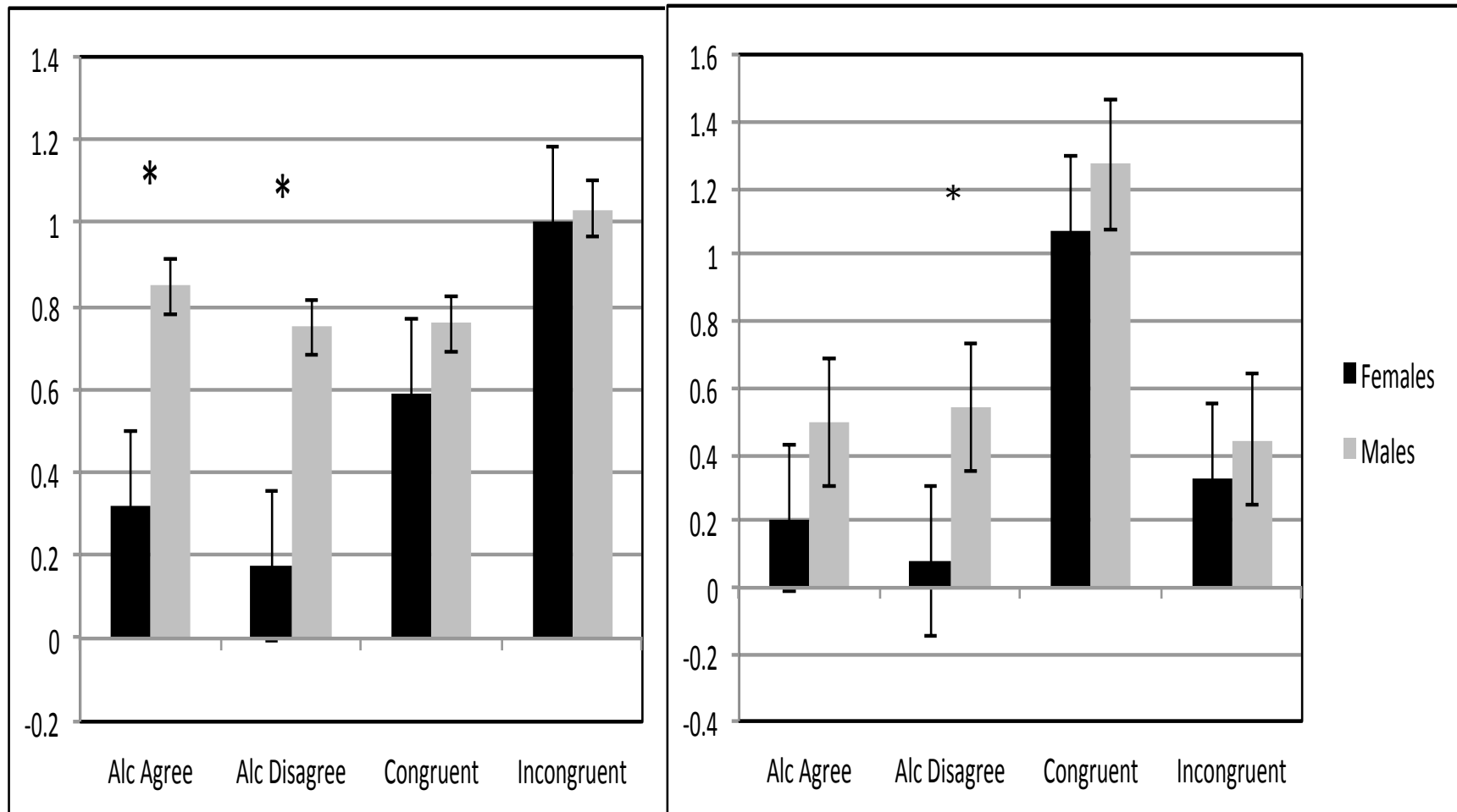
Figure 9. Sentence Agreement analysis factor score comparisons for P300 (SF2-TF4), left frame; and for N400 (SF2-TF2), right frame.
Note: * *p*<.05

Noun – Adjective Word Pairs

      Word pair ratings. Participants rated how likely each of the fifty-five adjective targets were to occur after consuming the four alcohol nouns (alcohol, beer, liquor, wine). Nine group averages were created from the 55 expectancy adjectives (Mad, Negative Emotion, Externalizing, Intoxicated, Physically Impaired, Outgoing, Carefree, Sexual, and Relaxing; see Appendix B for group composition). These groups were established *a priori* as informed by previous research (e.g., Goldman & Darkes, 2004), and were confirmed via confirmatory factor analysis on the average likelihood ratings. The word 'quiet' did not factor with the expected word group and was excluded from the averages. While the task was designed to examine individuals' expectancies across all types of alcoholic beverages, individuals often hold different expectancies based on the type of beverage being consumed (e.g., Pederson, Neighbors, & Larimer, 2010). Thus, average ratings of the nine word groups were compared across the four noun primes. On average, participants rated the expectancy words as less likely to occur after drinking wine compared to the other three alcohol primes [main effect of prime; $F(3,79)=76.5$; Figure 10]. Since the design of the ERP task required averaging together adjectives presented across multiple noun primes, the words presented with 'wine' were not included in the group averages to preserve as much homogeneity as possible.

      The likelihood ratings were correlated with expectancy scales in the expected directions. For example, ratings for the Outgoing, Carefree, Sexual, Relaxing, and Intoxicated word groups were positively correlated with the AEMax Positive – Arousing second order factor (rs = .28-.49), AEQ Global Positive (rs = .22-.29), and with AEQ Social Assertion (rs = .24-.29). Also in line with predictions, ratings for the Mad, Negative Emotion, Externalizing, Intoxicated, and Physically Impaired groups were positively correlated with AEMax Negative and AEMax Sedating second order factors (rs = .29-.32 & .38-.54, respectively). Due to sex differences in other measures, Males' and Females' ratings were compared. Females rated Mad, Negative Emotion, Externalizing, Intoxicated, and Physically Impaired as more likely to occur after drinking compared to males [ts (82) = 2.2-3.9, ps<.05; Figure 11). This might

have been expected given the differences reported in AEMax Sedating scores (above) and the strong

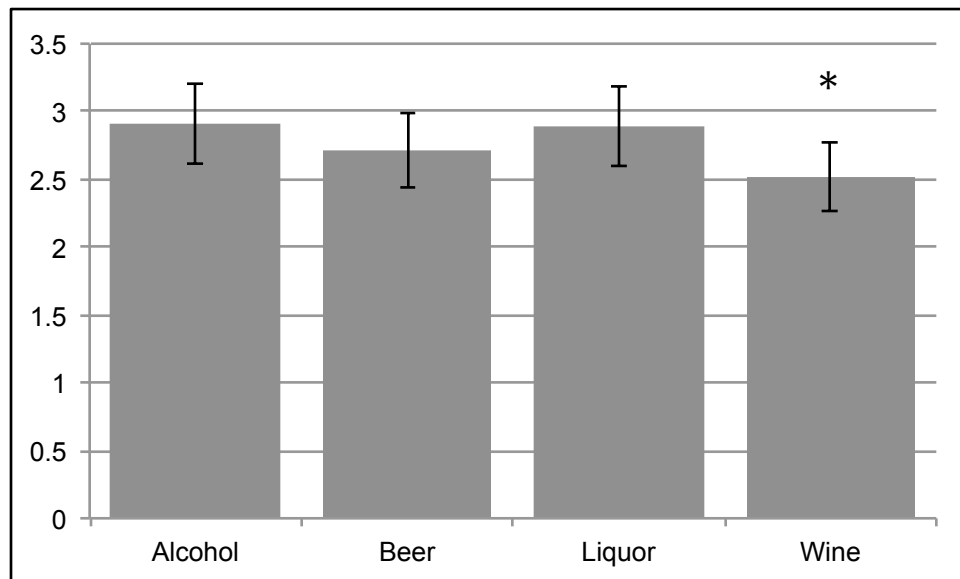correlations of these five word groups with Sedating expectancies.

Figure 10. Likelihood ratings from Noun-Adjective word pair task averaged by Prime.
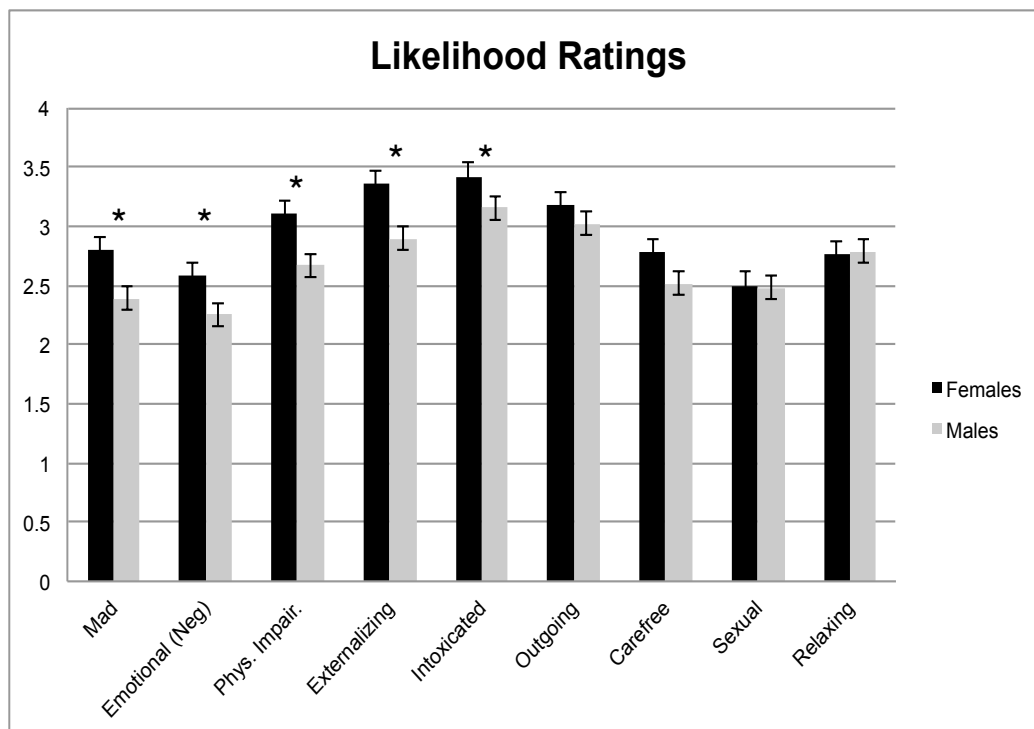*Note*: * *p*<.05

Figure 11. Likelihood Ratings for Noun-Adjective Word Group by sex.
Note: * *p*<.05

Word group ERPs. The word group averages were submitted to a PCA in which 10 factors were rotated, accounting for 84% of the total variance. A central scalp component (SF2) containing a negative peak at 400ms was selected as the index of the N400 from among the spatial factors (see first four factors in Figure 12-A), since no other spatial factors loaded highly in the central or centro-parietal scalp regions. Six factors were rotated in the temporal PCA on SF2, accounting for 92% of the variance. The temporal PCA produced a temporal factor (TF3) that peaked at 400ms (Figure 13). TF5 also appeared to overlap with the time window of interest, but upon further examination it seemed to capture the positivity that follows the N400; therefore, SF2-TF3 factor scores were extracted as the N400 component. No significant differences occurred between the sexes in any of the ERPs elicited by the word groups (ts < ±1.8, *ns*), and sex was not considered further in subsequent analyses.

The correlations between expectancy and drinking measures and the N400 component scores revealed several significant relationships. The AEQ Global Positive scale was negatively correlated with the N400 for Carefree (r=-.24), Outgoing (r=-.26), Externalizing (r=-.28), and Negative Emotion (r=-.25). So individuals who endorsed more positive expectancies exhibited larger N400s to each of the word groups above. AEQ Social and Physical Pleasure and AEQ Aggression/Arousal were also negatively correlated with the N400 from Negative Emotion (r=-.22 and r=-.25). Of the eight AEMax subscales, several were correlated with the N400 from Negative Emotion as well (AEM Sick: r=.23; AEM Woozy: r=.22; and AEM Social: r=-.23). In addition, AEMax Horny was significantly correlated with N400s from the Intoxicated word group (r=-.27). In these relationships negative correlations indicate an increase in the N400 as expectancies increase, which makes interpretation of this constellation of results difficult. Several of these correlations appear to fit with the hypothesized relationships; including the many correlations with Negative Emotion, since negative expectancies (e.g., Sick and Woozy) were positively correlated with this word group and positive expectancies (e.g., Global Positive, Social & Physical Pleasure, and Social) were negatively correlated with this word group. The relationships of AEQ Global Positive with positive word groups, however, are in the opposite direction of the hypothesis.

A.

SF1   SF2   SF3   SF4

B.
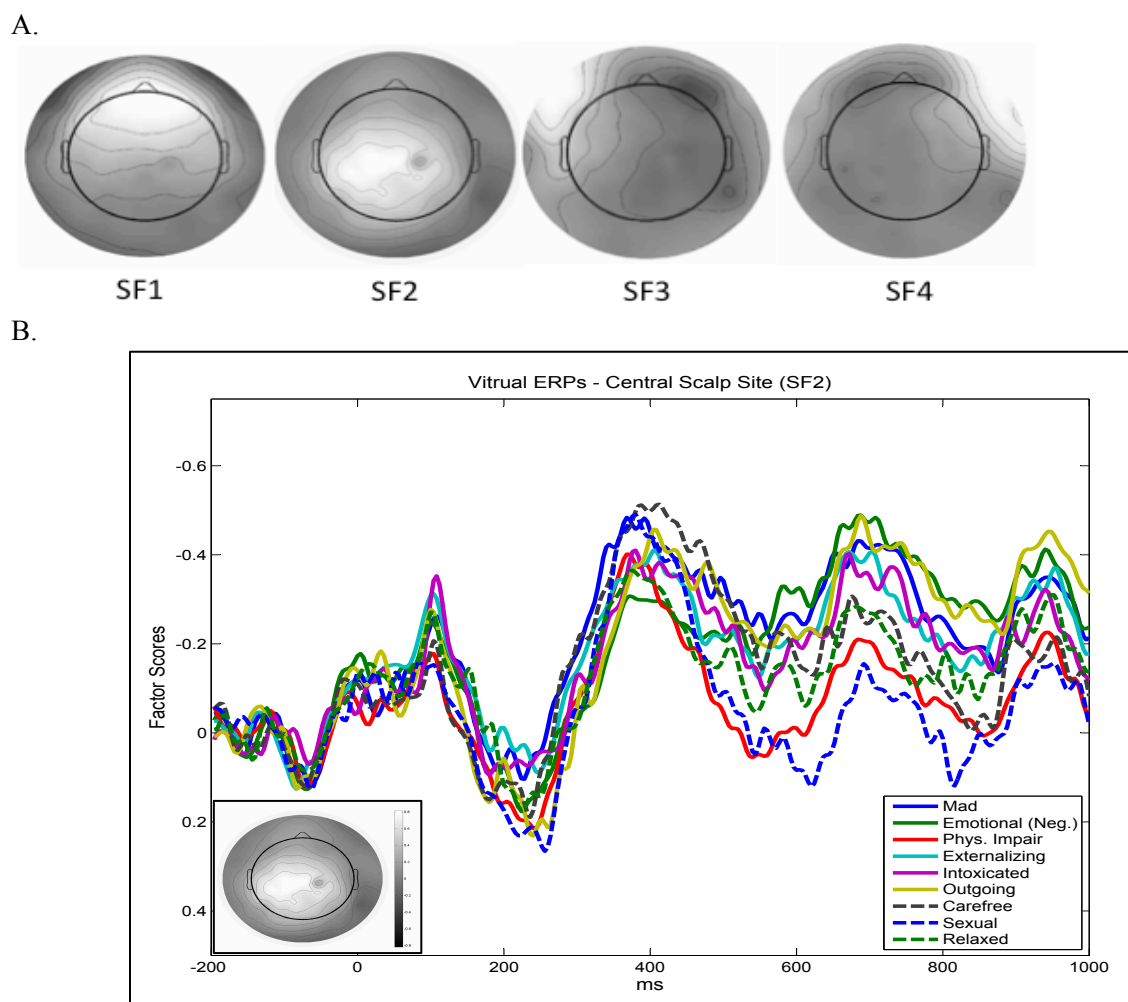
Figure 12. Results of PCA for Noun-Adjective Word pair task. A: Word Groups Virtual Electrodes. B: Virtual ERPs for SF2

In order to better understand the results from the AEQ Global Positive scale, which is a broad encompassing expectancy scale and was related to N400 size in several word groups, a median split of Global Positive was entered as a between subjects factor in a repeated measures ANOVA. By doing so, the influence of being high or lower on this scale could be examined across word groups simultaneously. This analysis indicated a main effect of AEQ Global Positive such that individuals who endorsed high Global Positive expectancies exhibited larger N400s across all word groups [$F(1,81)=4.8$, $p<.05$]. Since the word groups were of mixed valence (i.e., some were negative while others were positive), this result could indicate an anomaly in the high Global Positive AEQ group from this sample. Paired comparisons indicated that the high Global Positive group exhibited significantly larger N400s in five of the nine word

Figure 13. Temporal Factors from SF2 for Noun-Adjective Word Groups
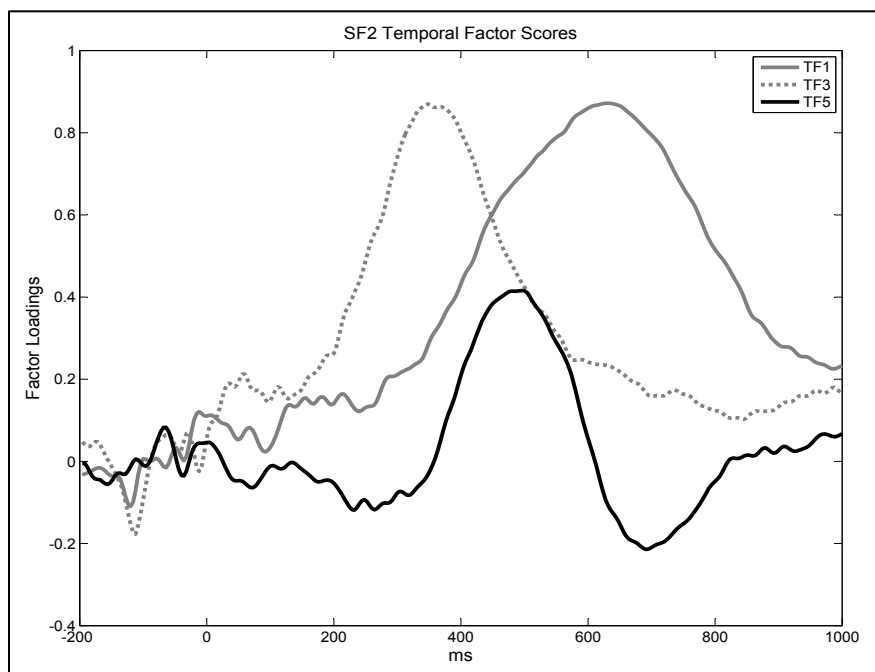
groups (Negative Emotion, Physically Impaired, Outgoing, Intoxicated and Externalizing). Therefore, it is possible that the relationship of AEQ Global Positive to N400 responses is at least partially independent of the expectancy content of the word groups. Overall, while these modest correlations in this task were neither resounding nor systematic in scope, most of the significant relationships supported the hypothesized relationship between N400 and expectancies. That is, the relationships existed between positive and arousing self-reported expectancies and word groups that were positive and/or arousing. In these cases the hypothesis that adjectives that violate one's expectancies would elicit larger N400s and words that fit with one's expectancies were expected to elicit smaller N400s was partially supported.

Adjective – Adjective Word Pairs

Likelihood ratings. The likelihood ratings individuals made for each of the 240 trials were averaged across all participants. These averages were then entered into a matrix for MDS. Since each of the words was presented with every other word twice, once as the prime and once as the target, the "forward" and "backward" ratings were entered as a square asymmetrical matrix for MDS. The 2-dimensional MDS model fit the data reasonably well (stress = .16; r^2=.91), and was relatively straight

forward to interpret. While the 3-dimensional model improved fit statistics (stress = .10; r^2=.96), the third dimension was not easily interpreted; therefore, the 2-dimensional model was selected. As can be seen in Figure 14, the words clustered into groups along dimensions that roughly correspond to valence (e.g., positive – negative) and arousal (e.g., arousing – sedating), which has been proposed previously in similar models (e.g., Aarons et al., 2003; Goldman & Darkes, 2004). On the right side of the plot positive expectancy words cluster together near the horizontal axis while a number of more negative words occur on the left side of the plot, indicating the horizontal axis corresponds roughly to valence. Furthermore, more arousing words (e.g., violent and dangerous) occur together near the bottom of the plot while more sedating words (e.g., sleepy, dizzy, and incoherent) occur together in the top half of the plot, indicating that the vertical axis corresponds roughly to arousal. Interestingly, 'drunk' hovers in the middle of the plot, which is fitting given recent research suggests the subjective associations with this word are particularly mixed across drinking levels (e.g., heavy drinkers view 'drunk' as positive, while lighter drinkers have more negative associations; Reich, Ariel, Darkes, & Goldman, 2012).

N400 component. In order to compare the N400 results from the Adjective – Adjective word pair block with the likelihood ratings, the ERPs elicited by the 240 word pairs were averaged across all participants and entered into a PCA. Ten factors were rotated accounting for 84% of the variance. After examining the scalp loadings (Figure 15-A) and virtual ERPs from the spatial factors, a central, midline spatial factor appeared to index the N400 as the virtual ERP of the grand average across all trials depicted a negative peak at 400ms (Figure 15-B). A subsequent temporal PCA in which 5 factors were rotated accounting for 83% of the variance produced a temporal factor that loaded highly at 400ms (TF4; see Figure 16). The N400 component factor scores (SF2-TF4) was extracted and entered into a matrix for MDS to compare to the MDS based on the averaged likelihood ratings. Again, since the N400 was calculated for each word pair 'forward' and 'backward', a square asymmetric matrix was entered into the MDS. The MDS model derived from the N400 component scores fit less well than the likelihood ratings MDS (stress = .26; r^2=.39), which might have been expected given the increased variability of ERP
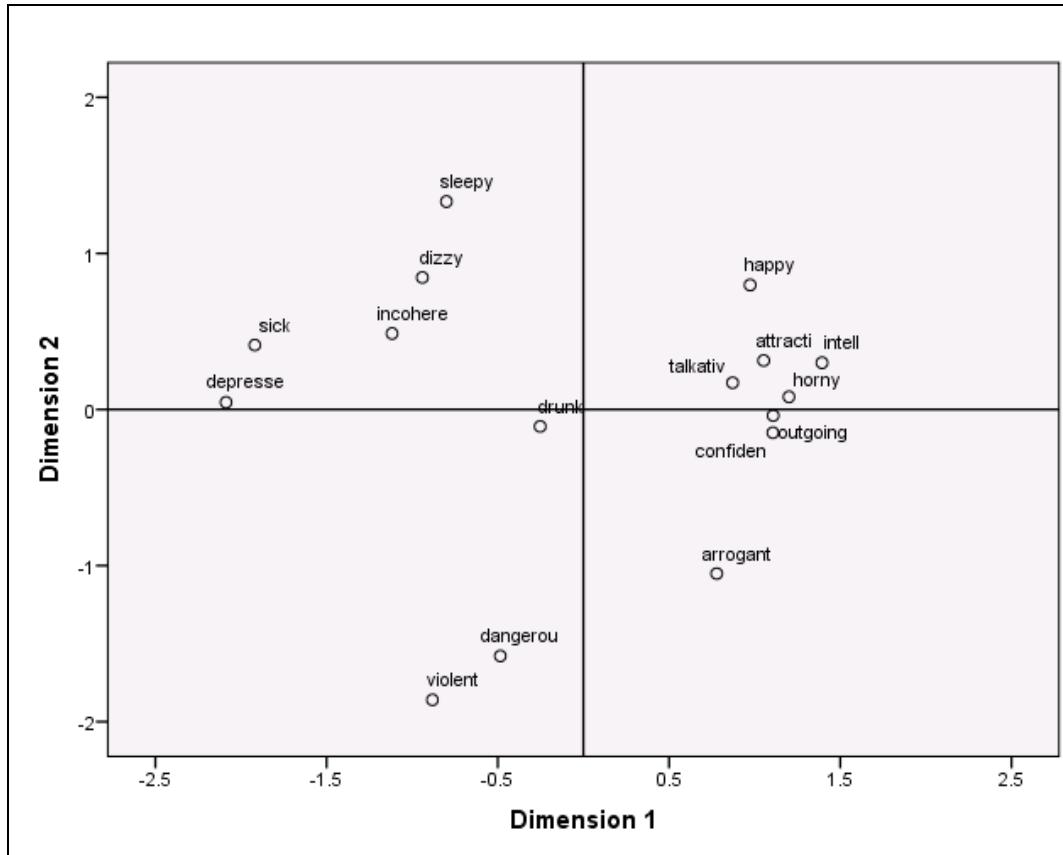
Figure 14. MDS plot derived from likelihood ratings of adjective-adjective word pairs

measures compared to the likelihood ratings. The MDS model was not easily interpretable, and it bore

little resemblance to the MDS from the likelihood ratings (Figure 17). In an attempt to simplify the

model, two separate MDS models were derived for the 'forward' and 'backward' pairs separately.

Unfortunately, neither of these models improved on the fit over the full model (stresses > .26; r^2s <.39),

and the models were no more interpretable than the full model. Due to the inability to make sense of the

MDS model derived from the N400 component score, it appeared that this exploratory aim of the current

study was not supported and no further analyses were conducted.

A.

SF1   SF2   SF3   SF4   SF5
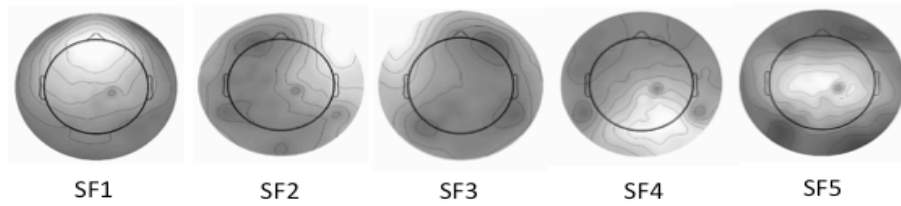
B.

Figure 15. PCA results for Adjective-Adjective word pair trials. A: Virtual Electrodes. B: Grand Averaged Virtual ERP for SF5 depicting N400 peak.

Figure 16. Temporal factors for central midline spatial factor (SF5) of the Adjective-Adjective word pair task

Figure 17. MDS model derived from N400 component factor scores for Adjective-Adjective pairs

Discussion

The current study sought to exploit the sensitivity of ERP measures to violations of subjective expectancy in an attempt to use ERP measures to in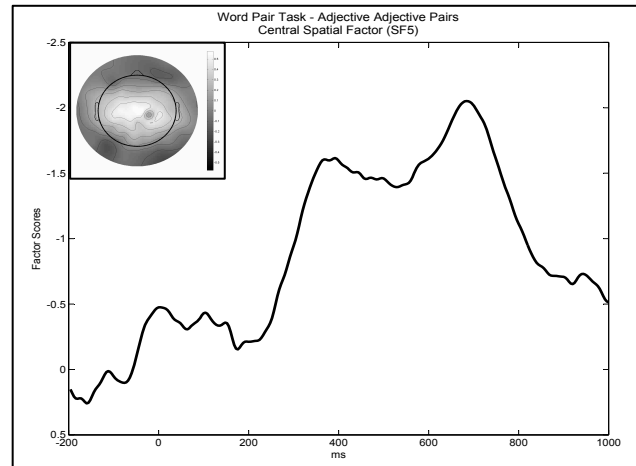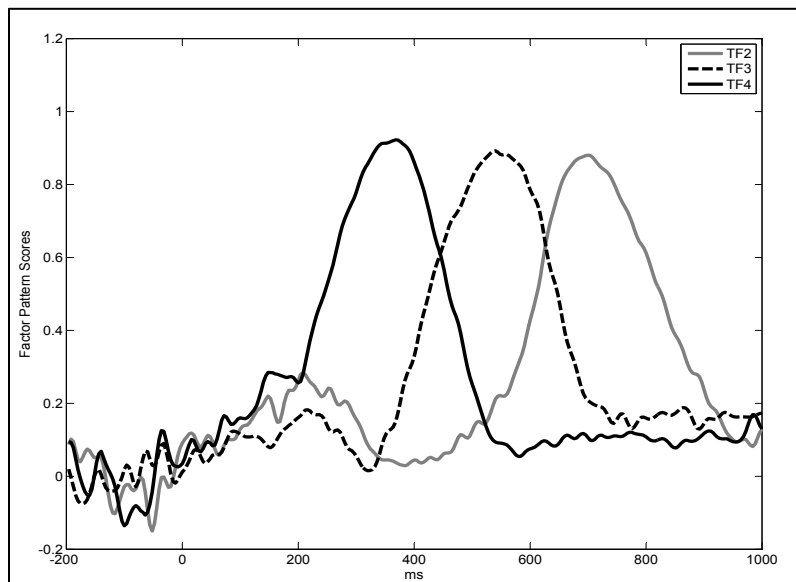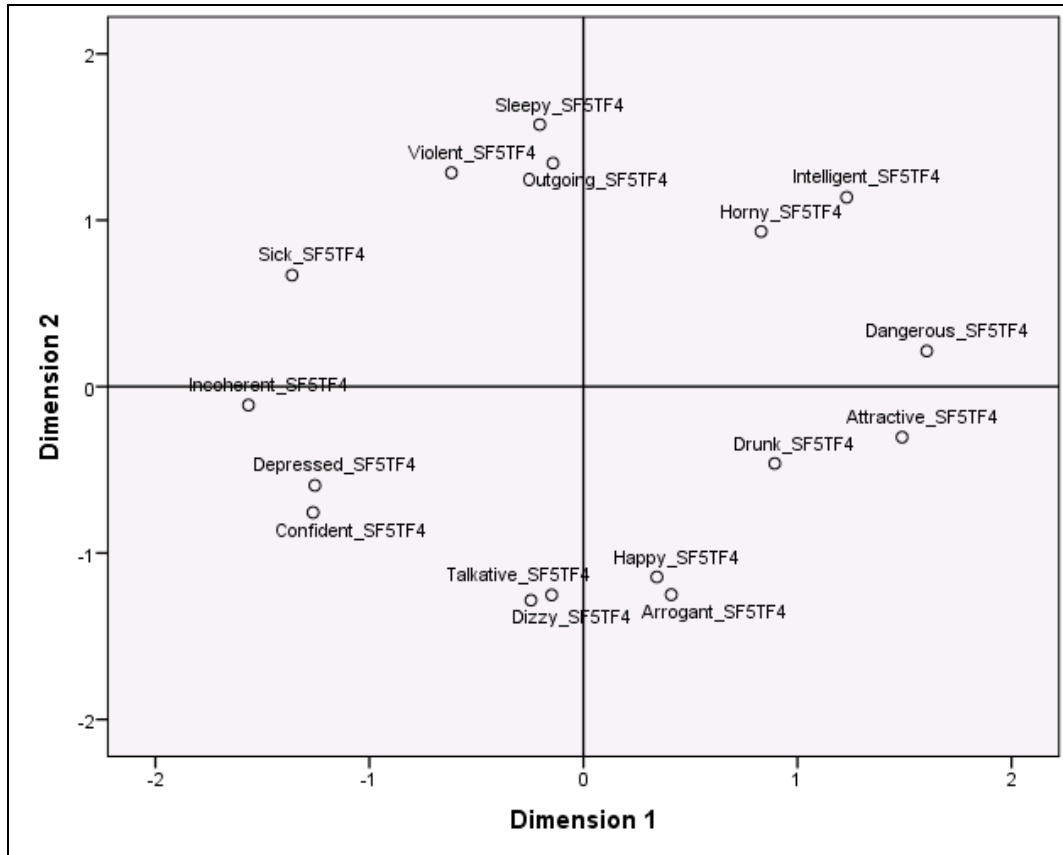dex alcohol expectancies. In doing so, the aim was to connect the domain of alcohol expectancy research to that of cognitive science through a more basic, non-deliberative, and fast acting index of neural activity. The study looked at two specific ERP components, the P300 and the N400, that have been shown to be sensitive to expectancy violations of different types. In the sentence task the P300 was predicted to be related to individuals' alcohol expectancies and in the word pair task the N400 was predicted to index these expectancies. As was presented above, the P300 and N400 were both related to alcohol expectancies in the sentence task and the N400 was related to alcohol expectancies in the word pair task, but the results were not unequivocally in accordance with the hypothesized relationships. Furthermore, there were unexpected differences between males and females in this sample that interacted with the effect of expectancy on ERPs.

Sentence Task: N400 versus P300

In the current study, hypotheses were made for the P300 as an index of subjective expectancy violation in sentences based on prior research (Fishman, Goldman, & Donchin, 2008). The findings of the current study did not model the results of this previous study. In the current study, the P300 did not show increases as violations of expectancy. Instead, most of the significant results actually contradicted the hypothesis such that larger P300s were associated with more congruent alcohol expectancy sentences. On the other had, several of the findings for the N400 in the sentence task actually fit with the theory that N400 would be increased for expectancy violating sentences. While this was not a primary hypothesis of the current study, the results present additional questions for future research. For example, are the P300 results affected by the amplitude of the temporally preceeding N400?

While the P300 and N400 have been extensively described in the literature over the last half-century, the precise nature of their interaction is still a bit cloudy. Studies specifically designed to disentangle the two components have concluded that the two components likely interact when individuals are processing linguistic stimuli that violate expectations (e.g., Arbel, Spencer, & Donchin, 2011). In the current study the P300 was larger for Positive alcohol sentences and was positively correlated with endorsement of positive alcohol expectancies. While this relationship was in the opposite direction of the prediction, the results were complicated by sex differences and the relationship of the N400 and alcohol expectancy violations. Overall, males exhibited larger P300s and smaller N400s than females, and when males and females were separated only the males' P300s were related to alcohol expectancies in predicted (Negative sentences) and unpredicted (Positive sentences) directions, while females' P300s were unrelated to alcohol expectancies. On the other hand, females' N400s were related to alcohol expectancy violation for sedating sentences indicating that females may have been more sensitive to sedating expectancies when evaluating alcohol related sentences. It is interesting that this apparent sensitivity was indexed via the N400, which may suggest that females had a more entrenched semantic expectancy (i.e., cloze probability) for sedating expectancies. Overall, the N400 actually appeared to be more closely related to alcohol expectancy violations than the P300, which leads to questions of the interdependence of these components that overlap both spatially and temporally.

The correlation of the N400 and P300 components in the sentence task indicated that the two components were not operating independently. For each of the sentence types, including Congruent and Incongruent sentences, the N400 (SF2TF2) and P300 (SF2TF3) were highly correlated (rs=.41-.60). That is, P300s were larger when N400s were smaller regardless of the sentence type. While the goal of using PCA is to separate out components both spatially and temporally, in this instance it was not able to fully separate the components of interest as both the N400 and P300 were represented in centro-parietal spatial factors. While this interdependence did not likely reflective a common underlying cognitive process, it is highly plausible that the antecedent signal of the negative going N400 could cancel out some of the signal of the positive going P300 since ERPs are measured as the cumulative electrical signal at the scalp. Given

that the N400 occurs first chronologically, the P300 may in fact be dependent on the size of the N400 that precedes it. This would be particularly problematic in cases when tasks like the one currently employed are not designed to compare eliciting conditions of the P300 and N400 separately (e.g., using physically deviant word to enhance the P300; cf. Arbel, Spencer, & Donchin, 2011).

The results from the sentence agreement analysis indicated that sentences to which individuals agreed and disagreed did not differ significantly in either the N400 or the P300. This result paints a more complex picture of the way expectancy violations influence ERPs. That is, sentences to which individuals disagreed were expected to elicit larger P300s (or N400s), since they were presumably less expected. Clearly, the relationship was not that simple and straightforward when measured in responses to sentences in this task. The tendency for males to exhibit larger P300s overall, and particularly to Alcohol Positive sentences, may indicate that males attached more salience to the Alcohol Positive sentences (since salience is one of the factors shown to affect P300 amplitude, cf. Donchin, 1981). Several factors could have contributed to these results in the current study. For example, while males and females did not differ in their endorsement of positive expectancies, males endorsed fewer sedating expectancies which could lead the positive expectancies to be more salient (i.e., there were fewer sedating expectancies to temper or conflict with the activity of the positive expectancies for males). In addition, there is evidence for alcohol stimuli to elicit larger P300s based on salience for individuals who attach greater subjective value to alcohol stimuli over other types of stimuli (e.g., heavier drinkers, Bartholow, Henry, & Lust, 2007; Lust & Bartholow, 2009). It is possible that some instantiation of this phenomenon is one of the factors underlying the results in the current study.

Word Pair Task: Noun-Adjective Pairs

The N400 elicited by adjectives following noun primes were related to expectancies in the hypothesized direction, with the greatest number of effects coming to the Negative Emotion word group. This group of words encompasses a number of more cognitive and emotional adjectives that could occur after drinking. Interestingly, the N400 appeared to be sensitive to both positive and negative expectancies in this word group. While the correlations were modest, it was promising that the hypothesis was born out

in both directions. The fact that the N400 exhibited these differences in this task indicates that alcohol expectancies operate even in a very simplified task with little "context" provided by single word primes, as opposed to the richer context provided by sentences or other types of visual stimuli (cf. Lust & Bartholow, 2009).

Future studies could utilize similar paradigms with a greater diversity of primes to parse out the expectancy effects for different primes. The current study was designed to average across the noun primes, which obviously sacrifices expectancy effects that differ by type of alcoholic beverage. It would be interesting in the future to examine these differences, perhaps by collecting individuals' preferred beverage type. In addition, future studies could include non-alcoholic beverage primes as a control condition to further validate the role expectancy plays in N400 responses.

Word Pair Task: Adjective-Adjective Pairs

The adjective-adjective word pair task in the current study was an exploratory aim, seeking to examine whether the N400 represented semantic distance in a way that could be modeled and compared to models of subjective ratings. While the current design did not pan out, it is possible that tasks could be designed to better incorporate ERP data into such models. The current task design required individual trials to be averaged across all participants, which is an unorthodox way of treating ERP data. This way of averaging the data is problematic in that there ERP data are highly variable between subjects at the level of individual trials. Future studies could utilize a design that incorporates more trials in order to allow for averaging within subject before averaging across subjects. This would undoubtedly increase the signal-to-noise ratio, and may provide a better dataset to model in MDS space.

Limitations

The sample in this study was recruited as a convenience sample of college student drinkers, and steps were taken to ensure that all participants were social drinkers. The results indicate that on average the sample proved to be relatively light drinking. For example, using the NIAAA guidelines for heavy or at risk drinking (i.e., more than 7 drinks a week for females or more than 14 drinks a week for males; NIAAA, 2005), only 4 females and 2 males in the sample met criteria for heavy drinking. Based on

epidemiological data and experimental data from similar samples, it was expected that a pseudo-random sample of college student drinkers would endorse more drinking (O'Malley & Johnston, 2002; Goldman et al., 2011). Furthermore, based on epidemiological data (e.g., O'Malley & Johnston, 2002), it was somewhat surprising that males in this college sample did not report higher drinking levels than females. These two factors combined may have contributed to some of the unsupported hypotheses and sex differences observed in the current study. Since heavier drinkers tend to endorse more positive and arousing expectancies and are also purported to have more engrained expectancies about alcohol given their "expertise", recruiting a sample of heavier drinkers in future studies or recruiting separate samples of heavier and lighter drinkers may improve the probability of parsing out the effect of expectancies in stimulus evaluation in ERP tasks.

Conclusion

The study provides evidence that ERPs index alcohol expectancies to some degree. The results provide evidence of ERPs indexing domains of meaning within the alcohol expectancy spectrum, rather than being indices in one-to-one relationships. That is, this study does not provide evidence that individuals' ratings of a specific word will be directly related to their ERP response to that word in a word pair or sentence task. It does, however, provide some evidence that some of the variance in broader alcohol expectancy domains is accounted for by ERPs elicited by alcohol expectancy words. While this study attempted to exploit the fact that ERPs index violations of expectation, this influence on ERPs is only one of many factors accounting for variance in these tasks. As mentioned above, there are a number of influences specific to language and word stimuli that this study was designed to accommodate. These considerations were secondary to using well-established alcohol expectancy words in the design, which resulted in the forfeiting of control over factors such as word frequency, word complexity, and number of trials included in ERP averages.

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Appendix A
Sentences Used in the Alcohol Sentence Task

Alcohol Positive Sentences

A couple of drinks can make me…	**energetic**
A couple of drinks make me more...	**aroused**
A couple of drinks make me more...	**outgoing**
A few drinks makes me feel less...	**shy**
After a few drinks I am…	**funnier**
After a few drinks of alcohol, I feel...	**sexier**
After a few drinks, I feel more...	**social**
After a few drinks, I feel...	**energized**
Alcohol makes me feel more...	**assertive**
Alcohol makes me feel more...	**confident**
Alcohol makes me feel more...	**sociable**
Alcohol makes me feel...	**happy**
Alcohol makes me more...	**exciting**
Alcohol makes me more...	**outgoing**
Alcohol makes parties more…	**lively**
Drinking alcohol makes me feel...	**friendly**
Drinking alcohol makes me feel...	**happy**
Drinking alcohol makes me more…	**confident**
Drinking alcohol makes me more…	**content**
Drinking alcohol makes me...	**horny**
Drinking at bars makes me more…	**lustful**
Drinking at bars makes me more…	**social**
Drinking beer makes me feel...	**cheerful**
Drinking beer makes things more…	**exciting**
Drinking is a way for me to…	**escape**
Drinking makes it easier to…	**cope**
Drinking with friends makes me feel…	**carefree**
When I drink alcohol, I expect to have...	**fun**
When I drink beer, I feel...	**content**
When I drink, I feel more…	**erotic**

Alcohol Negative Sentences

A couple of drinks make me more...	**anxious**
A few drinks makes me feel…	**scared**
After a few drinks of alcohol, I feel...	**silly**
Alcohol makes me feel more...	**nervous**
Alcohol makes me feel...	**down**
Alcohol makes me feel...	**nauseous**
Alcohol makes parties more…	**dangerous**

Alcohol makes parties more…	**foolish**
Drinking alcohol makes me feel...	**hostile**
Drinking alcohol makes me feel...	**mad**
Drinking alcohol makes me feel...	**stupid**
Drinking alcohol makes me...	**nauseous**
Drinking makes me feel...	**foolish**
When I drink alcohol, I get	**irritated**
When I drink beer, I feel…	**sick**
When I drink, I become easily	**aggravated**

Alcohol Sedating Sentences

A couple of drinks can make me…	**sleepy**
A couple of drinks make me...	**miserable**
After a few drinks I am…	**woozy**
After a few drinks of alcohol, I feel...	**dizzy**
After a few drinks, I feel...	**drowsy**
After a few drinks, I feel...	**exhausted**
After a few drinks, I feel...	**tired**
After a long day, drinking makes me...	**sleepy**
Drinking alcohol makes me feel...	**depressed**
Drinking alcohol makes me feel...	**drowsy**
Drinking alcohol makes me feel...	**sad**
Drinking alcohol makes me...	**sad**
Drinking makes me feel...	**unhappy**
When I drink beer, I feel...	**depressed**

Appendix B
Word Groups from Word Pair Task: Noun – Adjective Block

Social
social
friendly
cheerful
exciting
energetic

Emotional–Negative
emotional
confused
moody
sad
unhappy
miserable
anxious
nervous

Mad
aggressive
aggravated
irritated
mad
mean

Externalizing
wild
loud
noisy
unpredictable
irresponsible
reckless
obnoxious
boisterous
foolish
cocky
stupid

Physically Impaired
stumble
wobbly
nauseous
drowsy
ill
tired
sluggish
slow
lazy

Intoxicated
intoxicated
wasted
woozy
inebriated

Relaxing
relaxed
mellow
calm
fun
*quiet

Carefree
carefree
content
escape
cope

Sexual
erotic
sexy
beautiful
pretty

*quiet was predicted to cluster with the "relaxing" group, but did not factor with these words in the factor analysis and was excluded from analyses