Midfrontal Theta Activity and Social Decision Making in Binge Drinkers

by

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A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Auburn, Alabama
August 8, 2026

Keywords: social avoidance behavior, midfrontal theta, binge drinking

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Abstract

Alcohol Use Disorder (AUD) and Social Anxiety Disorder (SAD) are highly comorbid, and their comorbidity is associated with worse outcomes for both disorders. Social avoidance behavior (SAB) influences the development of SAD and has also been associated with alcohol misuse. Further, EEG research has shown that the frontal midline theta (FMθ) is involved in approach-avoidance conflict and altered in people with AUD relative to healthy controls. Importantly, binge drinking is a known risk factor for the development of AUD; this risk is enhanced when combined with SAB. However, little is known about the neurophysiological underpinnings of SAB in people who binge drink. The current study used a community and undergraduate sample, placed into either an infrequent user control or binge drinking group. Drinking patterns and social anxiety were assessed at baseline, and FMθ activity and SAB were measured with a social approach-avoidance conflict task during an EEG session. There were no differences in FMθ activity, response time, or avoidance behavior between the infrequent user control and binge drinking groups in response to ambiguous and conflict face morph stimuli. As such, these results indicate that FMθ may not differ between those who engage in binge drinking and those who infrequently consume alcohol and that the neural and behavioral correlates of social conflict processing may differ from those of other conflict stimuli (e.g., financial risk).

Artificial Intelligence (AI) Use Disclosure Statement

In preparation of this thesis, no Artificial Intelligence (AI) tools were used.

Digital Accessibility Disclosure Statement

In the preparation of this thesis, the following digital accessibility tools were used to ensure this document complies with federal requirements: Microsoft Word. The author acknowledges full responsibility for the intellectual content of this work and has made a good faith effort to comply with digital accessibility requirements in publishing, wherein the nature of the content does not significantly change in order to do so. Furthermore, all content has been reviewed and revised to meet these requirements prior to final publication.

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List of Abbreviations

AUD	Alcohol Use Disorder
SAD	Social Anxiety Disorder
NIAAA	National Institute on Alcohol Abuse and Alcoholism
SAB	Social Avoidance Behavior
SAAC	Social Approach Avoidance Conflict
EEG	Electroencephalography
FMθ	Frontal Midline Theta
DSM-5	Diagnostic and Statistical Manual of Mental Disorders Fifth Edition
DIAMOND	Diagnostic Interview for Anxiety, Mood, OCD and Related Disorders
EC-TLFB	Enhanced Cannabis Timeline Follow Back
SMSAD	Severity Measure for Social Anxiety Disorder (Social Phobia)
EOG	Electrooculogram
CBAS	Cognitive Behavioral Avoidance Scale
DMQR	Drinking Motives Questionnaire - Revised
FCz	Frontocentral Zero

Introduction

Alcohol use disorder (AUD) is a significant public health crisis with 28.9 million individuals 12 years and older having the disorder in the United States alone (USDHHS, 2025). Binge drinking is a known risk factor for the development of AUD and often predicts worse treatment outcomes, yet 21.7% of US adults engage in this behavior at least monthly (SAMHSA, 2023). Social anxiety disorder (SAD) is also a prevalent issue with about 12.1% of U.S. adults experiencing the disorder within their lifetime (Kessler et al., 2005). Further, the lifetime prevalence of comorbid AUD and SAD is 2.4% (Schneier et al., 2010), and this comorbidity has been associated with worse trajectories for both disorders (Marmorstein, 2012; Xu et al., 2012). As such, it is important to study the mechanisms underlying the comorbidity between AUD and SAD in binge drinkers to understand the development and trajectories of these disorders, thus informing more efficacious treatment approaches.

Alcohol Use Disorder and Social Anxiety Disorder

AUD is defined in the DSM-5 as a pattern of alcohol use that is problematic, leading to clinically significant impairment or distress (American Psychiatric Association, 2013). The current diagnosis integrates the two DSM-IV disorders, alcohol abuse and alcohol dependence, into one disorder with mild, moderate, and severe sub-classifications (American Psychiatric Association, 2000; USDHHS, 2021). Symptoms can include drinking more alcohol or using it over longer periods of time than intended, unsuccessful efforts to cut down or control alcohol use, and craving. Various other symptoms fall under the concept of aversion-resistant drinking (i.e., use despite negative consequences). This could involve continued alcohol use despite its causing interpersonal, physical or psychological problems, and giving up various activities that are important to the individual in order to use alcohol.

Importantly, individuals who engage in alcohol misuse, which includes binge drinking and heavy alcohol use, are at a greater risk for developing AUD (USDHHS, 2025). A binge alcohol episode is defined by the NIAAA as drinking enough alcohol that brings blood alcohol concentration to 0.08 percent or higher in about two hours, which is typically equivalent to consuming five or more drinks for males or four or more drinks for females. Binge drinking can be both deadly and costly: Approximately 178,000 individuals died from excessive alcohol use between 2020 and 2021, and one third of those deaths resulted from binge drinking or drinking too much during a single occasion (CDC, 2024). Further, binge drinking accounted for approximately 191.1 billion dollars in healthcare expenditures, lost productivity, and criminal justice related expenses, which is 77% of the total economic cost of alcohol misuse (Sacks et al., 2015).

Another risk for developing AUD is comorbid psychiatric disorders such as SAD. SAD is characterized in the DSM-5 by significant fear or anxiety about social situations in which an individual may be scrutinized by others (American Psychiatric Association, 2013). These situations could include social interactions, performing in front of others, and being observed. Individuals with SAD have fears of being negatively evaluated that are out of proportion to the actual threat and almost always experience fear or anxiety surrounding social situations. As such, they often avoid social environments or endure them with intense fear or anxiety. Similarly to AUD, individuals with SAD often experience impairment in important areas of functioning such as social or occupational responsibilities as a result of their fear, anxiety, and avoidance. Anxiety disorders, including SAD, also present an economic burden with a global cost of about 6.5 trillion dollars (Konnopka & Konig, 2020), comprising more than 30% of the total expenditures for psychiatric disorders in the United States (Arikian & Gorman, 2001). Further, individuals with anxiety disorders have been shown to be 56% more likely to frequently use medical services (Kavelaars et al., 2023).

Several studies have shown an association between SAD and AUD with SAD onset preceding the onset of AUD in most cases (Buckner et al., 2008; Buckner et al., 2009; Bulley et al., 2016; Grant et al., 2005; Hofmann et al., 2014). Importantly, this comorbidity is often associated with increased severity of both AUD and SAD symptoms and low rates of treatment-seeking (Oliveira et al., 2018; Patel et al., 2024; Schneier et al., 2010). Individuals with SAD may be especially vulnerable to using substances to manage fears of negative evaluation, anxious arousal, and to encourage social interactions (Buckner et al., 2013; Bulley et al., 2016). Indeed, consuming alcohol could reduce attentional biases toward social threat and motivate future use by alleviating social anxiety symptoms related to negative cognitive patterns (Bacon & Ham, 2010). In this manner, the effects of alcohol on individuals' experience of social anxiety symptoms result in increased AUD and SAD comorbidity.

Social Avoidance Behavior

Social avoidance behavior (SAB) is known to play a key role in the development of SAD and other psychiatric disorders, and it is defined by prematurely ending social interactions, disengaging during social interactions, and/or entirely avoiding these interactions (Blalock & Joiner, 2000). Unsurprisingly, SAD and SAB have been shown to be correlated such that social anxiety symptoms in early adolescence relate to increased SAB over time (Miers et al., 2014). Further, there is evidence to suggest that fear and avoidance of social situations constitute the primary conceptual network for SAD (Heeren & McNally, 2018). Notably, individuals displaying high levels of social avoidance report both avoiding social situations when alcohol is not present and greater rates of drinking to cope to manage their anxiety in social settings (Buckner & Heimberg, 2010; Collins et al., 2021). Specifically, these coping-related drinking motives were correlated with greater heavy drinking which is known to be both a predictor and characteristic of alcohol-related problems (Collins et al., 2021). As such, SAB is an important target for understanding the development of comorbid SAD and AUD.

Affective Facial Expressions

One of the primary influences on social behavior and thus SAB, is affective facial expressions (Barrett et al., 2019; Frith, 2009). Beginning in infancy, humans develop a preference for face-like configurations, which allows expertise in facial perception to evolve (Young & Burton, 2018). Specific facial configurations are considered universal expressions of emotions or personality characteristics and consequently influence how people interact with others (Barrett et al., 2019). Happy facial expressions commonly signal social reward and elicit approach behavior, and angry facial expressions signal social threat, eliciting avoidance behavior (Radke et al., 2018; Renard et al., 2016; Stins et al., 2011). Most individuals, however, will experience more ambiguous affective facial expressions in everyday social interactions (i.e., not 100% happy or angry) (Barrett et al., 2019; Beevers et al., 2009; Matsumoto & Hwang, 2014). This creates conflict between the social reward and threat signals as individuals decide whether to approach or avoid another person. Indeed, the use of blended facial expressions, such as in the

Social Approach-Avoidance Conflict (SAAC) task (Evans et al., 2026), is important in understanding the nuances of social conflict and avoidance behavior in real-life settings. The SAAC task includes pure, ambiguous, and conflict face morphs to assess responses to varying degrees of co-occurring social reward and threat. As such, the task accounts for the complexity of facial expressions and social decision making that individuals encounter in everyday social interactions.

Electroencephalography

Understanding SAB and its involvement in AUD-SAD comorbidity should include an approach that integrates both physiological and behavioral measures. One such physiological measure is electroencephalography (EEG) which is an electrophysiological technique that involves recordings of the electrical activity arising from dynamic cerebral functioning (Louis & Frey, 2016). The recorded electrical activity is generated by the summation of inhibitory and excitatory postsynaptic potentials of large groups of neurons. Notably, the advantage of using EEG to capture neural activity is its exceptional temporal sensitivity. As such, researchers can acquire a real-time display of cortical activity during a behavioral task such as social approach-avoidance conflict. To study higher cognitive functioning, such as social conflict, oscillatory neural activity is characterized by converting continuous EEG signals to the frequency domain (Tan et al., 2024). Using the signals' frequency characteristics, spatial distribution, and functional properties, they are then divided into frequency bands, such as theta (Kuhman, 1980).

EEG research to date has linked simple response conflict processing to the frontal midline theta (FMθ) in various behavioral paradigms (Cavanagh et al., 2012; Cohen and Donner, 2013; Cohen and Ridderinkhof, 2013; Duprez et al., 2020; Gulbinaite et al., 2014; McDermott et al., 2017; Nigbur et al., 2011; Oehrn et al., 2014; Töllner et al., 2017; van Driel et al., 2015; Zuure et al., 2020). FMθ activity has also been linked more specifically to approach-avoidance conflict, with stronger activity in response to an uncertain outcome (i.e., when a punishment was as likely as a reward) and the condition in which there was a strong behavioral conflict (Lange et al., 2022). Although stronger FMθ activity seems to be correlated with response conflict in individuals without psychopathology, several studies have shown the opposite pattern in those with alcohol and externalizing pathology. Notably, weaker FMθ activity in adolescence, prior to the onset of alcohol use, has been shown to predict increased drinking in late adolescence and the onset of alcohol misuse (Harper et al., 2021). Further, theta band event-related oscillation power has been shown to be weaker in individuals with current and past AUD and externalizing disorders in general (Andrew & Fein, 2010; Burwell et al. 2014; Jones et al., 2006; Yoon et al., 2013). Indeed, impairment in prefrontal cortex functioning, including attentional processes and decision making, has been correlated with alcohol and other substance use (Koob & Volkow, 2010).This difference in FMθ activity in individuals with alcohol and externalizing pathology suggests that it is an important target for understanding how this population responds to social conflict.

Present Study

Despite the high comorbidity between AUD and SAD, the known relationship between SAB and negative drinking outcomes, and evidence of shared neural and behavioral markers, the nature of this relationship remains largely understudied in binge drinkers, a population at increased risk for developing AUD. As such, we recruited male and female binge drinkers and infrequent users ages 18-64 (n = 33) for one EEG session during which participants viewed various face morphs in a social approach-avoidance task.

Psychophysiological Hypotheses

Our first aim was to determine whether binge drinkers and infrequent users differ in their FMθ activity when faced with social conflict. We hypothesized that individuals in the binge drinking group would demonstrate less FMθ activity as compared to infrequent user controls when viewing the ambiguous and conflict face morph stimuli. We also predicted that there would not be differences in FMθ activity between binge drinkers and infrequent user controls for the pure happy, angry, or neutral face morphs.

Behavioral Hypotheses

Our second aim was to determine whether there are differences in avoidance behavior between binge drinkers and infrequent users when faced with social conflict. We hypothesized that the binge drinking group would exhibit more avoidance behavior and greater response times in response to the ambiguous and conflict face morph stimuli than infrequent user controls. Additionally, we hypothesized that there would not be differences in avoidance behavior or response times for the pure happy, angry, or neutral face morphs between the two drinking groups.

Materials and Methods

Participants

Thirty-three male and female participants were recruited from a large southeastern university and the surrounding community via the SONA Human Subject Pool Software, local flyers, and social media advertisements as part of a larger study, which also includes cannabis users. For participants who chose to receive SONA credit, they received 2.5-3.5 hours (.5 credit per half hour), and for those who chose to receive payment, they received $60-$90 at the end of the lab session depending on the amount of time they were in the lab ($15 per half hour). After providing informed consent, participants were asked to complete a 5-10 minute REDCAP eligibility screener with inclusion criteria of English fluency and being 18-64 years of age. The screener included questions about demographic characteristics (i.e., race, ethnicity, sex, income) in addition to alcohol and cannabis use frequency. On average, participants reported being 26.12 years of age (*SD* = 9.65) with most reporting “some college” (*n* = 13, 39.4%) or “Bachelor’s Degree” (*n* = 9, 27.3%) as their level of education. There were approximately equal numbers of males and females (*n* = 17 and *n* = 16, respectively), and most participants identified as White (*n* = 27, 81.8%). For the full sample characteristics, please see **Table 1.** After completing the eligibility survey, participants were notified of their eligibility status and scheduled for their in-person laboratory session.

At intake, individuals were categorized into either an infrequent user control or binge drinker group. Infrequent users had weekly alcohol use over the past year not to exceed 3 standard drinks/week for females and 7 standard drinks/week for males, with 0 occasions of binge drinking in the past year. They also had less than 20 times of lifetime cannabis use and no use within the past month (confirmed with a negative urine toxicology screen). Binge drinkers had regular alcohol use over the past year of at least 8 standard drinks/week for females and at least 15 standard drinks/week for males and binge drinking at least twice monthly required. A binge alcohol episode is defined by the NIAAA as drinking enough alcohol that brings blood alcohol concentration to 0.08 percent or higher in about two hours, which is typically equivalent to consuming five or more drinks for males or four or more drinks for females. Additionally, individuals in the binge drinking group had no more than two times of cannabis use per month as confirmed with the Enhanced Cannabis Timeline Follow-Back.

Procedure

At the beginning of the lab session, participants were given a urine drug screen to test for cannabis and other drug use and a breath alcohol test to confirm sobriety. The results from the drug screen, in addition to the Enhanced Cannabis Timeline Follow-Back, were used to ensure appropriate study group assignment. Further, individuals who tested positive for drugs other than cannabis or stimulants (related to Attention-Deficit/Hyperactivity Disorder medication) were excluded from the study. After the breath alcohol test confirmed that the participants were not intoxicated, they provided informed consent for the full study. The lab visit lasted approximately 2-3 hours with participants completing self-report questionnaires during the EEG setup. A trained research assistant also administered clinical interviews to assess alcohol and cannabis use and alcohol-related impairment during the EEG setup. A face viewing computerized task was completed during the EEG.

Clinician-administered interview

DSM-5 criteria for AUD were assessed using the Diagnostic Interview for Anxiety, Mood, and Obsessive-Compulsive and Related Neuropsychiatric Disorders (DIAMOND), which was administered by trained research assistants under the supervision of a clinical psychologist. Participants were asked to report their patterns of drinking behavior in addition to drinking-related impairments. The DIAMOND substance use disorder module has been shown to have very good ($\kappa = .65$) interrater reliability with a standard error of 0.1, and a 95% CI ≤ 0.5 in addition to very good ($\kappa = .76$) test-retest reliability (Tolin et al., 2018).

Enhanced Cannabis Timeline Follow-Back

Trained research assistants also administered the self-reported Enhanced Cannabis Timeline Follow-Back (EC-TLFB) at the beginning of the session, a validated measure for assessing standard THC units for research (Petrilli et al., 2023). Participants reported their frequency of cannabis use, method of administration, and type of cannabis product used. They were also asked to report the number of standard drinks they have and in what timeframe they consume the drinks each day for the past month (Sobell et al., 1986). Using timeline methods to assess drinking history has been shown to have high reliability ($r \geq .87$) in both males and females (Sobell et al., 1986).

Cahalan Quantity and Frequency Variability Index

Drinking frequency was also assessed using the self-reported Cahalan Quantity and Frequency Variability Index, administered by a trained research assistant (Cahalan, et al., 1969). Participants were asked to report their drinking frequency and quantity and the length of time that they have been engaging in their current drinking behaviors.

Drinking Motives Questionnaire – Revised

Drinking motives were assessed using the self-reported Drinking Motives Questionnaire Revised (DMQR) (Cooper et al., 1994). Participants were asked to report their drinking motives in the following categories: social, coping, enhancement, and conformity. Each of the 20 items asks the individual to rate how frequently their drinking is motivated by that reason, using a 5-point scale: 1=Almost Never/Never, 2=Some of the time, 3=Half of the time, 4=Most of the time, 5=Almost Always/Always. The four scale scores are calculated as the sum of their respective items. This four-factor model has shown a good fit to self-reported drinking data via the Normed Fit Index (.93) and Comparative Fit Index (.94). In the current sample, the DMQR had a mean of 31.06, a standard deviation of 14.92, and demonstrated good internal consistency (Cronbach's α=0.93).

Cognitive-Behavioral Avoidance Scale

Self-reported social avoidance was measured using the Social Avoidance Behavior subscale of the Cognitive-Behavioral Avoidance Scale (CBAS) (Ottenbreit & Dobson, 2004). Each of the 8 items asks participants to rate how true each statement is for them on a 5-point scale: 1=Not at all, 2=Somewhat, 3=Moderately, 4=Very much, 5=Extremely. The CBAS has been shown to have good test-retest reliability with a coefficient of 0.92 and good convergent and divergent validity (Ottenbreit & Dobson, 2004). In the current sample, the CBAS had a mean of 12.41, a standard deviation of 6.06, and demonstrated good internal consistency (Cronbach's α=0.90).

Severity Measure for Social Anxiety Disorder (Social Phobia)

Social anxiety (social phobia) symptom severity was assessed using the self-report Severity Measure for Social Anxiety Disorder (Social Phobia) (Craske et al., 2013). Each of the 10 items asks the individual to rate the severity of his/her social anxiety disorder (social phobia) for the past 7 days. The items are rated on a 5-point scale: 0=Never; 1=Occasionally; 2=Half of the time; 3=Most of the time; and 4=All of the time. After scoring, the individual's SAD can be categorized as none (0), mild (1), moderate (2), severe (3), or extreme (4). This measure has very high internal consistency (Cronbach's alpha = 0.86) in addition to convergent validity ($r = 0.5$), and discriminant validity ($r = 0.3$) (Lebeau et al., 2016). In the current sample, the Severity Measure for Social Anxiety Disorder had a mean of 4.00, a standard deviation of 5.79, and demonstrated good internal consistency (Cronbach's α=0.93).

Social Approach-Avoidance Conflict

The SAAC task has been previously administered and validated as an assessment of SAB (Evans et al., 2026). It consists of a 47-minute session during which participants view a face on the screen and are asked to make a response about the face using the left or right button (**Figure 1**). In response to each face, they indicated if they would prefer to Approach OR Avoid the individual in a social situation. Under the face, they saw the word "Approach" on the left/right side and the word "Avoid" on the right/left side. These options indicate if they would prefer to Approach the individual and start interacting with them in a social situation or if they would prefer to Avoid the individual to prevent interacting with them in a social situation. When they make their choice, the selection will be made for that trial, and when the gray box turns red, they cannot change their response on that trial. For each trial, the participant had 2 seconds to respond, and they were told to respond (Approach or Avoid) on every trial. Participants viewed 576 face morph stimuli with 64 trials of each individual face morph (i.e., pure angry, pure happy, etc.). The stimuli contain faces from individuals who are biologically male and female, and sides that Approach and Avoid appear on were counterbalanced across participants. Measures of both avoidance behavior (Cronbach's α=0.97) and response time (Cronbach's α=0.97) demonstrated good internal consistency.

The participants underwent three SAAC trials consisting of three different face morphs each (**Figure 2**). The happy angry trial will involve morphs that are (1) 100%Happy + 0%Angry ("pure happy"), (2) 50%Happy + 50%Angry (conflict), and (3) 0%Happy + 100%Angry ("pure angry"). The neutral angry trial includes morphs that are (1) 100%Neutral + 0%Angry ("pure neutral"), (2) 50%Neutral + 50%Angry (ambiguous), and (3) 0%Neutral + 100%Angry ("pure angry"). Finally, the neutral happy trial includes morphs that are (1) 100%Neutral + 0%Happy ("pure neutral"), (2) 50%Neutral + 50%Happy (ambiguous), and (3) 0%Neutral + 100%Happy ("pure happy").

Psychophysiological Data Collection

Electrocortical activity was recorded with Brain Vision Recorder at 1000hz using an active electrode EEG system (ActiCHamp, Brain Products GmbH) and a 32-channel cap placed using the 10-20 system (ActiCap. Brain Products GmbH) and the ActiCHamp amplifier system (Brain Products GmbH). Frontocentral Zero (FCz) was the reference node, with a ground electrode placed at Anterior Frontal Zero (AFz) and impedances at or below 10 kΩ attained using electrolyte gel. Electrooculogram (EOG) recordings of eye movements were collected using four electrodes aligned with the pupils. To measure vertical movement, one electrode was placed above and one below the left eye, and horizontal movement was measured with an electrode on the outer canthi of each eye. Participants were instructed to look straight at the monitor during electrode placement to ensure EOG electrodes were aligned with the pupil.

EEG Data Processing and Analysis

EEG data was analyzed using BrainVision Analyzer (BrainVision Analyzer, Brain Products GmbH, Gilching, Germany). Raw data was down-sampled to 250 Hz and re-referenced to the average mastoids (TP9/TP10) and high-pass (0.10 Hz) filtered along with a notch filter (60 Hz). Artifacts from eye movements were corrected using EOG measurements with the regression-based algorithm developed by Gratton et al. (1983). Trained research assistants removed artifacts using FASTER (Nolan et al., 2010) and a visual inspection to manually validate automated algorithm-flagged segments. After artifact rejection, the number of trials retained for analysis was high across face morph stimuli and drinking group. For the infrequent user controls, the following number of trials were rejected for each face morph stimulus: 76 pure happy (7.42%), 78 pure angry (7.62%), 79 pure neutral (7.71%), 84 neutral/happy (8.20%), 72 neutral/happy (7.03%), and 81 happy/angry (7.91%). The following number of trials were rejected for the binge drinking group: 89 pure happy (8.18%), 80 pure angry (7.35%), 82 pure neutral (7.54%), 84 neutral/happy (7.72%), 88 neutral/happy (8.09%), and 89 happy/angry (8.18%). Overall, 982 (7.75%) of the 12,672 trials were rejected.

To conduct the time-frequency analysis, FMθ was extracted as mean power within 4 Hz to 8Hz at FCz, consistent with prior research on approach-avoidance conflict (Lange et al., 2022). Theta power was decibel corrected per frequency layer using the average power of all trials of the respective task within the -800 to -300ms baseline time window averaged across all task trials. This pre-stimulus window was selected to avoid edge artifacts when removing pre-stimulus activity from post-stimulus activity. Also consistent with Lange et al., 2022, a wavelet transformation was applied using 30 complex morlet wavelets from 1 to 30 Hz in logarithmic steps. Three wavelet cycles were used to balance temporal and frequency precision. Four and five wavelet cycles were also examined wherein temporal precision is reduced in favor of greater frequency precision. The SAAC task was optimized for this analysis by including a longer minimum inter-trial interval (ITI) duration of 1800ms to facilitate utilization of longer pre-stimulus windows. To quantify FMθ activity, personalized peaks were determined by extracting wavelets 11-18 and finding the peak decibel for each participant within the early (146-434ms) and the late (436-724ms) post-stimulus windows, based on findings from Lange et al., 2022. Once this decibel value was determined, we added and subtracted 50ms from the post-stimulus time that the decibel peak occurred to create the time parameters for each participant's FMθ extraction. FMθ power across the sample in response to both the ambiguous/conflict and pure face morphs is shown in **Figures 3 and 4**

Data Analytic Plan

All statistical analyses were performed using JASP statistical software (JASP Team, 2024). To address our first hypothesis, we used a 2x3 mixed model ANOVA. Factors included drinking group (binge drinkers vs infrequent users) and face morph for each of the three ambiguous and conflict face morphs: 50% happy+ 50% angry, 50% neutral + 50% angry, and 50% neutral 50% happy. To address our second hypothesis, we used a 2x3 mixed model ANOVA. Factors included drinking group (binge drinkers vs infrequent users) and face morph for each of the pure face morphs: 100% happy, 100% angry, and 100% neutral. The dependent variable was FMθ activity. For our third hypothesis, we also used a 2x3 mixed model ANOVA. Factors included drinking group (binge drinker vs infrequent users) and face morph for each of the three ambiguous and conflict face morphs: 50% happy+ 50% angry, 50% neutral + 50% angry, and 50% neutral 50% happy. The dependent variables were avoidance behavior (i.e., the number of times participants select the Avoid option for the face morphs) and response time. For our fourth hypothesis, we used a 2x3 mixed model ANOVA. Factors included drinking group (binge drinker vs infrequent users) and face morph for each of the pure face morphs: 100% happy, 100% angry, and 100% neutral. The dependent variables were avoidance behavior and response time. Sex, age, education, and social anxiety were included as covariates. There were no significant differences between groups.

Results

Psychophysiological Hypotheses

H1: Individuals in the binge drinking group will demonstrate less FMθ activity as compared to infrequent user controls when viewing the ambiguous and conflict face morph stimuli.

Two 2x3 mixed model ANOVAs were conducted to analyze differences in FMθ activity in response to the ambiguous and conflict face morphs between binge drinkers and infrequent user controls (**Figure 5**). Sex, age, education, and severity measure for social anxiety disorder scores, were added as covariates to isolate the associations between face morph, FMθ activity, and drinking group.

Prior to conducting the ANCOVAs, assumptions of the analysis were assessed for both the early and late windows. Normality of residuals was assessed through inspection of the Q-Q plot of standardized residuals. The residuals appeared to follow the diagonal reference line reasonably closely, indicating that the assumption of normality was adequately met for both post-stimulus windows. Homogeneity of variances was assessed using Levene's test. Regarding the early window, results indicated that the assumption was met for the neutral/angry ($F(1, 31)=2.25$, $p=0.14$) and the neutral/happy ($F(1, 31)=0.18$, $p=0.67$) conditions. However, Levene's test was significant for the happy/angry (conflict) condition ($F(1, 31)=5.805$, $p=.02$), indicating a violation of the homogeneity of variance assumption for this comparison. ANCOVA is generally considered relatively robust to moderate violations of homogeneity when group sizes are approximately equal (Tabachnick & Fidell, 2019). Therefore, the analysis was retained, although results for this comparison should be interpreted with caution. For the late window, results indicated that the assumption of homogeneity was met for the neutral/angry ($F(1, 31)=1.31$, $p=0.26$), neutral/happy ($F(1, 31)=0.36$, $p=0.55$), and happy/angry ($F(1, 31)=0.81$, $p=0.38$) conditions. The assumption of sphericity was examined using Mauchly's test of sphericity. Results indicated that the assumption of sphericity had not been violated for the early ($W=0.96$, $\backslash\chi^2(2)=0.97$, $p=0.62$) or late ($W=0.85$, $\backslash\chi^2(2)=3.97$, $p=0.14$) windows.

There was no significant main effect of face morph ($F(2, 52) = 0.19$, $p = 0.82$) or drinking group ($F(1, 26) = 2.37$, $p = 0.14$) on FMθ activity during the early window. There was also no interaction effect between face morph and drinking group ($F(2, 52) = 0.80$, $p = 0.454$). For FMθ activity during the late window, there was also no significant main effect of face morph (F(2, 50) = 0.60, p = 0.55) or drinking group (F(1, 25) = 3.21, p = 0.085) and no significant face morph x drinking group interaction (F(2, 50) = 2.67, p = 0.079).

H2: There will not be differences in FMθ activity between the binge drinking and infrequent use controls for the pure happy, angry, or neutral face morphs.

Two 2x3 mixed model ANOVAs were conducted to analyze differences in FMθ activity in response to the pure happy, angry, and neutral face morphs between binge drinkers and infrequent user controls (**Figure 6**). Sex age, education, and severity measure for social anxiety disorder scores, were added as covariates to isolate the associations between face morph, FMθ activity, and drinking group.

Prior to conducting the ANCOVAs, assumptions of the analysis were assessed for both the early and late windows. Normality of residuals was assessed through inspection of the Q-Q plot of standardized residuals. The residuals appeared to follow the diagonal reference line reasonably closely, indicating that the assumption of normality was adequately met for both post-stimulus windows. Homogeneity of variances was assessed using Levene’s test. Regarding the early window, results indicated that the assumption was met for the pure happy (F(1, 31)=3.44, p=0.07), pure angry (F(1, 31)=1.99, p=0.17), and pure neutral (F(1, 31)=0.55, p=0.46) conditions. For the late window, results indicated that the assumption of homogeneity was met for the pure angry (F(1, 31)=0.94, p=0.34), pure neutral (F(1, 31)=0.01, p=0.91) conditions. The assumption of homogeneity was not met for the pure happy condition (F(1, 31)=11.54, p=0.002). ANCOVA is generally considered relatively robust to moderate violations of homogeneity when group sizes are approximately equal (Tabachnick & Fidell, 2019).

Therefore, the analysis was retained, although results for this comparison should be interpreted with caution. The assumption of sphericity was examined using Mauchly's test of sphericity. Results indicated that the assumption of sphericity had not been violated for the early (W=0.91, $\backslash\chi^2(2)=3.97$, p=0.32) window. The assumption of sphericity was violated for the late window (W=0.61, $\backslash\chi^2(2)=12.08$, p=0.002), so a Greenhouse-Geisser correction was applied ($\varepsilon = 0.72$).

Regarding the early window, there was no significant main effect of face morph ($F(2, 50) = 0.72$, $p = 0.49$) or drinking group ($F(1, 25) = 3.01$, $p = 0.095$) and no significant face morph x drinking group interaction ($F(2, 50) = 0.36$, $p = 0.70$). For FMθ activity during the late window, there was also no significant main effect of face morph ($F(1.43, 35.83) = 0.42$, $p = 0.60$) or drinking group ($F(1, 25) = 3.77$, $p = .06$) and no significant face morph x drinking group interaction ($F(1.43, 35.83) = 0.75$, $p = 0.44$).

Behavioral Hypotheses

H1: The binge drinking group will exhibit more avoidance behavior and greater response times in response to the ambiguous and conflict face morph stimuli than the infrequent user controls

Two 2x3 mixed model ANOVAs were conducted to analyze differences in avoidance behavior and response times between drinking groups in response to the conflict and ambiguous face morphs (**Figure 7**). Sex age, education, and severity measure for social anxiety disorder scores, were added as covariates to isolate the associations between face morph, avoidance behavior or response time, and drinking group.

Prior to conducting the ANCOVAs, assumptions of the analysis were assessed for both avoidance and response time. Normality of residuals was assessed through inspection of the Q-Q plot of standardized residuals. The residuals appeared to follow the diagonal reference line reasonably closely, indicating that the assumption of normality was adequately met for both avoidance behavior and response time. Homogeneity of variances was assessed using Levene's test. Regarding avoidance behavior, results indicated that the assumption was met for the neutral/angry ($F(1, 31)=4.23$, $p=0.05$), neutral/happy ($F(1, 31)=1.11$, $p=0.30$), and happy/angry ($F(1, 31)=2.99$, $p=0.09$) conditions. For response time, results indicated that the assumption of homogeneity was met for the neutral/angry ($F(1, 31)=0.40$, $p=0.53$), neutral/happy ($F(1, 31)=0.03$, $p=0.88$), and happy/angry ($F(1, 31)=0.16$, $p=0.69$) conditions. The assumption of sphericity was examined using Mauchly's test of sphericity. Results indicated that the assumption of sphericity had not been violated for avoidance behavior ($W=0.92$, \$\chi^2(2)=2.00$, $p=0.37$) or response time ($W=0.9$, \$\chi^2(2)=2.64$, $p=0.27$).

Regarding avoidance behavior, there was no significant main effect of face morph ($F(2, 52) = 2.49$, $p = 0.09$) or drinking group ($F(1,26) = 0.57$, $p = 0.46$) and no significant face morph x drinking group interaction ($F(2, 52) = .658$, $p = 0.66$). For response times, there was also no significant main effect of face morph ($F(2, 52) = 0.18$, $p = 0.83$) or drinking group ($F(1,26) = 0.12$, $p = 0.73$) and no significant face morph x drinking group interaction ($F(2, 52) = 0.19$, $p = 0.83$).

H2: There will not be differences in avoidance behavior or response times for the pure happy, angry, or neutral face morphs between the binge drinking and infrequent user controls.

Two 2x3 mixed model ANOVAs were conducted to analyze differences in avoidance behavior and response times between drinking groups in response to the pure face morphs (**Figure 8**). Sex age, education, and severity measure for social anxiety disorder scores, were added as covariates to isolate the associations between face morph, avoidance behavior or response time, and drinking group.

Prior to conducting the ANCOVAs, assumptions of the analysis were assessed for both avoidance and response time. Normality of residuals was assessed through inspection of the Q-Q plot of standardized residuals. The residuals appeared to follow the diagonal reference line reasonably closely, indicating that the assumption of normality was adequately met for both avoidance behavior and response time. Homogeneity of variances was assessed using Levene's test. Regarding avoidance behavior, results indicated that the assumption was met for the pure angry ($F(1, 31)=0.10$, $p=0.75$), pure happy ($F(1, 31)=0.46$, $p=0.50$), and pure neutral ($F(1, 31)=0.91$, $p=0.35$) conditions. For response time, results indicated that the assumption of homogeneity was met for the pure angry ($F(1, 31)=0.004$, $p=0.95$) and pure neutral ($F(1, 31)=0.20$, $p=0.66$) conditions. The assumption of homogeneity was not met for the pure happy condition ($F(1, 31)=5.22$, $p=0.03$). ANCOVA is generally considered relatively robust to moderate violations of homogeneity when group sizes are approximately equal (Tabachnick & Fidell, 2019). Therefore, the analysis was retained, although results for this comparison should be interpreted with caution. The assumption of sphericity was examined using Mauchly's test of sphericity. Results indicated that the assumption of sphericity had not been violated for avoidance behavior ($W=0.90$, \$\chi^2(2)=2.70$, $p=0.26$) or response time ($W=0.87$, \$\chi^2(2)=3.61$, $p=0.16$).

There was a significant main effect of face morph on avoidance behavior ($F(2, 52) = 4.27$, $p = 0.19$). *Post-hoc* Bonferroni tests revealed that there was more avoidance for the pure angry morph compared to the pure happy and neutral morphs ($p < .001$) and more avoidance behavior for the neutral face morphs compared to the happy face morphs ($p < .001$). There was no significant main effect of drinking group ($F(2, 52) = 0.003$, $p = 0.95$) or face morph x drinking group interaction ($F(2, 52) = 0.58$, $p = 0.57$). Regarding response time, there was no significant main effect of face morph ($F(2, 52) = 1.82$, $p = 0.17$) or drinking group ($F(1, 26) = 0.01$, $p = 0.92$) and no significant face morph x drinking group interaction ($F(2, 52) = 0.94$, $p = 0.40$).

Discussion

The present study sought to identify shared neural and behavioral markers for the relationship between SAB and binge drinking. Specifically, we recruited binge drinkers and infrequent user controls to engage in a social approach-avoidance task, while undergoing EEG measurement of FMθ. Contrary to our hypotheses, infrequent user controls did not differ from binge drinkers in their FMθ activity, avoidance behavior, or response times when viewing the ambiguous and conflict face morph stimuli. Drinking groups also did not differ in their FMθ activity, avoidance behavior, or response times when viewing the pure face morph stimuli which was consistent with our hypotheses.

Our results are surprising because FMθ activity has been consistently linked to conflict processing and cognitive control in a number of behavioral paradigms (Cavanagh et al., 2009; Cavanagh et al., 2012; Cavanagh & Frank, 2014; Cohen and Donner, 2013; Cohen and Ridderinkhof, 2013; Duprez et al., 2020; Gulbinaite et al., 2014; McDermott et al., 2017; Muralidharan et al., 2023; Nigbur et al., 2011; Oehrn et al., 2014; Töllner et al., 2017; van Driel et al., 2015; Zuure et al., 2020). Specifically, stronger FMθ activity has been correlated with better performance in working memory, memory encoding and retrieval, novelty detection, and other tasks that engage in top-down control (Cavanagh et al., 2012; Itthipuripat et al., 2013; Jacobs et al., 2006; Rutishauser et al., 2010). As such, we hypothesized that FMθ would be involved with conflict processing in the SAAC task and that individuals who engage in binge drinking would have lower FMθ activity, more avoidance behavior, and longer response times when faced with the conflict face morph stimuli compared to infrequent user controls.

These hypotheses were based on a rich literature demonstrating harmful effects of substance use on prefrontal cortex functioning (Goldlstein & Volkow, 2011; Koob & Volkow, 2010; Zucker et al., 2011). For example, substance use disorders typically involve overvaluation of drug reinforcers compared to natural reinforcers and difficulties with inhibitory control, demonstrating the critical role of an underperforming prefrontal system in the development and maintenance of these disorders (Koob & Volkow, 2010). Several studies have shown that individuals with substance use disorders have weakened prefrontal cortex activity during exposure to higher-order cognitive or emotional challenges yet demonstrate widespread activation in this region in response to drug use and drug-related cues (for review see Goldstein & Volkow, 2011). Further, FMθ has been identified as a candidate endophenotype of the development of problematic substance use (Harper et al., 2019). Indeed, several studies have demonstrated a relationship between FMθ activity and alcohol use such that weaker

FMθ activity has been associated with earlier initiation of alcohol use and higher binge drinking frequency in adolescents (Boer et al., 2025; Harper et al., 2021).

Although non-significant, the results of the present study appear to follow this pattern, demonstrating lower FMθ activity in individuals who engage in binge drinking compared to those who infrequently consume alcohol. This trend was present during both the early and late windows in response to the ambiguous, conflict, and pure face morph stimuli. This suggests that there could be some degree of FMθ involvement in the way binge drinkers process social stimuli, regardless of the degree of social reward, threat or conflict. Indeed, lower FMθ activity and P3 amplitude have been linked to externalizing disorders such as antisocial personality disorder, attention deficit hyperactivity disorder, conduct disorder, AUD, and cannabis use disorder (Yoon et al., 2013; Neo et al., 2023), all disorders with distinct symptoms related to deficits in social interactions and interpersonal relationships. Similar to the Lange et al. (2022) approach-avoidance task, there also appeared to be differences in FMθ activity between the early and late windows; however, in the present study, there was weaker FMθ activity in the late window, whereas Lange et al., 2022 found significantly stronger activity in the late window compared to the early window. Perhaps this discrepancy is a result of participants engaging in social conflict processing in the present study compared to a monetary approach-avoidance task.

FMθ activity is clearly related to both conflict processing and substance use disorders; however, our results suggest that the midfrontal region may not be related to differences in conflict processing between binge drinkers and individuals who infrequently drink alcohol when faced with the SAAC task. Further, a paired samples t-test was conducted to compare FMθ activity in response to viewing the pure face morph stimuli compared to the ambiguous/conflict stimuli in the binge drinking group. For the early window, there was no significant difference in FMθ activity between the pure trials ($M = 0.33$, $SD = 1.75$) and ambiguous/conflict trials ($M = 0.01$, $SD = 0.99$; $t(50) = 1.49$, $p = 0.14$). There was also no significant difference in FMθ activity between the pure ($M = -0.86$, $SD = 1.74$) and ambiguous/conflict ($M = -1.07$, $SD = 1.06$) trials during the late window ($t(50) = 0.91$, $p = 0.37$). This suggests that FMθ may not be related to conflict processing in binge drinkers when faced with the SAAC task; however, further confirmation is required. As such, it is interesting to speculate that characteristics of the behavioral paradigm may have played a role in this discrepancy. When considering the SAAC task, it is important to note that in the present study, participants demonstrated a significantly greater number of “Avoid” responses when interacting with the pure angry face morph stimuli compared to the pure happy and neutral stimuli and when viewing the pure neutral stimuli compared to pure happy. This aligns with previous literature, suggesting that social judgments and decisions are sensitive to changes in social signal intensity (Evans et al., 2024) and further demonstrates that the SAAC paradigm influences the intensity of social reward, threat, and reward-threat conflict (Evans et al., 2026). However, there were no differences in response time, an outcome previously associated with social conflict processing in the SAAC task (Evans et al., 2026), nor were there significant differences in “Avoid” selections or response times for the ambiguous or conflict face morphs. Although the present results align in part with previous studies, the discrepancies suggest a need for closer examination of the paradigm as it relates to FMθ activity.

To further understand the sensitivity of FMθ to conflict in the SAAC task, we conducted a paired samples t-test comparing differences in FMθ activity between the pure face morph stimuli and ambiguous/conflict stimuli across the entire sample. Regarding the early window, there was no significant difference in FMθ activity between the pure trials ($M = 0.56$, $SD = 1.68$) and ambiguous/conflict trials ($M = 0.31$, $SD = 1.34$; $t(98) = 2.24$, $p = 0.07$). However, analysis of the late window indicated a significant difference in FMθ activity between the pure ($M = -0.53$, $SD = 1.58$) and ambiguous/conflict ($M = -0.84$, $SD = 1.16$) trials ($t(98) = 2.24$, $p = 0.03$). Similar to Lange et al. (2022), our results suggest that there may be differences in FMθ response between the early and late windows. However, in contrast with prior literature suggesting that FMθ activity is greater in response to conflict (Cohen and Donner, 2013; Cohen and Ridderinkhof, 2013; McDermott et al., 2017; Muralidharan et al., 2023; Oehrn et al., 2014; Töllner et al., 2017; van Driel et al., 2015), our results indicate that FMθ activity was greater in response to the pure trials rather than the ambiguous/conflict trials. Conceivably, this discrepancy could be due to differences in conflict processing related to encountering social reward/threat stimuli compared to other kinds of stimuli (e.g., financial risk/reward or risk of physical discomfort). Although FMθ may not have been insensitive to conflict in the SAAC task, it could still be important to examine how the design of the SAAC paradigm influenced the discrepancy between the present results and the previous literature.

Indeed, recent studies have suggested that an individualized approach to studying approach-avoidance conflict may better capture conflict processing. Similar to our results, in an experiment using a flanker task, conditions with higher conflict did not elicit reliable behavioral changes in participants (Pinner & Cavanagh, 2018). Notably, significant variance was accounted for by individual differences in FMθ power, suggesting that the appraisal of conflict costs varies among individuals (i.e., costs may be aversive to some and act as investments for others), and FMθ may be a marker of this processing. Further, Lin et al., (2018) conducted a study in which participants made intertemporal decisions in the days leading up to the primary experiment and each participants' intertemporal preferences and subjective choice conflict were used to generate delayed rewards that were participant specific. They found that FMθ power was modulated by subjective conflict, further suggesting that FMθ may be elicited more in behavioral tasks that have been individualized to participants' subjective experiences of conflict appraisal. Indeed, FMθ sensitivity to approach-avoidance conflict seems to be observed primarily in response to individually defined, or subjective, forms of behavioral conflict (Lange et al., 2022; Pandey & Osinksy, 2025). As such, the present study may not have fully captured FMθ sensitivity to the conflict manipulation because the SAAC paradigm is not adjusted based on individual differences in participants' experience of conflict appraisal.

It is also interesting to consider the impact of the inclusion criteria for the present study's drinking groups and whether studying binge drinking exclusively may have influenced the results. For instance, several studies have recruited participants who meet criteria for AUD as one of their drinking groups which resulted in differences in neural connectivity between these individuals and healthy control groups (Meyers et al., 2021; Richard et al., 2026; Song et al., 2024). The present study included individuals who engaged in binge drinking behavior; however, there were no inclusion criteria regarding severity of other alcohol-related impairments, including meeting criteria for AUD. Perhaps the drinking characteristics of the binge drinking group in the present study were not severe enough to elicit differences in neural activity when tasked with conflict processing.

Additionally, alcohol use has been shown to influence network oscillations in the frontal cortex which can then result in increased alcohol consumption, creating a feedback loop that can lead to increased risk for alcohol misuse (DiLeo et al., 2022; DiLeo et al., 2024; Henricks et al., 2019). It is well-established that impaired cognitive control is both a risk factor for and a consequence of substance misuse and substance use disorders (Goldstein & Volkow, 2002). As such, these findings suggest that individuals with more severe drinking pathology may differ more greatly from controls in their neural activation as a result of the bidirectional relationship between the frontal cortex and alcohol consumption. Moreover, the average age of the present study was 26.12 which is younger than that of the aforementioned studies that found neural differences between drinking groups. Conceivably, age could work in tandem with the impact of alcohol on the fronto-cortical circuitry, leading to greater neural differences as one progresses across the lifespan.

Limitations and Future Research

Although this study possesses many strengths, the results should be considered with several limitations in mind. First, this study utilized self-report measures to gather data on alcohol use and social anxiety and avoidance symptoms. As such, participants may have under- or overreported their alcohol use and symptoms due to social desirability biases or poor insight. Further, this study used a cross-sectional design, so the impact of binge drinking on social avoidance and FMθ activity over time cannot be determined. Future studies may benefit from using longitudinal designs to better capture the long-term effects and risks of binge drinking, including the development of AUD.

An additional limitation of this study is its generalizability due to the sample characteristics (i.e., primarily white individuals from the southeast). Thus, future studies may benefit from collecting data across multiple sites in various geographical regions to assess how intersectional factors may influence neural and behavioral correlates of SAB and alcohol use. Further, the average age of the present sample (26.12 ± 9.65) is younger than that of other studies that found individuals who exhibited alcohol misuse to have lower FMθ activity in response to conflict (Gilmore & Fein, 2012; Jones et al., 2006; Kamarajan et al., 2004; Meyers et al., 2021; Richard et al., 2026; Song et al., 2024). Certainly, alcohol influences neural functioning as individuals continue to consume large amounts of alcohol over time, so the present results may be influenced, in part, by the average age of the participants. Future studies could utilize an experimental design that includes multiple, distinct age groups (i.e., young adult (18-25), adult (26-39), middle-aged adult (40-59), mature adult (60-64), senior (65-74), etc.) to determine whether age and number of years of binge drinking influences FMθ as a correlate for SAB and binge drinking. This would also increase the results' generalizability to a wider range of individuals.

Variance of drinking-related behaviors and impairments within the binge drinking group could have also been a limitation of the study. Although inclusion criteria for this group required a minimum number of drinks per week and binge episodes per month, there was neither an upper limit nor inclusion criteria associated with alcohol-related impairment. It is conceivable, therefore, that variance within this group could have influenced the results of the study. It would be important for future studies to incorporate additional drinking groups, to better understand the dimensional nature and impact of alcohol use. Groups could, for example, include infrequent users, social drinkers, heavy drinkers, binge drinkers, and individuals who meet criteria for AUD. Indeed, Sloan et al. (2020) conducted a study in which they recruited participants who were “low-risk social drinkers,” “high-risk social drinkers,” and “heavy drinkers.” They excluded individuals who met criteria for AUD, and their inclusion criteria for the high-risk social drinkers not only involved number of drinks consumed per week but also risk factors such as family history of AUD and high levels of impulsivity. Their results suggest that even within one drinking category (i.e., social drinkers) there is variance that accounts for increased risk for future alcohol related consequences such as the development of AUD. This underscores the importance of future studies incorporating a more dimensional approach to the typical categorical groups used in substance use research.

Although the SAAC paradigm has been previously validated (Evans et al., 2026), it is possible that the design was a limitation to the current study. More specifically, the lack of significant differences in response to the pure stimuli compared to the ambiguous/conflict stimuli suggests for the binge drinking group, FMθ may not have been sensitive to conflict. Further, when assessing FMθ activity across both drinking groups, the results demonstrated that FMθ may have shown sensitivity to conflict stimuli in the late window; however, there was more FMθ activation in response to the pure stimuli as compared to the ambiguous/conflict stimuli. Several studies have demonstrated that FMθ is sensitive to conflict appraisal in a variety of behavioral paradigms (Cavanagh et al., 2009; Cavanagh et al., 2012; Cavanagh & Frank, 2014; Cohen and Donner, 2013; Cohen and Ridderinkhof, 2013; Duprez et al., 2020; Gulbinaite et al., 2014; McDermott et al., 2017; Muralidharan et al., 2023; Nigbur et al., 2011; Oehrn et al., 2014; Töllner et al., 2017; van Driel et al., 2015; Zuure et al., 2020); however, its sensitivity to SAAC seems to be revealed when the study design involves an individualized behavioral paradigm (Lange et al., 2022; Lin et al., 2018; Pandey & Osinksy, 2025). In the present study, each participant was exposed to the same face morph stimuli to which they could select to “approach” or “avoid” that individual in a social situation. Other studies that have investigated SAAC suggest that future research could utilize a more individualized approach wherein participants are exposed to face morph stimuli that they personally find to induce or reduce conflict processing. Specifically, participants could undergo a “practice session” during which they would be exposed to the face morph stimuli, and their response times and avoidance behavior would be collected. The stimuli that induce the longest response times and most avoidance would then be used as each participants’ “conflict” stimuli.

Conclusion

This study is one of the first to our knowledge to investigate FMθ as a shared neural marker for social avoidance behavior and binge drinking. Prior literature indicates that FMθ is involved in conflict processing and varies among individuals with and without AUD. The present results suggest that FMθ may not differ between those who engage in binge drinking and those who infrequently consume alcohol, although future research is warranted. As such, these results indicate that the neural and behavioral correlates of social conflict processing may differ from that of other conflict stimuli (e.g., financial risk) and that it is important to study substance use related neural correlates along a spectrum of use profiles (i.e., infrequent users, heavy drinkers, binge drinkers, AUD diagnosis, etc).

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Tables and Figures

Table 1

Sample Characteristics

	Binge Drinkers	Infrequent Users
Variable	**Mean (SD)**	**Mean (SD)**
Age	23.06 (7.2)	29.38 (11)
Demographics	***n* (%)**	***n* (%)**
Sample Size	17 (51.5%)	16 (48.5%)
Sex		
Male	11 (64.7%)	6 (37.5%)
Female	6 (35.3%)	10 (62.5%)
Race/Ethnicity		
Black/African American	1 (5.9%)	1 (6.3%)
White	13 (81.3%)	13 (81.3%)
Hispanic/Latinx	1 (5.9%)	1 (6.3%)
Other	1 (5.9%)	1 (6.3%)
Education		
High School	2 (11.8%)	4 (25.0%)
Some College	12 (70.6%)	1 (6.3%)
Bachelor's	2 (11.8%)	7 (43.8%)
Post-Graduate	1 (5.9%)	4 (25.0%)
Severity Measure for Social Anxiety Disorder		
None	11 (64.7%)	11 (68.8%)
Mild	4 (23.5%)	5 (31.3%)
Moderate	1 (5.9%)	0 (0%)
Severe	1 (5.9%)	0 (0%)
Extreme	0 (0%)	0 (0%)

N = 33

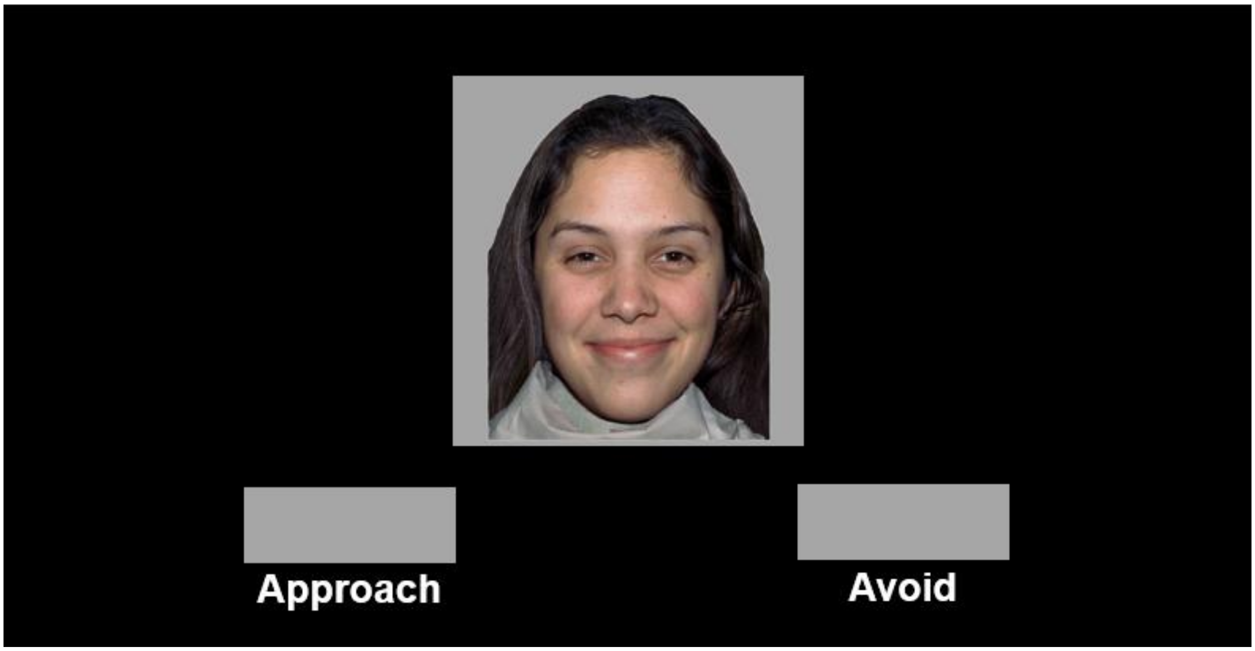

Figure 1. Social Approach Avoidance Conflict task screen
Participants view a face on the screen and are asked to indicate if they would prefer to Approach or Avoid the individual in a social situation. When they make their choice, the corresponding gray box turns red. Participants have 2 seconds to respond to each trial.

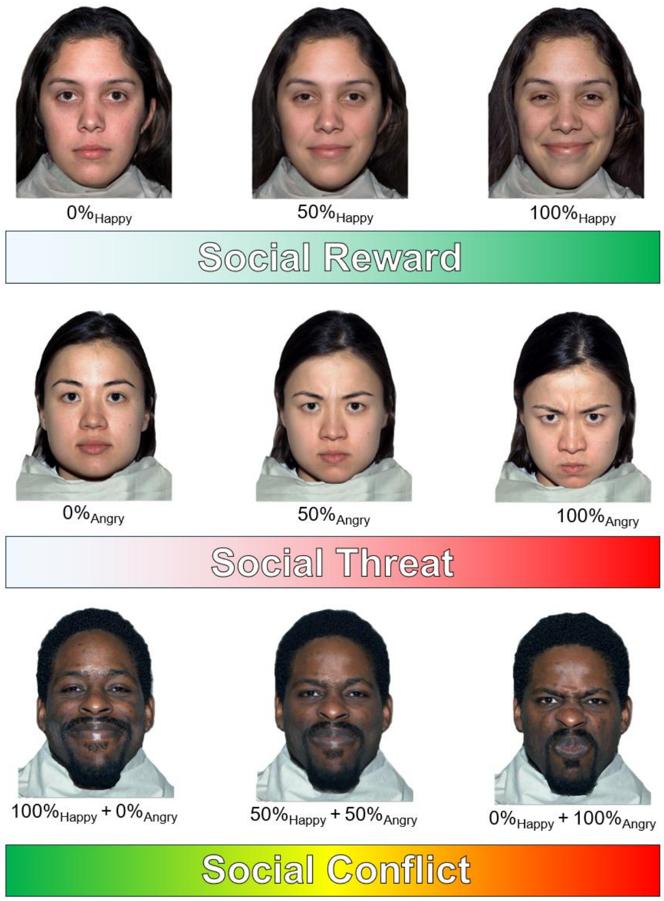

Figure 2. Social Approach Avoidance Conflict trials

Participants will undergo three social approach avoidance conflict trials consisting of three different face morphs each: Neutral Happy, Neutral Angry, and Happy Angry. For the Neutral Happy trial, there is an increase in social reward as the percentage of happy increases in the face morphs. 50% Happy represents the ambiguous face morph. For the Neutral Angry trial, there is an increase in social threat as the percentage of angry increases in the face morphs. 50% Angry represents the ambiguous face morph. The Happy Angry trial presents participants with social conflict when viewing the 50% Happy+50% Angry face morph.

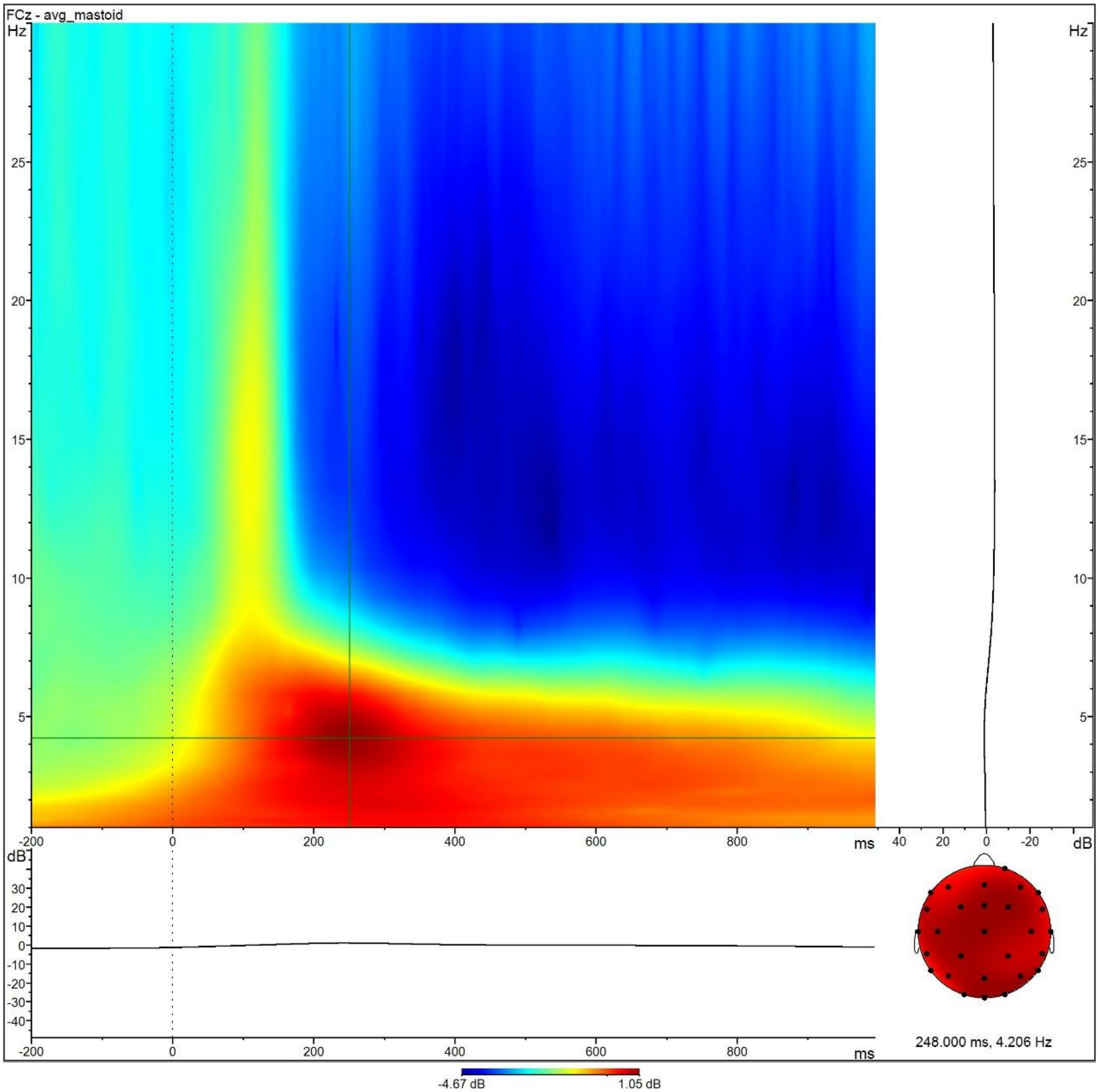

Figure 3. Time-frequency activity at FCz in response to viewing the ambiguous and conflict face-morph stimuli in the SAAC task.

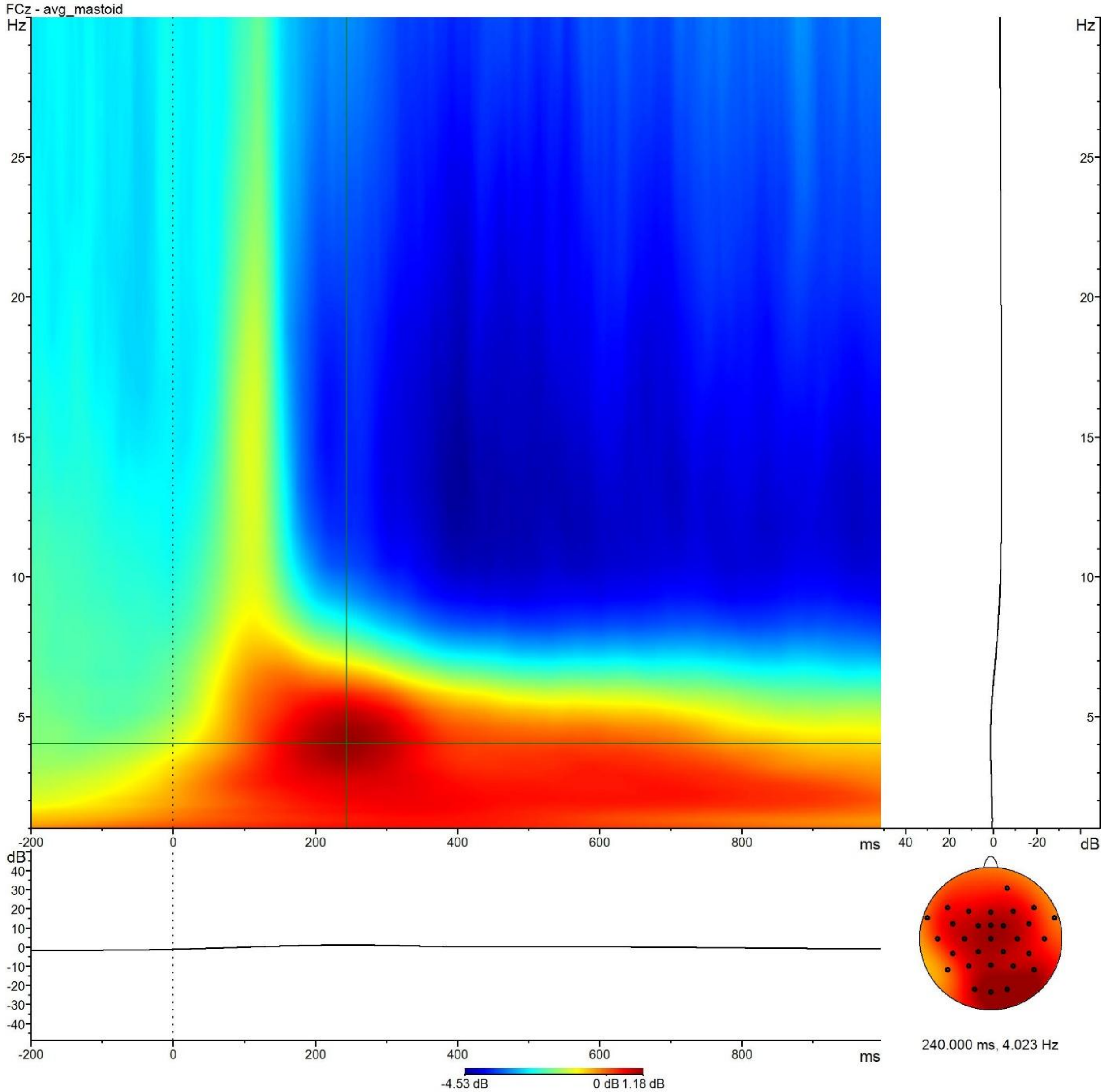

Figure 4. Time-frequency activity at FCz in response to viewing the pure happy, angry, and neutral face-morph stimuli in the SAAC task.

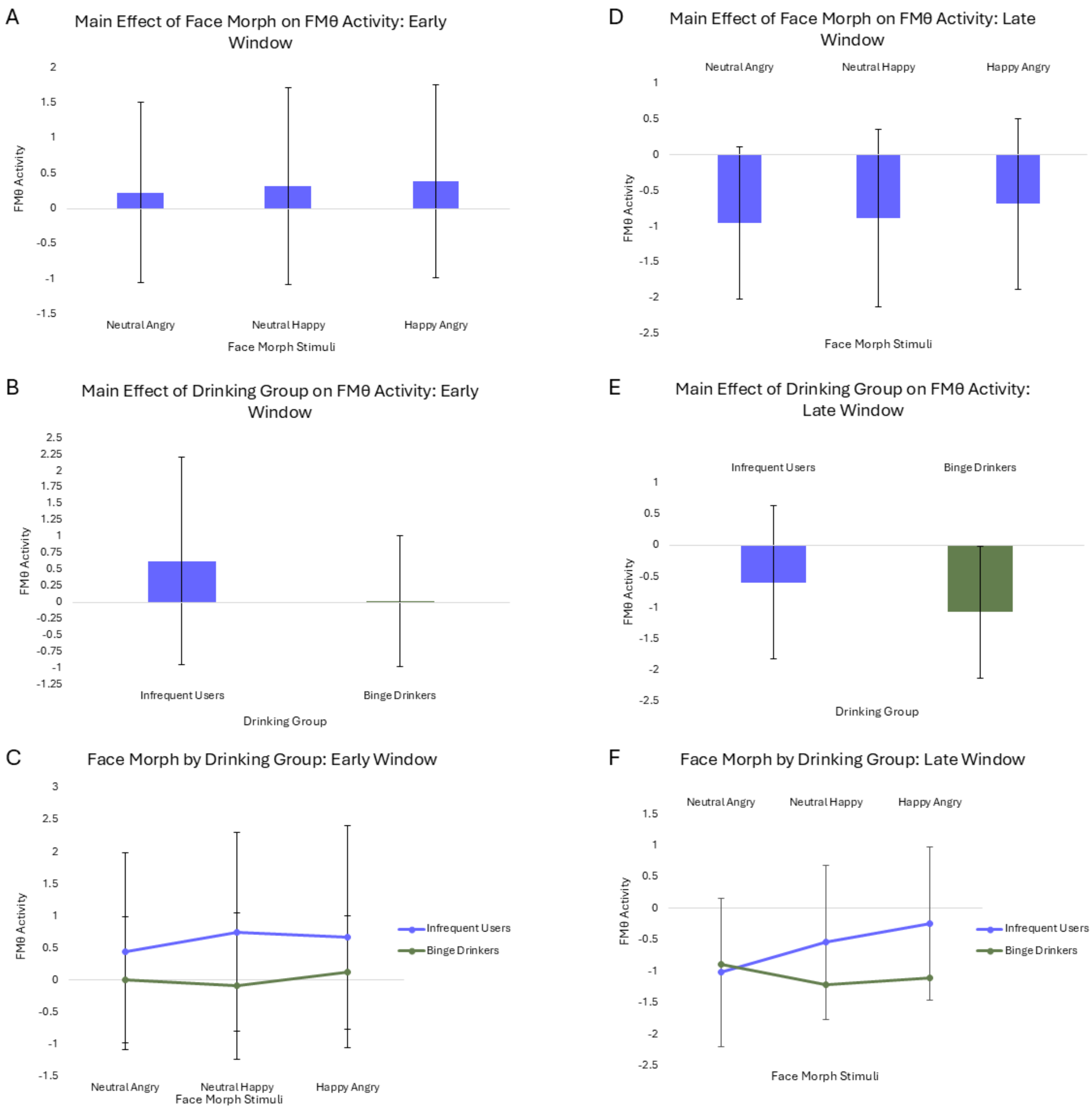

Figure 5. Drinking group and face morph stimuli do not influence FMθ activity in response to the ambiguous or conflict face morph stimuli.

A) Neither face morph nor **B)** drinking group influenced FMθ activity in response to the ambiguous or conflict face morph stimuli during the early window. **C)** There was no significant interaction effect of face morph or drinking group on FMθ activity in response to the ambiguous and conflict face morph stimuli during the early window. **D)** Neither face morph nor **E)** drinking group impacted FMθ activity for the ambiguous or conflict face morph stimuli during the late window. **F)** There was no significant interaction effect of face morph or drinking group on FMθ activity in response to the ambiguous and conflict face morph stimuli during the late window.

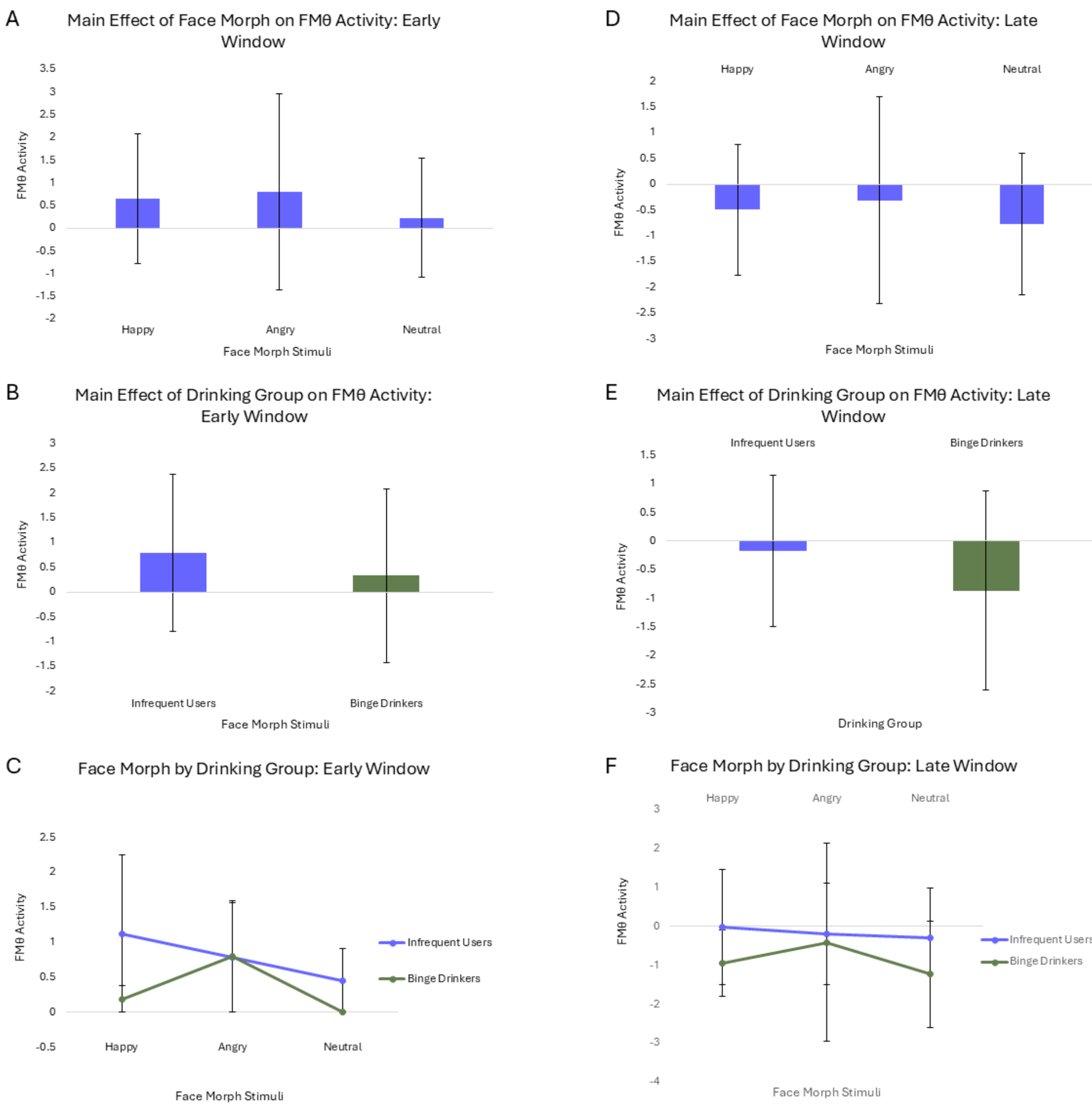

Figure 6. **Drinking group and face morph stimuli do not influence FMθ activity in response to the pure face morph stimuli.**

A) Neither face morph nor **B)** drinking group influenced FMθ activity in response to the pure face morph stimuli during the early window. **C)** There was no significant interaction effect of face morph or drinking group on FMθ activity in response to the pure face morph stimuli during the early window. **D)** Neither face morph nor **E)** drinking group impacted FMθ activity in response to the pure face morph stimuli during the late window. **F)** There was no significant interaction effect of face morph or drinking group on FMθ activity in response to the pure face morph stimuli during the late window.

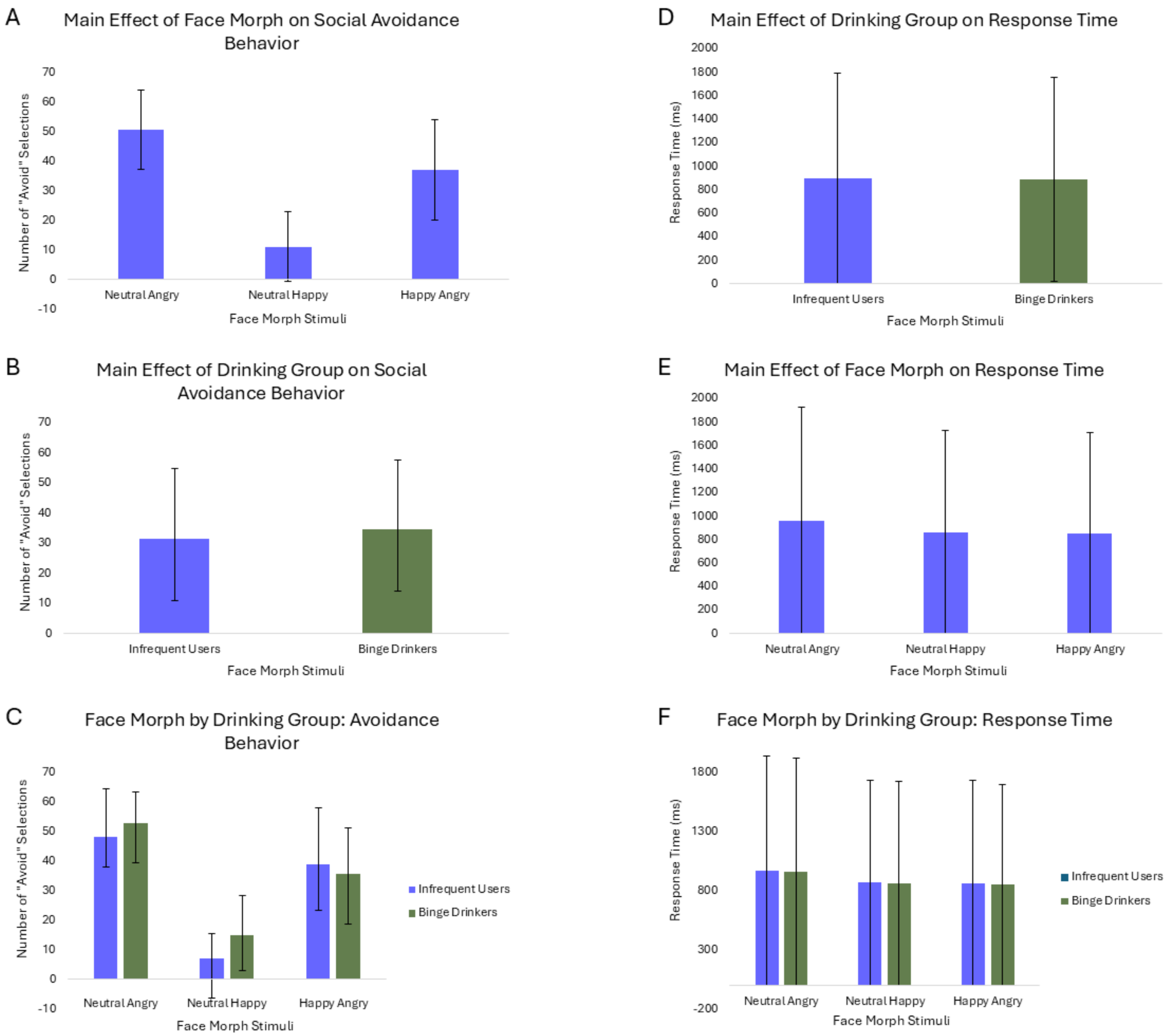

Figure 7. Drinking group and face morph stimuli do not influence avoidance behavior or response time in response to the ambiguous or conflict face morph stimuli.

A) Neither face morph nor **B)** drinking group impacted avoidance behavior in response to the ambiguous and conflict face morph stimuli. **C)** There was no interaction effect of face morph and drinking group on avoidance behavior in response to the ambiguous and conflict face morph stimuli. **D)** Neither face morph nor **E)** drinking group impacted response time for the ambiguous and conflict face morph stimuli. **F)** There was no interaction effect of face morph and drinking group on response time for the ambiguous and conflict face morph stimuli.

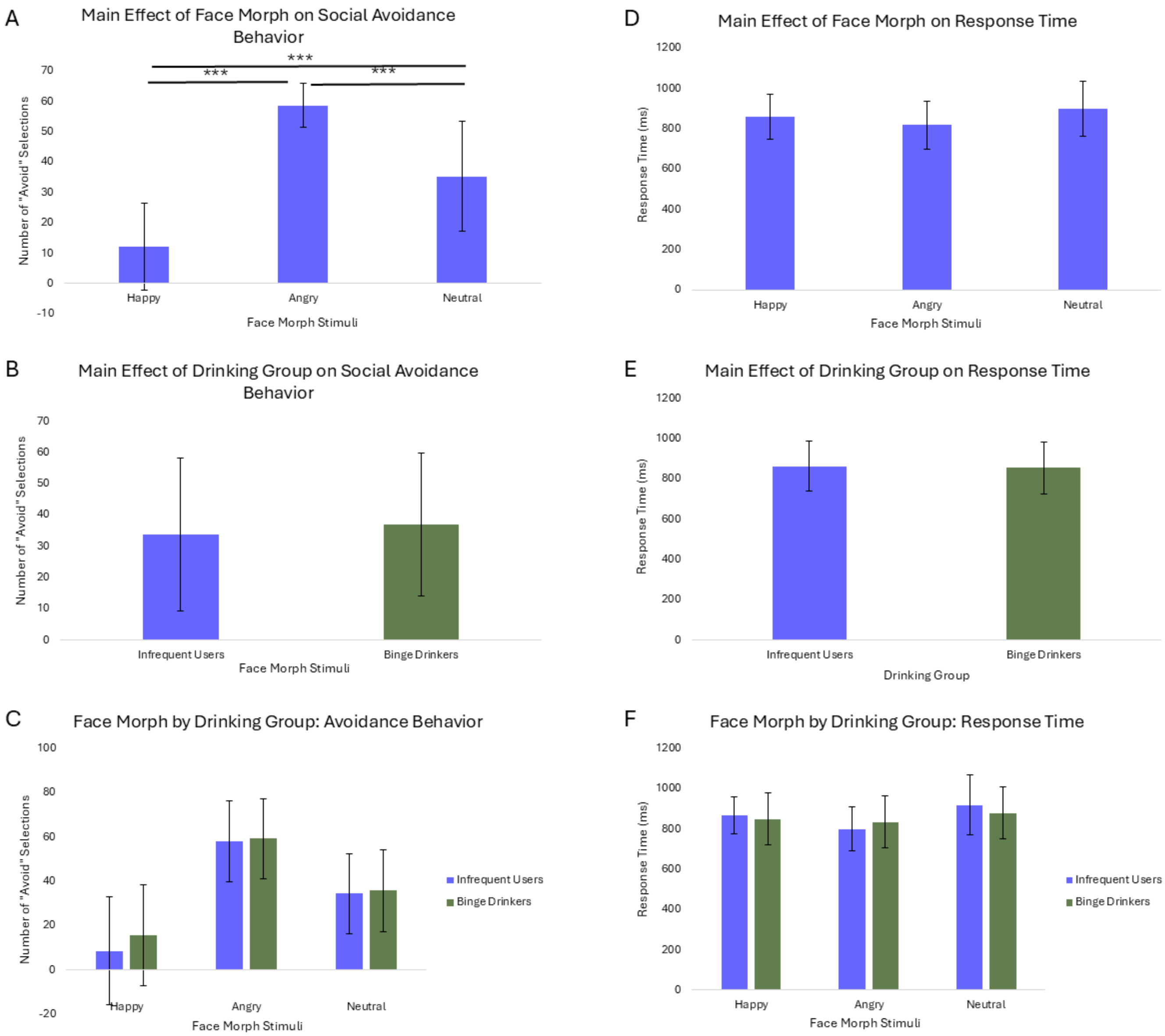

Figure 8. Drinking group and face morph stimuli do not influence avoidance behavior or response time in response to the pure face morph stimuli.

A) Avoidance behavior was significantly higher when participants viewed the angry face morph stimuli compared to viewing the happy and neutral face morphs ($p < 0.001$). Avoidance behavior was also significantly higher when participants viewed the neutral face morph stimuli compared to the happy face morphs ($p < 0.001$). **B)** Drinking group did not impact social avoidance behavior in response to the pure face morph stimuli. **C)** There was no interaction effect of face morph and drinking group on social avoidance behavior in response to the pure face morph stimuli. **D)** Neither face morph nor **E)** drinking group impacted response time for the pure face morph stimuli. **F)** There was no interaction effect of face morph and drinking group on social avoidance behavior in response to the pure face morph stimuli.