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College Students' Implicit Attentional and Affective Responses to Alcohol Cues

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ABSTRACT PAGE

The present study examined undergraduate drinkers' implicit attentional and affective responses to alcohol cues using behavioral and psychophysiological responses to alcohol and control cues during the Affect Misattribution Procedure (AMP). It was hypothesized that dependent drinkers i.e., those who were considered at-risk for alcoholism (*n* = 17), would show more positive implicit affective responses to alcohol cues as well as greater psychophysiological attentional processing of such cues compared to non-dependent drinkers (*n* = 26). To test this hypothesis, participants completed the AMP while electroencephalograph (EEG) was recorded. Behavioral results revealed no difference between groups in implicit affective responses to alcohol cues. However, event-related brain potential analyses revealed that non-dependent drinkers exhibited significantly larger N1 and marginally larger N2 amplitudes to alcohol cues compared to dependent drinkers. Dependent drinkers showed marginally larger P2 amplitudes and a trend towards larger P3 amplitudes to alcohol cues compared to non-dependent drinkers. These results suggest that early attentional patterns of processing of alcohol cues seem to differ based on alcohol dependence. These findings have implications for intervention programs aimed at altering dependent drinkers' attentional processing of alcohol cues to prevent further dependent drinking behavior

College Students' Implicit Attentional and Affective Responses to Alcohol Cues

According to data from the National Epidemiologic Survey on Alcohol and Related Conditions, 12.5% of Americans will suffer from alcohol dependence at some point in their lifetimes (Hasin, Stinson, Ogburn, & Grant, 2007). The Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) defines alcohol dependence as a hazardous drinking pattern which meets at least three of the following seven criteria: presence of physical withdrawal symptoms (i.e. headaches, sweating, nausea, shaking, delirium tremens, anxiety, etc.); tolerance that requires larger amounts of alcohol to be consumed before feelings its effects; loss of control and an inability to quit drinking once one has started; craving for alcohol and a significant amount of time devoted to satisfying that craving; inability to cut-down on drinking; giving up meaningful social or work-related activities to drink instead; continued use of alcohol despite physical or psychological problems that result from or are worsened by drinking (American Psychological Association, 1994).

Young adults between the ages 18-29 years have the highest rates of alcohol dependence across the lifespan (Grant, Dawson, Stinson, Chou, Dufour, & Pickering, 2004). A study by Knight, Wechsler, Kuo, Seibring, Weitzman, and Schuckit (2002) surveyed 14,000 students from 119 colleges across the United States and found that over 40% of respondents met at least one criterion for alcohol abuse or dependence, and schools with heavier drinking environments had greater numbers of respondents who were positive for alcohol dependence (Knight et al., 2002). Longitudinal research provides evidence that hazardous drinking patterns that develop in college, especially alcohol dependence, can lead to lifelong addiction (Jennison, 2004). Therefore it is important to understand contributing factors to alcohol dependence among this population.

One factor that may contribute to dependence is enhanced attention to alcohol-related cues. This has been supported by research that has shown that drugs and their associated paraphernalia attract attention in those who are addicted to these substances (Noël et al., 2007; Stormark, Laberg, Nordby, & Hugdahl, 2000). According to Robinson and Berridge's (2001) incentive sensitization model of addiction, addictive substances alter the organization of brain structures involved in reward. As a result, these structures become sensitized to the drug and to drug-related cues and interact with associative learning processes. This causes drug-related cues to acquire incentive salience, making them powerful attractors of attention relative to other cues in the environment (Robinson & Berridge, 2001), in spite of conscious efforts to ignore them (Field, Mogg, Zetteler, & Bradley, 2004). This attentional bias to drug-related cues can be problematic; indeed, attentional bias to alcohol-related cues is associated with patterns of heavy and problem drinking (Cox & Bauer, 1998; Murphy & Garavan, 2011; Sharma, Albery, & Cook, 2001; Stormark, Laberg, Nordby, & Hugdahl, 2000). Indeed, several studies using the Stroop task have found that alcoholics receiving treatment and non-dependent heavy drinking college students show an attentional bias to alcohol-related words, such that their response times were longer for naming the color of alcohol-related words compared to neutral words (Cox & Bauer, 1998; Sharma et al., 2001). Behavioral work by Townshend and Duka (2001) demonstrated that non-dependent heavy drinkers, but not light social drinkers, showed an attentional bias to alcohol-related pictures in a dot-probe task. Taken together, these studies demonstrate that those individuals who show heavy drinking patterns and problems with alcohol display an attentional bias to alcohol-related cues.

According to Franken (2003), increased attention to drug-related cues in turn enhances subjective craving, causing cues to become "motivational magnets", making them more wanted. Whether these cues also become better "liked" is an important question that continues to be addressed in the literature and involves affective processes more so than attentional processes. According to Berridge and Robinson (1995), "wanting" and "liking" are controlled by different brain pathways and therefore do not always operate in tandem; for example, drugs that are wanted or craved are not necessarily liked (Berridge & Robinson, 1995). Although little research has investigated this question in humans, studies have found that affective reactions of "liking" for alcohol-related stimuli have been positively associated with drinking experience (Jajodia & Farleywine, 2003; Palfai & Ostafin, 2003; Payne, Govorun, & Arbuckle, 2008), although the results are less clear than those examining the relationship between attention and drinking habits.

When examining affective responses to alcohol cues, implicit measures are preferred over explicit measures because it is believed that the "wanting" associations that people have with alcohol-related stimuli are automatic and thus individuals may be unaware of these associations (Hofmann, Gawronski, Gschwender, Le, & Schmitt, 2005). In addition, when it comes to the consumption of alcohol, especially among college students, most of whom are not yet legally old enough to drink, implicit measure are beneficial as they are not subject to the influence of self-presentation biases which can pose a threat to explicit measures (Hofmann et al., 2005; Sayette et al., 2000). However, some implicit measures also have particular weaknesses. For example, work using the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998) has demonstrated that heavy drinkers have positive associations with alcohol cues (Jajodia & Farleywine, 2003; Palfai & Ostafin, 2003) while others show that both light and heavy drinkers have negative associations with alcohol cues (Wiers, van Woerdan, Smulders, & de Jong, 2002). These inconsistencies may be due to the use of different stimulus categories across studies or methodological weaknesses of the IAT, which has been criticized for capturing social norms and cultural sensitivities rather than an individual's actual attitudes (Olson & Fazio, 2004).

In order to address the weaknesses of the IAT, Payne, Cheng, Govorun, and Stewart (2005) developed a behavioral task to measure implicit affective responses to stimuli using the Affect Misattribution Procedure (AMP). In the AMP, participants are briefly shown an alcohol or neutral cue followed by a Chinese symbol and are asked to indicate whether the Chinese pictograph is pleasant or unpleasant by pressing one of two keys on a keyboard. As the Chinese pictographs are ambiguous stimuli, participants rely on the primes to evaluate the pictographs. It is believed that while the IAT measures associations between stimuli, the AMP measures affective reactions to the stimuli, which are more indicative of "liking" (Payne et al., 2005). Indeed, AMP research by Payne, Govorun, and Arbuckle (2008) showed that all participants judged cues depicting alcohol to be less pleasant than cues depicting water. Individuals with more positive implicit affective responses to the alcohol stimuli were more likely to choose beer over water in a taste test and were more likely to considered hazardous drinkers based on norms established by Sanchez-Craig, Wilkinson, and Davila (1995). Furthermore, positive associations were found between AMP responses and drinking frequency and quantity as well as the number of life problems (e.g., getting into a fight, being arrested for DWI/DUI) that were reported as a result of drinking (Payne et al., 2008). The AMP also was shown to better predict drinking behavior than both explicit drinking measures and the IAT, likely because the AMP measures affective reactions to stimuli based on direct evaluation of the stimuli rather than on reaction times to categorizations of the stimuli.

Although implicit behavioral measures such as the AMP are thought to be more sensitive than explicit measures, they rely on a response, such as a button press. Because these responses are at least partially under the conscious control of the participant, they may confound concept activation with response output processes (Ito, Thompson, & Cacioppo, 2004). In contrast, psychophysiological measures provide a multifaceted look at the underlying neural events associated with attentional and affective processes involved in the perception of alcohol-related cues. Physiological measures also assess exactly when affective and attentional effects occur and can separate component processes in the stream of information processing (Stern, Ray, & Quigley, 2001), allowing for the distinction between automatic and controlled processes. Researchers interested in the time course of cognitive activity associated with affective and attentional processes have measured event-related potential (ERPs). ERPs are determined by averaging electroencephalogram (EEG) signals obtained from the scalp over time and across multiple presentations of stimuli. This signal averaging technique ultimately separates activity associated with stimulus processing from spontaneous, background EEG activity (Cacioppo, Crites, Gardner, & Berntson, 1994; Stern, Ray, & Quigley, 2001). ERPs are generally described in terms of components, the amplitude of which reflects engagement of a particular cognitive process. In addition to not being dependent on the speed of motor processes and task requirements (Ito & Cacioppo, 2000), ERPs are useful because of their excellent temporal resolution; that is, the ERP is time-locked to the presentation of a specific stimulus type and thus is a direct manifestation of processing related to that cue. Once a stimulus is presented, ERPs illustrate precisely, on the order of milliseconds, when particular aspects of information processing are carried out.

There are several ERP components of interest that have been associated with the affective and attentional processing of different types of stimuli. The N1 component occurs around 100 milliseconds (ms) after stimulus presentation and is maximal at fronto-central electrodes. Although the N1 reflects early perception of and attention to stimuli, research has found that increased N1 amplitudes to pictorial stimuli may indicate negative valence (Olofsson, Nordin, Sequeira, & Polich, 2008), such that unpleasant images command more attention in early processing. One study exploring early attentional responses to alcohol cues found that non-dependent heavy drinkers showed decreased N1 amplitudes in response to alcohol cues relative to neutral cues, whereas light drinkers did not show this pattern (Herrmann, Weijers, Wiesbeck, Böning, & Fallgatter, 2001). Decreased N1 amplitudes to the alcohol cues could reflect an initial shift in attention away from the alcohol stimuli. Other early attentional components, the P2 and N2, have not been explored in connection with alcohol abuse. Both the P2 and N2 are indexes of visual attention, with greater amplitudes indicating greater attention to a stimulus. The P2 is maximal at anterior-central electrodes and occurs around 200 ms after a stimulus. The N2 is maximal at fronto-central electrodes and occurs between 200-400 ms after a stimulus. The N2 component is also influenced by a stimulus's valence, such that unpleasant stimuli evoke decreased N2 amplitudes compared to pleasant stimuli (Olofsson et al., 2008).

The P3 component occurs between 300-600 ms after a stimulus and is maximal over the parietal region. The P3 is thought to reflect attentional, emotional, and motivational reactions to relevant stimuli such that stimuli that evoke strong emotional responses produce larger P3 amplitudes because attention is focused on these stimuli which leads to emotional reactions, which then activate motivational responses to approach or avoid such stimuli. The P3 component is the most widely researched component in connection to alcohol abuse. P3 amplitude has been repeatedly linked to alcoholism, with previous research finding reduced P3 amplitudes to both auditory and visual stimuli in dependent drinkers (Cohen, Ji, Chorlian, Begleiter, & Porjesz, 2002; Glenn, Parsons, & Smith, 1996) as well as those with a family history of alcoholism (Pollock, Polich, & Bloom, 1994; Van Der Stelt, 1999), suggesting its utility as a potential marker for risk of alcoholism. However, research examining P3 amplitudes specifically to alcohol cues (both words and pictures) has found the reverse pattern. Dependent drinkers demonstrate increased P3 amplitudes to alcohol-related words relative to neutral words (Genkina & Shostakovich, 1983; Hermann, Weijers, Wiesbeck, Aranda, Böning, & Fallgater, 2000; Shostakovich, 1987) and to alcohol pictures relative to neutral pictures (Namkoong, Lee, Lee, Lee, & An, 2004) when compared to non-dependent drinkers. Heavy social drinkers not dependent on alcohol have also shown increased P3 amplitudes to alcohol cues compared to light social drinkers (Bartholow, Henry, & Lust, 2007; Herrmann et al., 2001). Moreover, P3 amplitude to alcohol cues has been found to positively correlate with measures of craving (Namkoong et al., 2004), which is consistent with the understanding that the P3 amplitude is larger to motivationally salient stimuli.

In the current study, college drinkers completed the AMP for alcohol and control cues while their EEG was recorded. Based on previous research which found that heavy drinkers have more positive associations with alcohol-related stimuli compared to light drinkers (Jajodia & Farleywine, 2003; Palfai & Ostafin, 2003; Payne et al., 2008), we hypothesize that, compared to non-dependent drinkers, dependent drinkers (classified by their scores on the Michigan Alcohol Screening

Test, MAST; Selzer, 1971) will show more positive behavioral responses to alcohol cues on the AMP. If this hypothesis is supported, it would suggest that dependent drinkers have more positive implicit affective responses to alcohol-related stimuli than non-dependent drinkers. As Herrmann and colleagues (2001) reported decreased N1 amplitudes to alcohol cues in heavy drinkers but not in light drinkers, we expect dependent drinkers to show decreased N1 amplitudes to alcohol cues compared to non-dependent drinkers, which could indicate that initial attention is directed away from alcohol-related stimuli in dependent drinkers more so than non-dependent drinkers. Previous research has found increased P3 amplitudes to alcohol cues in both alcoholics (Genkina & Shostakovich, 1983; Hermann et al., 2000; Namkoong et al., 2004; Shostakovich, 1987) as well as non-dependent heavy drinkers (Bartholow, Henry, & Lust, 2007; Herrmann et al., 2001) when compared to light drinkers. Therefore, we hypothesize that dependent drinkers will show increased P3 amplitudes, indicative of greater processing of motivationally salient stimuli, to alcohol cues relative to non-dependent drinkers. Although previous work has not explored N2 and P2 amplitudes to alcohol cues, we expect to find different patterns of responding for dependent drinkers compared to non-dependent drinkers. However, as ERP patterns of neural responses tend to be consistent across positive and negative components in other areas of research (see Bartholow & Dickter, 2011), we expected dependent drinkers to show lower amplitudes to alcohol cues than non-dependent drinkers for both N1 and N2, and the opposite pattern for both P2 and P3.

Method

Participants

Ninety-six (36 male) right-handed undergraduate students at a medium-sized liberal arts college participated in this study for introductory psychology course credit. The majority of participants were White ($n = 61$), with the remaining participants of the following races (19 Asian, 5 Black, 8 Hispanic, and 3 Mixed or "Other"). Participants' ages ranged from 18-28 years ($M = 19.47$ years, $SD = 2.49$). All procedures were approved by the College's Protection of Human Subjects Committee, and written informed consent was obtained from each participant.

Materials

Stimuli. The stimuli consisted of 80 color photographs, 20 of which were alcohol-related items[1] and another 20 were matched control pictures. Twenty photographs depicted a stimulus in an active setting, characterized by interaction with a person, whereas the remaining twenty photographs depicted a stimulus in an inactive scene, characterized by the stimulus alone. Neutral pictures were created to resemble alcohol cues in terms of brightness, color, and object position. All pictures were pilot-tested with 10 undergraduate students to verify that the contents could be correctly identified and judged as drug-related. The average accuracy rate for alcohol and non-alcohol-related photographs was 97% ± 0.19 (Range: 80%-100%).

Affect Misattribution Procedure. Participants completed the Affect Misattribution Procedure (AMP) as a measure of implicit affective response to alcohol cues (Payne et al., 2008). Participants were instructed to quickly classify Chinese pictographs as either pleasant or unpleasant by pressing one of two keys on a keyboard (counterbalanced between participants). As participants were not familiar with Chinese characters and such stimuli are effectively neutral, categorizations of pleasant and unpleasant reflect affect towards the alcohol or non-alcohol primes. The task consisted of 80 trials, in which an alcohol, smoking, or neutral prime was presented for 200 milliseconds (ms), followed by a blank screen for 125 ms, and then a Chinese pictograph ,which remained on the screen until participants responded (Payne, Cheng, Govorun, & Stewart, 2005). The intertrial interval was 1000 ms. The timing used in the current study was altered from the original timing sequence for the AMP, which presented primes for 75 ms, followed by a blank screen for 125 ms, then the Chinese pictograph for 100 ms, and finally a masking screen appeared until participants made a response (Payne et al., 2005). The timing scheme was altered so that ERPs to the primes could be examined. A pilot study was conducted to test whether the amended time scheme would produce results comparable to the original AMP. Forty non-smoking (27 female) participants aged 18-21, (M = 18.9) were recruited to pilot test the altered timing sequence. A paired-samples t test revealed a significant difference in judgments between classifying a pleasant nonsmoking picture and a pleasant smoking picture, t (39) = 3.48, p = .001, as well as between an unpleasant smoking picture and an unpleasant nonsmoking picture t (39) = -3.47, p = .001. Participants were more likely to respond with "unpleasant" to Chinese pictographs following smoking primes (M = 0.57, SE = 0.04), which replicate the original findings (M = 0.66, SE = 0.04; Payne, McClernon, & Dobbins, 2007).

EEG. EEG data were recorded using a DBPA-1 Sensorium Bioamplifier (Sensorium Inc., Charlotte, VT) with an analog high-pass filter of 0.01 Hz and a low-pass filter of 500 Hz (four-pole Bessel). The EEG was recorded from 74 Ag-AgCl sintered electrodes in an electrode cap, placed using the expanded International 10-20 electrode placement system. All electrodes were referenced to the tip of the nose and the ground electrode was placed in the middle of the forehead, slightly above the eyebrows. Eye movement and blinking were recorded from bipolar electrodes placed on the lateral canthi and peri-occular electrodes on the superior and inferior orbits, aligned with the pupils. Before data collection was initiated all impedances were adjusted to within 0-20 kilohms. EEG was recorded continuously throughout the computer task, and was analyzed offline using EMSE software (Source Signal Imaging, San Diego, CA). Data were undersampled at 500 Hz. The data were segmented between 200 ms prior to stimulus onset and 1000 ms post stimulus onset. After baseline correction over the pre-stimulus interval segmented data was averaged for each subject in each of the conditions. Sample-wide ERPs were identified from the grand-averaged waveforms.

Questionnaires:

Michigan Alcohol Screening Test. Participants completed the Michigan Alcohol Screening Test (MAST; Selzer, 1971) to determine whether they are at-risk for alcoholism. The MAST contains 25 questions that measured the severity of participants' drinking behaviors (i.e. if they have ever experienced delirium tremens, lost a significant other, or gotten into trouble at work due to their alcohol use).

Answers to each question are assigned weighted values of zero, one, two, or five points, and a total score of five or above (range 0-53) is classified as at-risk for alcoholism (Gibbs, 1983; $\alpha = .83$).

CAGE. To further screen for possible alcoholism, the CAGE questionnaire (Ewing, 1984) was administered to participants. The CAGE is a questionnaire designed to identify heavy drinkers and those at-risk for alcoholism. The acronym stands for K/Cut-down, Annoyance, Guilt, and Eye-opener which pertain to the four questions asked by the CAGE. K/Cut-down was evaluated by asking if participants had ever felt that they ought to cut down on their drinking. Annoyance was assessed by asking participants if people have annoyed them by criticizing their drinking. Guilt was measured by asking participants if they felt bad or guilty about their drinking. The eye-opener question asked if participants ever had a drink first thing in the morning to stead their nerves or to get rid of a hangover. Participants who answered "yes" received one point per affirmative answer and negative responses received zero points, with a possible range of 0-4 points. A total score of two or above indicated a pattern of drinking behavior considered at-risk for alcoholism (O'Hare & Tran; $\alpha = .81$).

Drinking Motives Questionnaire. Participants were asked a series of 18 questions regarding their motivations to drink, ranging from social reasons such as "because it makes social gatherings more fun", to coping reasons such as "to forget your worries" (Cooper, 1994). Possible answer choices were Almost never/never, Some of the time, Half of the time, Most of the time, and Almost always/always.

General Drinking Behavior and Demographics. In an interview with an experimenter, participants were asked how often they drink wine, beer, and liquor and the amount that they typically consume. Participants also gave an account of the alcohol that they had consumed in the three weeks prior to the study using a time-line follow-back time procedure, which reconstructed daily drinking via a calendar (Sobell & Sobell, 1992). From this, the total number of standard drinks was calculated by using the following conversions (increments of 1.5 ounces, or the equivalent of one shot of liquor, five ounces of wine, or 12 ounces of beer). Additionally, participants were asked to complete a demographic questionnaire which asked them to indicate their gender, age, race, family income, and parental education levels.

Procedure

After completing the informed consent form, participants were seated approximately 70 cm from a computer monitor at a private computer station in an electrically shielded Faraday cage. The electrodes were attached and tested for low impedances and participants were asked to refrain from excess movement throughout the task to reduce noise in the data. Participants then received instructions on how to complete the Affect Misattribution Procedure, followed by one practice trial to familiarize themselves with the task. Next, they completed the first experimental block consisting of the Affect Misattribution Procedure, which lasted approximately seven minutes. Participants then completed the electronically-based questionnaires described above and participated in an interview with an experimenter regarding their drinking habits, which lasted a total of 20 minutes. Participants were then debriefed, thanked, and dismissed.

Results

Participant Characteristics

Of the 96 participants recruited, 53 were excluded either because they were familiar with Chinese characters ($n = 15$), experienced a computer error during trials ($n = 7$), were missing data ($n = 9$), fell asleep during the study ($n = 2$), or had too many artifacts in the EEG data ($n = 6$). Because the focus of the present study was to examine implicit affective responses to alcohol cues in drinkers, an additional 14 participants were excluded because they reported that they never drank alcohol. The remaining 43 participants were separated into two drinking groups: non-dependent drinkers (those who were not considered at-risk for alcoholism according to the MAST; $n = 26$) and dependent drinkers (those who were classified as at-risk for alcoholism per MAST criteria; $n = 17$). As shown in Table 1, the two groups did not differ from one another in terms of age, gender, or family income (all p values > 0.05). As expected, compared to non-dependent drinkers, dependent drinkers had significantly higher MAST scores, reported drinking significantly more drinkers per occasion, and drank significantly more alcohol over the previous three weeks than non-dependent drinkers. They also reported that they were more likely to get into fights when drinking and forget events after drinking. Dependent drinkers also had higher escape scores (Cahalan et al., 1969). As for perceptions of their drinking behavior, dependent drinkers were more likely to feel guilty about their drinking and report that they felt that they should cut down on their drinking.

Behavioral AMP Responses

Behavioral responses to the AMP stimuli were determined according to Payne et al. (2005) by calculating the average proportion of pleasant responses to the alcohol pictures and non-alcohol pictures for each participant. To test whether implicit affective responses to alcohol cues would differ based on drinking status and stimulus type, a 2 (Drinking category: Non-dependent drinkers *vs.* Dependent drinkers) x 2 (Stimulus type: Alcohol *vs.* Non-alcohol pictures) mixed-model ANOVA with repeated measures on stimulus type was conducted. Results revealed a significant main effect of stimulus type, $F(1, 39) = 17.65$, $p < .001$, $\eta^2 = .312$, such that participants showed a greater proportion of pleasant responses to non-alcohol cues ($M = .62$, $SE = .03$) compared to alcohol cues ($M = .47$, $SE = .03$) overall.

Physiological Data

Visual inspection of the grand averaged waveforms across all participants demonstrated that the AMP elicited the N1, P2, N2, and P3 components. The N1 was maximal at Fz and was quantified as the mean amplitude between 100 ms to 152 ms. Inspection of P2 amplitude at all electrode sites demonstrated that P2 amplitude was maximal across 19 electrodes (P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, PO3, PO4, PO7, PO8, POz, Pz , O1, O2, and Oz). P2 amplitude was quantified as the average amplitude of these 19 electrodes between 152 ms to 260 ms. Inspection of N2 amplitude at all electrode sites demonstrated that N2 amplitude was maximal at Fz and was quantified as the average amplitude between 212 ms to 436 ms. Inspection of P3 demonstrated that P3 amplitude was maximal across 19 electrodes (P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, PO3, PO4, PO7, PO8, POz, Pz , O1, O2, and Oz). P3 amplitude was quantified as the average amplitude of these 19 electrodes between 288 ms to 388 ms. For each of these ERP components, a 2 (Drinking category: Non-dependent drinkers vs. Dependent drinkers) x 2 (Stimulus type: Alcohol vs. Non-alcohol) mixed-model ANOVA with repeated measures on stimulus type was conducted to examine the effects of drinking category and stimulus type on ERP amplitudes. Analyses examining electrode as an additional factor found that electrode did not significantly interact with any variables of interest and thus the analyses below are reported collapsed across electrode site. Greenhouse-Geisser-adjusted *p* values are reported for analyses involving multiple numerator degrees of freedom.

N1. As depicted in Figure 1, the results revealed a drinking category x stimulus type interaction, $F(1, 41) = 8.74$, $p = .005$, $\eta^2 = .176$. Simple main effects analyses demonstrated that non-dependent drinkers exhibited significantly larger N1 amplitudes in response to alcohol cues ($M = -2.95$, $SE = .92$) compared to dependent drinkers, ($M = .13$, $SE = 1.01$), $t(41) = -2.19$, $p = .034$. The two drinking categories did not differ in their amplitudes to non-alcohol cues.

P2. As shown in Figure 2, the interaction between drinking category and stimulus type was significant, $F(1, 41) = 4.09$, $p = .050$, $\eta^2 = .091$. Simple main effects analyses revealed that dependent drinkers had marginally larger P2 amplitudes to alcohol cues (*M* = 11.92, *SE* = 1.25) compared to non-dependent drinkers, (*M* = 8.50, *SE* = 1.48), $t(41) = -1.75$, $p = .088$. There were no differences between the groups in amplitudes to non-alcohol cues.

N2. Results revealed a marginally significant main effect of stimulus type, $F(1, 41) = 3.02$, $p = .090$, $\eta^2 = .069$, such that participants showed marginally larger N2 amplitudes in response to non-alcohol cues (*M* = -9.00, *SE* = 1.16) compared to alcohol cues (*M* = -7.48, *SE* = 1.09). As depicted in Figure 1, this effect was qualified by a significant interaction between drinking category and stimulus type, $F(1, 41) = 11.94$, $p = .001$, $\eta^2 = .226$. Simple main effects analyses demonstrated that non-dependent drinkers showed marginally larger N2 amplitudes to alcohol cues (*M* = -9.44, *SE* = 1.24) relative to dependent drinkers (*M* = -5.52, *SE* = 1.91), $t(41) = -1.80$, $p = .079$.

P3. As depicted in Figure 2, the results revealed a significant interaction between drinking category and stimulus type, $F(1, 41) = 7.03$, $p = .011$, $\eta^2 = .146$. Visual inspection of Figure 2 suggests that dependent drinkers showed a trend towards larger amplitudes to alcohol cues (*M* = 10.89, *SE* = 1.47) compared to non-dependent drinkers (*M* = 7.52, *SE* = 2.03); however, simple main effects analyses revealed that this effect was not significant, $t(41) = -1.21$, $p = .233$.

Relationships between Behavioral, Physiological, and Questionnaire Measures

To examine the relative proportion of pleasant responses to alcohol compared to non-alcohol cues and its relationship with other measures, a behavioral difference score was calculated in which the proportion of pleasant responses on non-alcohol trials were subtracted from the proportion of pleasant responses on alcohol trials. Positive difference scores indicated greater positive implicit affect to the alcohol pictures relative to the non-alcohol pictures. As shown in Table 2, this behavioral bias score was not correlated with any of the ERP component bias scores or explicit questionnaire measures.

Bias scores were also created to examine the relative amplitude of each ERP component to alcohol compared to non-alcohol cues. These difference scores were each calculated by subtracting amplitudes on trials with a non-alcohol prime from amplitudes on trials with an alcohol prime for each ERP component. For the N1 and N2 components, more negative difference scores indicate greater amplitudes to the alcohol pictures relative to the non-alcohol pictures. Whereas for the P2 and P3 components, more positive difference scores indicate greater amplitudes to the alcohol pictures relative to the non-alcohol pictures. N1 alcohol bias scores were positively correlated with scores on the CAGE, mean scores on the conformity subscale of the drinking motives questionnaire, and the frequency as well as the total amount of alcohol that participants reported drinking in the past three weeks. P2 bias scores were positively correlated with mean scores on the conformity subscale of the drinking motives questionnaire. N2 bias scores were positively correlated with CAGE scores and were marginally positively correlated with frequency of drinking in the past three weeks. P3 bias scores were marginally positively correlated with CAGE scores.

Discussion

The goal of the present study was to explore attentional and affective reactions to alcohol stimuli in dependent and non-dependent college-aged drinkers. Behavioral results using the AMP paradigm did not reveal significant differences between drinking groups in affective responses to alcohol cues. However, psychophysiological results were consistent with the hypothesis that non-dependent and dependent drinkers would show different patterns of early attention for ERP amplitudes to alcohol relative to non-alcohol cues. Specifically, non-dependent drinkers showed greater N1 and N2 amplitudes to alcohol cues and smaller P2 and P3 amplitudes to alcohol cues than dependent drinkers.

These findings indicate that non-dependent drinkers directed more early attention initially to the alcohol cues, as indexed by the N1, possibly because these cues might be relatively novel to this group. As a result, these cues may command more attentional processing than a matched control picture of a stimulus that they may encounter more frequently. That dependent drinkers demonstrated greater P2 amplitudes to the alcohol cues than non-dependent drinkers suggests a shift in attention, which was closely followed by another shift such that N2 amplitudes to alcohol cues were larger for non-dependent drinkers than dependent drinkers. This pattern of results may seem peculiar; however, ERP patterns of neural responses tend to be consistent across positive and negative components, as demonstrated in other areas of research such as attention to individuals differing by social group (see Bartholow & Dickter, 2011). The current pattern of results should be interpreted with caution, however, because while the N1 amplitudes were significantly different between drinking groups, dependent drinkers' P2 and N2 amplitudes to alcohol cues were only marginally different from those of non-dependent drinkers.

While the present study's attentional results were somewhat clear, the affective results were less conclusive. Behavioral results of the present study revealed a significant overall effect of stimulus type, with alcohol-related cues judged as less pleasant than neutral cues both for dependent and non-dependent drinkers, which replicates previous work (Payne et al., 2008). Although previous research has additionally found that dependent drinkers show higher levels of pleasant implicit responses to alcohol cues relative to non-alcohol cues in the AMP (Payne et al., 2008), our findings were not consistent with this. We found no significant relationships between AMP alcohol bias scores and measures of drinking behavior and dependence. This is inconsistent with past work which has demonstrated that positive responses to alcohol cues in the AMP correlated with frequency of drinking, amount of alcohol consumed in the previous week, attitudes towards alcohol, and hazardous drinking behaviors in past research (Payne et al., 2008). Perhaps significant relationships were not found among these variables due to the difference in student populations from which participants were obtained. Previous research using the AMP was conducted at the University of North Carolina at Chapel Hill (e.g. Payne et al., 2008), which might have a broader range of drinking behavior than the College of William and Mary. A restricted range of drinking behaviors may have prevented finding significant correlations among drinking variables and AMP responses. Another possible reason for the lack of significant findings in the AMP is the altering of the timing configuration of the AMP. Though necessary for EEG recording, this might have biased the AMP behavioral responses as the alcohol and non-alcohol primes in the present study were presented for more than twice as long as the original paradigm. Future research could manipulate presentation time for the AMP primes to test for a possible effect of varied presentation time as past research has found that presentation time does impact drinkers' behavioral responses to the alcohol cues (Field et al., 2004; Forestell, Dickter, & Young, 2012).

The psychophysiological results in the current study suggest that dependent drinkers showed somewhat greater P3 amplitudes to alcohol-related cues compared to non-dependent drinkers, indicating that dependent drinkers had greater affective processing of alcohol-related cues. Increased amplitudes may directly relate to the cues' rewarding qualities and ability to elicit craving as past research has found that exposure to substance-related cues can elicit craving (Tiffany, Cox, & Elash, 2000) and that levels of alcohol craving relate to P3 amplitude (Namkoong et al., 2004). However, this difference did not reach statistical significance and thus should be interpreted cautiously. For the P3 component, the lack of a significant effect might be a result of timing differences in our study compared to previous research. In the current paradigm, primes were only presented for 200 ms, therefore the P3 component may have been contaminated by the stimulus offset-this is, the neural response to the stimulus leaving the screen. Perhaps if the current study had presented alcohol-related images for a longer duration, this effect would have research significance.

Because both the AMP and the ERP measures of N1, P2, N2, and P3 components used in the present study have been shown to be implicit measures of affect, it may seem surprising that they did not correlate with one another. However, past research comparing implicit and behavioral measures has found no correlation between these measures (Bosson, Swann, & Pennebaker, 2000; Payne et al., 2008; Sherman, Rose, Koch, Presson, & Chassin, 2003). This may be due to methodological differences and measurement error. However, correlations were found between ERP responses and several measures of drinking behavior and motivation. Early attentional processing of alcohol cues, indexed by the N1, correlated with frequency of drinking, total amount of alcohol consumed in the past three weeks, CAGE scores measuring dependence, and conform drinking motives, that is the degree to which participants cited their willingness to drink to fit in or to be liked by others. Another index of early attentional processing, P2 bias scores, also correlated with the drinking motive of conformity. N2 bias scores correlated with CAGE scores and marginally correlated with frequency of drinking. Affective processing of alcohol cues, as indexed by P3 bias scores, marginally correlated with CAGE scores. These correlations support our finding that dependent and non-dependent drinkers show different patterns of implicit responses to alcohol cues.

Past research using behavioral paradigms has demonstrated that heavy drinking patterns are associated with both attentional biases to alcohol-related cues

(Murphy & Garavan, 2011) and positive affective reactions to such cues (Payne et al., 2008), however little psychophysiological research has been conducted examining implicit attentional and affective responses specific to alcohol cues. Unlike the previous behavioral work, psychophysiological research allows us to better understand how the brain responds to alcohol-related cues very early in processing. Different patterns of attentional processing, such as those found in the present study, could reflect differences in craving and reinforcement. Dependent drinkers showed marginally larger P2 amplitudes to alcohol cues compared to non-dependent drinkers, suggesting greater attentional processing of alcohol-related stimuli reminiscent of the attentional biases to alcohol cues found previously in heavy drinkers (Cox & Bauer, 1998; Murphy & Garavan, 2011; Sharma, Albery, & Cook, 2001; Stormark, Laberg, Nordby, & Hugdahl, 2000).

The present study is the first to explore ERPs to alcohol-related and non-alcohol-related stimuli during an implicit affective paradigm (i.e., the AMP) in dependent and non-dependent college-aged drinkers. Previous work has focused on amplitude differences between groups of drinkers for the N1 (Herrmann et al., 2001) and P3 components in response to alcohol-related stimuli (Bartholow et al., 2007; Genkina & Shostakovich, 1983; Hermann et al., 2000; Namkoong et al., 2004; Shostakovich, 1987). The current study was the first to report P2 and N2 amplitudes to alcohol cues in dependent and non-dependent drinkers, adding to our understanding of early attentional processes that occur in response to alcohol cues. Also, past research examining ERP amplitudes to pictorial alcohol cues has focused on either alcohol-dependent patients aged 25-50 (Namkoong et al., 2004), heavy and light drinking adults (Herrmann et al., 2001), or undergraduates scoring high and low in alcohol sensitivity (Bartholow et al., 2007), whereas the current study focused on a more general sample of dependent and non-dependent college student drinkers. College students are an important group to study as they are at a particularly high risk for alcohol-related problems, reporting high levels of binge drinking (Wechsler et al., 1994) as well as alcohol abuse and dependence (Knight et al., 2002).

Limitations of the current study include the fact that our sample was drawn from a college student population at a medium-sized liberal arts school. Therefore our effects may not generalize to older populations of dependent drinkers who have had more experience with alcohol. Perhaps future research can longitudinally test dependent drinkers' attentional and affective reactions to alcohol-related stimuli as these reactions may change over time and with experience. Second, in the current study participants were also exposed to smoking stimuli. This exposure to another type of drug-related cue may have biased participants' reactions to the alcohol cues. Prior research examining implicit attentional and affective responses used only alcohol and neutral stimulus categories (Bartholow et al., 2007; Hermann et al., 2001; Namkoong et al., 2004). Finally, our sample size of dependent drinkers was not sufficiently large enough to pursue possible gender effects. Future research may explore gender as a factor in implicit reactions to alcohol-related stimuli.

In conclusion, these findings suggest that dependent and non-dependent college drinkers show different patterns of early attention to alcohol-related images, as indexed by ERP components. Given that college students have the highest rates of alcohol dependence across all age groups (Grant et al., 2004) and over 12.5% of Americans are projected to suffer from alcohol dependence in their lifetimes (Hassin et al., 2007), future research should continue to examine the complex relationship between affective and attentional responses to alcohol cues and drinking behaviors in dependent and non-dependent college students. This research will better inform targeted intervention efforts aimed at altering dependent drinkers' processing of alcohol cues in an attempt to prevent further dependent drinking patterns.

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Footnotes

[1]This study also included 60 images of smoking and non-smoking related stimuli. Only reaction times to alcohol and non-alcohol-related target stimuli presented together (i.e. 40 relevant trials) were analyzed as the present study focused exclusively on attentional bias to alcohol cues.

Table 1

Participant Characteristics as a Function of Drinking Behavior (% or mean ± SEM)

	Non-dependent Drinker (n = 26)	Dependent Drinker (n – 17)	Test Statistic
Age [in years]	19.12 ± 0.31[1]	19.59 ± 0.63	$t(41) = -.75$
Gender [% Female]	65.40	41.20	$\chi^2(1) = 2.44$
Family Total Yearly Income [%]			
<$50,000	8.00	12.50	$\chi^2(1) = .22$
>$50,000+	92.00	87.50	$\chi^2(1) = .22$
Drinking Measures			
Michigan Alcohol Screening Test (MAST)			
Mean score	1.85 ± 0.27	9.24 ± 1.09	$t(41) = -7.88^{**}$
Drinks before noon [%}	19.20	35.30	$\chi^2(1) = 1.39$
Forgets events after drinking [%]	42.30	82.40	$\chi^2(1) = 6.77^{**}$
Fights when drinking [%]	4.20	35.30	$\chi^2(1) = 7.46^{**}$
Cahalan Escape Drinking Scale			
% Escape Drinkers	50.00	70.60	$\chi^2(1) = 1.79$
Mean score	1.54 ± 0.28	2.71 ± 0.42	$t(41) = -2.42^{*}$
Cooper Drinking Motives			
Mean coping score	1.51 ± 0.15	1.87 ± 0.22	$t(41) = -1.41$
Mean social score	3.25 ± 0.17	3.49 ± 0.24	$t(41) = -.85$
Mean conform score	1.37± 0.09	1.67 ± 0.20	$t(41) = -1.55$
Mean enhance score	2.65 ± 0.22	2.93 ± 0.27	$t(41) = -.82$

Desire for Alcohol Questionnaire (DAQ)			
Strong Desires	1.18 ± 0.06	1.49 ± 0.13	$t(41) = -2.40^{*}$
Negative Reinforcement	1.61 ± 0.15	2.37 ± 0.23	$t(41) = -2.95^{**}$
Control	4.01 ± 0.24	3.47 ± 0.29	$t(41) = 1.45$
Mild Desires	3.10 ± 0.21	3.38 ± 0.27	$t(41) = -.84$
Drinking behavior over previous three weeks			
% consumed alcohol	88.50	82.40	$\chi^2(1) = .32$
Number of drinking occasions	3.27 ± 0.52	4.76 ± 1.05	$t(41) = -1.41$
Highest # drinks per occasion	4.67 ± 0.59	7.91 ± 1.41	$t(41) = -2.41^{*}$
Mean number of standard drinks			
Beer	6.46 ± 2.69	17.90 ± 6.41	$t(41) = -1.86^{+}$
Wine	1.42 ± 0.75	0.90 ± 0.37	$t(41) = .53$
Wine cooler	0.20 ± 0.14	1.19 ± 0.63	$t(41) = -1.85^{+}$
Liquor	5.32 ± 1.29	11.54 ± 3.45	$t(41) = -1.95^{+}$
Total drinks	13.40 ± 3.41	31.53 ± 8.32	$t(41) = -2.29^{*}$
Perceptions about drinking behavior			
Feels guilty about drinking [%]	15.40	58.80	$\chi^2(1) = 8.83^{**}$
Feels they should cut down [%]	23.10	64.70	$\chi^2(1) = 7.45^{**}$
Others worry about drinking [%}	7.70	23.50	$\chi^2(1) = 2.15$
Family history of alcoholism [%]	34.60	58.80	$\chi^2(1) = 2.44$

Notes. [1] Denotes standard error of the mean

$^{+}$ Denotes marginal effects at $p<0.1$

*Denotes statistical significance at $p<0.05$

** Denotes statistical significance at $p<0.01$

Correlations between AMP Proportions, ERP Component Bias Scores, and Questionnaire Measures

Measure	N1 Bias Score	P2 Bias Score	N2 Bias Score	P3 Bias Score	AMP Bias
Conform Drinking Motive	.391*	.347*	.192	.240	.034
Frequency of Drinking	.429**	.182	.275+	-.082	.027
Total Alcohol Consumed	.345*	.036	.249	.122	.019
CAGE Score	.366*	.225	.398**	.294+	.095

Notes. + Denotes marginal effects at $p<0.1$

*Denotes statistical significance at $p<0.05$

** Denotes statistical significance at $p<0.01$

Figure 1. *ERP Grand Average Waveform at electrode Fz*
Dependent and Non-dependent Drinker' N1 and N2 Attentional Responses to Alcohol and Non-alcohol Cues

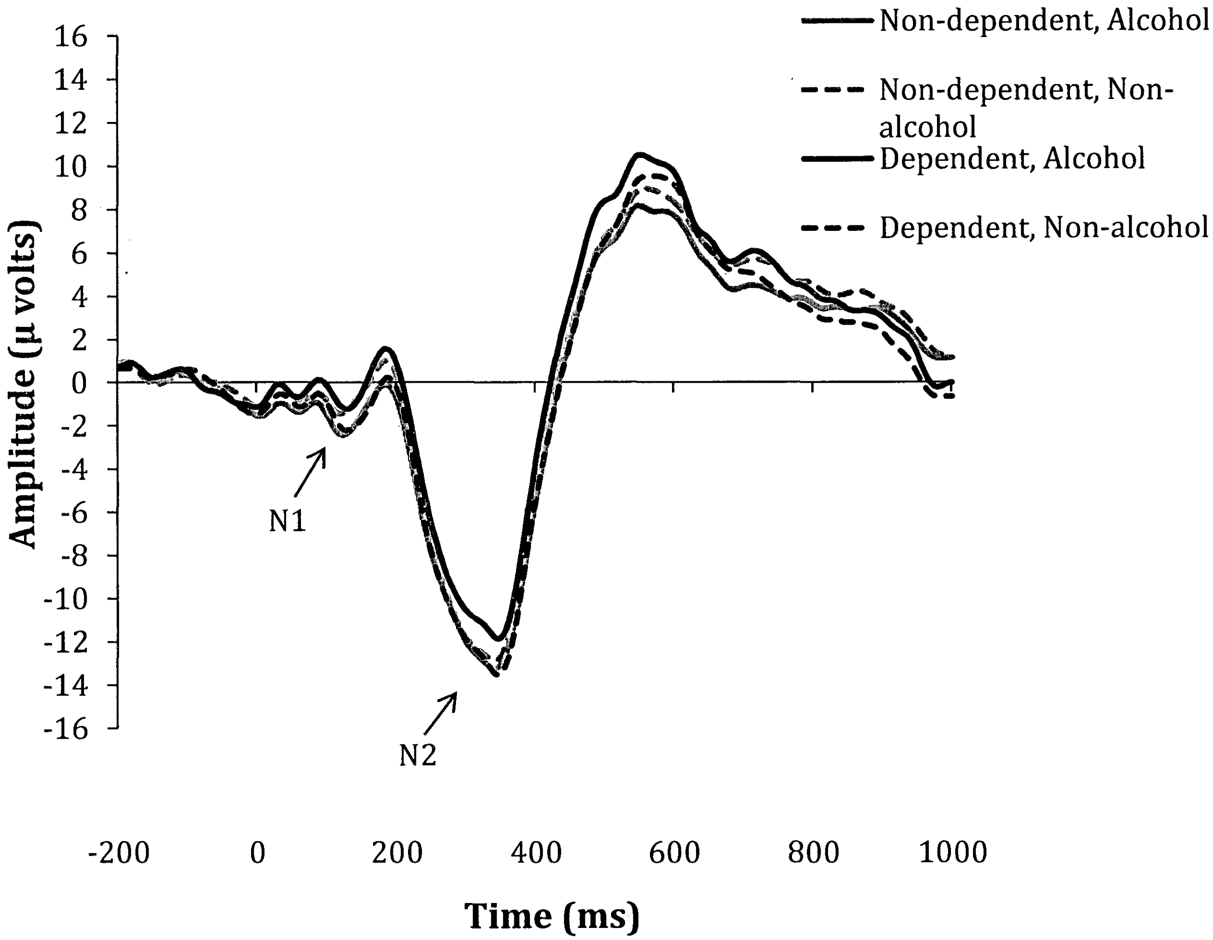

Figure 2. *ERP Grand Average Waveform at electrode Pz*
Dependent and Non-dependent Drinker' P2 and P3 Amplitudes to Alcohol and Non-alcohol Cues