Memory for Emotional Picture Cues During Acute Alcohol Intoxication

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ABSTRACT. Objective: Memory affects behavior by allowing events to be anticipated and goals to be planned based on previous experiences. Emotional memory, in particular, is thought to play a central role in behavior in general and in drinking behavior in particular. Alcohol intoxication has been shown to disrupt intentional, conscious memory, but not unintentional, implicit memory for neutral stimuli; however, its effects on emotional memory are not well understood. This study examined whether alcohol intoxication affected memory for emotionally valenced stimuli by testing explicit recall and implicit repetition priming of emotional picture cues. **Method:** Participants were 36 young adults (21–24 years old, 16 women) who received an alcohol, placebo, or no-alcohol beverage. Both cue exposure and memory testing occurred after beverage consumption (i.e., during intoxication for the alcohol group). **Results:** Alcohol intoxication impaired explicit recall of all cue types

but did not impair implicit repetition priming. Emotionally negative and positive cues were more often recalled compared with neutral cues across all beverage groups, and emotionally negative cues demonstrated more priming than emotionally positive or neutral cues in all beverage groups. **Conclusions:** Alcohol intoxication disrupted effortful recall of all cues, although the relative memory advantage of emotionally valenced over-neutral stimuli remained even after drinking. The effects of alcohol on unintentional memory priming were not statistically significant, but the effects of emotionally negative cues were. Further research is needed to better understand alcohol intoxication and emotional valence effects on memory processes during implicit memory tasks and the possibility that negative mood facilitates memory priming of negative emotional stimuli. (*J. Stud. Alcohol Drugs*, 73, 718–725, 2012)

ALCOHOL IS KNOWN TO MODULATE the experience of emotion. Drinkers commonly expect reductions in negative affect and enhancement of positive affect during intoxication (Cooper et al., 1995; Wills and Shiffman, 1985). Yet how alcohol affects emotional memory processing is unclear, and little is known about whether acute intoxication influences how emotional stimuli are processed and remembered, or whether alcohol selectively disrupts the memory processing of distressing information.

Emotional memories serve as an important survival function and maintain a “privileged status” (p. 54) compared with emotionally neutral memories (LaBar and Cabeza, 2006). Processing of emotionally laden memories has been associated with unique neural (Ritchey et al., 2011) and autonomic nervous system responses (Buchanan and Lovullo, 2001; Cahill and McGaugh, 1998; Garcia et al., 2011; Schwabe et al., 2008). These distinct brain and body responses to emotional stimuli result, at least in part, from the

ability of emotional cues to enhance arousal, draw greater attention, and achieve greater relevance than stimuli without emotional content (e.g., Croucher et al., 2011; LaBar and Cabeza, 2006). Emotional cues also often incite psychological processes that can further reinforce or suppress memory formation and retention (e.g., Hayes et al., 2010). Based on alcohol’s ability to influence emotional experience and the many psychological processes that control emotional regulation, it is possible that disruption of emotionally laden memories by alcohol may contribute to the cascade of psychological and physiological events that can lead to dysregulated, uncontrolled drinking.

The importance of understanding the operation of memory processes during alcohol intoxication is further highlighted by theories suggesting that memory processes affect the development and maintenance of alcohol and other drug use behaviors, even in the face of explicitly recognized negative consequences (Anderson et al., 2011; Robinson and Berridge, 2008; Tiffany, 1990). Memory is a complex, multidimensional construct (e.g., Dew and Cabeza, 2011). For example, in addition to the effortful and intentional memory processes engaged—for example, when we try to remember items on a grocery list, a person’s face, or the driving route to a store (i.e., explicit memory)—faster and less effortful memory processes are involved in the control of attention allocation and contingency-guided decision making (e.g., Lambert and Sumich, 1996) outside of awareness (i.e., im-

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plicit memory). A consistent literature documents that, for emotionally neutral cues, acute alcohol intoxication often disrupts intentional, explicit memory while leaving implicit memory intact (Garfinkel et al., 2006; Lister et al., 1991; Ray and Bates, 2006; Ray et al., 2004; Tracy and Bates, 1999). The current study was designed to examine whether acute alcohol intoxication differentially influences memory for emotionally valenced and neutral picture cues using both explicit recall and implicit repetition priming tasks.

Explicit memory processes are based on deliberate and effortful recall of past events and require attention and conscious awareness (Dew and Cabeza, 2011; Mulligan, 2012; Schacter and Tulving, 1994; Schacter et al., 2007; Tulving et al., 1982). Using a free-recall test to tap explicit memory processes, a memory bias for emotional cues compared with emotionally neutral cues has been consistently observed (e.g., Cahill and McGaugh, 1998; Hamann, 2001; Strongman, 1982). This emotional bias in recall was also observed in participants who were exposed to picture cues approximately 1 hour after drinking alcohol and tested 2–3 hours later, although recall in general was significantly reduced by alcohol (Knowles and Duka, 2004). Interestingly, acute alcohol intoxication also enhanced the internal experience of emotion (reports of more positive mood after vs. before drinking) and the perception of emotional content in exteroceptive cues (alcohol, compared with the placebo beverage group, reported higher valence scores). Furthermore, recall was significantly better for cues that were considered more arousing and tended to be better for cues whose valence was rated as more pleasant (Knowles and Duka, 2004).

Although emotional content consistently facilitates performance on explicit memory tests, the effect of emotional valence on tests of implicit memory is less studied and less clear. Implicit memory processes proceed unintentionally, without conscious awareness, and require little attention or other cognitive resources (Dew and Cabeza, 2011; Graf and Schacter, 1985; Roediger et al., 2007; Schacter and Tulving, 1994; Schacter et al., 2007; Tulving et al., 1982). Implicit compared with explicit memory processes appear to be relatively inflexible and more influential determinants of behavior (Bargh and Chartrand, 1999; Watkins et al., 1996), which may be particularly important for understanding the development and maintenance of problematic alcohol use behaviors (Wiers et al., 2007). Using a repetition priming task (the facilitation of performance because of prior exposure) to tap implicit memory processing, an emotional bias for negative emotional versus neutral picture cues was observed, but only when subjects were asked to categorize pictures based on valence (negative or neutral) during the test phase (LaBar et al., 2005), not when categorization was independent of valence (Dillon et al., 2007) or when a stimulus detection task was used (Marchewka and Nowicka, 2007). Dillon and colleagues (2007) argued that the valence categorization test procedure used in LaBar's study (2005)

may have enhanced detection of an emotional bias in implicit processing by channeling participants' attention toward the emotional salience of cues, but other differences in the design of these studies may also explain this discrepancy. We know of no studies that have examined the influence of alcohol intoxication on implicit memory for emotional stimuli. Thus, further characterization of how the emotional characteristics of stimuli affect memory processing in implicit tasks is needed, as is research on the influence of acute intoxication on implicit memory for emotional cues.

This study sought to build on the limited existing literature on the interplay between alcohol, emotion, and explicit memory (i.e., Knowles and Duka, 2004) and explore the yet-unstudied relationship between alcohol, emotion, and implicit memory. To accomplish this, participants received either an alcohol, a placebo, or a no-alcohol beverage and were exposed to emotionally valenced and emotionally neutral picture cues. Then, they were tested using a free-recall task (as a measure of explicit memory) and a repetition priming task (as a measure of implicit memory). We expected to replicate the common finding (e.g., Dillon et al., 2007; Knowles and Duka, 2004) that free recall for positively and negatively valenced emotional cues is greater than for neutral cues in the no-alcohol and placebo conditions. We also hypothesized that this emotional recall bias would be observed in the group receiving alcohol (Knowles and Duka, 2004). In keeping with prior studies, we predicted that alcohol would not impair priming for neutral cues using an implicit repetition priming task. The limited literature studying priming for emotionally valenced cues was insufficient to generate a hypothesis; these analyses were exploratory.

Method

Participants

This study was approved by the university institutional review board for the protection of human subjects involved in research. Thirty-six volunteers (16 women) between the ages of 21 and 24 years were recruited through advertisements of a study on emotion, memory, and alcohol in university and community newspapers, as well as on bulletin boards. Exclusion criteria were history of a childhood learning disability or special education, first language other than English, positive history of psychiatric or neurological disorder or treatment, medical conditions that preclude alcohol administration, 20% over- and under-weight from the ideal for age and gender, current alcohol dependence, regular (weekly) illicit or prescription drug use, history of treatment for a substance use disorder, positive familial history of alcohol use disorders, lifetime history of any substance use disorder on the part of the prospective participant's biological mother (to rule out prenatal alcohol exposure effects), and, for women, pregnancy. Participants reported their race as White, not

of Hispanic origin (60%); Asian or Pacific Islander (23%); Hispanic (6%); Black, not of Hispanic origin (3%); or other (9%). All participants reported at least some college education. To ensure that participants were not exposed to alcohol exceeding their regular drinking levels, two individuals who consumed less than four standard alcohol drinks (three drinks for women) per occasion less than twice per month in the previous year were also excluded, in line with Recommended Council Guidelines on Ethyl Alcohol Administration in Human Experimentation (National Advisory Council on Alcohol Abuse and Alcoholism, 1989).

Beverage conditions

Alcohol doses were calculated based on weight (0.90 ml/kg for men, 0.75 ml/kg for women) and were mixed with orange juice in a ratio of 4 parts mixer to 1 part ethanol. The beverage was divided into three equal drinks, and each drink was consumed during a consecutive 5-minute interval. All participants consumed three volume-controlled drinks that were either 100% orange juice mixer (told no alcohol and received no alcohol), mixer with 100 μ l ethanol float per cup and other olfactory cues (placebo condition), or mixer plus 95% ethanol dose (alcohol condition). The alcohol doses were designed to achieve a target blood alcohol concentration (BAC) near the legal limit of intoxication for driving in the United States (80 mg/dl). These doses are consistent with intoxication levels commonly achieved by college-aged drinkers (Kraus et al., 2005).

Procedure

Participants provided written informed consent and were randomly assigned to one of the following three groups ($n = 12$ per group): an alcohol group, a placebo group, or a no-alcohol group. Participants in the alcohol and placebo groups were both told that they would receive some alcohol, whereas those in the no-alcohol group were told that they would not receive alcohol. This design allowed us to examine the potential effects of alcohol expectancy on memory. Each participant individually completed one laboratory session that lasted approximately 3.5 hours and consisted of a questionnaire completion phase, a picture-cue exposure phase, and a memory task phase. All participants were asked to refrain from alcohol or any other drug use (except caffeine and nicotine) for 24 hours before the laboratory session and to eat a light meal 3 hours before arrival. Absence of alcohol at the time of testing was confirmed by breath alcohol analysis. Following questionnaire completion, participants were seated in a comfortable chair in front of a television screen in a sound-attenuated, dimly lit testing room. Sensors for physiological recording were attached to them (physiological data during cue exposure are reported in Vaschillo et al., 2008). To equate their cognitive load before picture presentation,

participants performed a standardized, low-demand "plain vanilla" task (Jennings et al., 1992) for 5 minutes, wherein they viewed colored rectangles and silently counted the number of blue rectangles. Immediately after participants performed this baseline task, they consumed beverages. When a BAC of ~ 60 mg/dl was reached on the ascending limb of the BAC curve (or after 10 minutes in placebo and no-alcohol conditions), participants performed the baseline task again, followed by the picture-cue learning phase.

At the end of the experiment, participants rated perceived level of intoxication during the experiment on a scale of 1 = *not at all* to 7 = *moderately intoxicated*. The participants in the alcohol-challenge group reported higher levels of perceived intoxication ($M = 4.45$, $SD = 1.81$) than did the participants in the placebo-challenge ($M = 2.55$, $SD = 0.82$) and no-alcohol ($M = 1.00$, $SD = 0.00$) groups.

Picture-cue learning phase

Participants viewed six categories of pictures: emotionally negative, emotionally positive, and emotionally neutral pictures and alcohol-, marijuana-, and polydrug-related pictures. The focus of the present study was emotional memory processing; thus, only data from the emotionally negative, positive, and neutral cue blocks were analyzed. Emotional pictures were from the International Affective Picture System (IAPS; Lang et al., 1995). Based on the IAPS standardized ratings, negative and positive pictures were matched on the ratings of arousal but varied in valence. Neutral picture cues were of moderate valence and low arousal. Each category of pictures (i.e., picture cue block) contained a set of 15 pictures that were presented twice; the order of picture presentation within sets was randomized. Each picture was presented for 5 seconds, with a 5-second inter-picture interval (blank screen). During the inter-picture interval, participants verbally provided either a liking or arousal rating for each picture cue using a 9-point Self-Assessment Manikin (Lang et al., 1995). The order of liking and arousal ratings was counterbalanced across sets within blocks. Each cue block lasted for 5 minutes, with a 30-second inter-block interval. Cue blocks were presented in counterbalanced order across participants. The mean BAC of participants in the alcohol group at the beginning of the cue learning phase was 77 mg/dl ($SD = 25$ mg/dl), and participants were on the ascending limb of the BAC.

Memory tests

The free-recall task started approximately 10 minutes after the picture-cue learning phase ended. Participants were given 10 minutes to verbally recall, one at a time and in detail, as many picture cues as possible from the series of pictures seen during the learning phase. Two independent raters determined whether the description of the picture cue

represented a correctly recalled picture. To be identified as correct, all of the recalled content information had to be accurate, and the picture had to be identifiable on the basis of the description (Knowles and Duka, 2004). There were no disagreements between two independent raters across the 36 subjects. The mean BAC of participants in the alcohol group at the beginning of the free-recall task was 70 mg/dl ($SD = 12$ mg/dl), and participants were on the descending limb of the BAC.

The repetition priming task was administered next, approximately 25 minutes after the completion of the picture-cue learning phase. We previously showed that repetition priming is not contaminated by a prior free-recall task that involves the same stimulus cues (Ray and Bates, 2006). Participants gave “picture/nonpicture” decisions for 360 items presented sequentially in random order. Items included the 90 pictures that had been previously viewed (15 from 6 cat-

egories), 90 new pictures (i.e., not previously viewed) from the same 6 categories, and 180 nonpictures. Nonpictures were created by electronically distorting pictures that were not used in the experiment. Each stimulus was presented for 10 seconds, and participants were asked to indicate their picture/nonpicture decision for each stimulus as quickly and as accurately as possible by making one of two keyboard responses. Reaction time and accuracy data were collected. The mean BAC of participants in the alcohol condition at the beginning of the repetition priming task was 69 mg/dl ($SD = 8$ mg/dl).

Data analysis

Two repeated-measures analysis of variance were conducted to examine the effects of alcohol intoxication (three between-subject beverage groups: alcohol, placebo, and

FIGURE 1. (A) The average number of emotionally neutral, emotionally negative, and emotionally positive picture cues recalled. (B) The average number of picture cues (regardless of cue type) recalled by individuals in the alcohol-challenge, placebo-challenge, and no-alcohol beverage conditions. There were significant main effects of picture cue type (Panel A, $*p < .05$) and beverage group (Panel B, $*p < .05$); however, there was no beverage Group $\times$ Picture Cue Type interaction.

FIGURE 2. The average amount of priming to emotionally neutral, emotionally negative, and emotionally positive picture cues by individuals in the alcohol-challenge, placebo-challenge, and no-alcohol beverage conditions. Priming was calculated as the difference between mean reaction time to previously viewed picture cues and mean reaction time to new picture cues. There was a significant main effect of picture cue (* $p < .05$, negative vs. positive and neutral) but no significant differences between beverage groups. The beverage Group $\times$ Picture Cue Type interaction did not reach statistical significance but demonstrated a medium effect size.

no-alcohol), picture cue type (three within-subject repeated measures: negative, positive, and neutral), and their interaction on free recall and repetition priming of picture cues. For free recall, the dependent variable was the total number of picture cues accurately recalled per picture cue block. For the repetition priming task, the dependent variable was the difference between mean reaction time to previously viewed picture cues and mean reaction time to new picture cues, calculated separately for each of the three cue blocks (Burgund et al., 2003; Carlesimo, 1994; Horner and Henson, 2009; Joordens and Becker, 1997; Ober et al., 1991; Waszak and Hommel, 2007). All reaction times fell within a priori established limits (i.e., 399 ms–2000 ms). On average, the response error rate was 3.5%; incorrect response trials were excluded from analyses. A square root transformation of the reaction time data (cf., Artes et al., 2002; Wilson et al., 2005) was conducted before analyses to normalize the distribution.

Results

Beverage condition significantly affected explicit recall of the picture cues, $F(2, 33) = 8.37$, $p < .01$, partial $\eta^2 = .34$. As illustrated in Figure 1, individuals who received alcohol recalled fewer pictures than those who received no alcohol or placebo beverages ($ps < .05$). Recall was not different between the no-alcohol and placebo groups. In addition, the

emotional valence of the picture cues significantly affected how well they were recalled, $F(2, 66) = 25.06$, $p < .01$, partial $\eta^2 = .43$. A greater number of positive and negative emotional cues were recalled compared with neutral picture cues—negative vs. neutral picture cues, $F(1, 33) = 56.00$, $p < .01$, partial $\eta^2 = .63$; positive vs. neutral picture cues, $F(1, 33) = 30.39$, $p < .01$, partial $\eta^2 = .48$. The lack of significant interaction between picture cue type and beverage condition, $F(4, 66) = .39$, $p = .82$, partial $\eta^2 = .02$, suggested that acute alcohol intoxication impaired explicit free recall equally for all picture cue types.

Figure 2 illustrates the results of parallel analysis of repetition priming data. There was a significant main effect of picture cue type, $F(2, 66) = 4.92$, $p < .01$, partial $\eta^2 = .13$. Participants showed an enhanced amount of priming for negative emotional picture cues compared with a lower and virtually equivalent amount of priming for positive emotional and neutral picture cues—negative vs. neutral picture cues, $F(1, 33) = 11.14$, $p < .01$, partial $\eta^2 = .25$; positive vs. neutral picture cues, $F(1, 33) = 0.14$, $p = \text{n.s.}$, partial $\eta^2 = .00$. There was no significant main effect of beverage condition, $F(2, 33) = .35$, $p = .71$, partial $\eta^2 = .02$, suggesting that neither alcohol nor placebo disrupted priming compared with the no-alcohol beverage. Nor was there a Picture Cue Type $\times$ Beverage Condition interaction, $F(4, 66) = 1.44$, $p = .23$, partial $\eta^2 = .08$.

Discussion

Learning and memory have long been considered powerful influences on alcohol use behaviors and the development of alcohol use disorders, as well as on outcome success following treatment for substance use disorders. Yet very little is known about how salient characteristics of stimuli in the environment, such as emotional valence, affect intentional and unintentional memory processes during states of acute intoxication. In this study, we examined how different modes of memory for emotionally valenced visual cues in the environment are disrupted during a single episode of alcohol intoxication.

The results showed that effortful recall of negatively and positively emotionally valenced stimuli is impaired by acute alcohol intoxication. Yet despite an overall depression of explicit memory during intoxication, alcohol did not selectively interfere with the explicit memory advantage engaged by emotional picture cues. In other words, even when intoxicated, participants recalled more negative and positive emotional cues compared with neutral picture cues. Thus, we found no evidence that alcohol selectively interfered with the memory processing of negative information. The maintained precedence of emotional over neutral visual information processing during acute intoxication in the present study supports Knowles and Duka (2004), who showed that emotional cues were better recalled than neutral cues when cues were learned under the influence of alcohol. We further extended Knowles and Duka by demonstrating that this emotional precedence was maintained even when memory retrieval occurred closer in time to cue exposure and at a higher level of intoxication. The present study tested cue recall starting 10 minutes after cue exposure, when average BACs were 70 mg/dl, whereas Knowles and Duka tested recall approximately 3 hours after cue exposure, when BACs were at or below 40 mg/dl. These findings suggest that the disruptive effects of alcohol on effortful memory are insufficient to override the advantage of emotionally laden stimuli for neural resource allocation.

This was the first study to examine acute alcohol intoxication effects on unintentional memory priming for emotional cues. We found that alcohol intoxication did not interfere with this mode of implicit memory processing for neutral and emotional picture cues. Although this lack of a main alcohol effect was consistent with the previous literature that used emotionally neutral word cues (Garfinkel et al., 2006; Lister et al., 1991; Ray and Bates, 2006; Ray et al., 2004; Tracy and Bates, 1999), there was a medium effect-size (partial $\eta^2 = .08$) interaction between beverage group and emotional cue valence (Figure 2) that did not reach statistical significance. This may suggest that memory priming for emotional cues may be enhanced during acute intoxication; however, studies of larger samples are needed before strong conclusions can be reached.

The present study adds new insight into how the emotional characteristics of visual cues may influence implicit memory processing more generally. We found a priming bias for negative emotional versus neutral and positive picture cues across beverage group conditions. This parallels the results of LaBar et al. (2005) but contrasts those of Dillon et al. (2007). There are important similarities and differences between the present study and these prior studies. All three studies used emotionally valenced and emotionally neutral picture cues selected from the IAPS and tested priming using a categorization task; however, a major distinction between studies is the type of categorization task used for testing. In LaBar et al. (2005), participants were asked to categorize pictures based on valence (i.e., negative vs. neutral) during the test phase. In Dillon et al. (2007), subjects were asked to categorize pictures based on location (i.e., indoor vs. outdoor). The use of an emotionally relevant categorization strategy was suggested (Dillon et al., 2007) to explain why a priming bias for negative cues was noted in LaBar et al. (2005) but not in Dillon et al. (2007). The present study used a picture/nonpicture categorization task, which would seem to parallel Dillon et al. (2007) in that the categories were not emotionally based, making it difficult to understand why our results parallel those in LaBar et al. (2005). However, another notable difference between the present study and both of the prior studies is the way in which picture cues were presented during the learning phase. In the present study, pictures were presented in blocks (e.g., all negative cues were presented sequentially), whereas in the prior studies, stimulus order was pseudorandom such that no more than two or three neutral or negative cues were presented consecutively. Presenting pictures in blocks may have induced a mood state that was consistent with the block's valence (Bradley et al., 1996; Sutton et al., 1997), and this mood state may have been sufficiently strong to facilitate an emotional bias in priming, at least in the case of the emotionally negative cues. This raises the possibility that the block design of the learning phase in this study acted in much the same way as the use of an emotionally relevant categorization task in LaBar et al. (2005); that is, both may have acted to enhance conceptual elaboration of the emotional content of negative stimuli. This idea is consistent with the mood-congruent bias in conceptually driven implicit memory noted in individuals with depression (Watkins et al., 2000) and provides preliminary support for these mood-congruent effects in a healthy, nonclinical sample. The reason that this emotional bias in priming was not observed for the positive picture cues is unclear but warrants further examination. There may be mediating factors; for example, the content of the positive cues may have been insufficiently "positive" to induce positive mood within the experimental context, or these cues may not have had the same impact (i.e., significance or relevance) on the participants as the negative cues (Croucher et al., 2011).

There are also limitations to the conclusions of this study. The relatively modest sample size reduced power to detect significant interactions. Furthermore, this study was not designed to differentiate alcohol effects on encoding and retrieval (i.e., both learning and memory tests occurred after alcohol was consumed). This study tested memory in a relatively young, healthy sample of individuals who were predominantly non-Hispanic White and who had achieved some level of college education; thus, the results may not generalize to older, unhealthy, or ethnic minority populations. The between-subject design of this study did not allow for assessment of within-person changes in implicit and explicit memory task performance in the sober versus intoxicated condition, which may have identified individual differences in susceptibility to alcohol-induced memory impairments (Wetherill and Fromme, 2011). Finally, the memory tasks and stimulus cues used in this study had the advantages of validation and standardization. IAPS pictures were drawn in many cases from the news report and public media and, thus, represent real-world stimuli. Nonetheless, these cues were presented in a controlled laboratory setting, which is less complex (i.e., temperature controlled, sound attenuated, fewer competing stimuli from surroundings) and personally meaningful than the environmental contexts often encountered in everyday life (Axmacher et al., 2010). Thus, it will be important to examine whether the present results generalize to effortful recall, memory priming because of repeated exposure, and other memory processes (e.g., semantic priming) in naturalistic environments (i.e., in a bar).

In conclusion, the present study found that both alcohol intoxication and the emotional content of environmental cues influence visual memory. An emotional bias in effortful memory recall was maintained even during acute alcohol intoxication, although it was not strong enough to overcome the generalized memory impairment caused by alcohol. Unintentional memory priming for all picture cues was resistant to the effects of alcohol intoxication but was enhanced by negatively valenced emotional content in picture cues. Further research is needed to better understand alcohol intoxication and emotional valence effects on memory processes during implicit memory tasks and the possibility that negative mood may facilitate memory priming of negative emotional stimuli. Understanding the nuanced relationship between alcohol intoxication and emotional memory processing may help elucidate the underlying body and brain mechanisms that contribute to changes in drinking behavior.

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