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A Multimodal, Longitudinal Investigation of Alcohol's Emotional Rewards and Drinking over Time in Young Adults

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Abstract

Theories of Alcohol Use Disorder (AUD) have long suggested that alcohol's emotional rewards play a key role in reinforcing problematic drinking. Studies employing survey methods, in which participants recall and aggregate their experiences with alcohol in a single questionnaire, indicate that self-reported expectancies and motivations surrounding alcohol's emotional rewards predict problematic drinking trajectories over time. The current study is the first to combine laboratory alcohol-administration, ambulatory methods, and longitudinal follow-ups to assess whether alcohol's ability to enhance positive mood and reduce negative mood predicts later drinking problems. Sixty young heavy social drinkers (50% female) participated in laboratory-based alcohol-administration, attending both alcohol (target BAC .08%) and no-alcohol laboratory sessions. Forty-eight of these participants also wore transdermal alcohol monitors and completed mood surveys outside the laboratory for 7-days. Participants reported on their drinking at 18-month follow-up (90% compliance). Controlling for baseline drinking, greater negative mood reduction from alcohol at baseline predicted more drinking problems at follow-up, an effect that emerged as consistent across methods capturing alcohol's emotional rewards in the laboratory, b= −.24, p=.02, as well as via ambulatory methods, b=−3.14, p=.01. Greater positive mood enhancement from alcohol, captured via laboratory methods, also predicted drinking problems, b=.16, p=.03, and binge drinking, b= 3.22, p=.02, at follow-up. Models examining drinking frequency/quantity were non-significant. Results provide support for emotional reward as a potential factor in the development of problematic drinking.

Keywords

Alcohol; emotion; longitudinal; laboratory; ambulatory

Research has long suggested that an understanding of alcohol's emotional rewards is integral to the understanding of problematic drinking (Blane & Leonard, 1999; Koob & Le Moal, 1997). Alcohol consumption has the ability to induce intense feelings of elation and happiness and, in some contexts, reduce feelings of distress (Sher et al., 2005). Emotional responses to alcohol are widely believed to reinforce drinking and, in some individuals,

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promote problematic levels of consumption. In line with such suppositions, research indicates that individuals at risk for developing an alcohol use disorder (AUD) are more sensitive to alcohol's emotional rewards (Fairbairn, Sayette, Aalen, et al., 2015; Levenson et al., 1987; Sher & Walitzer, 1986), and drinkers overwhelmingly report that the desire to increase positive mood and reduce negative mood are primary factors motivating their drinking (Cooper et al., 1995; Goldman et al., 1999).

To further explore associations between emotional responses to alcohol and drinking problems, a number of longitudinal survey studies have been conducted that hint at important links between alcohol's emotional effects and subsequent problematic drinking patterns (Jones et al., 2002; Kuntsche et al., 2005). More specifically, in such studies, (sober) participants complete questionnaires reporting on their expectations for how alcohol might impact them (e.g., "Alcohol makes me feel happy") and/or their specific motivations for drinking alcohol (e.g., "Because it's exciting") and these same participants' drinking behavior is then assessed over time (Anderson et al., 2013; Christiansen et al., 1989; Cooper et al., 2008). This research has provided valuable information about associations between people's broad schemas and perceptions surrounding alcohol and subsequent drinking patterns. However, relying on participants' perceptions surrounding alcohol and thus requiring them to recall and aggregate experiences across time and contexts, these studies are unable to speak to how alcohol might "truly" affect these individuals. Thus, while informative surrounding participants' beliefs, this research leaves unanswered questions of alcohol's effects and the relationship between these effects and subsequent drinking.

H2

Alcohol's Emotional Rewards: Theory and Research Methods

The notion that alcohol's emotional rewards drive consumption has not only inspired empirical research but also addiction theory. Indeed, the notion that alcohol consumption yields powerful emotional rewards represents a cornerstone of many modern theories of Alcohol Use Disorder (AUD). These theories diverge in the specific mechanism, systems, and context of focus: some take a neurobiological approach, examining the impact of alcohol on brain reward systems (Koob & Le Moal, 1997), others focus mainly on alcohol's tension reducing effects, emphasizing alcohol's mood-enhancing effects within the context of stress (Greeley & Oei, 1999; Stritzke et al., 1996), and still others take a cognitive approach, hypothesizing that alcohol's emotional rewards can be understood through examining alcohol-related cognitive impairment (Hull, 1981; Sayette, 1993; Steele & Josephs, 1990). While the specific proposed mechanism varies across theoretical frameworks, these theories are united in that they view alcohol's emotional rewards as directly reinforcing problematic drinking behavior.

Although prior longitudinal research exploring alcohol's emotional effects has centered around retrospective/aggregate recall surveys, several different approaches have been employed that permit the direct examination of alcohol's emotional effects (Sher et al., 2005). One paradigm that is often used to examine alcohol's impact on mood is ambulatory methodology, which involves the repeated assessment of alcohol consumption and also mood within participants' daily lives (Mehl & Conner, 2013; Shiffman et al., 2008).

Although ambulatory alcohol research initially relied mainly on self-report measures of drinking, technological advances have recently expanded the range of measurement options available to ambulatory researchers (Mehl & Conner, 2013). These advances have included transdermal alcohol biosensors which assess the concentration of alcohol within insensible perspiration and, upon individual calibration, may be used to produce estimates of blood alcohol concentration (BAC; Fairbairn et al., in press; Leffingwell et al., 2013; Luczak & Rosen, 2014). Ambulatory studies offer notable advantages for the investigation of drinking, permitting the examination of alcohol's effects on mood within the everyday contexts in which alcohol is actually consumed (Armeli et al., 2003; Fairbairn et al., 2018; Piasecki et al., 2012). The limitations of standard ambulatory methods include likelihood for enhanced measurement noise (compared to measurements taken in controlled laboratory settings) and the inability of these methods to directly inform causal inferences.

A second method that has long been applied to the examination of alcohol's impact on emotion is the laboratory alcohol-administration paradigm (Levenson et al., 1980; Sayette et al., 2012; Sher & Walitzer, 1986). Alcohol-administration studies involve the administration of either alcohol or a non-alcoholic beverage in a laboratory setting (Higgins & Marlatt, 1975; Wilson & Lawson, 1976), with some variants of these paradigms also permitting alcohol self-administration (Hendershot et al., 2016; Junger et al., 2016; Wardell et al., 2015). Conducted in a controlled setting and permitting the random assignment of alcohol or no-alcohol conditions, such methods allow for the minimization of measurement noise and may also be used to inform causal inferences regarding the alcohol-emotion link. However, the ecological validity of such studies is often low, and researchers have surmised that this may impact the usefulness of the results (Fairbairn & Sayette, 2014). Improving the ecological validity of laboratory studies has thus been an area of interest, and alcohol-administration researchers have made efforts to incorporate into the laboratory setting elements of everyday drinking contexts including simulated bar environments (Corbin et al., 2015; Fromme & Dunn, 1992) as well as social drinking contexts featuring groups (see Fairbairn & Sayette, 2014 for a review; Sayette et al., 2012).

Some important laboratory research has been conducted indicating that acute effects of alcohol, along several dimensions, could have key predictive implications for drinking trajectories over time. Specifically, responses to alcohol, measured according to the low level of response scale including motor markers (e.g., body sway) as well as subjective feelings of drunkenness (e.g., "high," "dizzy"), has been shown to predict alcohol-related problems up to 20 years later (Schuckit, 1994; Schuckit et al., 2011; Schuckit & Smith, 1996, 2000). Furthermore, research by King and colleagues found that alcohol-related stimulation and sedation measured with the Biphasic Alcohol Effects Scale (BAES; Martin et al., 1993), could be used as predictors of drinking behavior at 2–6 year follow-up among social and heavy social drinkers (King et al., 2011, 2014). Note that some items used to assess alcohol's subjective effects in both Schuckit's and also King's work overlap with those used to assess positive mood (e.g., I feel excited), and thus findings of these prior studies might indicate promise for positive mood as a predictor of subsequent drinking behavior. The current study is the first to combine laboratory and ambulatory measures of alcohol's emotional rewards and examine these as predictors of later drinking outcomes.

The Current Study—This work seeks to build on prior retrospective survey findings (Jones et al., 2002; Kuntsche et al., 2005) and laboratory research exploring alcohol responses including stimulation and sedation (King et al., 2011; Schuckit, 1994), examining how alcohol's emotional rewards assessed via laboratory and also ambulatory methods predict drinking over time. In particular, this study combined ambulatory methods employing individually-calibrated transdermal alcohol sensors with laboratory procedures employing an ecologically valid group drink procedure to examine the extent to which alcohol's emotional rewards predict drinking at longitudinal follow-up. Our prior work reports on baseline associations in this same sample of individuals, establishing robust overall positive mood-enhancing and negative mood reducing effects of alcohol in both laboratory and ambulatory settings (Fairbairn et al., 2018). This work further indicated some degree of correlation between alcohol's emotional rewards assessed using ambulatory and laboratory methods, with the effects of alcohol on negative mood being correlated across laboratory and field contexts (negative mood β=.31; positive mood β=*ns*; Fairbairn et al., 2018). The current research builds on these prior findings by adding a longitudinal follow-up to examine how alcohol's emotional rewards at baseline might predict drinking over time. We apply these methods within a sample of young adult heavy social drinkers—individuals of clinical interest not only because of their enhanced risk for developing AUD later on, but, in addition, because their current heavy drinking behavior (i.e., frequent binge drinking) represents a significant problem that has been associated with major economic and interpersonal costs (Bouchery et al., 2011). Although not the focus of the current investigation, we also incorporate supplementary analyses assessing alcohol's stimulative and sedative effects as predictors of longitudinal drinking trajectories—analyses intended to assess the specificity of our findings to measures targeting emotion.

In sum, the primary aims of the current study are to: 1) Examine using both laboratory and ambulatory methods how alcohol's emotional rewards, which we operationalize here as alcohol-related increases in positive mood and decreases in negative mood (Fairbairn et al., 2018; Fairbairn & Sayette, 2013), predict drinking at longitudinal follow-up; 2) Examine the extent to which the relationship between alcohol's emotional rewards and longitudinal drinking outcomes varies across positive vs. negative mood outcomes as well as over measures aimed at assessing general drinking patterns (e.g., quantity and frequency) vs. measures explicitly targeting more problematic drinking behaviors (e.g., drinking problems and binge drinking status).

Methods

Participants

Participants consisted of a sample of 60 young heavy social drinkers recruited through the use of paper handouts, online advertisements, and referrals (see Fairbairn et al., 2018). Exclusion criteria included medical conditions that contraindicated alcohol consumption, a diagnosis of AUD as indexed by the Diagnostic and Statistical Manual of Mental Disorders (5^{th} Edition; American Psychiatric Association, 2013), extreme BMI score, and pregnancy in women. Of these 60 participants, 55% were European American, 11.7% were African American, 5% were Hispanic, 20% were Asian, and 8.3% "other" racial category. Regarding

education, 43% of participants reported having completed less than the equivalent of a bachelor's degree, 35% the equivalent of a bachelor's degree, and 22% reported having completed some graduate study. Precisely half the participants were men and half women, with an average age of 22.5 (range 21–28 years old). Of these 60 participants, 48 also participated in the ambulatory study[1] (50% Female, 56% White, average age 22.6; See also Fairbairn et al., 2018). At baseline, all participants in our study met the National Institute on Alcohol Abuse and Alcoholism's criteria for heavy or "at risk" drinking (NIAAA, 2017), drinking 2–3 times a week and an average of 4 drinks per occasion.

From this original sample of participants, 90% also completed a longitudinal follow-up survey at 18 months (N=54 laboratory sample, N=43 ambulatory sample). Follow-up non-responders were somewhat more likely to classify as regular binge drinkers at baseline than non-responders (p=.083), which is consistent with trends found in prior substance use research (Gilmore & Kuperminc, 2014). Otherwise, non-responders did not significantly differ from the 54 responders along any criteria examined, including gender, age, race, average emotion ratings, or baseline drinking problems (all p's >.363). Note that, in light of the within-subject design at baseline, the final sample size in this study provided >80% power to detect effect sizes similar in magnitude to those achieved within prior longitudinal studies predicting drinking patterns from acute alcohol response (King et al., 2011). All of the methods and procedures employed in this study were approved by the Institutional Review Board at the University of Illinois at Urbana-Champaign.

Procedures

Ambulatory Orientation.—Participants who met eligibility criteria were invited to a study initiation visit, during which they were oriented to ambulatory assessment procedures and fitted with the transdermal sensor. Participants attended all laboratory sessions in the same group of three. Groups were unacquainted prior to study participation (Fairbairn & Sayette, 2013). To measure Transdermal Alcohol Concentration (TAC), we used the Secure Remote Alcohol Monitoring System (SCRAM; Alcohol Monitoring Systems, Inc., Littleton, CO)—currently the most reliable and valid transdermal alcohol-sensor (Leffingwell et al., 2013). During their ambulatory orientation sessions, participants were informed they would receive random survey prompts six times a day on the Metricwire survey app (Trafford, 2016) in response to which they would supply self-reports of their mood. [Further discussion of the choice of random-prompt schedule is presented in the discussion section.] Participants responded to prompts directly on smartphones or, for participants who did not own a smartphone, on one of the lab's own iPod touch devices. Participants were also instructed that they would be supplying daily self-reports regarding their alcohol consumption. The period of ambulatory assessment lasted seven days, a time period chosen as one likely to capture several drinking episodes among our sample of heavy drinking participants while not leading to excessive response fatigue.

[1]The first four groups of participants (12 in total) did not complete ambulatory assessments of mood, and instead engaged in alternative ambulatory procedures not focused on emotion (see Fairbairn et al., 2018).

Laboratory Beverage-Administration.—Also during the 7 days of the study, participants attended two separate laboratory beverage-administration sessions. The first of these visits occurred during the ambulatory assessment period, allowing us to check in with participants about their ambulatory compliance as well as regarding the fit of the transdermal bracelet. During one of these experimental sessions, groups were administered an alcoholic beverage, and, during the other session, the same group was administered a control beverage, with the order of sessions being counterbalanced across groups. A placebo condition was omitted, as studies employing similar measures/procedures to the current research indicate that such placebo manipulations can lead to unanticipated compensatory reactions (Fairbairn, Sayette, Amole, et al., 2015; Sayette et al., 2012; Testa et al., 2006). Prior to beverage administration, participants completed self-report measures of mood (PANAS; Watson et al., 1988), anxiety (STAI; Spielberger et al., 1970), and alcohol-related stimulation and sedation (BAES; Martin et al., 1993).

During the alcohol session, men were then administered a 0.82 g/kg dose of alcohol, and women were administered a 0.74 g/kg dose (Sayette et al., 2001). Beverages were administered as a cranberry/vodka mix. Control participants consumed an isovolumic amount of cranberry juice and were not deceived about the content of their beverages. Beverages were administered to participants in 3-person groups (Fairbairn et al., 2018). Each drinking period (alcohol/control) lasted 36 minutes, with drinks being served in 3 equal parts at 0 minutes, 12 minutes, and 24 minutes. Participants were instructed to consume their beverages evenly across the three intervals. Immediately after drinks were complete, participants' BrACs (Breath Alcohol Content) were recorded using the Intoximeters Alco-Sensor IV breathalyzer and participants were brought into separate rooms to complete self-report measures. During the alcohol session, participants' BrACs were measured every 30–45 minutes. Participants were required to stay in the lab until their BrACs dropped below .03%, and their TAC curve had peaked and started to descend. During the final lab visit, all participants, except the first five groups enrolled in the study, reported on the extent to which ambulatory procedures affected their drinking behavior.

Longitudinal Follow-Ups.—All 60 participants were contacted at 18-months after the date of their original study participation, then given the opportunity to complete a brief longitudinal follow-up survey. When participants did not respond to an initial email, we attempted to contact them via phone, text, and social media. Participants completed a 20–30-minute online survey, within which they answered questions about their drinking behaviors along with a battery of personality and mood assessments. We asked participants to complete the survey online versus via in-person or telephone interview for several reasons, including: 1) Baseline assessment of drinking took place in response to written (i.e., not verbal) prompts (Fairbairn et al., 2018); 2) We thought that some participants might feel more comfortable accurately reporting their drinking practices through an online portal versus directly to another person. Participants were compensated with a $40 electronic gift card for completion of follow-up surveys, and, in an effort to incentivize prompt responding, participants were given the opportunity to win larger gift cards (e.g., $300) if they responded to their assessment link within 2 weeks. Out of the 54 respondents, 52 assessments were received within two-weeks of the send date (96%).

Measures

Ambulatory Alcohol Episodes.—Transdermal sensors were calibrated to each individual participant in the study within the laboratory-based alcohol-administration session. Importantly, due to factors such as the thickness of an individual's skin, the relationship between TAC and BAC can vary depending on the individual in question (Luczak & Rosen, 2014). During the laboratory visits, BrAC and TAC were measured with the SCRAM and a handheld breathalyzer, enabling us to create individualized equations accounting for individual-differences in the TAC-BrAC relationship (see Fairbairn et al., 2018). TAC measurements from SCRAM sensors were run through a MATLAB code (BrAC Estimator Software), which outputs an estimated breath alcohol concentration (eBrAC) based on the first principles forward model (Dumett et al., 2008; Luczak et al., 2013; Luczak & Rosen, 2014; Rosen et al., 2014, 2013). The output provides eBrAC for each minute of the ambulatory assessment period—data which was then synchronized with mood surveys. For the purposes of primary analyses, the eBrAC output was converted from a continuous variable to a binary variable to assist with the examination of mood effects, and the resulting variable allowed for separating alcohol episodes from no-alcohol episodes (Barnett et al., 2011, 2014)—although secondary analyses also examined eBrAC in its raw continuous form. As in our prior work (Fairbairn et al., 2018), we chose a cutoff of .01% eBrAC as the threshold for determining an alcohol episode—occasions on which participants displayed an eBrAC value above .01% were classified as "alcohol episodes." This specific cutoff was chosen as the point that maximized the comparability of alcohol models across laboratory and ambulatory settings—with the cutoff of .01% for determining an "alcohol episode," the average of all eBrAC values for occasions classified as alcohol episodes in an our ambulatory study was equivalent to the peak target BAC for our laboratory study (.08%).

Mood Measures.—Laboratory-based positive and negative mood was assessed after alcohol consumption using an eight-item mood scale. This measure was chosen as one that had proven sensitive to alcohol's effects in a laboratory context within our prior research (Fairbairn, Sayette, Wright, et al., 2015; Fairbairn & Sayette, 2013). The eight-item mood measure indexes four negative mood states (annoyed, sad, irritated, bored) and four positive mood states (cheerful, upbeat, happy, content). Participants are asked the extent to which they are experiencing these emotions "at the present moment," responding on a six-point Likert scale from 0 (not at all) to 5 (extremely). The negative and positive items were averaged to create separate subscales (α = .64 for negative scale[2], α = .89 for positive scale).

For our ambulatory mood measure, we chose the six mood items—three positive and three negative—from the laboratory eight-item mood measure indicated by our prior research as being most sensitive to alcohol's effects. With a view to avoiding anchoring effects and allowing for variation in response patterns across laboratory and ambulatory contexts, we also introduced four additional items. Specifically, we referenced research on emotion and also ambulatory alcohol response (Armeli et al., 2003; Yik et al., 2011) and consulted a team

[2]We note that the alpha is low for both of our negative mood measures. As noted by Schmitt (1996), this should only influence the interpretation of nonsignificant results because lower alphas make it more difficult to detect significant effects (Schmitt, 1996). Thus, any significant effects should still be significant at higher reliabilities, whereas some nonsignificant results may be significant with more reliable scales.

of thirteen lab assistants, to select four additional mood items. This process produced a ten-item ambulatory mood measure including five negative mood states (nervous, sad, irritated, lonely, bored; $\alpha = .62$) and five positive mood states (upbeat, content, happy, euphoric, energized; $\alpha = .90$).

An exploratory factor analysis was conducted for both laboratory and ambulatory mood measures employed in this study (see Supplemental materials for full results). As might be expected given increased measurement noise associated with the field assessment setting, cumulative explained variance was higher for laboratory vs. ambulatory assessments, and factor loadings were higher for positive mood items vs. negative mood items. Nonetheless, taken as a whole, results supported a 2-factor solution for both scales corresponding to "positive" and "negative" valence domains.

Longitudinal Drinking Outcomes.—Drinking was assessed at both baseline and 18 month follow-up using the following items: 1) Drinking Days: Participants were asked to report on how many days out of the past 30 they had consumed any alcohol; 2) Drinking Quantity: Participants were asked to report, on the days that they did drink alcohol, how many drinks they consumed on average per drinking occasion; 3) Drinking Problems: Participants completed the Short Inventory of Problems (SIP), a 15-item self-report measure that assesses drinking problems across physical, interpersonal, intrapersonal, impulse control, and social responsibility domains. Participants responded to each item on a 4-point (0–3) scale, from which a total score (0–45) was calculated (Miller et al., 1995). Norms for this scale based on a large sample of individuals presenting for alcoholism treatment are provided in supplemental materials; and 4) Binge Drinking: Participants indicated how often they engaged in binge drinking in the past 30 days (4+ standard drinks in a sitting for women, 5+ standard drinks for men). Those who reported binge drinking on average weekly or more over the past 30 days were classified as regular binge drinkers (see King et al., 2011). We chose a binary categorization of binge drinking status in the current study for both practical and conceptual reasons. Regarding practical reasons specific to this particular study, an issue arose with our survey logic such that the fully continuous binge drinking measure did not distinguish between individuals with "0" and "1" binge episodes. In conceptual terms, prior research in this area has tended to group individuals into binary categories according to binge drinking status, with the view that such categories can have clinical utility (e.g., King et al., 2011), and so this choice is consistent with similar longitudinal alcohol research.

Data Analytic Strategy

Analyses were conducted using regression models examining emotional reward from alcohol in laboratory and field settings as a predictor of drinking outcomes at 18-month follow-up, while controlling for baseline drinking patterns. Visual inspection of outcome variables indicated that Drinking Days approximated a normal distribution, whereas Drinking Quantity and Drinking Problems followed a Poisson distribution. We therefore employed a linear regression model to examine Drinking Days and a Poisson regression to examine Drinking Quantity and Drinking Problems. Regular Binge Drinking status, a binary variable, was assessed using logistic regression. As effect size metrics, event rate ratios

(*Exp(B)*—interpreted as the factor change in the dependent variable for each unit increase in the independent variable) are provided for Poisson regression models, and odds ratios (*OR*) are provided for logistic regression models. Regarding drinking controls, the precise baseline covariate included in models depended on the outcome being examined, such that baseline covariate matched outcome—e.g., the model predicting drinking problems at 18-month follow-up controlled for baseline drinking problems, the model predicting binge drinking status at 18-month follow-up controlled for baseline binge drinking status, etc. In models examining laboratory emotional reward from alcohol, the order of sessions (alcohol session first or control session first) was entered as a covariate.

In line with analytic procedures employed in our prior research (see Fairbairn et al., 2018), to examine the effect of alcohol reward in the lab, an individual's mood score (positive or negative) on the control session was subtracted from that individual's mood score on the alcohol session, both assessed immediately post-drink (although see supplemental analyses for effects at additional time points). In order to calculate the effect of alcohol reward in ambulatory settings, where individuals often provided mood ratings during multiple drinking episodes and also multiple moments of sobriety, hierarchical linear models were run predicting mood outcomes using alcohol episode effects that were allowed to vary randomly across individuals, and these individual-level random effects were then saved (see Fairbairn et al., 2018). In order to capture changes in mood over time, baseline mood controls were incorporated into both laboratory and ambulatory models. Specifically, laboratory regression models controlled for pre-drink mood assessed using the PANAS (i.e., positive or negative subscales), and ambulatory hierarchical linear models controlled for lagged mood (i.e., positive or negative mood rating at the prior assessment point). In order to separate ambulatory effects of alcohol from other factors that tend to covary with consumption, ambulatory models also controlled for the presence of other individuals, time of day, and day of the week (see Fairbairn et al., 2018). Finally, throughout the results and within the supplemental materials we present a series of additional analyses and robustness checks, including models exploring limb effects, models examining alcohol's effects on measures tapping alternative conceptualizations of alcohol "reward" (e.g., stimulation and sedation), as well as ambulatory models exploring continuous eBrAC.

Results

Sample Characteristics

Consistent with normative patterns observed for young adults (Bachman et al., 2002), participants reduced their drinking over the course of the study, demonstrating lower frequency and quantity of consumption at follow-up compared to baseline. There was, however, marked heterogeneity in this trend, with some participants continuing to drink heavily at follow-up (see Table 1). When compared to normative data based on a sample of treatment-seeking alcoholics, participants in our sample displayed drinking problems that ranged from very low to moderate in magnitude, with most participants classifying as having very low or low problem levels (see supplemental materials for full description of SIP norms). Table 2 provides correlations among all measures of drinking and drinking problems as assessed at baseline and follow-up.

Laboratory Manipulation Check.—During the laboratory sessions on which alcohol was administered, participants were on the ascending limb of the BrAC curve immediately following the drink period (M=0.064%; SD=.01), when primary mood measures were administered, ultimately rising to a peak BrAC of .074% (SD=.01) about 60 minutes after the completion of the drink period.

Ambulatory Compliance and Descriptives.—On average, participants responded to 93.1% of prompts (SD=10.6). All but 3 participants (94%) engaged in at least one drinking episode outside the laboratory over the week-long ambulatory assessment period. On average, participants drank on 3.3 days (SD=1.56), not counting drinks consumed during the laboratory visit, with a mean estimated BrAC of .081% (SD=.11) on drinking episodes.

The period for ambulatory assessment in the current study overlapped with the first experimental visit (see methods). However, we did not observe substantial reactivity to laboratory procedures in the current study. Specifically, there was no significant difference in either positive mood, p=.40, or negative mood, p=.49, between subjects who had been assigned to receive alcohol first vs. control beverage first on the day following this experimental session. Participants who had been assigned to consume alcohol appeared to drink slightly less alcohol on the day following this session than those who had been assigned to consume control beverage, but the difference in average eBrAC was not large (.012%, p=.03).

Finally, we performed several validity checks on data from transdermal sensors, including examining the correspondence between eBrAC and both photographic and also self-report indicators of drinking collected during the ambulatory assessment period. The correlation between daily self-reports of drinking quantity and the daily average eBrAC was large in magnitude, β=.73, t=5.66, p<.0001. With respect to the momentary drinking data, when photographs and/or their accompanying captions were coded as featuring/referencing a drinking setting, 82% of the time the eBrAC also was positive for that same time point (see Fairbairn et al., 2018, see also Fairbairn et al., in press for more detailed analyses).

Baseline Alcohol Effects and Correlations: As reported elsewhere (Fairbairn et al., 2018), at baseline, in the laboratory arm of the study, positive mood was higher, β=.36, t=3.81, p=.0003, and negative mood lower, β=−.30, t=−3.46, p=.0009, following beverage administration on alcohol sessions vs. control sessions. In the ambulatory arm of the study, positive mood was higher, β=.13, t=4.73, p<.001, and negative mood lower, β=−.07, t=−2.62, p=.009, during alcohol episodes vs. no-alcohol episodes, although effect sizes were smaller than in the laboratory arm of the study. In terms of concordance in the effects of alcohol, the effect of alcohol on an individual's negative mood in a laboratory setting was related to the effect of alcohol on that individual's negative mood outside the laboratory, β=.31, t=2.18, p=.035. The relationship between ambulatory and laboratory measures of alcohol's effects on positive mood did not reach significance, β=−.15, t=−1.01, p=.32 (see Fairbairn et al., 2018 for more details of baseline analysis).

Longitudinal Models—Laboratory Alcohol Effects.—The effect of alcohol on mood, as measured using experimental laboratory methods, was used to predict drinking at 18-

month follow-up. We first examined the effect of alcohol on positive mood as a predictor of longitudinal drinking outcomes. Here we found that alcohol's enhancement of positive mood, assessed in the lab, significantly predicted both Drinking Problems, b=.16, $Exp(B)$=1.17, SE=.07, p= .026, and also Binge Drinking status, b= 3.22, OR=25.04[3], SE= 1.37, p= .019, at 18-month follow-up. More specifically, the larger the individual's positive mood enhancement from alcohol at baseline, the more likely that individual was to have drinking problems and qualify as a regular binge drinker at follow-up. In contrast, when measures of drinking frequency (Drinking Days) and quantity (Drinking Quantity) were examined, no significant effects of positive mood enhancement on longitudinal drinking patterns emerged, p's>.318. Table 3 provides full results of models controlling for baseline drinking patterns (as presented here), longitudinal models with no baseline control, and cross-sectional models.

We next examined the effect of alcohol on negative mood as a predictor of longitudinal drinking outcomes. Here we found that alcohol-related reduction of negative mood, assessed in the lab, significantly predicted Drinking Problems at 18-month follow-up, b=−.24, $Exp(B)$=.79, SE= .11, p= .024. More specifically, the larger the negative mood reduction from alcohol at baseline, the more likely that individual was to have drinking problems at follow-up. In contrast, when measures of Binge Drinking, Drinking Days, and Drinking Quantity were examined, no significant effects of negative mood reduction on longitudinal drinking patterns emerged, p's>.174. Note that, as factor loadings for some specific laboratory negative mood items were relatively low ("bored" and "sad"), and one of these items ("bored) also tended to cross-load on the positive mood subscale, we repeated negative mood analyses using a recalculated negative mood subscale including only items that demonstrated relatively high factor loadings and no positive mood cross-loading (i.e., "annoyed" and "irritated" items). Results of analyses using this new negative mood subscale including only "annoyed" and "irritated" items were nearly identical to those including all negative mood items—alcohol-related reduction of negative mood significantly predicted Drinking Problems at 18-month follow-up, b=−.19, $Exp(B)$=.83, SE= .09, p= .027, and no other significant effects emerged.

Longitudinal Models—Ambulatory Alcohol Effects.—The effect of alcohol on mood, as measured using ambulatory methods, was used to predict drinking at 18-month follow-up. Alcohol's effects on positive mood, measured using ambulatory methods, did not significantly predict Drinking Days, Drinking Quantity, Drinking Problems, or Binge Drinking, p's>.200.

Finally, we examined the effect of alcohol on negative mood, as measured using ambulatory methods, as a predictor of longitudinal drinking outcomes. Here we found that alcohol's reduction of negative mood significantly predicted drinking problems at 18-month follow-up, b= −3.14, $Exp(B)$=.04, SE= 1.22, p= .010. More specifically, the larger the individual's reduction in negative mood from alcohol at baseline, the more likely the individual was to have drinking problems at follow-up. In contrast, when measures of Binge Drinking,

[3]The very large odds ratio is an artifact of covariates included in the model. The effect size is substantially smaller, although significant, when baseline mood is omitted, b= 2.04, OR=7.70, SE= .80, p= .010. See also Table 3.

Drinking Days, and Drinking Quantity were examined, no significant effects of negative mood on longitudinal drinking patterns emerged, *p*'s>.729. Note that, as factor loadings for some ambulatory negative mood items were relatively low ("bored" and "sad"), we repeated negative mood analyses using a recalculated negative mood subscale including only items that demonstrated relatively high factor loadings and no positive mood cross-loading (i.e., "irritated," "lonely," and "nervous" items). Results of analyses using this recalculated ambulatory negative mood subscale were nearly identical to those including all negative mood items—alcohol-related reduction of negative mood significantly predicted Drinking Problems at 18-month follow-up, *b*= −3.42, *Exp(B)*=.03, *SE*= 1.29, *p*= .008, and no other significant effects emerged.

Although, for the reasons noted above (see Methods) our primary ambulatory analyses examined the effect of alcohol on mood with alcohol episode examined as a binary predictor (Fairbairn et al., 2018), we also examined the robustness of ambulatory results to eBrAC entered as a continuous predictor of mood. In other words, we examined whether the relationship between continuous eBrAC and mood ratings during the baseline ambulatory assessment period significantly predicted drinking at follow-up. Results of ambulatory models examining continuous eBrAC produced nearly identical results to models examining (binary) alcohol episode. In particular, a significant relationship emerged between alcohol-related reduction in negative mood and drinking problems at 18-month follow-up, *b*= −.24, *Exp(B)*=.78, *SE*= .12, *p*= .042—individuals whose negative mood ratings decreased to a greater extent as BrAC increased during the baseline ambulatory assessment period were at greater risk for substance use problems at follow-up. Otherwise, no significant relationships emerged in continuous eBrAC models, *p*'s> 291.

Effects tended to differ somewhat across laboratory and ambulatory measures of alcohol reward. As noted in the methods section, we opted to implement somewhat different mood rating scales across ambulatory and laboratory arms of the study. Thus, one possible explanation for differential effects across laboratory and ambulatory study arms lies in this choice of mood measure. Importantly, however, when models were re-run using only the 6-mood items that overlapped across laboratory and ambulatory study arms, none of the above results changed in either their direction or their significance level. A second potential reason for differences across laboratory and ambulatory results is the somewhat larger sample size in the laboratory study arm. Of note, when laboratory models were repeated, examining only those 48 participants for whom we also had ambulatory data, the effect of laboratory-measured positive mood no longer predicted Drinking Problems at follow-up, *p*=.271. Otherwise, however, effects remained unchanged in this restricted laboratory sample.

Additional Analyses: Results of models parsing mood effects on ascending and descending limbs of the BAC curve, as well as effects for alternative indices of subjective state administered in the laboratory (e.g., anxiety, stimulation, sedation), are presented in supplementary materials. Although correlations between stimulation and positive mood were high (*r*=.84) and sedation and negative mood moderate (*r*=.43), alcohol-related stimulation and sedation emerged as less consistent predictors of drinking outcomes in the current sample (see supplementary material).

Discussion

Drawing on data from both laboratory and ambulatory samples, the current study examined emotional responses to alcohol as a predictor of drinking outcomes over time. Specifically, participants in this research attended two laboratory-based beverage administration sessions and engaged in a 7-day period of ambulatory assessment at baseline and then went on to provide reports of their drinking practices at follow-up. Results drawn from the laboratory arm of the study indicated that alcohol-related positive mood enhancement measured at baseline predicted both drinking problems and binge drinking status at 18-month follow-up. In other words, individuals who experienced more positive mood enhancement from alcohol in the lab were more likely to binge drink regularly and experience drinking problems later on. Similarly, alcohol-related reduction in negative mood in the lab predicted drinking problems at follow-up, such that individuals who experienced more alcohol-related reductions in negative mood were more likely to drink heavily 18 months later. In the ambulatory arm of the study, alcohol-related reductions in negative mood measured in everyday contexts significantly predicted drinking problems at follow-up.

One notable element to our findings is that emotional rewards from alcohol predicted drinking problems and, in some cases, heavy drinking status at follow-up, but alcohol's emotional rewards did not predict the overall frequency of drinking or the average quantity of alcohol consumed per drinking occasion in any model. Furthermore, the direction of (non-significant) effects for drinking days and average drinking quantity was not always the same as for drinking problems. There are a variety of potential explanations for this pattern of findings. One possibility is that emotional rewards from alcohol become particularly important when drinking has reached a problematic level, whereas they are less central for motiving non-hazardous levels of drinking (Cooper et al., 1995). For example, one could imagine a variety of (potentially less compelling) reasons that might suffice to motivate someone to consume a few glasses of wine every night—social customs, a gustatory preference, mildly pleasurable physical sensations. However, in cases where drinking is causing more serious negative consequences and/or is regularly reaching hazardous levels, more potent motives may become relevant, such as intense alcohol-induced feelings of happiness or the desire to reduce feelings of sadness. Prior research on college-aged drinkers has also examined the relationship between negative affect and drinking outcomes, finding the association to be complex and the motivation to avoid unpleasant social situations might increase drinking in some and reduce the behavior in others (Armeli et al., 2010). Importantly, however, such predictions regarding mechanism are entirely speculative at this point, and future research would be required to replicate these effects and directly examine the factors underlying them.

Another element of our findings is that baseline emotional reward measured in the laboratory tended to predict drinking problems more consistently than did emotional reward measured using ambulatory models. In particular, positive mood effects observed in the laboratory predicted drinking, whereas no positive mood models examined based on ambulatory data reached significance. There are a variety of potential explanations for these differences, including the fact that data from laboratory drinking environments are more controlled, potentially leading to less noise, and further that relationships captured in

ambulatory studies are correlational and thus vulnerable to third variable confounds. Another explanation to consider is our ambulatory study design. In particular, in the current study, in line with paradigms often used in similar ambulatory alcohol research, we chose to employ random time-based prompts to assess mood and alcohol consumption (Piasecki et al., 2011; see Shiffman, 2009). Other means for assessing alcohol's rewards might involve repeated follow-up assessment of mood during a user-identified drinking episode (e.g., Piasecki et al., 2012; Treloar et al., 2015), and future research might supplement our current ambulatory approach with approaches using these or similar alternative ambulatory sampling strategies.

Our findings should be interpreted with consideration given to our participant sample. The current sample of drinkers were young and, although their drinking in many cases was problematic, participants in our study did not endorse current AUD. Factors that lead to the initial development of AUD may be different from those that lead to AUD maintenance. Indeed, several prominent addiction theories propose that alcohol's ability to induce positive emotions may play a role in the initial onset of AUD, whereas it is alcohol's ability to reduce negative emotions that serves to maintain consumption once AUD has developed (e.g., Koob & Le Moal, 1997). Thus, our findings, which emphasized both positive and negative mood as predictors of subsequent drinking, are likely best interpreted through a developmental lens, indicating factors that might maintain substance use among individuals in the earlier stages of drinking prior to the development of AUD.

Of note, neither the ambulatory nor the laboratory study designs in the current research offer the opportunity to parse pharmacological from expectancy-based effects of alcohol. When alcohol is consumed in the real world, responses may involve a combination of direct pharmacological effects of alcohol and the drinker's beliefs or expectancies about alcohol's effects (Goldman et al., 1999). In order to parse pharmacological from expectancy-based effects, laboratory alcohol-administration research has sometimes incorporated a "placebo" comparison group, in which participants administered no-alcohol are led to believe they are receiving alcohol (Rohsenow & Marlatt, 1981). However, as prior research suggests that interpretation of effects produced by such laboratory placebo manipulations are not always uncomplicated (Fairbairn, Sayette, Amole, et al., 2015; Sayette et al., 2012; Testa et al., 2006), here we opted to employ a non-placebo comparison group. Nonetheless, it is worth noting that, using the current experimental designs, pharmacological and expectancy effects of alcohol are not differentiable.

Limitations of this work should be noted. Our power in the present study, although sufficient to detect the effects of interest, was nonetheless not large. Small sample sizes not only decrease the chances of detecting a true effect, but may also increase chances of false positive findings (Ioannidis, 2005). Power may be especially low with respect to our binary measure of binge drinking status, as relatively few individuals were categorized as regular binge drinkers at follow-up. Thus, while the current study provides useful initial data, additional research employing larger participant samples will be required to replicate these effects. Furthermore, due to the relatively high burden of ambulatory procedures employed in this study, we opted to assess ambulatory alcohol response over only seven days. Future research should assess ambulatory responding over longer periods of time. Second, it's

important to note that transdermal alcohol sensors represent novel technology with their own limitations. Even individually-calibrated sensors are vulnerable to bias, and the relationship between TAC and BAC may vary depending on situational factors. When subjective outcomes, such as mood, are the primary object of interest, we argue that such bias is more likely to be noise rather than a confound, as might be the case were a self-report measure of drinking employed. Nonetheless, further research is needed to refine our understanding of the relationship between transdermal alcohol content and drinking.

Third, in this initial examination of alcohol's emotional rewards, we examine only self-report measures of drinking. Although the specific self-reported mood measure is based on one validated in one of the largest alcohol-administration studies ever conducted (Sayette et al., 2012), it has not as of yet undergone the sort of extensive psychometric evaluation that some other measures (e.g., Martin et al., 1993) have undergone. More generally speaking, we chose to rely on self-reports as a modality that has frequently been employed in the alcohol-emotion literature, and also as a measure that can be consistently applied across laboratory and ambulatory contexts. Nonetheless, not all affective experiences are accessible in conscious awareness, and future research should attempt to replicate these effects employing alternative measures of affective state. Fourth, since our primary aim was to assess emotional rewards of alcohol, we concentrated our main assessments of mood on the ascending limb of the BAC curve. Prominent models of drinking posit a key role for BAC limb in determining the relationship between alcohol's subjective effects and subsequent drinking (e.g., Morean & Corbin, 2010). Although we did conduct supplementary analyses attempting to parse limb effects, our study was not initially designed for this purpose. Future research should further examine alcohol's emotional rewards across different portions of the BAC curve in relation to subsequent drinking patterns. Fifth, consistent with trends observed in the broader alcohol literature (Gilmore & Kuperminc, 2014), we found that individuals classified as binge drinkers at baseline tended to be less likely to respond to follow-up assessments vs. non-binge drinkers. Although not a significant effect in this study, such effects can raise concerns with respect to external validity. Sixth, although we did assess several longitudinal associations in the current study, analyses did not employ p-values that corrected for multiple comparisons. Finally, in this initial study of alcohol emotional reward, we employ a longitudinal design that assess drinking at only one follow-up time point. Although sufficient to assess change over time, this does not allow us the ability to characterize more nuanced drinking trajectories. Future research should examine emotional rewards as predictors of drinking outcomes across multiple time points.

In sum, the current study combines laboratory and ambulatory assessment to examine alcohol's emotional rewards as a predictor of longitudinal alcohol consumption and alcohol problems. Results indicate that alcohol's ability to enhance positive mood and reduce negative mood predict problematic drinking patterns at follow-up, although not the average frequency and quantity of drinking. Future research might further explore these effects in larger samples of participants over longer periods of time.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1.

Descriptive Statistics for Participants at Baseline and 18-Month Follow-up

	Baseline (*N*=60)	**18-month follow-up (*N*=54)**
% Female	50.0%	50.0%
Race	55.0% White, 11.7% African American, 20.0% Asian, 5.0% Hispanic, 8.3% other	50.0% White, 13.0% African American, 22.2% Asian, 5.6% Hispanic, 9.2% other
Average age	22.5 (*SD*=1.9)	24.0 (SD=1.8)
Drinking days	10.3 (*SD*=5.5; *Range*=2–26)	7.2 (*SD*=5.8; *Range*=0–28)
Drinking quantity	4.0 (*SD*=2.0; *Range*=1–9)	3.0 (*SD*=2.0; *Range*=1–9)
Drinking problems	2.5 (*SD*=3.1, *Range*=0–17)	3.8 (*SD*=4.2, *Range*=0–22)
Binge Drinker	48.3%	17.0%

Note. The above are statistics for the full sample of participants who participated in the laboratory study. Information in drinking patterns refers to that collected during the time period specified in column headings (i.e., baseline vs. follow-up). “Drinking Days”: number of days /past 30 participant reported consuming any alcohol; “Drinking Quantity”: Average number of drinks consumed on drinking occasion /past 30 days; “Drinking Problems”: Participant’s total score on the Short Inventory of Problems (Miller, Tonigan, and Longabaugh 1995); “Binge Drinking”: Participants who reported binge drinking on average weekly or more over the past 30 days (see King et al., 2011).

Table 2.

Correlations among Drinking Measures at Baseline and 18-Month Follow-up

	F Drink Days	F Drink Quantity	F Drink Problems	F Binge Status	B Drink Days	B Drink Quantity	B Drink Problems	B Binge Status
F Drink Days								
F Drink Quantity	0.031							
F Drink Problems	.475**	0.185						
F Binge Status	.324*	0.269	.374**					
B Drink Days	.610**	0.045	.332*	0.169				
B Drink Quantity	−0.052	.351**	0.101	.288*	−0.017			
B Drink Problems	−0.121	0.093	.337*	0.244	0.243	0.186		
B Binge Status	0.160	0.199	.287*	.400**	.407**	.499**	.301*	

Note. F=measure taken at 18-month follow-up; B=measure taken at baseline; “Drink Days”: number of days /past 30 participant reported consuming any alcohol; “Drink Quantity”: Average number of drinks consumed on drinking occasion /past 30 days; “Drink Problems”: Participant’s total score on the Short Inventory of Problems (Miller, Tonigan, and Longabaugh 1995); “Binge status”: Participants who reported binge drinking on average weekly or more over the past 30 days (see King et al., 2011).

* $p<.05$

** $p<.01$

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Table 3.

Effects of Alcohol on Mood Assessed in Laboratory and Ambulatory Contexts as a Predictor of Drinking Problems and Drinking Behaviors

1. Models Predicting Drinking at 18-Month Follow-Up Controlling for Baseline Drinking								
	Laboratory Positive Mood Effects		**Laboratory Negative Mood Effects**		**Ambulatory Positive Mood Effects**		**Ambulatory Negative Mood Effects**	
	B	***p***	***B***	***p***	***B***	***p***	***B***	***p***
Drinking Days	.020	.974	1.293	.174	−1.795	.583	−2.700	.794
Drinking Quantity	.074	.318	−.003	.979	−.401	.386	.491	.729
Drinking Problems	.159	.026	−.238	.024	−.420	.311	−3.140	.010
Binge Drinking Status	3.221	.019	.282	.735	−4.525	.200	2.505	.762
2. Models Predicting Drinking at 18-Month Follow-Up No Control Baseline Drinking								
	Laboratory Positive Mood Effects		**Laboratory Negative Mood Effects**		**Ambulatory Positive Mood Effects**		**Ambulatory Negative Mood Effects**	
	B	***p***	***B***	***p***	***B***	***p***	***B***	***p***
Drinking Days	.016	.983	.731	.540	−3.998	.368	−.355	.980
Drinking Quantity	.086	.255	−.061	.602	−.499	.271	.636	.655
Drinking Problems	.204	.002	−.311	.002	−.387	.346	−3.225	.006
Binge Drinking Status	1.881	.007	−.169	.788	−2.170	.361	1.998	.783
3. Cross-sectional Models Predicting Baseline Drinking								
	Laboratory Positive Mood Effects		**Laboratory Negative Mood Effects**		**Ambulatory Positive Mood Effects**		**Ambulatory Negative Mood Effects**	
	B	***p***	***B***	***p***	***B***	***p***	***B***	***p***
Drinking Days	−.177	.806	−.856	.448	−3.667	.363	4.847	.697
Drinking Quantity	.022	.726	−.097	.314	−.032	.931	.108	.924
Drinking Problems	.077	.323	−.138	.247	.039	.934	−2.919	.031
Binge Drinking Status	.177	.496	−.385	.356	.989	.492	.537	.902

Drinking Problems: Assessed according to the Short Inventory of Problems (Miller, Tonigan, and Longabaugh 1995); Binge Drinking Status: Whether or not participants classified as regular binge drinkers, operationalized according to whether they reported binge drinking on average weekly or more over the past 30 days (see King et al., 2011); Drinking Days: The number of days out of the past 30 participants reported drinking any alcohol; Drinking Quantity: The average number of drinks per occasion participants reported consuming per drinking day in the past 30 days.

All of the above ambulatory models controlled for the presence of other individuals, time of day (evening vs daytime), day of the week (weekend vs. weekday), and lagged mood (i.e., positive or negative mood rating at the prior assessment point). Laboratory models controlled for the order of sessions (alcohol or control session first) as well as pre-drink mood assessed using the PANAS (i.e., positive or negative subscales). Models in table subsection 1 above also control for baseline drinking.