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# Alcohol Consumption, Drinking Context, and Subjective Responses to Alcohol in Binge-Drinking Episodes: An Ecological Momentary Assessment Investigation

By

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Abstract

Binge drinking is common among young adults, putting them at increased risk for severe alcohol related health outcomes and mortality. Past research links subjective responses to alcohol (i.e., how individuals experience its rewarding or impairing effects) to risk for future negative alcohol related health outcomes. Further work demonstrates that context (e.g. drinking in the presence of others or in certain locations such as bars and restaurants) may increase the rewarding effects of alcohol and drive heavy binge drinking behavior. However, most research on drinking context, subjective responses to alcohol, and drinking behavior has been conducted in the laboratory or using retrospective measures, which limits ecological validity.

High resolution ecological momentary assessment (HR-EMA) provides a promising solution to these limitations. HR-EMA allows researchers to measure drinking behavior and related outcomes (e.g., drinking context, alcohol subjective responses) in real time in a naturalistic setting. The present study used HR-EMA to evaluate subjective responses to alcohol in different contexts along two domains: in the presence or absence of others and in different physical locations. Participants were 21-29 year old regular heavy binge drinkers, who completed smartphone-based EMA sessions where they recorded the quantity and type of alcohol they consumed, as well as their context and subjective responses to alcohol.

Generalized estimating equations (GEE) analysis revealed significantly higher standard drinks consumed and eBAC levels for participants who drank with others as opposed to alone and those who drank in bars and restaurants compared to other locations. In addition, participants reported greater reward (stimulation and wanting more alcohol) when drinking with others compared to alone and when drinking at bars and restaurants compared to other locations. Significant interactions between time and context indicate that differences in subjective responses associated with reward are especially significant later in naturalistic drinking episodes.

Conclusions: Drinking in the presence of others and at certain locations associated with alcohol (e.g., bars and restaurants) increase both consumption and rewarding responses to alcohol among young adult heavy binge drinkers and present as a significant risk factor for increased alcohol use.

**Alcohol Consumption, Drinking Context, and Subjective Responses to Alcohol in Binge Drinking Episodes: An Ecological Momentary Assessment Investigation**

Excessive consumption of alcohol is an important risk factor for both major health problems and premature death (Rehm, 2011). In 2019, 41.6% of 21-25 year olds in the United States reported binge drinking, defined as consuming 5+ drinks for men (4+ drinks for women) within two hours (SAMHSA, 2019). Compared to their lighter drinking peers, young adult binge drinkers carry additional risk of increased alcohol use later in life and developing negative health problems (Bennett et al., 1999). In addition, heavy alcohol consumption accounts for a significant burden on society, with estimates of alcohol-related costs to individual countries reaching as high as 5.44% of their annual GDP (Thavorncharoensap et al., 2009). The consequences of heavy drinking cost the United States approximately 184 billion dollars annually, reflecting the economic impact of alcohol-related health issues, treatment, accidents, and productivity losses (Harwood, 2000). Identifying response phenotypes and contextual factors that lead to increased alcohol use can help mitigate excessive consumption and its negative effects by providing more efficient and targeted treatment for those at risk.

Past research has demonstrated that certain subjective responses to alcohol are correlated with future risk of increased consumption and major health problems. Subjective responses to alcohol refer to how one experiences both the impairing and rewarding effects of alcohol while drinking, and have been proposed by several models to predict future alcohol use. The *low level of response model* (LLRM) posits that people with a lower sensitivity to the sedating or impairing effects of alcohol will drink more heavily than others to achieve a desired level of intoxication (Schuckit, 1980), with the strongest effects seen amongst men with a family history of alcohol use disorder (Schuckit, 2009). AUD is a substance use disorder characterized by past-year

psychological, health, and psychosocial consequences due to excessive alcohol consumption (American Psychiatric Association, 2013). Longitudinal research demonstrated that decreased responses to the sedating effects of alcohol was a predictor of sustained high use or increased use of alcohol over time, thus identifying that response phenotype as a significant risk factor for AUD (Schuckit et al., 2007). However, there is debate among researchers with regards to the accuracy of the LLRM. For example, Newlin and Thomson (1990) noted that most LLRM studies evaluate subjective responses only during the descending portion of the blood alcohol concentration (BAC) curve, where blood alcohol level decreases. Research has shown that the effects of alcohol are biphasic, with the descending limb associated with greater sedative effects and the ascending limb associated with greater feelings of stimulation (Martin et al., 1993).

A second model, the *differentiator model* (DM), seeks to explain how subjective responses during the ascending and descending limbs of the BAC curve drive alcohol use. Specifically, the DM posits that alcohol for those at risk for AUD may have disproportionate rewarding effects on the ascending limb and fewer adverse effects on the descending limb of the BAC curve. In a laboratory study of both light and heavy drinkers, King et al. (2011) found evidence that experiencing the rewarding effects of alcohol was heavily correlated to past reported alcohol use. Heavy drinkers reported higher feelings of stimulation and reward and lower levels of sedation than light drinkers in response to a fixed, intoxicating dose of alcohol (0.8 g/kg; target BAC = 0.08 g/dL). Subsequent follow-up over the next two years revealed that heavier drinking and progression of AUD symptoms was significantly correlated with elevated stimulating and rewarding effects of alcohol, but not lower levels of sedation at baseline. Specifically, participants who reported liking and feeling stimulated by alcohol showed an increase in AUD symptoms

(King, 2014; King, 2016), suggesting that the more rewarded one was by alcohol, the more likely they were to develop AUD.

Research has additionally shown that context influences both subjective responses to alcohol and the amount of alcohol people choose to consume. In the laboratory, Childs and colleagues (2016) found that adults (21 – 40 year olds) who were conditioned to associate alcohol consumption with a specific room reported stronger rewarding effects of alcohol in the conditioned location than non-conditioned participants. Furthermore, Lutz et al. (2021) studied regular young adult binge drinkers who self-administered alcohol after being conditioned to associate alcohol consumption with a specific room. Compared to those who were placed in a novel room, those who returned to the conditioned location reported higher reward, increased stimulation, and consumed more alcohol, showing that certain locations can drive subjective responses to alcohol and consumption levels. In addition to location, research has evaluated the effects of different social contexts on subjective responses to alcohol. Corbin et al. (2020) instructed participants to blindly consume either alcohol or placebo (0.08% or 0% BAC) while alone or with a group of strangers. Interestingly, drinking with others influenced subjective responses regardless of the condition (0.08% BAC or placebo), such that participants reported more rewarding feelings when with others compared to being alone. These findings suggest that context, both in terms of presence of others and physical location, plays an active role in how much alcohol people consume and how rewarding they find its effects.

One limitation of prior laboratory studies on subjective responses to alcohol and context is that they lack ecological validity by not accurately capturing drinking behaviors in the real world. A promising solution to this limitation is ecological momentary assessment (EMA), which allows researchers to measure alcohol use and related outcomes in real time, often via applications

installed on participant smartphones (Piasecki, 2019). Using EMA to examine alcohol consumption has many benefits, including significantly reduced cost for conducting research compared to a laboratory setting, capturing alcohol episodes as they naturally occur, and minimizing recall errors and bias (Piasecki, 2019). Within EMA, high resolution EMA (HR-EMA; Piasecki, 2019), offers an effective approach for capturing contextual and subjective responses to alcohol intra-episode. High resolution EMA is characterized by high frequency assessments of alcohol consumption, context, and real time subjective effects in the natural environment of participants. Recently, HR-EMA methods have transitioned from palmtop computer technology to using smartphone applications, and this approach has demonstrated accuracy, feasibility, and safety when record drinking episodes (Fridberg et al., 2019).

To date, past research evaluating the relationship between context and subjective responses to alcohol in the real world has not been conducted on heavy binge-drinkers utilizing an HR-EMA methodology. However, subjective responses to alcohol and context have been examined longitudinally in naturalistic settings and provide evidence for contextual effects among heavy drinking populations. For example, Trela et al. (2018) used a daily diary EMA design to evaluate when young adult drinkers experienced craving over the course of twenty-one days. They found that specific physical locations and the presence of certain friends associated with alcohol use caused heavier drinkers to experience more craving for alcohol than light drinkers. Additionally, subjective responses to alcohol and contextual effects were examined using an HR-EMA design by Piasecki et al. (2012), but not among heavy binge drinkers. They evaluated the subjective interaction effects of smoking and alcohol during real world drinking episodes in college student light drinkers. Consistent with laboratory findings on rewarding effects of alcohol in the lab (King et al., 2011), Piasecki et al. (2012) found that the light social drinkers who drank more than their

peers experienced more stimulating and positive effects during the ascending limb of the eBAC curve than others. Furthermore, the light social drinkers who drank more experienced higher levels of the rewarding effects of alcohol during the ascending limb when with others and in bars or restaurants compared to lighter drinkers. However, Piasecki and colleagues (2012) studied a large subset of drinkers, with their inclusion criteria being anyone eighteen years or older who consumed alcohol at least four times (regardless of quantity) in the past month. The lack of research on how frequent, young adult, binge drinkers specifically respond to alcohol in different contexts is especially salient because of their heightened risk for increased drinking and negative alcohol related health outcomes later in life. Furthermore, Piasecki et al., (2012) examined current smokers during alcohol episodes, creating interaction effects between alcohol and tobacco and making it more difficult to disentangle the separate effects of both substances.

The current research had two main objectives. The primary objective was to extend the work conducted on real world drinking episodes and laboratory challenges with an HR-EMA design that allows detection of intra-episode variations on subjective responses to alcohol. Second, I sought to extend the work conducted by Piasecki et al., (2012) by examining acute subjective and contextual effects of alcohol on an at-risk, heavy-drinking, population. I had two hypotheses for the current study. First, I predicted that participants would consume more alcohol, and report increased rewarding effects of alcohol, in bars and restaurants as opposed to other locations. I also hypothesized that individuals would drink more and report higher ratings of the rewarding effects of alcohol in the presence of others as opposed to being alone.

## Method

### Participants

A total of 103 participants were initially recruited to participate in the study via referrals and social media advertisements on Facebook, Instagram, and Snapchat. Inclusion criteria were young adults (21-29 years old), who were heavy drinkers for the past year (a total average of ≥14 drinks/week for males, and a total average of ≥7 drinks/weeks for females) and who binged 1-4 times per week (defined as ≥5 drinks per occasion for males, ≥ 4 drinks per occasion for females). Candidates who passed initial screening where invited for an in-person visit to confirm their eligibility in the study. They were instructed to abstain from both alcohol and recreational drugs for 24 hours prior to the in-person lab visit, and their abstinence was confirmed from urine and drug toxicology tests. Current cannabis use was not ruled an exclusion criteria, as roughly one third of young adult heavy binge drinkers report cannabis use (Substance Abuse and Mental Health Services Administration, 2018). Participants were deemed eligible if their current cannabis use did not exceed 3 times per week, they agreed to abstain from use during their real world drinking episodes and they didn't meet criteria for cannabis use disorder as defined by the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM – 5).

The in person-visit started with informed consent procedures, and then included a brief description of study procedures, surveys and interviews conducted by trained study staff. Interviews included the Timeline Follow Back calendar (Babor et al., 2002) to establish past month drinking patterns, the Alcohol Quantity-Frequency Interview (Cahalan et al., 1969) for maximum and average drinking in the past 6 months, and the Structured Clinical Interview for the DSM-V (First et al., 2015). Candidates were excluded if they met criteria for severe AUD or major psychiatric disorders. Surveys included collection of demographic and health information, the Spielberger Trait Anxiety Inventory (Spielberger et al., 1961), the Alcohol Use Disorder Identification Test (Babor et al., 2002) and the Beck Depression Inventory (Beck et al., 1961).

We excluded a total of 20 participants for either not passing the initial screening criteria ($n$ = 10), not successfully recording at least one real-world drinking episode on their smartphones ($n$ = 6), and for making significant errors (i.e., reporting cumulative drinks at each time point instead of number finished since the last survey) when recording drink totals during the drinking episode ($n$ = 4). This resulted in a final sample of 83 participants ($M$ = 25.3, $SD$ = 2.6, 58% male) for analyses.

**Procedure**

Post-screening, participants were trained by study staff to use the MetricWire EMA app (Metric Wire, Toronto, ON, Canada) on their smartphones. Participants were instructed that they would use the app to record their alcohol use, subjective responses, and related experiences for three hours during up to two alcohol drinking episodes in their natural environment. Study staff referenced timeline follow-back data to help participants identify days during the week when drinking was likely to occur (i.e., a "typical" drinking episode) and instructed participants to avoid completing the smartphone-based assessments during atypical or special occasions (i.e., holidays or times of increased stress). Participants were instructed not to consume alcohol or recreational drugs before starting the mobile surveys, and to self-initiate the app to record a baseline survey assessing moods and behaviors 3 hours to 30 minutes prior to beginning each episode.

Figure 1 (see Appendix) depicts the smartphone assessment timeline for real world drinking episodes. After filling out the self-initiated baseline survey for each mobile episode, participants recorded when they finished their first drink of the night in the first drink survey. They reported the type of alcohol (beer, wine or spirits) and size of the drink consumed, and then completed surveys that evaluated their subjective responses to alcohol. The 3-item Drug Effects Questionnaire (DEQ; Morean et al., 2013) evaluated alcohol feeling, liking, and wanting more

(rated 0-100), and the 6-item Brief Biphasic Alcohol Effects Scale (B-BAES; Rueger et al., 2009) evaluated alcohol-related feelings of stimulation and sedation (each item rated 0-10). In addition, at each survey prompt, participants completed items regarding their current drinking context including their location ("Where are you?" with options consisting of "home," "bar/restaurant," "friend's home," "outside," "work/school," "vehicle," "other" and "Are you alone or with others?" with options consisting of "alone" or "with others").

After completing the post first-drink survey, the MetricWire software automatically prompted participants to complete follow-up surveys at 15, 30, 60, 90, 120, 150, and 180 minutes. As indicated in Figure 1, the episode surveys were triggered automatically via the application instead of being participant initiated (like the baseline and post-first drink survey). Episode surveys asked the same questions as the post first-drink survey (drinks consumed, effects of alcohol, and context), and during in-lab study orientation all participants were trained on how to record drinks and use all scales over the course of the night. Screenshots of example prompts during HR-EMA assessments are shown in Figure 2 (see Appendix). The user-friendly interface, which utilized touch screen sliders and radio buttons, was feasible for collecting data in a real-world setting; the surveys yielded 87.2% (507 out of 581) response rate over the course of the study (Fridberg et al., 2019). On average, episode surveys took 1-2 minutes for participants to complete. While previous EMA studies have used longer assessments, sometimes spanning several weeks (Piasecki, 2012), the three-hour data collection time frame was used for several reasons in this study. First, three hours and the low intrusiveness of the study (1-2 min surveys) reduced the burden on participants and decreased the likelihood of participant burnout, while previous research (King et al., 2011) suggests that a three-hour assessment period is likely to capture the ascending limb of the BrAC curve, as well as the peak and beginning of the descending limb of the BrAC curve. King and

colleagues (2011) studied a similar young adult, heavy risk, binge drinking population, whose reported drinking patterns over the course of real-world drinking episodes often fell within a window of three hours.

While surveys spanned three hours, participants were instructed to drink as they normally would; they could stop drinking before the three hours were up or continue drinking past the three hours, whatever was typical for them. At 11AM the following morning, participants were prompted to answer a next day survey which assessed their activities during the prior HR-EMA assessment period (time socializing, working, standing, sitting, playing games, engaging in physical activity) and their experiences of alcohol-related consequences as evaluated via the Brief Young Adult Alcohol Consequences Questionnaire (BYAACQ) (Kahler et al. 2005). Additionally, participants indicated if they continued drinking after the conclusion of the 3-hour assessment period, and how many drinks they consumed afterwards. Participants completed the study after finishing two alcohol drinking mobile episodes, and the two next day surveys. 73% (61 out of 83) participants completed two real world drinking episodes. Upon completion, the participants received payment (up to $180 if they completed both mobile drinking episodes and all measures) were thanked and debriefed.

## Statistical Analyses

The primary outcomes of interest were subjective responses to alcohol as measured by responses on the BBAES and DEQ over the course of the real-world drinking episodes. BBAES items assessing subjective feelings of “energized,” “excited,” and “up” were summed to compute the stimulation subscale of that measure, while the sum of the items for “sedated,” sluggish,” and “slow thoughts” comprised the sedation subscale. The reported standard drinks consumed during the episodes were used to calculate estimated blood alcohol concentration levels (eBAC) at each

study time point. Consistent with the equation proposed by Matthews and Miller (1979), eBAC levels were calculated by (eBAC = [(# of standard drinks consumed during the episode / 2) x (GC/w)] – (.017g/dl per hour x time in hours since drinking started) where GC is a gender constant (9.0 for women and 7.5 per men).

Generalized estimating equations (GEE; Hardin & Hilbe, 2003) analysis was used to examine both predicted subjective responses to alcohol (liking, wanting, feeling, stimulation, sedation) and alcohol consumption patterns (eBAC and total standard drinks consumed) based on location and presence of others. In all GEE models, calculations controlled for sex, baseline drinking (reported typical drinks/drinking days), time, the time x eBAC interaction, and eBAC. Marginal linear predictions obtained from GEE analysis were examined to evaluate the effects of the categorical predictors of location (coded 1 = "bar/restaurant" or 0 = "own home/friend's home/outside/work/school/vehicle/other location") and presence of others (coded 1 = "with others" and 0 = "alone"). Only the first mobile drinking assessment from each participant was included for the purposes of contextual analyses.

## Results

### Participant demographics and compliance with mobile assessments

Table 1 reflects information recorded during the in-person screening, including demographic information, drinking patterns in the past year, AUDIT scores, and DSM 5 AUD symptoms. During their real-world drinking episodes, 95 % (83 out of 87) of participants successfully completed their first mobile assessment. 4 participants were excluded from data analysis because of incorrectly reporting drinks throughout their drinking episode, responding with cumulative drink totals as opposed to recording drinks finished since the prior survey, as trained by study staff. In addition, 2.4% (16 out of 673) responses given by participants indicated an

eBAC greater than .30, a BAC that often results in loss of consciousness or death. Data from those time points were assumed to be incorrectly reported and dropped from subsequent analyses.

Table 1

*Participant demographics and drinking characteristics*

| **Outcome** | **Mean (SD)** |
|---|---|
| Age (yrs) | 25.3 (2.6) |
| Education (yrs) | 15.9 (1.8) |
| % Male | 58 |
| % Caucasian | 65 |
| % Drinking days (past mo) | 47.4 (19.0) |
| Drinks/drinking day (past mo) | 4.7 (1.5) |
| % Binge days (past mo) | 23.2 (10.3) |
| Drinks/binge day (past mo) | 6.5 (1.7) |
| AUDIT total | 11.1 (4.3) |
| DSM-5 AUD symptoms | 1.8 (1.3) |

**Drinking during and after the mobile assessments**

Participants consumed an average of 7.3 (SD 3.0) standard drinks over the course of the 3-hour drinking assessment, with an average eBAC reaching .13 (SD 0.07) g/dl as measured by the final time point (+180 minutes since post-first drink survey). Beer was the most common drink reported during the follow-up surveys, appearing in 48.1% (214 out of 445) of the total survey responses, followed by liquor (40.2%, 179 out of 445) and wine (16.9%, 75 out of 445). In addition,

71% of participants (59 out of 83) binged during their mobile alcohol assessment. In the first two hours of their assessments, binge drinkers consumed an average of 7.4 standard drinks (SD 2.8) and a total of 9.1 standard drinks (SD 2.9) over the course of the entire three-hour assessment. Their eBACs reached 0.14 (SD 0.06) g/dl during the first 2 hours of the assessment and rose to 0.17 (SD 0.07) g/dl for the entire 3-hour assessment. Participants who did not binge consumed an average of 2.9 standard drinks (SD 0.9) over the first 2 hours of the mobile alcohol assessment (eBAC 0.04 [SD 0.02]), and an average of 4.5 standard drinks (SD 1.8) over the entire 3-hour drinking episode (eBAC 0.07 [SD 0.03]).

In their next day survey, 60% (46 out of 77) participants reported drinking after the 3-hour mobile assessment had concluded. On average, participants drank for 2.7 more hours (SD 1.9) and consumed an average of 2.9 (SD 1.9) standard drinks. Table 2 reflects average participant drinking totals during the 3-hr drinking episode, drinking post-episode (as recorded during the next day survey) and next day consequences of drinking (BYAACQ).

Table 2

*Participant mobile assessment and post-assessment drinking data*

| | |
|---|---|
| Cumulative std. drinks @ 180 min. | 7.3 (3.0) |
| eBAC (g/dl) @ 180 min. | .13 (.07) |
| Duration of Drinking post-180min in hours (Next Day Survey) | 2.7(1.9) |
| Drinks consumed post-180min (Next Day Survey) | 2.9(1.9) |
| BYAACQ (past 24 hours) | 2.1(2.1) |

## Drinking Context

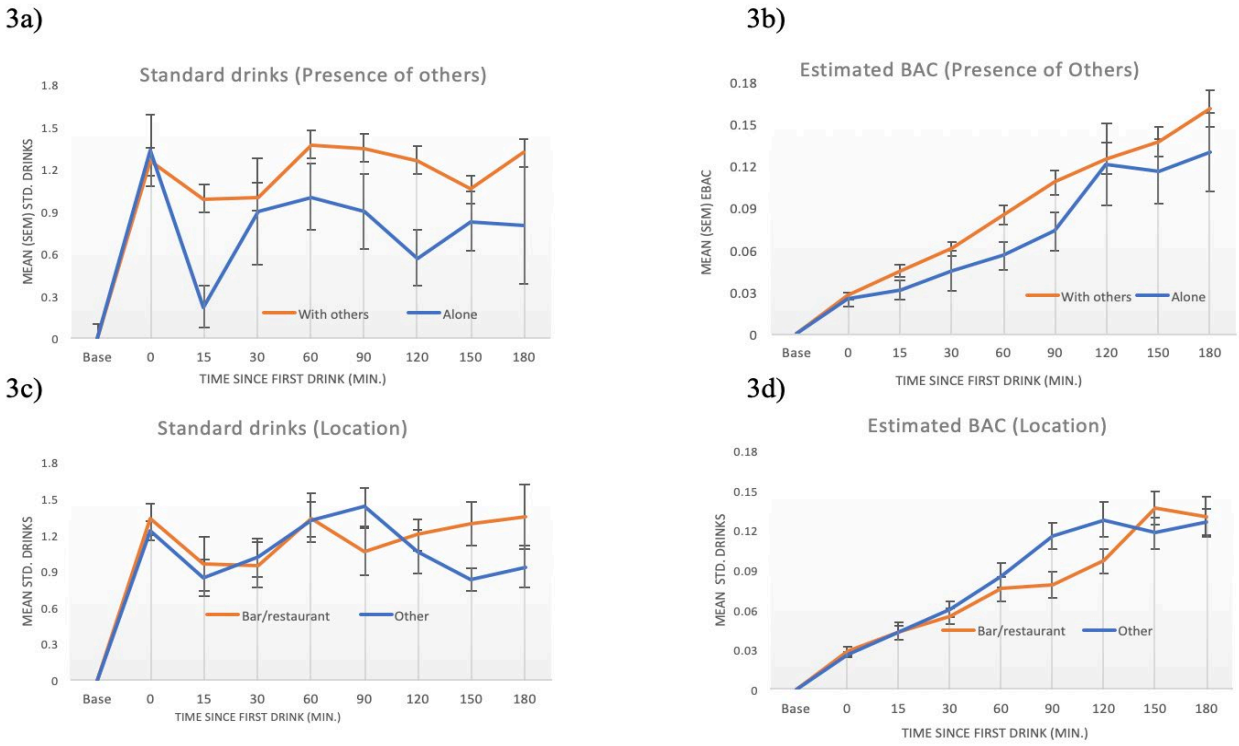
Participants reported drinking with others for 84.6% (556 out of 657) of the total survey prompts and alone for the other 15.4% (101 out of 657) over the course of the three-hour mobile assessment. 33.7% (221 out of 657) of prompts were completed in bars and restaurants, while 32.0% (210 out of 657) were completed in one's own home and 24.2% (159 out of 656) in a friend's home. Other locations (i.e., work/school, vehicle, other, outside) accounted for the final 10.1% (67 out of 657) of survey prompts. Participants were generally compliant with the instruction not to use tobacco during the HR-EMA episodes, with only 3% of all surveys indicating that participants had consumed tobacco. Similarly, only one participant reported any drug use (cocaine) at a single time point during the mobile assessments.

### *Contextual Effects on Alcohol Consumption and Subjective Responses to Alcohol*

Marginal linear effects from GEE analyses revealed several significant associations between location or presence/absence of others and study outcomes (total alcohol consumption and subjective alcohol responses). Predicted standard drinks at each time point were significantly higher when participants reported being with others as opposed to alone, $\chi 2\ (1) = 11.50$, $p < .001$ (See Figure 3a). Predicted MBrAC was also significantly higher when participants reported being with others as opposed to alone, $\chi 2\ (1) = 11.80$, $p < .001$ (Figure 3b). Location predicted both standard drinks consumed at each time point, $\chi 2\ (1) = 4.30$, $p < .05$ (Figure 3c) and MBrAC, $\chi 2\ (1) = 3.94$, $p < .05$ (Figure 3d) with individuals drinking more in bars and restaurants compared to all other locations.

Figure 3

*Contextual Effects on Alcohol Consumption*



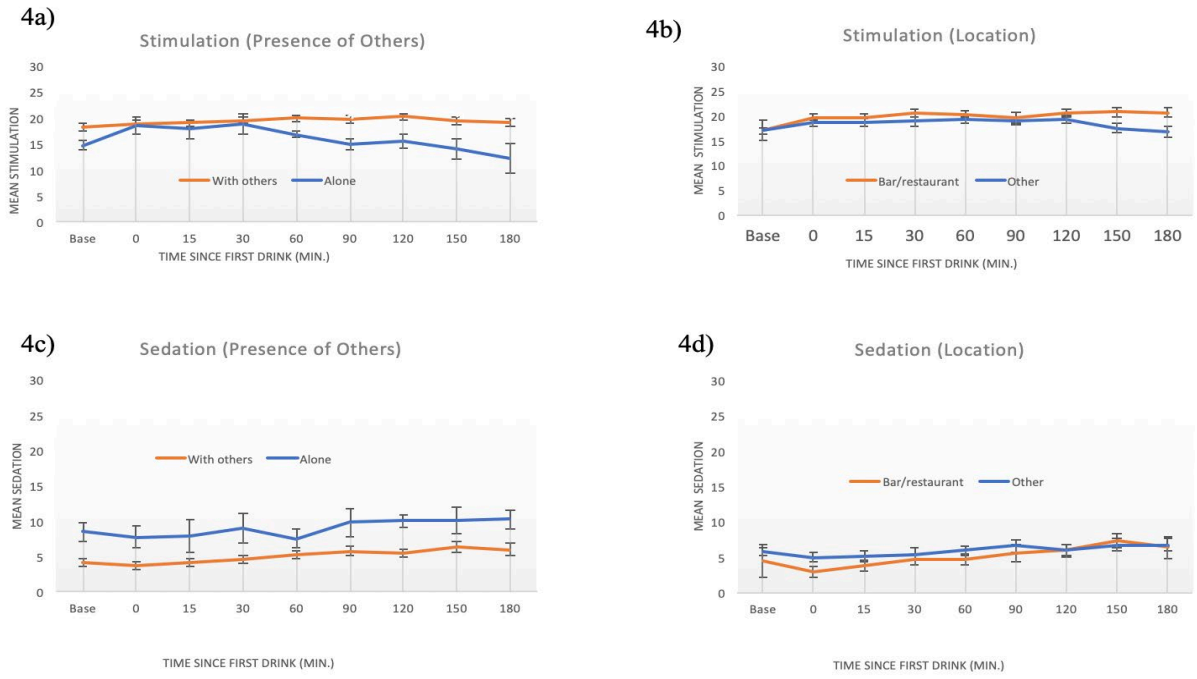

Note. eBAC calculated from eBAC = [(# of standard drinks consumed during the episode / 2) X (GC/w)] – (.017g/dl per hour x time in hours since drinking started) where GC is a gender constant (9.0 for women and 7.5 per men).

GEE analysis for subjective responses to alcohol revealed a significant interaction effect between drinking with others and time for measures of stimulation, $\chi 2\ (8) = 15.61$, $p < .05$ (See Figure 4a). Participants drinking with others reported greater alcohol stimulation versus participants who reported drinking alone, especially later in the episode. In addition, there was a significant main effect of drinking location on alcohol stimulation, $\chi 2\ (1) = 7.14$, $p < .01$ (Figure 4b), with people reporting higher ratings of stimulation at bars / restaurants compared to other places (own home, friend's home, outside, work / school, and other). There were no significant

effects of presence of others (Figure 4c) or location (Figure 4d) on reported alcohol sedation, *p*s > .07.

Figure 4

*Contextual effects on BBAES at each time point*

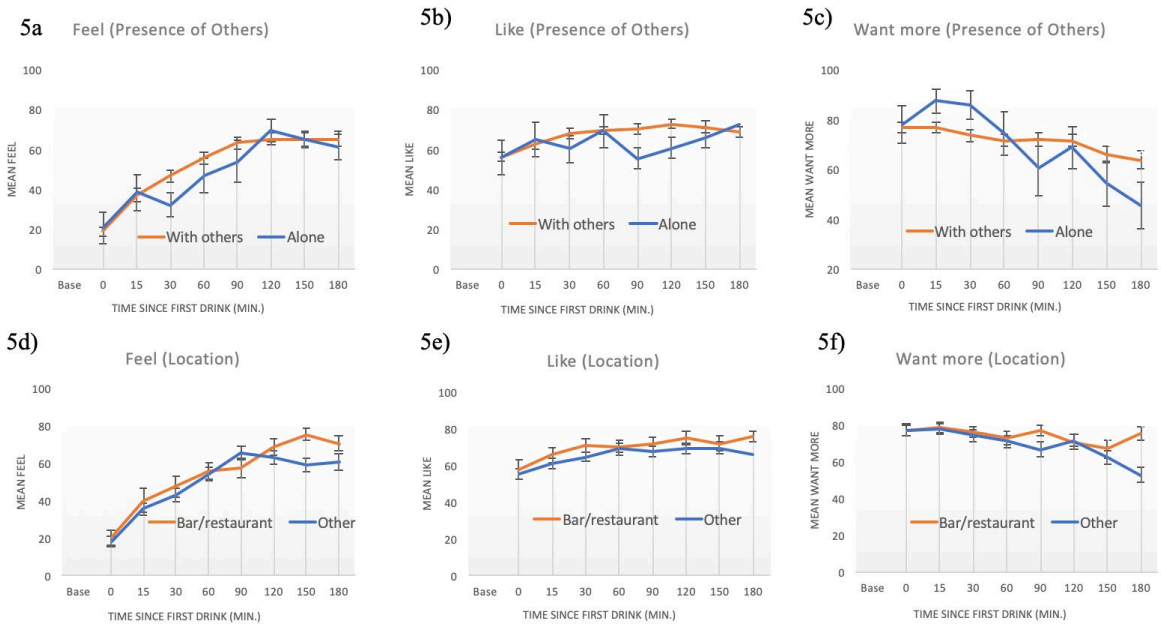



GEE analyses found significant effects of drinking context on DEQ outcomes during the real world drinking events. Specifically, there was a significant interaction effect for drinking with others and time on alcohol wanting, $\chi 2$ (7) = 42.94, p = .015 (Figure 5c). Drinking with others was associated with increased alcohol wanting, especially later in the drinking episode. There was no effect of drinking with others on DEQ feeling or liking (Figure 5a and Figure 5b, *p*s > .07). Similarly, for alcohol wanting, there was a significant interaction effect for location and time, $\chi 2$ (7) = 17.39, p = .015 (Figure 5f). People consuming alcohol in bars and restaurants wanted more

alcohol at each time point, especially later in the episode. There were no significant main effects of interactions of location on alcohol feeling (Figure 5d) or liking (Figure 5e), all *p*s > .067.

Figure 5

*Contextual effects on DEQ items at each time point*




## Discussion

The current study examined associations between drinking context (the presence of others and location) and alcohol consumption and associated subjective responses during real world drinking events in young adult heavy drinkers. By studying this group, we extended research of both laboratory alcohol challenges and prior ecological momentary assessment (EMA) studies which evaluated alcohol responses in lighter-drinking populations. Consistent with past laboratory research we found several significant relationships between context, alcohol consumption, and subjective alcohol effects.

Young adult binge drinkers consumed more alcohol and had higher eBAC ratings in the presence of others compared to when drinking alone. In addition, participants who reported

drinking in bars and restaurants consumed more alcohol and had higher eBAC ratings compared to those who drank at a private residence or elsewhere. This finding is consistent with past laboratory research which shows increased drinking in young adult drinkers at locations associated with alcohol (Lutz et al., 2021). Alcohol associated locations and the presence of others were a significant predictor for increased acute alcohol consumption in their naturalistic environment for the at-risk population we studied. Our data suggests that among young adult heavy drinkers, location and presence of others act as key forces for driving excessive alcohol consumption.

In addition to the behavioral measures recorded during the mobile drinking assessments, several subjective responses to alcohol were found to be significantly associated with contextual factors. When drinking with others, participants reported significantly higher feelings of stimulation (as assessed by the brief biphasic alcohol effects scale) compared to those drinking alone, especially later in the episode. This time X context interaction effect revealed that while participants drinking alone start off with similar ratings of alcohol stimulation compared to participants drinking with others, solo drinkers exhibit a sharper drop off in stimulation ratings later in the episode. A similar interaction effect was shown for location on ratings of stimulation, with participants at bars and restaurants remaining significantly more stimulated compared to those drinking at other locations later in the episode. This is consistent with laboratory findings that showed locations participants are taught to associate with alcohol increased reported reward when drinking there compared to other locations (Lutz et al., 2021; Childs et al., 2016).

Similar time interaction effects were found for both presence of others and location for the “wanting more” item of the Drug Effects Questionnaire. Participants who were drinking with others reported greater desire to continue drinking than those drinking alone, especially later in

the episode. Participants also reported a significantly higher desire to keep drinking when in bars and restaurants compared to other settings. Our data suggests that context (locations such as bars and restaurants and the presence of others) extends the rewarding effects of alcohol later into real world drinking episodes and drives increased alcohol consumption in heavy young drinkers.

Regardless of context, we found strong support for increased reward driving alcohol consumption on the ascending limb of the BAC curve. This is consistent with the *differentiator model* (DM) and extends its findings by evaluating subjective responses to alcohol in a naturalistic setting. The DM posits that higher stimulation on the ascending limb and lower sedative responses on the descending limb of the BAC curve contribute to increased risk for future alcohol related health problems. Participants tended to consume alcohol for the duration of the 3-hour monitoring period, which precluded our capturing data from the descending limb, when sedation scores typically predominate (Martin et al., 1993). For this reason, we could not conduct a full test of the differentiator model in the natural environment as participants did not record subjective responses during the descending limb. In fact, most participants in this sample reported drinking for an additional ~3 hours after completing the HR-EMA episode, so many may have been asleep while their BAC was declining (Fridberg et al., 2019). Future HR-EMA research should use a longer monitoring period to examine subjective responses to alcohol during both the ascending and descending limbs of the BAC curve. However, as noted above and by Piasecki (2019), this may be inherently difficult as most individuals are asleep when their BAC decreases.

Among the strengths of the present study was its ability to evaluate how participants consume and respond to alcohol in real-world settings. The many benefits of an HR-EMA

investigation include the reduced cost compared to alcohol challenge protocols, high external validity, and reduced recall bias (Piasecki, 2019). The present study had several additional strengths relative to past EMA research in this field. First, young adult frequent binge drinkers made up the sample population, a demographic which often partakes in risky drinking behaviors that have been associated with significant health problems later in life. By examining consumption and subjective responses to alcohol in this at-risk population, the current study was able to reveal important factors that contribute to experiencing more reward from alcohol and increased use. In addition, the sample reported only one instance of drug use across all surveys, and tobacco use in only 3% of participants, helping to limit their subjective responses to substances to alcohol. Last, the ability to control for past drinking while running GEE analysis eliminates the possible confound of increased BAC level driving heightened reward in those drinking with others or in bars and restaurants, compared to alone or elsewhere. Controlling for past drinks still revealed significant associations between context and reward.

While the current study had several strengths, it also had some limitations worth noting. First, mobile assessment location and presence of others were not randomly assigned variables. Participants may have chosen to drink with others or in bars and restaurants because they experience stimulation and heightened reward in those contexts regardless of what or how much they are drinking. To address this possible confound, future research should utilize an HR-EMA approach to compare an alcohol drinking and a non-alcohol drinking episode, where participants report their context, location, BAES and DEQ items. A future study could also ask participants to vary their location during multiple alcohol drinking episodes to compare the effects of drinking context on subjective responses within individuals. Second, the HR-EMA design used in this study was limited in its ability to capture an entire binge drinking episode in the real

world. 60% of participants continued drinking post 3-hour assessment, and on average consumed an average of 2.9 additional drinks over the course of 2.7 hours (Fridberg et al., 2019). The three-hour assessment therefore did not capture either the peak or the descending limb on the BAC curve for most study participants. Especially considering that GEE analysis found significant time interaction effects for presence of others and drinking in a bar/restaurant on stimulation and "wanting more" items, extending the mobile assessments past 3 hours would more accurately reveal how subjective responses to alcohol change over the course of the BAC curve. Last, while the present study created in-depth snapshots of real world drinking episodes, it did not follow participants or keep track of the progression of their AUD symptoms. Prior research conducted in the laboratory has followed participants over a decade or more and has shown that alcohol subjective responses, especially increased stimulation/reward and decreased sedation, are linked to continued binge drinking behavior and the development of alcohol related problems (King, 2014; King, 2016). Therefore, the current data do not speak to how subjective responses recorded by participants in this study may be associated with their future risk for AUD. Future work should examine whether total alcohol consumption or BAC during real-world binge drinking events may drive an increased progression in AUD symptoms, and whether this is the case while consuming alcohol alone or with others. Future research should look to build on our findings of subjective responses to alcohol in real-world settings to further our understanding of important risk factors associated with context for increased alcohol use.

In conclusion, HR-EMA smartphone assessments allowed us to capture evidence for significant differences in acute alcohol consumption and subjective responses to alcohol based on context in real world drinking episodes. Young adult heavy binge drinkers reported not only increased alcohol use in the presence of others and when drinking in restaurants or bars, but

reported certain subjective responses to alcohol (stimulation and “wanting more”) more rewarding. This data suggests that context may play an important role in binge drinking among young adults who are susceptible to risky drinking behavior. Future research should continue using HR-EMA methods over longer assessment periods and at follow-up to further determine how context influences drinking behavior and subjective responses to alcohol for acute and chronic alcohol consumption.

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# Appendix

Figure 1. Real – world mobile assessment timeline for an alcohol drinking episode

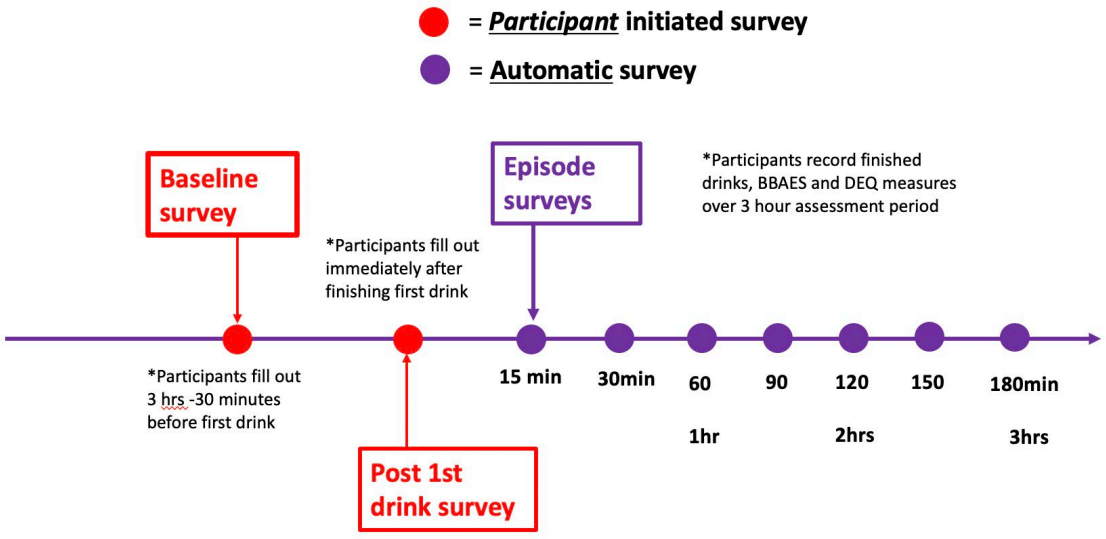


Figure 2. Screenshots from MetricWire: examples of the real time drinking assessments used for post-first drink and episode surveys with questions asking A) location; B) presence of others; C) finished drinks since previous survey; D) Brief Biphasic Alcohol Effects Scale item; E) Drug Effects Questionnaire item