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# Alcohol Demand Assessed Daily: Validity, Variability, and the Influence of Drinking-Related Consequences

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## Abstract

**Background:** Alcohol demand, typically assessed at the trait-level, via single administration, reflects individualized alcohol value. We examined correspondence between trait-level and a brief measure of daily alcohol demand, and whether demand changes day-to-day in response to recent drinking-related consequences. Understanding whether consequences influence demand fluctuations may provide insight into when demand can be reduced in the context of intervention.

**Methods:** Heavy drinking college students ($n$=95, age 18–20, 52% female) completed a baseline 14-item alcohol purchase task (APT). Observed demand indices were: intensity (consumption at zero cost), $O_{max}$ (maximum expenditure), and breakpoint (cost whereby consumption is suppressed to zero). Participants subsequently completed 28 daily reports including a 3-item APT (one item corresponding to each baseline index) and prior day drinking and consequences.

**Results:** Intraclass correlations revealed within-person variability (i.e., day-to-day change) across daily demand indices. In hierarchical linear models (HLM), each daily demand index was significantly predicted by its corresponding baseline full APT index, when all three baseline indices were entered, suggesting convergent validity of the daily measure. Lower day-level intensity was predicted by more prior day negative consequences, controlling for several day- and person-level variables in HLM. Recent positive consequences did not impact intensity, and daily $O_{max}$ and breakpoint were not predicted by any tested day- or person-level variables.

**Conclusions:** APT indices collected daily map on well to traditional single-administration APT metrics and change in response to recent consequences. Intensity demonstrated greatest within-

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Contributors

Dr. Jennifer Merrill designed the study and collected the data. Dr. Elizabeth Aston conducted the literature review. Both authors contributed to data analysis, manuscript drafting, and final approval of the manuscript.

**Declarations of Interest:** none

person variability, strongest association with its corresponding full APT index, and theoretically-consistent prediction by negative consequences of drinking.

**Keywords**

alcohol demand; alcohol consequences; daily assessment; behavioral economics; college students; alcohol purchase task

## 1. Introduction

High rates of drinking, heavy drinking, and alcohol use disorders (AUDs) occur among young adults (Grant et al., 2017), with approximately 10% of those aged 18–20 meeting AUD criteria (SAMHSA, 2015). Alcohol misuse is a public health concern particularly among those attending college (Johnston et al., 2016). College students report experiencing a range of negative alcohol-related consequences to self and others, including memory loss, sexual assault, and injuries (Hingson et al., 2009). While some studies show historical decreases in the prevalence of lifetime and past 30-day alcohol use in college students, we have not seen decreases in related negative outcomes such as hospitalizations associated with alcohol overdoses (White et al., 2011). As such, important tasks remain with respect to better understanding what drives such risky drinking behavior.

### 1.1. Alcohol Demand

One important construct used to understand alcohol use and related problems is behavioral economic alcohol demand. Alcohol demand is the association between alcohol cost and consumption, and the degree to which this interplay reflects individualized drinking reinforcement (Hursh et al., 2005). Level of alcohol reinforcement can be assessed via performance on a hypothetical alcohol purchase task (APT) which can be used as a model of drinking behavior (Jacobs and Bickel, 1999). Respondents are asked to designate the number of drinks they would purchase and consume at escalating cost levels under specific hypothetical conditions. Typically, as the price of alcohol increases, purchase and consumption declines. APTs allow for assessment of five alcohol demand indices including intensity (i.e., consumption at zero cost), $P_{max}$ (i.e., price at maximum expenditure), $O_{max}$ (i.e., peak expenditure for alcohol), breakpoint (i.e., cost at which consumption is suppressed to zero), and elasticity (i.e., the degree to which consumption declines with increasing price). Commonly used trait-level APT versions have good construct validity (Kiselica et al., 2016) and maintain stability over time (Acuff and Murphy, 2017).

Several studies have used the trait-level APT to examine demand as a predictor of alcohol use and consequences. Following a seminal study using a novel APT to demonstrate that alcohol demand was significantly associated with recent heavy drinking (Murphy and MacKillop, 2006), APTs have been used extensively to evaluate individualized rewarding properties of alcohol (Kaplan et al., 2018). Alcohol demand has been significantly related to level of consumption (e.g., Bertholet et al., 2015) and severity of alcohol problems (Murphy and MacKillop, 2006; Tucker et al., 2016), and has the propensity to predict response to therapeutic treatment (MacKillop and Murphy, 2007). Key demand indices, intensity and

$O_{max}$, have been strongly positively related to negative alcohol consequences (Kiselica and Borders, 2013).

### 1.2. Measurement of Trait versus State Demand

While APTs are frequently administered at a single time point, and are typically conceptualized as a trait measure, state-oriented purchase tasks can capture alterations in demand due to changes in context or environment. When administered repeatedly, the APT may be used to distinguish changes in demand that occur in response to varying subjective states or changes in environment (Heinz et al., 2012). Thus, alcohol demand reflects the intensity of desire for alcohol, and likely fluctuates over time. Such state-oriented purchase tasks have demonstrated cue-elicited increases in alcohol demand (MacKillop et al., 2010).

A brief 3-item version of the APT (Owens et al., 2015) was designed to capture three key alcohol demand metrics (intensity, $O_{max}$, and breakpoint). All three indices were shown to increase significantly following exposure to alcohol cues. Another study used a near-identical set of three single items to capture the same three demand indices repeatedly in the laboratory, among participants receiving an alcohol, placebo, or control beverage (Amlung et al., 2015a). The single items corresponded to demand indices derived from the full APT, and changes in craving were associated with changes in demand across the repeated assessments. These findings provided evidence for the validity of a brief APT when administered repeatedly in the laboratory.

This initial work was promising as it alleviates burden typically associated with administration of the full state version, which may impede utilization of this measure, particularly in studies where repeated administration is desired or necessary. However, additional work is needed to demonstrate promise for a brief APT measure when administered in the natural environment. Research using a brief APT within the context of daily data collection has yet to be conducted, despite the potential range of research questions that could be explored with daily assessment of demand.

While many studies have examined demand as a predictor of drinking behavior, other work tests demand as an outcome, exploring whether other key precursors such as episodic foresight (Bulley and Gullo, 2017) or implicit alcohol approach associations (Luehring-Jones et al., 2016) impact alcohol demand. However, no studies to our knowledge have investigated the impact of recent alcohol consequences on demand. Theoretically, negative consequences of drinking should “punish” while positive consequences should “reinforce” drinking behavior. As such, the specific experiences related to a recent drinking event may influence demand for the next drinking event. Relatedly, research has shown that demand can be strongly impacted by impending next-day responsibilities (Berman and Martinetti, 2017; Gentile et al., 2012; Skidmore and Murphy, 2011). As next-day responsibilities increase (e.g., next-day class, next-day exam), demand rapidly declines. It follows that demand for alcohol may change over time as one experiences or fails to experience consequences related to drinking. Understanding potential influences on fluctuations in demand may provide insight into when or how demand can be reduced in the context of intervention.

### 1.3. The Present Study

We sought to develop and test a demand measure administered daily for 28 days (i.e., a daily APT) to a sample of heavy drinking college students under the US legal drinking age. We also conducted secondary analyses on data collected for a larger study designed to understand the influence of alcohol consequences on subsequent drinking. Assessment in the natural environment is particularly valuable for examining consumption among such underage drinkers, for whom laboratory administration of alcohol is prohibited. We tested whether demand as assessed by a daily APT changes from one day to the next (i.e., within-person variability in demand) and examined associations among demand indices derived from a baseline assessment (using a traditional single-administration full APT) and those derived from a daily APT. Next, we tested the hypothesis that more negative alcohol consequences on a given day would be associated with lower demand for alcohol the following day, and more positive consequences would be associated with higher demand.

## 2. Materials and Methods

### 2.1. Participants

One hundred participants completed a 28-day assessment protocol; however, five were removed for analyses (four reported no drinking during the observation period and one only purchased alcohol at zero cost on the full APT). Thus, participants were 95 (52% female) college student drinkers (Table 1). To be eligible, participants reported age 18–20 years, access to a smartphone and data plan, enrollment in an undergraduate program at a local 4-year college or university, and either (a) weekly heavy episodic drinking (HED; 4+ drinks in a single sitting [women]/ 5+ drinks in a single sitting [men]) or (b) experience of at least 1 (of 10 assessed) negative alcohol-related consequence in the past two weeks. Exclusion criteria included illicit drug use other than marijuana in past two weeks or current treatment for a substance use disorder. All procedures were reviewed and approved by the Brown University Institutional Review Board.

### 2.2. Procedures

**2.2.1. Recruitment and orientation.—**Participants were recruited via flyers posted on and around local campuses and social media advertisements including a link to an online screening questionnaire (<5 minutes). A total of 488 individuals initiated the screener, 406 completed it, and 158 were eligible and therefore routed to an online form to provide consent for a baseline survey. Of these, 152 consented and 110 completed the baseline survey (~20 minutes) and scheduled a group orientation session (~60 minutes). They received $25 for the baseline survey and attendance at the orientation session. During orientation, participants provided informed consent for the daily assessment phase of the study. A total of 101 attended their orientation session and enrolled in the study. They were trained in reporting of standard drinks (1.5 oz liquor, 5 oz wine, 12 oz beer), downloaded the mobile application for daily report delivery onto their smartphones, and completed practice reports.

**2.2.2. Daily assessment protocol.—**Out of the 101 enrolled, 100 participants completed the daily assessment protocol. The 28-day protocol involved several device-

initiated surveys each day. A morning report was triggered at 7am, with a reminder sent at 9am if indicated. This report remained available for completion throughout the day; however, participants were instructed to complete it as close in time to waking up as possible. A notification was sent at 8pm to remind participants to log drinking events that occurred that evening, and required acknowledgment via a submit button. They also were instructed to complete reports during drinking events. However, only morning report data were used for the present study, because (a) this is when the daily APT was administered, (b) morning reports included a broader range of potential consequences that could not be assessed in real-time (e.g., hangover, blackout), and (c) morning reports had more complete data (479 drinking events compared to 430 in real-time). Participants were paid based on percent compliance with daily reports (e.g., morning, 8pm check-in), earning from $5 (for less than 20% compliance) to $45 (for at least 90% compliance) on week 1. Potential payments increased slightly each week, to a max of $51 (total possible for daily reports = $192).

## 2.3. Measures

### 2.3.1. Baseline Measures.

**2.3.1.2. Demographics:** Demographics assessed at baseline included age, gender, year in school, race, and ethnicity.

**2.3.1.2. Alcohol purchase task (APT).:** A 14-item APT was used to assess relative value of alcohol at the trait level (Murphy and MacKillop, 2006). Participants were provided with an instructional vignette prior to APT completion (see Murphy and MacKillop, 2006 for detailed instructions).

**2.3.1.3. Baseline brief APT.:** At baseline, we administered a brief 3-item version of the APT, which mapped onto the way demand was later assessed each day with the daily APT (see below). First, participants were asked to estimate the number of days until their next drink (0=today), followed by three items modified from prior work (Amlung et al., 2015a; Owens et al., 2015) designed to assess alcohol demand. Instructions read: "*For the next few questions, imagine the next time you drink (X days from now) and that you are purchasing alcohol only for yourself. Remember what a standard drink* is." Intensity was measured by the item: "If *drinks were free the next time you drink, how many do you think you would have?*" (response options from 0–25+ in single drink increments). $O_{max}$ was measured by the item: "*The next time you drink, if you had to pay for every drink you consumed, what is the maximum total that you would spend on drinking (approximately)?*" (response options from $0 to $100+ in $4 increments*)*. Breakpoint was measured with the item: "*The next time you drink, if you had to pay for every drink you consumed, what is the maximum that you would pay for a single drink?*" (response options from $0 to $20 in $2 increments).

**2.3.1.4. Non-essential spending money.:** To be used as a covariate in analyses examining demand, in an open-ended question, participants were asked how much money they had available to spend for non-essential items (e.g., clothing, movies) during the past 30 days. They were instructed not to include money budgeted for essentials, such as rent, groceries, and school books.

#### 2.3.2. Morning report measures.

**2.3.2.1. Alcohol use.:** When prior day drinking was endorsed, participants indicated the total number of standard drinks consumed.

**2.3.2.2. Alcohol consequences.:** Following drinking days, participants were asked whether they had experienced any of 9 negative consequences (i.e., nauseated or vomited, rude or obnoxious, neglected school-related obligations, hurt/inured self by accident, behaved aggressively, said or did embarrassing things, hangover, forgot what you did, drove a car when you knew you had too much to drink to drive safely) and 8 positive consequences of drinking (i.e., had something that normally would bother you fail to bother you, talked to someone probably wouldn't have otherwise, had a creative moment/experience, made a new friend/acquaintance, made others laugh, slept better, able to express feelings more easily, had something fun/exciting happen). Items were derived from several measures including the Brief Young Adult Alcohol Consequences Questionnaire (Kahler et al.,2005), the Positive Drinking Consequences Questionnaire (Corbin et al., 2008), a daily study of consequences conducted by Lee et al. (2017), and our formative work (Merrill et al., 2018b).

**2.3.2.3. Daily APT.:** Demand was assessed each morning, regardless of prior day drinking. Items were identical to the brief 3-item APT administered at baseline (described above). Because in this non-dependent sample of drinkers we did not expect much variability in (or even presence of) current state demand the morning after drinking, as noted above, participants reported on demand for alcohol at their next expected drinking event.

### 2.4. Analytic Plan

#### 2.4.1. Deriving baseline indicators of demand.—

Raw data from the full APT were examined for outliers using standard scores, with a criterion of Z = 3.29 to retain maximum data. A small number of outliers were detected (0.01%), determined to be legitimate high-magnitude values, and recoded as one unit higher than the next lowest non-outlying value (Tabachnick and Fidell, 2007). Five metrics of alcohol demand were obtained from the full APT: intensity, $O_{max}$, $P_{max}$, breakpoint, and elasticity. Observed values for $O_{max}$, $P_{max}$, and breakpoint were estimated by directly examining APT performance.

Elasticity of demand was derived by fitting individual curves in GraphPad Prism using the modified Koffarnus exponentiated demand equation (Koffarnus et al., 2015), $Q = Q_0 \times 10^{k(e^{-\alpha Q_0 C} - 1)}$, where $Q$ = quantity consumed, $Q_0$ = derived intensity, $k$ = a constant across individuals that denotes the range of the dependent variable (alcohol drinks), $C$ = the cost of the commodity, and $\alpha$ = elasticity or the rate constant determining the rate of decline in consumption based on increases in price (i.e., essential value). The appropriate $k$ value was determined by subtracting the $\log_{10}$-transformed average consumption at the highest price ($9.00) from the $\log_{10}$-transformed average consumption at the lowest price used in curve fitting ($0.25). The $k$ value used in analyses was 0.813. An $R^2$ value was generated to reflect percentage of variance accounted for by the demand equation (i.e., the adequacy of the fit of the model to the data).

**2.4.2. Substantive analyses.—**Following examination of descriptives, a series of hierarchical linear models (HLMs, day at Level 1 nested within person at Level 2) were run on the HLM 7.02 program (Raudenbush et al., 2013), using full maximum likelihood estimation. We relied on robust standard errors in the determination of effect significance. First, to test whether there was within-person variability in demand indices derived from the daily APT, three fully unconditional models were run to obtain intraclass correlation coefficients (ICCs). Second, to test correspondence between baseline and event-level APT measures, we used all three baseline full APT indicators (intensity, $O_{max}$, and breakpoint) as Level 2 predictors in three separate models, each one predicting a daily APT demand index at Level 1 (daily intensity, daily $O_{max}$, or daily breakpoint). Finally, to test the influence of consequences on daily demand, three models were run (one for each daily APT demand index). Level 1 predictors of interest included number of negative consequences and number of positive consequences, both person-centered. This allowed us to test whether deviations above or below the individual's own personal average number of consequences was associated with next-day demand. Level 1 covariates included day in the study, total number of drinks (person-centered), days until next expected drink (person-centered), and whether the event occurred on a weekend or weekday. Level 2 covariates (grand-mean centered) included the individual's average number of negative consequences, positive consequences, drinks across the course of the study, and spending money. Intercepts were specified as random effects, and for parsimony given the number of Level 1 variables, slopes were fixed. Of note, fixed effect significance levels did not change when slopes were specified as random.

## 3. Results

### 3.1. Descriptives

Sample descriptive characteristics are shown in Table 1. Outcome variables (daily intensity, $O_{max}$, and breakpoint) were normally distributed. For trait demand (baseline full APT), as expected, alcohol consumption decreased as a function of increasing price. Figure 1 depicts the consumption and expenditure curves derived from trait APT performance. The modified exponentiated demand equation (Koffarnus et al., 2015) provided an excellent fit to the overall demand data ($R^2$ = .938) and a good fit to the individual data (median $R^2$ = .824, interquartile range = .788 – .888). Across the 28 days, missing data were minimal, as surveys were completed on 2625 (out of 2660 possible; 99%) days. Participants reported a total of 486 prior-day drinking events (18.5% of morning reports completed). Time that the morning survey was submitted ranged from 7:01 in the morning to 10:44 at night, with an average time of 10:39 am. Correlations among demand indices assessed via three methods (daily APT, baseline brief APT, full APT at baseline) are shown in Table 2. Parallel indices across assessment methods were significantly correlated.

### 3.2. Substantive Models

**3.2.1. Daily variation in demand indices.—**The ICC for daily intensity was .77, indicating that 77% of the variability was attributable to between-person differences while 23% was attributable to differences within-person, over time. The ICC for daily $O_{max}$ was .84 and the ICC for daily breakpoint was .85. In other words, across all daily demand

indices, while most of the difference was due to how people differ from one another, there was still a substantial amount of difference from one day to the next.

**3.2.2. Associations between baseline full APT and daily APT demand indices.—**Each daily APT demand index was significantly predicted by its corresponding baseline full APT index, when all three baseline indices were entered. These findings suggest validity of the daily measure, in that there were strong associations between trait-level demand and state-level demand assessed repeatedly in the natural environment. Baseline $O_{max}$ was also significantly associated with daily breakpoint. Full model results are shown in Table 3.

**3.2.3. Associations between alcohol consequences and daily demand.—**Daily $O_{max}$ and breakpoint were not predicted by any tested day- or person-level variables. More prior day negative consequences was associated with lower next day intensity. In other words, when an individual reported experiencing more negative consequences than they typically did, they would consume fewer drinks even if those drinks were free. Positive consequences were not associated with any daily demand index. Though not a focal predictor, more total drinks than usual was significantly associated with *higher* daily intensity. Full model results are shown in Table 4.

## 4. Discussion

This study represents initial development of a brief measure of alcohol demand - a daily APT - that can be administered repeatedly in the natural environment. First, when studying this measure among underage heavy drinking college students, we demonstrated that three indices of daily demand - daily intensity, $O_{max}$, and breakpoint - varied significantly within-person over the course of 28 days, providing support for demand as a dynamic state-level construct. Second, we demonstrated that each of the daily demand indices was significantly related to its corresponding baseline index from the full APT, providing evidence of convergent validity. As such, we proceeded to use the daily APT demand indices to test a novel research question regarding the impact of recent alcohol-related consequences on alcohol demand. Experiencing more negative (but not positive) consequences of drinking one day predicted lower levels of intensity the following day among underage college drinkers. Findings have implications for inclusion of demand assessment in future daily-level studies, and highlight the role that recent negative drinking events may play in changing demand.

While the majority of the variability in all three daily demand indices was at the between-person level, a substantial proportion was due to differences within a person over time in this sample. The largest proportion of within-person variability was observed in daily intensity (23%) relative to daily $O_{max}$ and breakpoint. It may be that certain demand indices (e.g., $O_{max}$, breakpoint) are more impervious to alterations in context and internal state, while others (e.g., intensity) are susceptible to influence by external factors such as the experience of consequences. The existence of within-person variability in daily demand primes the investigation of several research questions involving demand as both a predictor (e.g., Is demand on a given day related to alcohol use later that day?) and an outcome (e.g., How

does demand change throughout the day or *during* a drinking episode, in response to increasing intoxication?). As noted, some research has assessed the impact of intoxication on demand for alcohol in the laboratory (Amlung et al., 2015a). However, our study provides support for efficient and repeated (i.e., daily) administration of a daily APT via mobile technology in one's own drinking environment. As such, the observation of changes in demand in response to real-world cues and changes in context, mood, and physiological states (e.g., intoxication) will be possible.

In the current study, the daily APT and full baseline APT indices were all significantly, though not necessarily highly correlated. As in previous research assessing a brief version of the APT (Owens et al., 2015; Amlung et al., 2015), corresponding $O_{max}$ and breakpoint indices were significantly correlated across both task versions, however, the relationships were not particularly strong. In contrast, intensity across both measures was highly correlated, echoing findings from a recent review (Zvorsky et al., 2019) indicating that intensity appears to be the index with the highest effect sizes across many investigations.

We sought to determine whether consequences of drinking influence daily alcohol demand among heavy drinking college students under age 21. As hypothesized, negative consequences were associated with next day intensity. Intensity reflects unrestricted alcohol access at zero cost. As the concept of cost is used as a proxy for consequences in behavioral economics (Aston et al., 2017), it can be inferred that intensity is reflecting drinking in the absence of perceived consequences and barriers, which is well-aligned with drinking environments for many college students. Our findings suggest that when a drinker has recently experienced more negative consequences than he/she typically does, their demand for alcohol is subsequently reduced. Of note, positive consequences did not influence any index of daily demand. This suggests that demand is a construct that is more reactive to recent negative effects of drinking (which are also endorsed less frequently) than recent positive effects of drinking.

We did not observe effects of either negative or positive consequences on the other two daily demand indices - $O_{max}$ and breakpoint. Of note, relative to these two indices, the item used to assess intensity at the daily level is likely most relevant for the college students sampled in this study. All participants were under the U.S. legal drinking age and were more likely attending parties and other events where alcohol is freely available with minimal restriction on amount consumed, rather than public venues where drink purchase is necessary. As such, a question regarding consumption at zero cost may have aligned most closely with students' personal experiences. Also of note is that there was more daily-level variability to be predicted in intensity as compared to the other predictors.

Importantly, the response options utilized in the current study for the brief APT questions differed slightly to those presented in other studies (Amlung et al., 2015a; Owens et al., 2015). In the current investigation, participants were provided with a greater range of responses for the daily measures of intensity (0–25 drinks, versus 0–20 drinks in Owens et al. and 0–14 in Amlung et al.) and $O_{max}$ ($0-$100, vs $0–40 in prior work). Yet, participants did not use the full range of these scales, and maximum values did not exceed those used in the prior work. Response options in subsequent research should be adapted to address

differences in average standard drink price as a function of both geographical location and sample characteristics (i.e., college student versus community sample).

By design, our daily measure of demand was keyed to the next time participants expected/planned to drink, rather than "right now," because we did not expect much variability in demand at morning assessments, and were interested in the impact of recent consequences on demand for later drinking. Further, limited instructions were provided for the brief APT (relative to the typical, longer instruction set for the full APT). Using different instructional sets may result in different findings than those in the present study, and future studies should examine how variability in key components including time, unit, and price alter demand for alcohol.

### 4.1. Limitations

Despite the novel contribution of this study, there are notable limitations. We only assessed a subset of potential positive and negative consequences of drinking. It is possible that the experience of other, more severe yet less common, negative consequences of drinking (e.g., hospitalization, trouble with police) would have a stronger impact on demand. Additionally, our sample included only heavy drinking college students under the legal drinking age. Studying alcohol use in the natural environment among underage drinkers is ideal, given restrictions on alcohol administration in the lab. As noted however, the age of our participants may have critical implications for alcohol purchasing behavior. Further, findings cannot be generalized to lighter drinkers, older drinkers, or non-college attending young adults. While we suspect that the daily demand measure examined here would be similarly associated with trait demand, and similarly influenced by consequences, in a sample of drinkers age 21 and older, future work is needed to replicate our study in other populations.

In order to reduce participant burden, demand was only assessed once daily, in the morning. While morning is when recent consequences are most likely to be salient and impactful on cognitions and behavior (Merrill et al., 2018a; Merrill et al., 2018b), it is unclear whether similar findings would emerge had demand been assessed at alternate times. Future work could measure demand multiple times per day to determine whether consequences have a more dynamic influence on demand than we were able to study here. Additionally, it has been argued that utilizing brief assessment of demand, rather than molar assessment, departs from the core nature of behavioral economic theory (Tucker and Vuchinich, 2015). Behavioral economics traditionally emphasizes the importance of singular choices in the context of a range of choices, thus truncating the traditional APT removes surrounding choices that reflect responses in the face of fluctuating price. Still, decisions regarding consumption at one price are not only influenced by choices regarding consumption at other prices, but are also greatly impacted by internal (e.g., craving) and external (e.g., context) factors that are occurring in-the-moment (Amlung et al., 2015b). Therefore, examination of demand for alcohol repeatedly over time using brief single items has the capacity to elucidate hitherto unknown demand fluctuations. A final limitation of this research includes the inability to assess the neurobiology of demand- related decision-making processes (Bickel et al., 2007). As participants were assessed in-the-moment in their chosen environment, we could not use common neuroeconomic techniques such as fMRI or PET to

examine momentary decision-making processes. This is an important area for subsequent research as a crucial next step will include assessment of changes in brain-related decisional processes in-the-moment in response to internal and external stimuli.

### 4.2. Conclusions and Future Directions

This study provides initial evidence for the concurrent validity of a brief APT administered daily via mobile technology, with demand indices that were uniquely related to those derived from a full APT administered at baseline and varied at the daily-level over time. Our findings suggest that one indicator of daily demand - daily intensity - was particularly variable over time and was influenced by recent negative alcohol consequences. Such a finding could have important intervention implications. The morning after drinking may be an opportune time to intervene upon hazardous drinking behavior, as recent consequences may reduce one's motivation for alcohol (or increase one's motivation to avoid alcohol). Such an intervention could be delivered via mobile application, for example, by assessing recent behavior and current demand, and sending intervention material that corresponds to a person's current level of demand and/or motivation to change. The design and testing of such an intervention is an exciting future direction.

While this study must be replicated in more generalizable samples, given that our findings suggest that consequences influence daily demand, an interesting next step will be to study whether lower demand is a pathway through which recent alcohol consequences may influence downward change in actual levels of subsequent drinking. Another exciting future avenue is administration of a brief APT at other times, such as the start of the next drinking event, which would allow understanding of whether prior consequences continue to impact demand over time. Demand might also be assessed in future work even more frequently, such as throughout an entire drinking episode. Such work would allow for comparisons of demand across the blood alcohol concentration curve, as it is likely that both subjective and biphasic response to alcohol differentially impact demand (Amlung et al., 2015a). Utilization of brief measures of demand administered in the natural environment, both for alcohol and across other substances, will greatly contribute to our understanding of dynamic changes in substance value, and will ultimately move the field forward.

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## Highlights

- This study utilized a brief alcohol purchase task (APT) administered at the daily level over time.
- Brief APT indices collected over time map on to traditional single-administration APT metrics.
- Brief alcohol demand for future drinking changes in response to recent consequences.
- Daily demand may be best captured via a single intensity item.

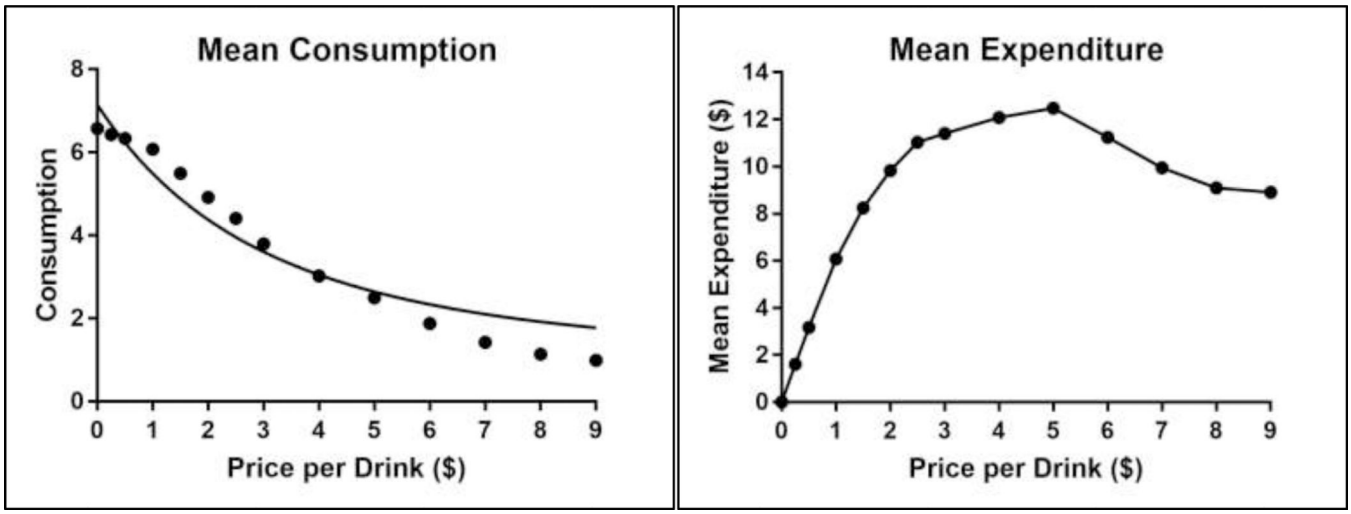


**Figure 1.**

Consumption and expenditure curves for purchase of alcohol drinks. The x-axis provides price in dollars ($) and the y-axis provides mean drinks purchased and mean expenditure in dollars ($), respectively

**Table 1.**

Demographics, drinking behavior, and alcohol demand in a sample of underage college men and women (N=95)

| | Mean (SD) or n (%) |
|---|---|
| **Variables Assessed at Baseline** | |
| **Age** | 18.67 (0.66) |
| **Year in School** | |
| First year | 76 (80%) |
| Second year | 15 (15.8%) |
| Third or fourth year | 4 (4.3%) |
| **Female** | 49 (51.6%) |
| **Hispanic/Latino** | 14 (14.7%) |
| **Race (check all that apply)** | |
| White | 69 (72.6%) |
| Black or African American | 7 (7.4%) |
| Asian | 21 (22.1%) |
| Native American or Native Alaskan | 1 (1.1%) |
| Native Hawaiian or other Pacific Islander | 1 (1.1%) |
| Other | 5 (5.3%) |
| **Multiracial** | 13 (13.7%) |
| **Alcohol Use (past 30 days)** | |
| Drinks per week | 10.53 (6.36), range 0–33 |
| Drinking days per week | 2.31 (0.93), range 0–6 |
| **Negative Consequences (past 30 days)** | 3.85 (3.20), range 0–15 |
| **Full Alcohol Purchase Task** | |
| Intensity | 6.58 (2.65), range 2.00–15.00 |
| $O_{max}$ | 16.14 (8.66), range 2.00–49.00 |
| Breakpoint | 7.90 (1.64), range 1.50–9.00 |
| $P_{max}$ | 5.08 (2.09), range 1.00–9.00 |
| Elasticity | 0.03 (0.02), range 0.00–0.20 |
| **Brief Baseline Alcohol Purchase Task** | |
| Intensity | 5.86 (2.53), range 2–15 |
| $O_{max}$ | 16.28 (8.88), range 0–50 |
| Breakpoint | 5.53 (3.08), range 1–20 |
| **Aggregated Data Reported over 28 Daily Assessments** | |
| **Daily Alcohol Purchase Task reported over 28 days** | |
| Daily Intensity | 5.35 (2.46), range 0–19 |
| Daily $O_{max}$ | 10.83 (6.94), range 0–32 |
| Daily Breakpoint | 3.89 (2.74), range 0–16 |
| **Drinking behavior reported over 28 days** | |

| | Mean (SD) or n (%) |
|---|---|
| **Variables Assessed at Baseline** | |
| Negative cons per drinking day | 0.79 (1.10), range 0–6 |
| Positive cons per drinking day | 2.49 (1.85), range 0–8 |
| Drinks per drinking day | 5.23 (2.85), range 0–17 |

**Note:** Negative consequences were assessed with the Brief Young Adult Alcohol Consequences Questionnaire (Kahler et al., 2005), Intensity = consumption at zero cost , $O_{max}$ = peak expenditure for alcohol, Breakpoint = cost at which consumption is suppressed to zero, $P_{max}$ = price at maximum expenditure, Elasticity = the degree to which consumption declines with increasing price; Aggregated data from 28 days of assessment represent 2625 (out of 2660 possible) daily assessment points

**Table 2.**

Correlations among demand indices assessed via daily Alcohol Purchase Task (APT) measure, brief APT at baseline, and full APT at baseline in a sample of 95 underage male and female college student drinkers

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Daily intensity (mean) | 1 | | | | | | | | | | | |
| 2. Daily $O_{max}$ (mean) | .27** | 1 | | | | | | | | | | |
| 3. Daily breakpoint (mean) | .12 | .83** | 1 | | | | | | | | | |
| 4. Brief baseline intensity | **.77**** | .13 | .05 | 1 | | | | | | | | |
| 5. Brief baseline $O_{max}$ | .16 | **.40**** | .34** | .05 | 1 | | | | | | | |
| 6. Brief baseline breakpoint | −.10 | .28** | **.43**** | −.10 | .53** | 1 | | | | | | |
| 7. Full baseline intensity | **.76**** | .18 | .11 | .87** | .26* | −.03 | 1 | | | | | |
| 8. Full baseline $O_{max}$ | .25* | **.48**** | .46** | .29** | .61** | .45** | .33** | 1 | | | | |
| 9. Full baseline breakpoint | −.08 | .28** | **.37**** | −.09 | .34** | .36** | −.09 | .50** | 1 | | | |
| 10. Daily drinks (mean) | .46** | .21* | .21* | .42** | .24* | .10 | 39** | .21* | .02 | 1 | | |
| 11. Daily neg cons (mean) | .15 | .08 | −.01 | .16 | −.02 | .02 | .09 | −.02 | −.23* | .16 | 1 | |
| 12. Daily pos cons (mean) | .13 | .15 | −.01 | .09 | −.04 | −.06 | .04 | −.03 | −.26* | .08 | .55** | 1 |

Note:

** p<.01

* p<.05

Bolded correlations are parallel variables across different versions of the APT; Intensity = consumption at zero cost , $O_{\max}$ = peak expenditure for alcohol, Breakpoint = cost at which consumption is suppressed to zero; “Daily” (mean) measures represent person averages calculated across 28 days of assessment; overall there were 2625 (out of 2660 possible) daily assessment points

**Table 3.**

Hierarchical linear model associations between baseline and daily demand indices in a sample of 95 underage male and female college student drinkers assessed over 28 days

| | **Predicting daily intensity** | | | | **Predicting daily $O_{max}$** | | | | **Predicting daily breakpoint** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **B** | **SE** | **t** | **P** | **B** | **SE** | **t** | **P** | **B** | **SE** | **t** | **P** |
| Intercept | 5.35 | 0.16 | 32.69 | <.001 | 10.83 | 0.62 | 17.52 | <.001 | 3.89 | 0.24 | 15.92 | <.001 |
| Baseline Intensity | **0.70** | **0.10** | **7.04** | **<.001** | 0.12 | 0.26 | 0.48 | .629 | 0.01 | 0.10 | 0.10 | .920 |
| Baseline $O_{max}$ | 0.00 | 0.02 | 0.121 | .904 | **0.35** | **0.09** | **3.81** | **<.001** | **0.12** | **0.05** | **2.30** | **.024** |
| Baseline Breakpoint | −0.02 | 0.11 | −0.18 | .858 | 0.29 | 0.40 | 0.74 | .462 | **0.31** | **0.15** | **2.01** | **.048** |

Note: Baseline meaures come from the full Alcohol Purchase Task; bolded effects are significant at p<.05; Intensity = consumption at zero cost , $O_{max}$ = peak expenditure for alcohol, Breakpoint = cost at which consumption is suppressed to zero; Overall there were 2625 (out of 2660 possible) daily assessment points

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**Table 4.**

Hierarchical linear model associations between alcohol consequences and daily demand indices in a sample of 95 underage male and female college student drinkers

| | Predicting daily intensity | | | | Predicting daily $O_{max}$ | | | | Predicting daily breakpoint | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **B** | **SE** | ***t*** | ***P*** | **B** | **SE** | ***t*** | ***P*** | **B** | **SE** | ***t*** | ***P*** |
| Intercept | 5.72 | 0.29 | 19.93 | <.001 | 11.34 | 0.81 | 13.99 | <.001 | 4.15 | 0.34 | 12.32 | <.001 |
| **Level 1 predictors** | | | | | | | | | | | | |
| Negative consequences | −0.21 | 0.06 | −3.31 | .001 | −0.24 | 0.17 | −1.42 | .156 | −0.10 | 0.07 | −1.45 | .149 |
| Positive consequences | 0.05 | 0.05 | 1.00 | .318 | −0.02 | 0.12 | −0.15 | .885 | 0.06 | 0.06 | 0.98 | .327 |
| Total drinks | 0.09 | 0.04 | 2.20 | .029 | −0.03 | 0.09 | −0.34 | .732 | 0.01 | 0.03 | 0.21 | .831 |
| Day in study (1–28) | −0.02 | 0.01 | −1.98 | .048 | −0.04 | 0.03 | −1.33 | .185 | −0.02 | 0.01 | −1.23 | .219 |
| Weekend | −0.07 | 0.20 | −0.33 | .744 | −0.34 | 0.41 | −0.82 | .415 | −0.15 | 0.19 | −0.81 | .419 |
| Next drinking day | −0.06 | 0.05 | −1.13 | .257 | −0.10 | 0.07 | −1.44 | .150 | 0.00 | 0.04 | 0.10 | .918 |
| **Level 2 predictors** | | | | | | | | | | | | |
| Spending money | −0.00 | 0.00 | −3.21 | .002 | 0.00 | 0.00 | 0.31 | .760 | 0.00 | 0.00 | 0.38 | .706 |
| Avg negative consequences | 0.17 | 0.45 | 0.38 | .704 | −0.74 | 1.04 | −0.71 | .480 | −0.45 | 0.39 | −1.14 | .258 |
| Avg positive consequences | 0.23 | 0.25 | 0.94 | .352 | 0.93 | 0.63 | 1.47 | .146 | 0.02 | 0.23 | 0.10 | .918 |
| Average drinks | 1.68 | 0.23 | 7.22 | <.001 | 2.22 | 1.25 | 1.78 | .078 | 0.86 | 0.64 | 1.34 | .184 |

Note: SE=standard error, Intensity = consumption at zero cost , $O_{max}$ = peak expenditure for alcohol, Breakpoint = cost at which consumption is suppressed to zero; Weekend coded as 0 = Sunday through Wednesday, 1= Thursday, Friday or Saturday; ; Overall there were 2625 (out of 2660 possible) daily assessment points