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Further Examination of the Temporal Stability of Alcohol Demand

Samuel F. Acuff, B.S.[a] and **James G. Murphy, Ph.D.**[a,*]

[a]Department of Psychology, The University of Memphis, 400 Innovation Drive, Memphis, TN 38152 United States

Abstract

Demand, or the amount of a substance consumed as a function of price, is a central dependent measure in behavioral economic research and represents the relative valuation of a substance. Although demand is often utilized as an index of substance use severity and is assumed to be relatively stable, recent experimental and clinical research has identified conditions in which demand can be manipulated, such as through craving and stress inductions, and treatment. Our study examines the 1-month reliability of the alcohol purchase task in a sample of heavy drinking college students. We also analyzed reliability in subgroup of individuals whose consumption decreased, increased, or stayed the same over the 1-month period, and in individuals with moderate/severe Alcohol Use Disorder (AUD) vs. those with no/mild AUD. Reliability was moderate in the full sample, high in the group with stable consumption, and did not differ appreciably between AUD groups. Observed indices and indices derived from an exponentiated equation (Koffarnus et al., 2015) were generally comparable, although P_{max} observed had very low reliability. Area under the curve, O_{max} derived, and essential value showed the greatest reliability in the full sample (rs = .75–.77). These results provide evidence for relative stability over time and across AUD groups, particularly in those whose consumption remains stable.

Keywords

Alcohol demand; Alcohol use disorder; Behavioral Economics; Reliability

1. Introduction

Behavioral economics frames substance misuse as behavioral choices made in the context of environmental constraints (Bickel et al., 1995). A demand curve analysis plots consumption of a given drug across a range of prices and is a central dependent measure in behavioral economic research. Demand curves prototypically exhibit steady consumption at low prices with decreasing levels of consumption as price increases (Lhachimi et al., 2012; Mackillop

*Corresponding Author: Current Address: Department of Psychology, 400 Innovation Dr., Memphis, TN, 38152. jgmurphy@memphis.edu (James G. Murphy, PhD), sfacuff@memphis.edu (Samuel F. Acuff).

et al., 2012b; Skidmore and Murphy, 2011; Wagenaar et al., 2009). Further, demand curves produce multifaceted information about the reinforcing properties of a substance which are theorized to characterize degree of motivation to consume a substance (Bickel et al., 2000). Psychopharmacology researchers initially used demand curve analyses to examine differences in abuse liability across various drugs as well as the impact of environmental manipulations on drug demand (Hursh et al., 2005; Hursh and Winger, 1995; Ko et al., 2002), and more recently human researchers have used demand curves to measure individual differences in drug reward valuation (Murphy & MacKillop, 2006).

1.1 Hypothetical Purchase Tasks

Human substance demand studies in laboratories are often time-consuming and costly, and ethical guidelines prohibit the examination of high consumption amounts. Consequently, researchers have developed hypothetical purchase tasks (HPTs) to assess reported demand for alcohol (Mackillop et al., 2010a; Murphy and MacKillop, 2006; Skidmore and Murphy, 2011), marijuana (Aston et al., 2016, 2015; Collins et al., 2014; Metrik et al., 2016), cigarettes (Field et al., 2006; Mackillop et al., 2012b; MacKillop and Tidey, 2011), prescription drugs (Pickover et al., 2016), and other illicit drugs (Jacobs and Bickel, 1999) in situations where it would be impractical to estimate demand based on actual laboratory drug consumption/purchases. Individuals are asked how much of a given substance they would purchase and consume across a series of escalating prices, and consumption is plotted as a function of price to create a demand curve. The measure produces nine values found using two approaches: four that can be observed directly from plotting consumption and expenditure values (intensity, breakpoint, O_{max}-observed, P_{max}-observed; Murphy & MacKillop, 2006), and six that are derived from regression equations that model consumption as a function of price (elasticity, Q_0, P_{max}-derived, and O_{max}-derived, area under the curve, and essential value). Intensity refers to consumption when cost is zero; Q_0 is intensity derived. Breakpoint refers to the price when consumption reaches zero. O_{max} is the maximum expenditure, or the highest amount spent on the reinforcer, and P_{max} is the price at which O_{max} is reached. Both P_{max} and O_{max} are found using the observed and derived methods. Elasticity refers to the sensitivity of demand to changes in price, and was traditionally derived using an exponential equation described by Hursh and Silberberg (2008). This equation has recently been modified to allow for the inclusion of zero into the curve fits by raising both sides to the power of 10 (Koffarnus et al., 2015):

$$Q = Q_0 * 10^{k\,(e^{-\alpha P} - 1)}, \quad (1)$$

Where Q = quantity consumed, k = the range of the dependent variable (standard drinks) in logarithmic units, P = price, and α = elasticity of demand. O_{max}-derived is the predicted maximum expenditure from the equation and P_{max}-derived is the price associated with O_{max}. The new equation avoids poor model fits due to exclusion of zeros in the equation (Yu et al., 2014). Area under the curve (AUC) refers to individual's total reported consumption across all prices (Amlung et al., 2015), represented by the total amount of geometric area under the demand curve. AUC may be statistically redundant with O_{max} (r=.92; Amlung et al., 2015).

AUC is calculated by drawing lines from each data point on the curve to the *x*-axis, creating a series of trapezoids. Each trapezoid can be represented by the following equation:

$$(\chi^2 - x^1)\,[(y^1 + y^2)/2] \quad (2)$$

Where x^1 and χ^2 are successive prices, and y^1 and y^2 are the respective consumption values of the prices (Amlung et al., 2015). While other indices of demand provide partial information about the construct, AUC may provide a global picture of demand since it encompasses much of each metric in the final outcome (Amlung et al., 2015). AUC is different from elasticity in that it accounts for both the slope at which price decreases and the intercept at which it begins, while elasticity only represents the slope. Similarly, essential value (EV) represents a global index of valuation, is inversely proportional to elasticity (α), and accounts for *k* to allow for comparison between studies (Hursh, 2014). EV is calculated using the following formula:

$$EV = 1/(100 \cdot \alpha \cdot k^{1.5}) \quad (3)$$

Where α = elasticity of demand and k = range of possible consumption (Hursh, 2014). Factor analytic studies have revealed that the HPT metrics correspond to two heterogeneous aspects of demand – amplitude and persistence (MacKillop et al., 2009; Skidmore et al., 2014) – which may be equally important in understanding the valuation of a substance. Intensity and O_{max} form a factor labeled amplitude – the amount consumed and spent – and elasticity, breakpoint, O_{max} and P_{max} form a factor labeled persistence – sensitivity of consumption to changing price. Demand estimates generated from HPTs correlate highly with *in vivo* purchase tasks (Amlung & MacKillop, 2015; Amlung et al., 2012), suggesting strong validity for the self-report task.

1.2 Demand as an Index of Substance Problem Severity

The introduction of the HPT allowed investigators to examine how individual differences in demand predict future consumption, response to treatment or other manipulations, and substance use severity. For example, multiple studies have observed associations between demand metrics and alcohol use, with intensity and O_{max} demonstrating the most robust associations (Bertholet et al., 2015; Skidmore et al., 2014). In addition to consistent relations with consumption, elevated demand has exhibited relationships with problematic alcohol use (Bertholet et al., 2015; Skidmore et al., 2014). In a sample of 267 college students, Murphy and MacKillop (2006) found that heavy drinkers had significantly higher levels of intensity, breakpoint and O_{max} than light drinkers. Murphy and colleagues (2009) extended these findings by demonstrating that intensity predicted alcohol problems after controlling for consumption, suggesting that elevated demand may function as an unique index of severity; AUC was also uniquely predictive of alcohol problems in a sample of heavy drinking college students (Amlung et al., 2015). Elevated demand is also associated with alcohol use disorder (Bertholet et al., 2015; Mackillop et al., 2010a), and demand predicts brief alcohol intervention outcomes (MacKillop and Murphy, 2007). Similarly, elevated demand has been related to problematic use of cigarettes, marijuana, prescription opiates, and cocaine as well (Aston et al., 2016, 2015; Bruner and Johnson, 2014; Chase et al., 2013; Collins et al., 2014; Pickover et al., 2016; Vincent et al., 2016).

1.3 Stability of Demand

Despite the strong empirical evidence linking alcohol demand to alcohol misuse, further research is required to increase understanding of the construct as an individual difference measure, and in particular its relative degree of stability versus malleability. Surprisingly, questions about the stability of demand still exist. Although demand has demonstrated stability over short periods of time (1–2 weeks; Few et al., 2012; Murphy et al., 2009) and is frequently used as an individual difference variable, other studies indicate that demand can be manipulated in a number of different conditions. Understanding the conditions in which demand is relatively stable versus those in which it fluctuates is important to enhancing its theoretical and clinical utility.

Two reliability studies of HPTs have demonstrated strong stability over short time periods. Murphy and colleagues (2009) found good to excellent test-retest reliability for several indices of demand over a two-week period in a sample of 38 college student drinkers. Specifically, observed indices of intensity and O_{max}-observed were very stable (*r*s=.89 and .90, respectively), breakpoint and elasticity (derived from Hursh et al. 2008) were also stable (*r*s = .81 & .75), and P_{max}-observed was slightly less stable (*r* = .67). In the same study, the test-retest reliability of the derived values of intensity (Q_0), O_{max}, and P_{max} (*r*s = .64 – .84) were lower than the observed (*r*s = .67 – .90). Similar patterns emerged when testing the reliability of a cigarette purchase task. Evaluated over a one-week period, correlation coefficients obtained from a sample of 11 smokers recruited from the community were of a higher magnitude; intensity and O_{max}-observed still exhibited the strongest reliability, followed by elasticity and breakpoint (*r*s = .99, .95, .88, and .76; Few et al., 2012). Derived intensity, O_{max}, and P_{max} were not evaluated in this study.

The greater reliability of the amplitude indices – intensity and O_{max}-observed – suggests stronger stability for that factor, although composite scores of indices have not been directly examined. Both studies only included relatively small sample sizes (i.e., 38 and 11), and temporal stability has only been examined to two weeks. Further, more severe clinical samples may demonstrate different reliability coefficients for demand (Murphy et al., 2009). Individuals with more severe levels of alcohol use may report higher, more consistent levels of motivation for alcohol, in part due to internal motives, and thus less malleable demand. In contrast, the stability of alcohol demand for lighter drinkers may be more contingent upon environmental changes.

Despite strong reliability evidence in the above studies, behavioral economics posits that changes in one's environment could influence demand for alcohol. For example, craving, which can be understood as an acute increase in an individual's valuation of a drug (Loewenstein, 1999), increases demand for alcohol (MacKillop et al., 2010) and other drugs (Acker and MacKillop, 2013; Mackillop et al., 2012a), suggesting that it is sensitive to dynamic state changes in desire to drink associated with craving. Research has also documented the influence of stress on demand, such that stress inductions cause increases in the valuation of alcohol (Amlung and MacKillop, 2014; Owens et al., 2015; Rousseau et al., 2011), consistent with research examining the robust association between alcohol-related problems and stress (Tripp et al., 2015). Interestingly, demand seems to be susceptible to intervention, as both behavioral (Dennhardt et al., 2015; Murphy et al., 2015; Snider et al., 2016) and psychopharmacological treatments (Bujarski et al., 2012; Hitsman et al., 2008) have been shown to decrease demand. Finally, next-day responsibilities influence college student's valuation of alcohol, such that greater next-day responsibility is associated with lower levels of demand (Gentile et al., 2012; Gilbert et al., 2014; Skidmore and Murphy, 2011).

1.4 Present Study

Although demand is highly malleable in response to a variety of contextual events, it also appears to be stable at short (1–2 week) intervals. However, to date no research has carefully documented the relative stability of demand over longer time periods and specifically in high risk groups such as individuals with AUD, who may have greater stability due to stable, high motivation to consume (MacKillop et al., 2009; Murphy et al., 2009). Further, a range of indices are currently in use, and several indices have been theorized since the test-retest reliability was last examined (Amlung et al., 2015; Hursh, 2014; Koffarnus et al., 2015; Murphy et al., 2009). No study to date has examined the reliability of AUC, EV, and exponentiated demand. Information about the relative stability of the various indices – in several relevant groups – will help researchers prioritize which indices should be analyzed in a given study to best fit their practical/theoretical needs. For example, elasticity may provide a more stable index of enduring individual differences in alcohol reward value, whereas intensity may be more malleable and ideal for studies attempting to manipulate demand in an experimental paradigm. The primary goals of this paper are to examine and compare (where relevant) the relative reliability of commonly used demand indices. Our secondary goal is to examine the reliability in different subsamples that reflect variables that might influence the reliability of demand, such as groups that reported a change in recent alcohol use, or individuals who report alcohol use disorder symptoms. We hypothesize that 1) one-month test-retest reliability will be good, but slightly lower than previous 2-week results; 2) reliability for observed intensity will be higher than $Q_{0,}$ but observed and derived P_{max} and O_{max} will show similar reliability; 3) reliability will be greater for individuals who report stable drinking; and 4) reliability of demand will be greater for those with moderate/severe AUD compared to those with no/mild AUD.

2. Method

2.1 Participants

The sample consisted of 137 college students (57.7% female) recruited from the University of Memphis and the University of Missouri. Most of the sample identified as Caucasian (88.6%); the remaining participants identified as either African-American (7.3%), Hispanic, American Indian, Asian, or Other. All participants met inclusion criteria of at least two self-reported heavy drinking episodes (5/4 drinks per occasion for men/women) in the past month. All students were full-time first or second-year college students who enrolled in the study for research credit or payment (i.e., they were not seeking alcohol treatment).

2.2 Procedures

Participants were recruited via the SONA system, in class screeners, and online surveys at two large public universities in the US. The SONA system, a research management system, allows psychology students to sign up for studies posted by researchers for incentives. Recruitment was part of a larger study that examined the effect of a brief intervention on college student alcohol misuse. Because we were interested in examining the stability of alcohol demand in the absence of an intervention, only individuals who were randomly assigned to the assessment-only control condition were used for the present study. A federal (NIH) Certificate of Confidentiality was acquired to protect the privacy of the respondents. Participants completed all baseline assessment measures via a web-based survey in the context of individual research appointments in a private Psychology Department laboratory setting. One month after the initial appointment, the participants took the in-lab survey again. 90.6% of participants ($N = 125$) completed the follow-up survey. Participants were either paid $25 or received SONA credit for each survey session.

2.3 Measures

2.3.1 Alcohol consumption—Typical weekly alcohol consumption was measured with the Daily Drinking Questionnaire (DDQ), a commonly used and reliable measure of alcohol consumption (Collins et al., 1985). Respondents were asked to record alcohol consumption on each day of a typical week over the last month. Typical drinks per week were computed by summing typical daily consumption.

2.3.2 Alcohol demand—The alcohol purchase task (APT) – modeled after Jacobs and Bickel (1999) by Murphy and MacKillop (2006) – is a commonly used measure of alcohol demand. Before beginning, participants saw the following instructions: Imagine that you and your friends are at a party on a Thursday night from 9:00 PM until 1:00 AM to see a band.

> Imagine that you do not have any obligations the next day (i.e., no work or classes). The following questions ask how many drinks you would purchase at various prices. The available drinks are standard size domestic beers (12 oz.), wine (5 oz.), shots of hard liquor (1.5 oz.), or mixed drinks containing one shot of liquor. Assume that you did not drink alcohol or use drugs before you went to the party, and that you will not drink or use drugs after leaving the party. Also, assume that the alcohol you are about to purchase is for your consumption only during the party (you can't sell or bring the drinks home). Please respond to these questions honestly, as if you were actually in this situation.

A picture denoting the standard size of a typical drink was included with the measure. Respondents then report how many drinks they would consume at 20 escalating prices: $.00, $0.25, $0.50, $1.00, $1.50, $2.00, $2.50, $3.00, $3.50, $4.00, $4.50, $5.00, $5.50, $6.00, $7.00, $8.00, $9.00, $10.00, $15.00, $20.00. Consumption values were then plotted alongside each price. Expenditure was computed by multiplying price by consumption. Four indices were produced from this measure which can be observed from the aforementioned consumption and expenditure data: intensity (the amount consumed if drinks are free), breakpoint (the price when the individual consumes zero drinks), O_{max}-observed (maximum expenditure), and P_{max}-observed (price associated with O_{max}). Six indices are derived from three equations: elasticity, Q_0 (intensity derived), O_{max}-derived, P_{max}-derived, AUC, and EV. Elasticity refers to the sensitivity of demand to changes in price, and is here calculated using the exponentiated model (equation 1; Koffarnus et al., 2015), a modified version of Hursh and Silberberg's (2008) exponential model. Although the exponential model has been widely used, the exponentiated model allows for the inclusion of zeros, which improves model fit (Yu et al., 2014). Graphpad Prism 6 was used to fit data for equations 1 and 3. EV is found using equation 3 (Hursh, 2014). EV, P_{max} and O_{max} (derived) were calculated using an excel macro created by Kaplan and Reed (2014). Finally, AUC is calculated using equation 2 (Amlung et al., 2015). Participants (n = 20) who reported consumption through the highest value were given a breakpoint value equivalent to the highest value ($20); in cases of O_{max} scores with two equally high expenditures, the score associated with the lower P_{max} was used. Each metric falls into one of two factors that represent two heterogeneous aspects of demand: amplitude, the amount spent or consumed (intensity and O_{max}), and persistence, the sensitivity to changes in price (MacKillop et al., 2009; Skidmore et al., 2014). We calculated composite amplitude and persistence scores by transforming relevant variables for each factor into z-scores and averaging z-scores.

2.3.3 Alcohol use disorder

Past year Alcohol Use Disorder was assessed using self-report questions that parallel DSM-5 criteria for alcohol use disorder. Symptom scores were summed to create total scores. Cutoff scores were determined using DSM-5 diagnostic severity categories (American Psychiatric Association, 2013): No AUD (0–1), Mild AUD (2–3), Moderate AUD (4–5), Severe AUD (6 or greater).

2.4 Data Analysis Plan

The focus of the current study was to further examine and compare (where relevant) the temporal stability of the various indices derived from the APT. Further, we evaluated the stability of alcohol demand in those whose consumption decreased, increased, or stayed the same during the follow-up period and as a function of alcohol use disorder classification. As a secondary focus, we compared the stability of derived vs. observed indices. Data analysis was performed in four stages.

First, Pearson's r was used to examine the reliability of the APT. Paired sample t-tests assessed any significant changes in individual APT price points, as well as with all demand indices. Next, reliability was examined in students with decreases, increases, and no change in alcohol consumption over the 1-month follow-up period. To determine consumption groups, consumption from time 1 was subtracted from time 2. Percent change was then calculated by dividing change scores from time 1 scores. There are no established criteria for classifying degree of change in drinking. Those with −16% or below change in consumption were placed in the decreased consumption group; Those with −15% to 15% change in consumption were deemed to have minimal change in consumption; those with 16% or greater change in consumption were placed in the increase in consumption group. Pearson correlation coefficients determined reliability for all demand indices in those whose consumption remained relatively stable.

In order to assess stability as a function of alcohol use disorder classification, Participants were separated into two groups: No AUD/Mild AUD (0–3) and Moderate/Severe AUD (4 and above). Test-retest reliability was evaluated separately using Pearson correlation coefficients for each AUD group. Significant differences between scores were tested using Fisher's *r* to *z* transformation. We also used Fisher's *r* to *z* transformations to examine significant differences in test-retest reliability coefficients for derived and observed indices of demand.

3. Results

3.1 Descriptive Statistics and Demand Curve Model Accuracy

Twelve participants did not attend the 1-month follow-up. Baseline alcohol consumption, AUD status, or alcohol-related problems for these twelve participants did not significantly differ from those who completed the follow-up. Another participant reported inconsistent consumption across prices (three inconsistencies) and two participants reported no demand (0 drinks when they are free); these participants were removed from the analysis. As a result, a total of 122 individuals were used in prospective analysis of the observed demand indices. We required at least 5 consumption values greater than zero in order to calculate AUC. Consequently, only 115 participants were used in prospective analysis of the AUC. The exponentiated equation allows for consumption values of zero to be included in the model. We required at least three non-zero values to fit the curve; for this reason, two participants were excluded, and 120 participants were included in prospective analysis of elasticity, Q_0, EV, P_{max}-derived, and O_{max}-derived. Outliers greater than 3.29 standard deviations away from the mean were detected and recoded as one unit above the next most extreme score, as suggested by Tabachnick and Fidell (2013). Observed alcohol demand variables were transformed using square root transformation due to skewness and kurtosis values exceeding −2 or 2 (Field, 2013; Trochim & Donnelly, 2006). Q_0 and O_{max}-derived were log transformed. Elasticity was transformed using the square root function. AUC, EV, and P_{max}-derived did not need to be transformed. Intensity (observed) was still slightly kurtotic (3.08) after transformations. Participants averaged 17.54 (SD = 13.06) alcoholic drinks per typical week in the past month and reported an average of 3.01 (*SD*=2.45) AUD symptoms. Descriptive data for demand indices can be found in Table 2. The exponentiated equation (Koffarnus et al., 2015) provided a very good fit for participant level data (T1: N=135, mean R^2 = .89, median R^2 = .91, range = .59 – .98; T2: N=122, mean R^2 = .89, median R^2 = .92, range =.60 – .99). and an excellent fit for the aggregate data (R^2 = .99 at both time points).

3.2 Alcohol Purchase Task Reliability Analysis

Table 2 shows the mean consumption scores for each of the APT prices across the baseline and 1-month administrations. Paired sample *t*-tests revealed only two significant group-level differences in consumption means across the two time points ($7.00 and $10.00) across the 20 prices included on the APT. Pearson's *r* correlation was used to determine the reliability of observed (intensity, breakpoint, O_{max}, P_{max}) and derived (elasticity, Q_0, P_{max}, O_{max}, and AUC, and EV) indices (Table 3). Using a *t*-test analysis, we found four small, but significant group-level reductions from time 1 to time 2 (AUC, P_{max}-derived, O_{max}-derived, EV) and, one small but significant increase (breakpoint). For observed indices, reliability was moderate for intensity of demand (*r*=.69), breakpoint[1] (*r*=.70), and O_{max} (*r*=.65), and weak for P_{max} (*r*=.31). For derived indices, reliability was also moderate for Q_0 (*r*=.67), P_{max} (*r*=.67), and elasticity (*r*=.71); O_{max} (.76), EV (*r*=.76) and AUC (*r*=.77) displayed good reliability[2]. Amplitude reliability was good (*r*=.77), while persistence demonstrated poor reliability (*r*=.56).

3.3 Reliability by Change in Consumption

We then examined reliability of demand in groups with decreases, increases, and relatively constant reported levels of typical weekly alcohol consumption from time 1 to time 2 (Table 3). Overall, test-retest correlations were much higher in the stable drinkers than in the full sample or in the group that decreased consumption. Generally, the indices exhibited low reliability among those whose consumption decreased. In contrast, reliability was excellent for those whose consumption stayed the same and good for those whose consumption increased.

3.4 Reliability by AUD classification

The sample was separated into two groups based on AUD classification in order to further understand the influence of AUD on the reliability of alcohol demand. Those reporting three or less AUD symptoms were classified as having no or mild AUD (n = 77) while those reporting four or more AUD symptoms were classified as having moderate or severe AUD (n = 46). Results are reported in Table 3. We found no statistically significant differences between AUD group reliability coefficients using Fisher's *r* to *z* transformations. Reliability estimates were, overall, moderate (*r*s = .65 – .80).

3.5 Utility of Observed vs. Derived Demand Indices

Reliability coefficients of observed indices were compared with theoretically parallel derived indices using Fisher's *r* to *z* transformations. Fisher's *r* to *z* transformations revealed that differences between observed and derived intensity and O_{max} are nonsignificant ($p > .05$, two tailed). The difference in P_{max}-observed and P_{max}-derived, however, was significant ($p < .01$, two-tailed), suggesting that P_{max}-derived is more stable than P_{max}-observed.

4. Discussion

This study analyzed the reliability of demand curve indices derived from the hypothetical APT over a one-month period. Alcohol demand curves exhibited prototypical trends, with consumption decreasing as price increased. The exponentiated demand equation provided an excellent fit for the data (Koffarnus et al., 2015). As expected, 1-month reliability coefficients were lower than the 2-week reliability coefficients found in previous research (Murphy et al., 2009). Q_0, AUC, O_{max} derived, and EV showed the greatest reliability in the full sample (*r*s = .73–.77), but these values, though adequate, were lower than the 2-week reliability values for intensity (.89) and O_{max} observed (.9) in Murphy et al. (2009). Further,

[1]Since 20 participants reported consumption at $20, we examined the test-rest reliability of breakpoint when defined as "the last price at which the participant reported consumption." Reliability did not change.

[2]We also examined the reliability of elasticity, Q_0, P_{max}-derived, O_{max}-derived, and EV using the exponential equation (Hursh and Silberberg, 2008). Reliability was typically lower, with the exception of EV and O_{max}-derived (which were equivalent).

there was a very small but significant reduction in means for several derived indices from baseline and the one-month follow-up, suggesting some instability in the overall sample for derived indices likely due to corresponding small reductions in drinking over that timeframe. Consistent with previous research (Murphy et al., 2009), the amplitude factor (combination of intensity and O_{max}) had good reliability and the persistence factor (combination of elasticity, O_{max}-observed, P_{max}-observed, and breakpoint) was not reliable. Overall, observed and derived indices showed similar reliability with the exception that P_{max}-derived was more stable than P_{max}-observed.

This study also examined factors that may influence the reliability of alcohol demand, such as stability of reported alcohol consumption over the 1-month follow-up period and the presence of moderate/severe AUD. As hypothesized, demand was highly stable over 1-month in the absence of changes in consumption, with values consistent with the results of Murphy et al. (2009; intensity = .94, EV = .85, amplitude =.95). In contrast, reliability of demand was quite low in the group that reported a decrease in consumption. These results are consistent with behavioral economic theory, which suggests that alcohol demand is not an immutable characteristic of the individual, but is instead impacted by changes in environmental and affective variables (Hursh, 1980; Skidmore and Murphy, 2011). Reliability of demand in the increase in consumption group, however, demonstrated only slightly lower reliability compared to those who reported no change in consumption.

We also hypothesized that greater endorsement of AUD symptoms might reflect stable levels of high motivation for alcohol possibly due to internal factors such as minimized subjective response to alcohol, greater sensation seeking, or heightened negative affect. We suspected the reliability of alcohol demand to be less contingent upon environmental factors and therefore more stable due to internal motivation for alcohol. In contrast, lower endorsement of AUD symptoms may reflect lower levels of motivation for alcohol that is primarily driven by contextual and environmental factors. Contrary to our hypothesis, stability of demand indices did not differ significantly by AUD classification. Even those with severe AUD may have slightly malleable demand, suggesting that even in severe drinkers alcohol demand is somewhat contingent upon environmental factors and may reasonably be targeted through intervention (Bujarski et al., 2012; Dennhardt et al., 2015). Further, these results provide support for the reliability of the APT across the spectrum of AUD severity in young adult samples, considering reliability estimates were moderate to good.

Interestingly, AUC and EV had reliability values that were relatively similar between the full sample, AUD groups, and change in consumption groups, suggesting that these indices may be particularly stable across various populations. Further, their reliability coefficients were relatively high, which is consistent with the theoretical assumption that both reflect global measures of overall reward value rather than one specific facet of demand (Murphy and MacKillop, 2006), both of which were highly stable only when change in drinking was constrained. It is also noteworthy that EV – which is derived from elasticity, but takes into account the overall k – was slightly more stable than elasticity, providing further support for the utility of this metric (Hursh, 2014). Although AUC and EV have only been included in a few studies, these initial studies suggest that both metrics are associated with alcohol consumption and problems (Amlung et al., 2015; Lemley et al., 2016). Both indices may be useful predictors of other behaviors moving forward, although AUC is highly correlated with O_{max}, suggesting possible redundancy (Amlung et al., 2015). EV may be preferable to elasticity, considering that it accounts for *k* and is slightly more stable across groups; more research, however, should examine its association with problematic alcohol misuse. Researchers who are interested in documenting relatively stable individual differences in alcohol valuation over time should consider using EV or AUC, given their relatively high reliability across groups. In our sample, these two indices were highly correlated (r=.93), suggesting redundancy.

Reliability of P_{max}-observed was extremely low[3]. This is not particularly surprising, given the relatively low P_{max} reliability in previous studies compared to other demand indices (Murphy et al., 2009). Reliability was also relatively low for P_{max}-derived. Along with frequently null or negligible findings (Bertholet et al., 2015; MacKillop and Tidey, 2011; Skidmore et al., 2014), these results question the utility of P_{max} as an individual difference variable derived from HPTs.

4.1 Strengths, Limitations, and Future Directions

Our study was the first to evaluate the 1-month test-retest reliability of demand in a large sample and to examine reliability as a function of AUD severity. This was also the first study to examine the test-retest reliability of two relatively new indices of demand – AUC (Amlung et al., 2015) and EV (Hursh, 2014) – and composite factor scores for amplitude and persistence. Although our study had a large enough sample to perform reliability analyses, the individual group analyses decreased our sample size significantly. A larger sample size of those with AUD or who do not change their consumption could be used to replicate these findings and confirm the stability of demand. Further, the current iteration of the APT only includes prices to $20. In our sample, 20 participants reported consumption at this price point. An APT which includes higher price points for heavier drinkers may be necessary to avoid ceiling effects associated with high levels of reported consumption, and our breakpoint reliability value was likely influenced by this. Further, in the absence of an established convention for determining meaningful changes in consumption, we established change in consumption groups based on a > 15% percent change. These results should also be extended to other substances. Additional limitations include the lack of objective verification of drinking and the inclusion of a college student sample comprised entirely of heavy drinkers (although with variability in AUD status and drinking level). Future research should evaluate the reliability of the APT in community residing adults and adolescents and in treatment seeking samples.

Future research should also identify factors that precipitate change in either consumption or demand. Behavioral economics posits a strong influence of environmental factors on valuation and consumption of substances (Hursh, 1980; Hursh et al., 2005; Hursh and Winger, 1995). Previous research has documented the influence of craving, stress, and academic/vocational responsibilities on demand (Amlung and MacKillop, 2014; Owens et

[3] O_{max} and P_{max} are closely related theoretically. Despite this connection, O_{max} reliability values were much stronger. This may be because P_{max} values are limited to the price points presented in the APT, whereas O_{max} reflects the maximum expenditure (price x consumption) and generates a larger range of values, thereby allowing for greater covariation.

al., 2015), and two studies have shown enduring reductions in demand following a brief intervention (Dennhardt et al., 2014; Murphy et al., 2015). These brief intervention trials also suggest that change in demand measured immediately post-treatment portends subsequent change in drinking. Future longitudinal research should more comprehensively assess the relations between changes in contextual factors, drinking, and demand over time.

4.2 Conclusion

The overall pattern of results suggests that the APT generates highly reliable indices of alcohol valuation over a 1-month period assuming actual recent drinking levels are relatively stable. Mean APT consumption values were highly stable, AUC, O_{max}-derived, and EV showed the greatest reliability in the full sample, and the amplitude composite (intensity and O_{max}-observed) was also reliable. Persistence and P_{max} had the lowest reliability across groups. All APT indices were equally stable across AUD severity, supporting its use with a variety of at-risk and AUD+ populations. However, it is noteworthy that in the full sample of young adult heavy drinkers there was significant fluctuations in drinking, even in the absence of an intervention, and that under these circumstances individual participant demand estimates are only modestly stable over a 1-month period. Consistent with previous research, these findings suggest that alcohol demand is malleable enough to function as a state measure of alcohol valuation that is influenced by treatment and factors such as stress, craving, and contextual demands (Amlung and MacKillop, 2014; Dennhardt et al., 2015; Gilbert et al., 2014; MacKillop et al., 2010b), but several indices are also stable enough to function as individual difference variables.

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Highlights

- One-month test-retest reliability of the Alcohol Purchase Task is examined.
- Exponentiated and derived indices are compared with observed indices.
- Change in alcohol demand may be closely related to change in consumption.
- AUD does not significantly influence demand stability.

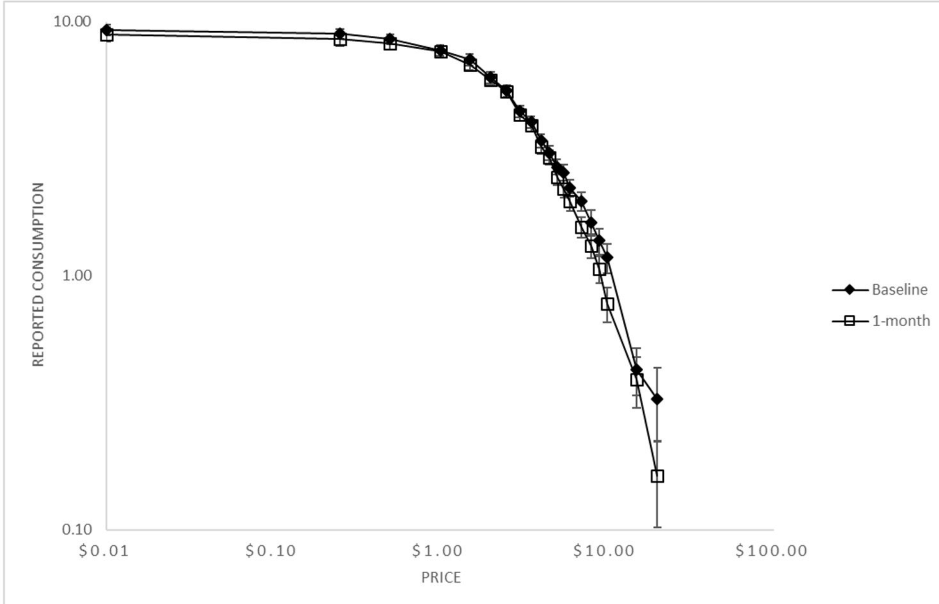

Figure 1.
Demand curve for consumption of standard alcoholic drinks at baseline and 1-month. The x-axis is log-transformed price in dollars and the y-axis is the log-transformed self-reported consumption. Each data point represents the sample mean of consumption for each individual price point; error bars represent the standard error of the mean.

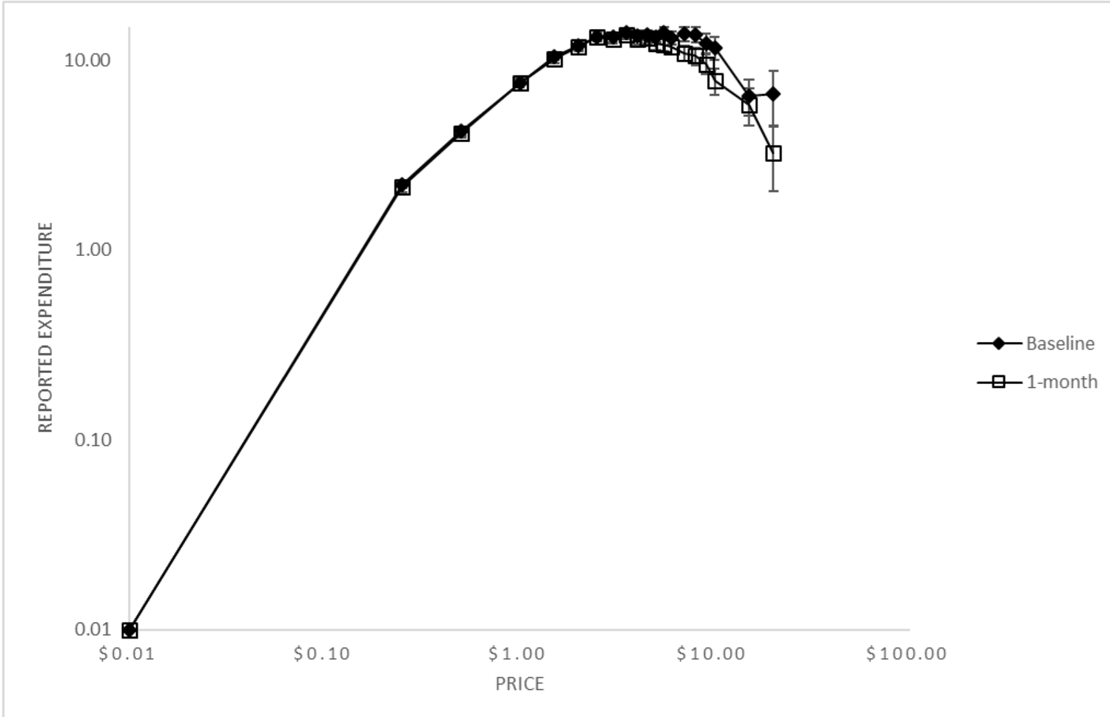

Figure 2.

Demand curve for expenditure of standard alcoholic drinks at baseline and 1-month. Expenditure is calculated by multiplying price by consumption. The x-axis is log-transformed expenditure in dollars and the y-axis is the log-transformed self-reported expenditure. Each data point represents the sample mean for each individual expenditure point; error bars represent the standard error of the mean.

Table 1

Sample Characteristics (N=137)

	N	Percentage	Mean	*SD*
Age	130		18.8	1.01
Gender	137			
Male	59	43.1		
Female	78	56.9		
Class	137			
Freshman	84	61.3		
Sophomore	53	38.7		
Race	137			
White	116	84.7		
Black	9	6.6		
Non-Black Minority	12	8.7		
Alcohol Consumption	137		17.74	12.44
AUD	137			
No/Mild	84	61.3		
Moderate/Severe	53	38.7		
Change in Consumption	126			
Decrease	51	37.2		
No Change	35	25.5		
Increase	40	29.2		

Table 2

Baseline and One-month Consumption Means for Individual Price Points on the Alcohol Purchase Task (N=122)

	Consumption value on the alcohol purchase task				
	Time 1		Time 2		
	Mean	***SD***	**Mean**	***SD***	***t*-test**
Free	9.23	4.88	9.02	6.63	NS
$0.25	8.91	4.78	8.62	5.66	NS
$0.50	8.47	4.61	8.26	4.89	NS
$1.00	7.64	4.14	7.64	4.30	NS
$1.50	7.01	4.02	6.80	3.70	NS
$2.00	5.99	3.59	5.89	3.01	NS
$2.50	5.33	3.28	5.33	2.94	NS
$3.00	4.41	2.81	4.32	2.54	NS
$3.50	4.02	2.48	3.90	2.37	NS
$4.00	3.39	2.45	3.22	2.15	NS
$4.50	3.02	2.15	2.93	2.00	NS
$5.00	2.67	2.01	2.44	1.75	NS
$5.50	2.53	1.91	2.21	1.73	NS
$6.00	2.20	1.83	1.96	1.62	NS
$7.00	1.97	1.69	1.56	1.43	.03
$8.00	1.62	1.87	1.32	1.34	NS
$9.00	1.37	1.53	1.06	1.12	NS
$10.00	1.17	1.45	.78	1.01	.01
$15.00	.43	.81	.39	.67	NS
$20.00	.33	.81	.16	.43	NS
	Observed demand indices				
Intensity	9.18	4.69	8.75	4.63	NS
Breakpoint	10.32	6.01	9.46	5.60	.03
O_{max}	17.88	10.26	17.19	10.35	NS
P_{max}	4.70	3.60	4.24	2.74	NS

	Consumption value on the alcohol purchase task				
	Time 1		**Time 2**		
	Mean	***SD***	**Mean**	***SD***	***t*-test**
	Derived demand indices				
Q_0	10.09	4.99	9.83	4.98	NS
P_{max} derived	4.88	2.78	4.61	2.37	.04
O_{max} derived	15.20	10.00	14.16	8.47	.03
Elasticity	.0077	.0061	.0079	.0064	NS
AUC	.0369	.0233	.0346	.0204	.04
Essential Value	.5533	.3640	.5153	.3081	.03
Amplitude	.000	.881	.000	.884	NS
Persistence	−.001	.476	.015	.471	NS

Note. Derived indices were calculated with a smaller sample due to slightly more stringent calculation requirements (*N*=120)

Table 3

One-month Test-Retest Reliability of Demand Indices in the Full Sample and by Consumption Group and AUD Classification

		Change in Consumption			AUD Classification		
	Full sample (*N* =122)	Decrease in Consumption (*n*=51)	No change in consumption (*n* = 34)	Increase in consumption (*n*=39)	No/Mild AUD (*n* = 76)	Moderate/Severe AUD (*n* = 46)	Difference
Intensity	.69***	.42**	.94***	.85***	.69**	.68***	NS
Breakpoint	.70***	.63***	.81***	.73***	.66***	.75***	NS
P_{max}	.30**	.33*	.30	.29	.22	.35*	NS
O_{max}	.70***	.66***	.84***	.72***	.69***	.72***	NS
AUC	.77***	.66***	.92***	.83***	.79***	.69***	NS
Koffarnus et al. (2015) Exponentiated equation							
Elasticity	.71***	.64***	.84***	.72***	.71***	.68***	NS
Essential Value	.76***	.71***	.87***	.76***	.80***	.68***	NS
Q_0	.73***	.61***	.90***	.75***	.65***	.75***	NS
P_{max} derived	.67***	.64***	.70***	.68***	.69***	.66***	NS
O_{max} derived	.76***	.71***	.87***	.76***	.80***	.68***	NS
Amplitude	.77***	.67***	.95***	.84***	.76***	.75***	NS
Persistence	.56***	.51**	.77***	.50**	.47***	.60***	NS

*** $p \leq .001$,

** $p \leq .01$

Note. Two-tailed *p*-values were used to calculate differences between AUD groups. Persistence used elasticity calculated with the exponential equation.