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Further Examination of the Temporal Stability of Alcohol Demand

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FURTHER EXAMINATION OF THE TEMPORAL STABILITY OF ALCOHOL DEMAND

by

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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 assumed to be relatively stable, recent clinical research has identified conditions in which demand can be manipulated. This study examines the 1-month reliability of the alcohol purchase task in a sample of heavy drinking college students, in subgroup analyses 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. These results provide evidence for relative stability over time and across AUD groups, particularly in those whose consumption remains stable.

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Introduction

Behavioral economics frames substance misuse as behavioral choices made in the context of environmental constraints (Bickel, Green, & Vuchinich, 1995). Demand, or the amount of a substance consumed as a function of price, is a central dependent measure in behavioral economic research. Demand is quantified using a demand curve analysis that plots consumption of a given drug across a range of prices. Demand curves prototypically exhibit steady consumption at low prices with decreasing levels of consumption as price increases (Lhachimi et al., 2012; Mackillop, Few, et al., 2012; Skidmore & Murphy, 2011; Wagenaar, Salois, & Komro, 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, Marsch, & Carroll, 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, Galuska, Winger, & Woods, 2005; Hursh & Winger, 1995; Ko, Terner, Hursh, Woods, & Winger, 2002). For example, Hursh (1980) gave monkeys a choice between food or heroin during a specified number of trials per day. Over time, the number of trials per day decrease, forcing the monkeys to choose between an essential commodity and a nonessential commodity with diminishing resources. When forced to choose, the monkeys declined heroin in order to gain food. This representation of economic constraint demonstrates a key contribution of behavioral economics: the value of a substance cannot be measured without considering the economy and environment in which reinforcers are delivered. Even minor changes – moving a food pellet tray further from a lever – are followed by changes in elasticity of demand (Roper, 1975). Much research has replicated these findings in human laboratory studies as well (Higgins, Bickel, & Hughes, 1993), making it clear that fluctuations in demand are expected and occur naturally as a function of the environment and the economy in which demand is assessed.

Hypothetical Purchase Tasks

Human demand studies in laboratories are often time-consuming, costly, and ethically controversial. As human demand research became more prevalent, researchers needed more efficient and attainable methods for measuring demand. This was made more feasible by hypothetical purchase tasks. Hypothetical purchase tasks (HPTs) have been developed to assess reported demand for alcohol (MacKillop, Amlung, & Acker, 2010; Murphy & MacKillop, 2006; Skidmore & Murphy, 2011), marijuana (Collins, Vincent, Yu, Liu, & Epstein, 2014), cigarettes (Field, Santarcangelo, Sumnall, Goudie, & Cole, 2006; Mackillop, Brown, et al., 2012; MacKillop & Tidey, 2011), prescription drugs (Pickover, Messina, Correia, Garza, & Murphy, 2016), and other illicit drugs (Jacobs & Bickel, 1999) in situations where it would be impractical to estimate demand based on actual laboratory consumption of alcohol or other drugs. Individuals are asked how much of a given substance they would purchase or 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 expenditures (intensity, breakpoint, O_{max}, P_{max}; Murphy & MacKillop, 2006), and six that are derived from equations (elasticity, Q_0, P_{max}, and O_{max}, area under the curve, and essential). 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 reinforcement, 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 degree at which demand decreases as a function of increasing price, found using an exponential demand curve equation (Hursh & Silberberg, 2008). Area under the curve (AUC) refers to individual's total reported consumption across all prices (Amlung, Yurasek, McCarty, MacKillop, & Murphy, 2015), represented by the total amount of area under the demand curve. AUC is highly correlated with O_{max} (r = .92; 2015), representing some possible redundancy. Finally, essential value represents a global index of valuation, is inversely proportional to elasticity (α), and accounts for k to allow for comparison between studies (Hursh, 2014).

Interestingly, the different metrics produced by HPTs correspond to two heterogeneous aspects of demand – amplitude and persistence (MacKillop et al., 2009; Skidmore, Murphy, & Martens, 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 – while 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, Acker, Stojek, Murphy, & Mackillop, 2012; Amlung & MacKillop, 2015), suggesting strong validity for the self-report task.

Demand as an index of substance problem severity

The introduction of the hypothetical purchase task allowed investigators to examine how individual differences in demand predict future consumption, response to treatment or other manipulations, and substance use severity (see Table 2 for consistency of relations). For example, demand – specifically intensity and AUC – both predict weekly drinking (Amlung, Yurasek, et al., 2015); in the same study, intensity, O_{max}, elasticity, and AUC were correlated with alcohol use. Bertholet, Murphy, Daeppen, Gmel, and Gaume (2015) found that all demand metrics (except P_{max} and breakpoint) correlate with alcohol use; Skidmore and colleagues (2014) extended the support by finding all demand metrics except P_{max} predict alcohol use. All indices except P_{max} predict marijuana consumption, suggesting that this relationship is not specific to a certain substance, but is a stable predictor of substance use across several substances (Collins et al., 2014). The above research demonstrates consistently the predictive utility of demand, and in particular intensity, O_{max}, elasticity, and AUC. Further, these relations suggest that changes in consumption may naturally accompany changes in demand.

In addition to consistent relations with consumption (Collins et al., 2014; Murphy, MacKillop, Skidmore, & Pederson, 2009), elevated demand has exhibited relationships with problematic substance 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. These findings were extended in a study by Murphy and colleagues (2009) in which intensity predicted alcohol problems after controlling for consumption, suggesting that elevated demand may function as a unique index of severity; AUC was also predictive of alcohol problems in a sample of heavy drinking college students (Amlung, Yurasek, et al., 2015). Further, demand predicts outcomes of brief interventions targeting college age drinking populations (MacKillop & Murphy, 2007). These relationships are not limited to alcohol use – elevated demand has been related to problematic use of cigarettes, marijuana, prescription optiates, and cocaine as well (Bruner & Johnson, 2014; Chase, MacKillop, & Hogarth, 2013; Collins et al., 2014; Pickover et al., 2016).

Elevated demand is also associated with substance dependence and substance use disorder. Intensity of demand was associated with AUD in a sample of heavy drinkers (Bertholet et al., 2015; Mackillop et al., 2010). This phenomenon is generalizable to other substances; several metrics of demand (particularly intensity, Omax, and elasticity) highly correlate with nicotine dependence in a sample of young adult smokers (Chase et al., 2013).

Finally, elevated demand has also exhibited relationships with psychiatric symptoms and disorders that often co-occur with substance misuse. For example, young adult heavy drinkers with symptoms of PTSD or depression report elevated demand relative to young adult heavy drinkers without those symptoms (Murphy et al., 2013; Tripp et al., 2015). Cigarette demand is also influenced by depression, although only in the presence of acute negative affect (Dahne, Murphy, & MacPherson, 2016).

Stability of Demand

Despite the strong empirical evidence linking alcohol demand to alcohol misuse one 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. For example, intelligence is generally thought of as highly stable (Hertzog & Schaie, 1986), and therefore will not vary following a short intervention, whereas mood is considered highly malleable and is generally influenced by one's environment. Understanding the stability of the aforementioned phenomena was key to building strong, testable hypotheses and understanding the potential scientific and clinical implications of these constructs.

Surprisingly, questions about the stability of demand still exist. Although demand has demonstrated stability over short periods of time (1-2 weeks; Few, Acker, Murphy, & MacKillop, 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 natural state of the stability of demand, as well as the conditions in which it fluctuates, is important to enhancing its theoretical and clinical utility (see Table 3). Next, we will first review the stability of demand by examining both reliability studies and studies that attempted to directly manipulate demand.

Test-Retest Reliability of Demand. Two reliability studies of HPTs have demonstrated strong stability over short time periods (see Table 1 for overview). Using the test-retest method, Murphy and colleagues (2009) found good to excellent 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} were very stable (*r*s = .89 and .90, respectively), breakpoint and elasticity (derived from Hursh & Silberberg, 2008) were moderately stable (*r*s = .81 & .75) and P_{max} was slightly less stable (*r* = .67). In the same study, the test-retest reliability of the derived values of intensity, O_{max}, and P_{max} were lower than the observed. 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} 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} – suggests stronger stability for that factor. However, both studies included relatively small sample sizes (i.e., 38 and 11), and temporal stability has only been examined to two weeks. More work should extend the temporal frame and test HPTs in other substance-using populations.

Malleability of Demand. Thus far, research has identified four major variables that alter demand: 1) craving; 2) stress; 3) behavioral and pharmacological treatment manipulations; and 4) next-day responsibilities.

Cue-Elicited Craving. The role of craving in the maintenance of substance use disorders is paramount and is reflected in its inclusion in the DSM-5 for substance use disorders (American Psychiatric Association, 2013). Behavioral economics understands craving as an acute increase in an individual's valuation of a drug (Loewenstein, 1999) and theorizes that changes in demand would parallel changes in craving. Research has begun to demonstrate this. For example, one laboratory study with heavy drinking college students (*n* = 92) found that substance-related cues eliciting craving significantly increase intensity, breakpoint, O_{max}, and P_{max} compared to neutral cues (MacKillop, O'Hagen, et al., 2010). These results extend to cigarette use as well. Several cigarette demand metrics – breakpoint, O_{max}, and elasticity – are influenced by cue-elicited craving (Acker & MacKillop, 2013; Mackillop, Brown, et al., 2012). Acute alcohol consumption also increases both craving and demand metrics (intensity and O_{max}; Amlung, McCarty, Morris, Tsai, & McCarthy, 2015). Withdrawal elicits craving as well, and elasticity significantly reduces with withdrawal-elicited craving, resulting in less sensitivity to changes in price (Mackillop, Brown, et al., 2012). The acute increases in valuation of a substance that accompanies craving may help explain the relationship between demand and substance misuse by increasing the likelihood of use or, in some cases, relapse. It is clear that, although demand has demonstrated stable relationships as individual difference variables, craving is one condition that can influence stability.

Stress. Although a relatively new area of inquiry, research has already been able to document the influence of stress on demand. While stress relates to addiction and relapse (Vuchinich & Tucker, 1996), increases in valuation during a stressful state could explain why. One study found that stress influences valuation of a substance (Rousseau, Irons, & Correia, 2011), only two studies have examined demand directly using a HPT. These studies found increases in intensity and O_{max} after a stress induction (Amlung & MacKillop, 2014; Owens, Ray, & MacKillop, 2015); breakpoint and elasticity, however, were only altered in the second study. Cigarette demand is also influenced by stress inductions for those participants who experienced greater acute increases in experimentally induced negative affect (Dahne et al., 2016). While these results are not conclusive, they highlight the relationship between stress, demand, and substance misuse. Future research can further explore the malleability of demand in stressful states.

Treatment Manipulation. Theoretically, pharmacological treatment for substance misuse decreases the relative value of the substance, which could be reflected in changes in demand. Bujarski, MacKillop, and Ray (2012) found that naltrexone (an approved pharmacological treatment for alcohol dependence) reduced intensity, O_{max}, and breakpoint in a sample of heavy drinking Asian Americans. In another study, depletion of tyrosine and phenylalanine, two precursors of dopamine, resulted in increased intensity (Hitsman et al., 2008), demonstrating the influence of pharmacology on the degree of stability of demand. Varenicline, a drug used to assist in smoking cessation, has been found to increase cigarette demand elasticity and to increase the likelihood of smoking cessation (McClure, Vandrey, Johnson, & Stitzer, 2013), although this was not replicated in a subsequent study (Schlienz, Hawk, Tiffany, O'Connor, & Mahoney, 2014).

Valuation of a substance – as reflected by demand – can also be influenced by psychotherapy. For example, Aa brief motivational intervention decreased intensity and O_{max} and increased elasticity in a sample of heavy drinking college students 1-month after the intervention was delivered; further, the degree of change in these values predicted drinking 6-months later (Dennhardt, Yurasek, & Murphy, 2015). Another study found changes in demand that persisted for 1-month in both a computer-administered intervention and an in-person BMI (Murphy et al., 2015), with larger reductions in demand for participants who received the BMI. A combination of treatment methods, counseling and bupropion also decreased elasticity in a sample of heavy smokers; but only in those that actually quit smoking during the treatment (Madden & Kalman, 2010).

A novel intervention task that encourages participants to vividly focus on a future event (episodic future thinking), has recently emerged as a possible method for increasing future-oriented thinking and reducing substance demand and use (Atance & O'Neill, 2001; Daniel, Stanton, & Epstein, 2013). In a sample of alcohol dependent people, intensity was significantly lowered following an episodic future thinking task, although elasticity did not change (breakpoint, O_{max}, and P_{max} were not reported; Snider, LaConte, & Bickel, 2016). Fortunately, while demand is relatively stable even in problematic drinkers, it is malleable enough for effective treatment to reduce relative valuation for alcohol.

Next-day Contingencies. Behavioral economic theory assumes that decisions about when and how much to drink are critically influenced by the response cost and the availability of alternative rewards that are relatively incompatible with drinking (Bickel et al., 1995). An interesting manipulation of the HPTs tests the role of environmental factors – namely next day academic or other responsibilities - on demand. Participants are asked to report consumption at escalating prices – as in normal HPTs – except they have a next day responsibility, such as an exam, work, internship, or volunteering. Responses in that next-day responsibility condition are then compared to responses in a standard HTP that stipulates the participant has no next-day responsibility. Several studies show level reductions in demand in the presence of next-day responsibilities (Gentile, Librizzi, & Martinetti, 2012; Gilbert, Murphy, & Dennhardt, 2014; Skidmore & Murphy, 2011). While demand that is typically stable is more malleable in the presence of these environmental contingencies, those with a family history of alcohol problems experience smaller reductions in alcohol demand as a function of academic constraints, suggesting that family history may diminish the influence of environmental constraints on demand (Murphy et al., 2014).

The aforementioned research suggests that demand is highly malleable in response to a variety of contextual events, and may also be stable at short intervals. However, to date no research has carefully documented a) the relative stability of demand over longer time periods and b) the extent to which demand is sensitive to changes in drinking. The current study proposes to better understand this by examining natural fluctuations in alcohol consumption and demand over a 1-month period in college student heavy drinkers. First we will examine the test-retest reliability of the observed and derived APT metrics over a 1-month period. Then, we will examine changes in demand in three groups: participants who increased alcohol consumption, participants who decreased alcohol consumption, and participants whose alcohol consumption stayed relatively stable. We hypothesize that 1) test-retest stability will be good, but slightly lower than previous 2-week results; 2) stability for derived indices will be slightly stronger than stability of observed indices; and 3) metrics will change depending on AUD status and change in consumption. Specifically, participants who report stable drinking will have relatively stable alcohol demand.

This study contributes to research in several key ways. First, it will extend the reliability findings from two weeks to one month, with a much larger sample size that previous studies. The larger sample size and longer follow-up period will allow us to evaluate changes in the alcohol purchase task overtime as a function of changes in actual levels of drinking. Further, the proposed study will be the first to evaluate the reliability of the AUC index of alcohol demand (Amlung, Yurasek, et al., 2015) and the essential value index of alcohol demand (Hursh, 2014). This will also be the first study to compare stability across the myriad of indices available as outcomes of the APT. Understanding natural stability of the different indices – and differences in stability by AUD group – will inform researcher's selection of APT outcomes depending upon the theoretical/practical goals of their research study.

Method

Participants

The sample consisted of 123 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%), with African American being the next largest group (7.3%). The remaining participants identified as either Hispanic, American Indian, Asian, or Other. All participants met criteria for heavy drinking at least two times in the past month. Participants averaged 17.54 (*SD* = 13.06) alcoholic drinks per typical week in the past month, 6.19 (*SD* = 4.07) past-month heavy drinking days (4/5 drinks in one day for females/males), and 13.25 past-month alcohol problems (*SD* = 8.58). 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).

Procedures

Participants were recruited via the SONA system, in class screeners, and online surveys at two large public universities in the US. Recruitment was part of a larger study that examines the effect of a brief behavioral economic intervention on college student alcohol misuse. All participants were 1st or 2nd year students who report past month alcohol consumption (specifically 2 or more heavy drinking episodes in the past month). Only individuals that 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. Before beginning the study, participants were asked to complete a web-based survey. Participants completed all 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. 91.3% of participants completed the follow-up survey. Participants were either paid $25 or received SONA credit for each survey session.

Measures

Alcohol Consumption. Typical weekly alcohol consumption was measured with the Daily Drinking Questionnaire (DDQ), a commonly used and reliable measure of alcohol consumption (Collins, Parks, & Marlatt, 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. Further, respondents reported the number of times they drank 4/5 drinks in one occasion for females/males. They were then asked the same question but are given a 2-hour time frame.

Alcohol Problems. The Young Adult Alcohol Consequences Questionnaire (YAACQ) was used to assess alcohol problems (Read, Kahler, Strong, & Colder, 2006). Respondents answered 49 dichotomous questions about whether or not they have experienced a variety of relatively common alcohol-related consequences over the past month, including blackouts, self-perception problems, self-care, social problems, risky behaviors, physiological dependence, and academic/occupational problems. Designed for use with college students, initial research has demonstrated validity and reliability for this measure (Keough, O’Connor, & Read, 2016; Read et al., 2006).

Alcohol Demand. The alcohol purchase task – 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, and $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} (maximum expenditure), and P_{max} (price associated with O_{max}); six indices are derived from three equations: elasticity, Q_0 (intensity derived), O_{max},

P_{max}, area under the curve (AUC), and essential value. Elasticity refers to the sensitivity of demand to changes in price, and is derived from the following exponential equation, described by Hursh and Silberberg (2008):

$$\ln Q{:} = \ln Q_{\max} + k\,(e^{-\alpha P} - 1),$$

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 was the predicted maximum expenditure from the equation and P_{max} was the price associated with O_{max}. Graphpad Prism 6 was used to fit the data. P_{max} and O_{max} (derived) were calculated using an excel macro created by Kaplan and Reed (2014). 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:

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

Where x^1 and χ^2 are successive prices, and y^1 and y^2 are the respective consumption values of the prices (Amlung, Yurasek, et al., 2015). While other indices of demand provide partial information about the construct, AUC may provide a more global picture of demand since it encompasses much of each metric in the final outcome (Amlung, Yurasek, et al., 2015). AUC, however, is highly correlated with O_{max}, suggesting some possible redundancy. Finally, essential value (EV) was calculated using the following formula:

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

Where α = elasticity of demand and k = range of possible consumption (Hursh, 2014). 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.

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: No AUD (0-1), Mild AUD (2-3), Moderate AUD (4-5), Severe AUD (6 or greater).

Data Analysis Plan

The focus of the current study was to further examine the temporal stability of the various indices derived from the alcohol purchase task. Further, we evaluated the stability of alcohol demand as a function of alcohol use disorder classification. As a secondary focus, we compared the stability of derived vs. observed indices. Data analysis will be performed in four stages.

First, Pearson's *r* was used to examine the temporal stability of the alcohol purchase task. A previous study established two-week reliability for a small sample; the present study extends these findings by evaluating the 1-month test-retest reliability in a larger sample. Paired sample *t*-tests were used to assess any significant changes in individual APT price points, as well as with all demand indices. Assuming correlations of approximately .7 (Murphy et al., 2009) and an alpha of .01, our study requires 20 participants to achieve adequate power (.80). Therefore, our sample of 123 is sufficient to evaluate our primary hypotheses.

Next, temporal stability was examined in students with minimal change in alcohol consumption over the 1-month follow-up period. To determine those with minimal change in consumption, consumption from time 1 was subtracted from time 2. Percent change was then calculated by dividing change scores from time 1 scores. Those between -15% to 15% change in consumption were deemed to have minimal change in consumption. Pearson correlation coefficients determined stability 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). Using split file, test-retest reliability was evaluated using Pearson correlation coefficients for each AUD group. Significant differences between scores will be tested using Fisher's r to z transformation.

To analyze the utility of both derived and observed indices of demand, we used Fisher's r to z transformations to examine significant differences in test-retest reliability coefficients.

Results

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 the 12 participants did not significantly differ from those who completed the follow-up. Another participant reported inconsistent consumption across prices and three 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. In order to calculate derived indices, we required at least 5 consumption values greater than zero in order to adequately fit a demand curve (Tripp et al., 2015). Consequently, only 115 participants were used in prospective analysis of the derived indices. Outliers greater than 3.29 standard deviations away from the mean were detected and corrected, 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). With the exception of AUC, all derived indices were transformed using the log function. Intensity (observed) was still slightly kurtotic (3.084) 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. Hursh and Silberberg (2008) exponential demand equation provided a good fit for participant level data (T1: *N* = 134, mean R2 = .88, median R2 = .90, range = .63 - .98; T2: *N* = 118, mean R2 = .88, median R2 = .91, range = .51 - .98).

Alcohol Purchase Task Reliability Analysis

Table 4 shows the mean consumption scores and *t*-test analysis for each time point. There were two significant group level differences in consumption means across the two time points, for $7.00 and $10.00. 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 essential value) indices (Table 5). Using a *t*-test analysis, we found two significant group level difference from time 1 to time 2 with AUC and breakpoint. For observed indices, reliability was moderate for intensity of demand (*r* = .69), breakpoint (*r* = .70), and O_{max} (*r* = .65); the reliability for P_{max}, however, was weak (*r* = .31). For derived indices, reliability was also moderate for Q_0 (*r* = .65), P_{max} (*r* = .62), and elasticity (*r* = .64); O_{max} (*r* = .75), essential value (*r* = .76) and AUC (*r* = .76) displayed slightly better reliability. Amplitude reliability was good (*r* = .77), while persistence demonstrated lower reliability (*r* = .56).

Reliability by AUD classification and Stable Consumption

We examined stability of demand in group with relatively constant consumption from time 1 to time 2 (Table 5). Overall, demand indices were much higher than demand indices in the full sample. The sample was separated into two groups based on AUD classification in order to further understand the influence of AUD on stability of alcohol demand. Those reporting 3 or less AUD symptoms were classified as having no or mild AUD (*N* = 77) while those reporting 4 or more AUD symptoms were classified as having moderate or severe AUD (*N* = 46). Results are reported in Table 5. We examined statistically significant differences between reliability coefficients using Fisher's r to z transformations; no indices were significantly different between the two AUD groups.

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.

Discussion

This study analyzed stability of demand derived from a hypothetical purchase task in a sample of heavy drinking college students. Although previous studies have examined the reliability of the alcohol purchase task, this study includes a larger sample and measures reliability at a greater distance in time (1-month). Further, no other study has examined differences in test-retest reliability by group (no/mild or moderate/severe AUD). We also examined and compared the reliability of both observed and derived indices in the full sample. Finally, this was the first study to examine the reliability of EV and AUC.

Demand curves exhibited prototypical trends, with consumption decreasing as price increased. Further, the exponential demand equation provided an excellent fit for the data (Hursh & Silberberg, 2008). As hypothesized, demand indices were slightly lower than the two-week test-retest reliability coefficients found in previous research (Murphy et al., 2009). AUC, EV, and O_{max} derived demonstrated the greatest reliability in the full sample (*r*s = .75-.77), although still slightly lower than the two-week reliability of intensity (.89) and O_{max} observed (.9; (Murphy et al., 2009). Overall, reliabilities of derived indices were comparable to observed indices. P_{max} derived, however, was significantly greater than its observed counterpart. The amplitude factor had greater reliability coefficients than persistence.

Our third hypothesis examined other factors that may be involved in regulating the stability of alcohol demand, such as alcohol consumption and AUD. As hypothesized, demand was more stable in the absence of changes in consumption, with reliability coefficients similar to that of the two-week reliability (Murphy et al., 2009). In the absence of changes in behavior or changes in the environment that influence behavior, alcohol demand seems to remains relatively stable, which supports behavioral economic theory (Bickel et al., 1995). Longitudinal studies examining both consumption and alcohol demand at multiple time points in a larger sample would be more appropriate for future inquiries in this question. Contrary to our hypothesis, however, stability of demand indices did not differ significantly by AUD classification. Although alcohol demand is related to severity of AUD, albeit in a community sample (Mackillop et al., 2010), the APT seems to produce stable indices of demand regardless of AUD severity, supporting its utility across the spectrum of AUD.

Interestingly, AUC and EV had stability values that were relatively similar across groups, suggesting that these indices may be less influenced by external factors. Further, their values were relatively high, which is theoretically consistent with what their values are supposed to represent: both are more global measures and hypothetically measure less precarious aspects of demand. Stability seems promising, and research – although minimal – suggests relations between both AUC and EV and alcohol problems and consumption (Amlung, Yurasek, et al., 2015; Lemley, Kaplan, Reed, Darden, & Jarmolowicz, 2016). Both indices may be useful predictors of other behaviors moving forward. Amplitude stability was higher than persistence, likely due to the low reliabilities of the indices that make up persistence. Future research should reexamine the factor structure of demand and consider including AUC and EV, and possibly the derived indices.

Stability of P_{max}-observed was surprisingly low. P_{max} is at least partially dependent on stable O_{max}, which may partially explain this phenomenon. 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 thus generates a larger range of values thereby allowing for greater covariation. These findings, along with the reliability and lack of P_{max} findings (Bujarski et al., 2012; Mackillop, Brown, et al., 2012; MacKillop & Murphy, 2007; Murphy & MacKillop, 2006), suggest discontinued use of P_{max} observed. Future studies should consider using P_{max} derived, which is much more stable over time.

Limitations and Future Directions

Our study was the first to evaluate the 1-month test-retest reliability of demand in a larger sample. This was also the first study to examine the test-retest of two relatively new indices of demand – AUC and EV – 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. These results also need to be extended to other substances. Nicotine, for example, may be more stable due to the greater abuse liability compared to alcohol. Using HPTs to understand stability in other substances would be an important next step in understanding the nuances of demand, specifically in how it operates differently in different contexts.

This study also highlights the need to study factors that influence changes in either consumption or demand. Indeed, factors such as craving and stress (Acker & MacKillop, 2013; Amlung & MacKillop, 2014; Mackillop, Brown, et al., 2012; Murphy et al., 2013), next-day responsibility (Gilbert et al., 2014; Skidmore & Murphy, 2011), and treatment (Dennhardt et al., 2015) influence alcohol demand and support the behavioral economic perspective suggesting that the environment influences an organism's valuation of a substance (Hursh, 1980, 1984; Hursh, Raslear, Shurtleff, Bauman, & Simmons, 1988). Specifically referring to treatment, these changes often subsequently predict changes in consumption during a follow-up period. Although this example seems to imply that change in demand predicates change in consumption, this has never been explored empirically in the natural environment. Considering the high levels of reliability in the subsample of college students whose consumption changed minimally, a longitudinal design with a large sample could help parse out the relation between alcohol consumption and demand, as well as identify factors that influence demand.

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Appendix

Table 1

Characteristics of Demand Indices – Observed and Derived

	Index	Factor	Reliability
Observed	Intensity	Amplitude	.89
	Breakpoint	Persistence	.81
	Pmax	Persistence	.67
	Omax	Amplitude and Persistence	.90
Derived	Q0	Amplitude	.64
	Omax	Amplitude and Persistence	.84
	Pmax	Persistence	.66
	Elasticity	Persistence	.75
	AUC	N/A	

Table 2

Summary of findings between demand indices, substance use and problems, and mood/mental health

Indices	Alcohol/drug Use	Substance Problems	Mood/Mental Health
Consistency of Relations			
Intensity	Consistent	Consistent	Consistent
Breakpoint	Inconsistent	Inconsistent	Inconsistent
Omax	Consistent	Inconsistent	Inconsistent
Pmax	Inconsistent	Inconsistent	Inconsistent
Elasticity	Consistent	Inconsistent	Consistent
AUC	Consistent	Consistent	N/A

Note. AUC has only recently been introduced and only one paper has presented findings. Relation is deemed consistent if found in more than 66% of reported outcomes; less than 20% of reported outcomes is deemed no relation.

Table 3

Summary of Manipulations of Demand

Study	Substance	Manipulation	Time	Intensity	Breakpoint	O_{max}	P_{max}	Elasticity	AUC
MacKillop et al., 2010b	Alcohol	Cue-elicited craving	in-lab	✓	✓	✓	✓		N/A
Acker & MacKillop, 2013	Tobacco	Cue-elicited craving	in-lab		✓	✓		✓	N/A
MacKillop et al., 2012b	Tobacco	Withdrawal-elicited craving	in-lab		✓		✓		N/A
Amlung et al., 2015	Tobacco	Craving	in-lab	✓	✓	✓			N/A
MacKillop et al., 2012b	Alcohol	Cue-elicited craving	in-lab					✓	N/A
Amlung & MacKillop, 2014	Alcohol	Stress	in-lab	✓	✓	✓	N/A		N/A
Amlung & MacKillop, 2014	Alcohol	Cue-elicited craving	in-lab		✓		N/A		N/A
Owens, Ray, & MacKillop, 2015	Alcohol	Stress	in-lab	✓	✓	✓	N/A	✓	N/A
Dahne, Murphy, & MacPherson, 2016	Tobacco	Stress and Depressive symptoms	in-lab	✓	✓		✓		N/A
Bujarski, MacKillop & Ray, 2012	Alcohol	Treatment (Naltrexone)	in-lab	✓	✓	✓		N/A	N/A

Note. N/A means data was not reported for that metric; a blank space represents null findings.

Table 3 (Continued)
Summary of Manipulations of Demand

Study	Substance	Manipulation	Time	Intensity	Breakpoint	O_{max}	P_{max}	Elasticity	AUC
McClure et al., 2013	Tobacco	Treatment (Varenicline)	one week		N/A	N/A	N/A	✓	N/A
Dennhardt, Yurasek, & Murphy, 2015	Alcohol	Treatment	one month	✓	N/A	✓	N/A	✓	N/A
Madden & Kalman, 2010	Tobacco	Treatment (Buproprion)	one week		N/A			✓	N/A
Snider, LaConte, & Bickel, 2016	Alcohol	Episodic Future Thinking	in-lab	✓(Q0)	N/A	N/A	N/A		N/A
Skidmore & Murphy, 2011	Alcohol	Next day responsibilities	in-lab	✓	✓	✓	✓	✓	N/A
Gilbert, Murphy, & Dennhardt, 2014	Alcohol	Next day responsibilities (differently for different responsibilities)	in-lab	✓	N/A	N/A	N/A	N/A	N/A
Gentile, Librizzi, & Martinetti, 2012	Alcohol	Next day responsibilities	in-lab	✓	N/A	✓		✓	N/A

Note. N/A means data was not reported for that metric; a blank space represents null findings.

Table 4

Baseline and One-month Consumption Means for Individual Price Points on the Alcohol Purchase Task

	Consumption value on the alcohol purchase task				
	Time 1		Time 2		
	Mean	*SD*	Mean	*SD*	*t*-test
Free	9.23	4.877	9.02	6.628	NS
$0.25	8.91	4.778	8.62	5.658	NS
$0.50	8.47	4.611	8.26	4.889	NS
$1.00	7.64	4.140	7.64	4.304	NS
$1.50	7.01	4.024	6.80	3.692	NS
$2.00	5.99	3.588	5.89	3.011	NS
$2.50	5.33	3.280	5.33	2.935	NS
$3.00	4.41	2.806	4.32	2.543	NS
$3.50	4.02	2.478	3.90	2.369	NS
$4.00	3.39	2.447	3.22	2.148	NS
$4.50	3.02	2.152	2.93	1.999	NS
$5.00	2.67	2.007	2.44	1.751	NS
$5.50	2.53	1.913	2.21	1.725	NS
$6.00	2.20	1.828	1.96	1.624	NS
$7.00	1.97	1.685	1.56	1.427	0.031
$8.00	1.62	1.873	1.32	1.344	NS
$9.00	1.37	1.533	1.06	1.116	NS
$10.00	1.17	1.447	.78	1.005	0.002
$15.00	.43	.806	.39	.670	NS
$20.00	.33	.809	.16	.426	NS
Observed demand indices					
Intensity	9.18	4.685	8.75	4.631	NS
Breakpoint	10.63	6.697	9.46	5.596	.013
P_{max}	17.88	10.258	17.19	10.349	NS
O_{max}	4.70	3.603	4.24	2.741	NS
Derived demand indices					
Q_0	10.25	5.326	10.15	5.317	NS
P_{max} derived	5.00	2.790	4.70	2.484	NS
O_{max} derived	15.72	10.109	14.48	8.145	NS
Elasticity	.0066	.00453	.0070	.0052	NS
AUC	.0369	.02328	.0346	.02040	.042
Essential Value	.5649	.36925	.5190	.292	NS

Table 5

1-month test-retest reliability of demand indices in full sample, no change group, and by AUD classification

	Full sample	No change in consumption (*N* = 34)	AUD Classification		
			No/Mild AUD (76)	Moderate/Severe AUD (46)	Difference
Intensity	.69***	.94***	.69**	0.68***	NS
Breakpoint	.70***	.81***	.56***	.75***	NS
P_{max}	.30**	.30	.22	.35*	NS
O_{max}	.70***	.84***	.69***	.72***	NS
Elasticity	.64***	.80***	.64***	.66***	NS
AUC	.77***	.92***	.79***	.69***	NS
Essential Value	.76***	.85***	.78***	.70***	NS
Q_0	.65***	.80***	.58***	.68***	NS
P_{max} derived	.62***	.66***	.64***	.61***	NS
O_{max} derived	.75***	.85***	.76***	.71***	NS
Amplitude	.77***	.95***	.76***	.75***	NS
Persistence	.56***	.77***	.46***	.61***	NS

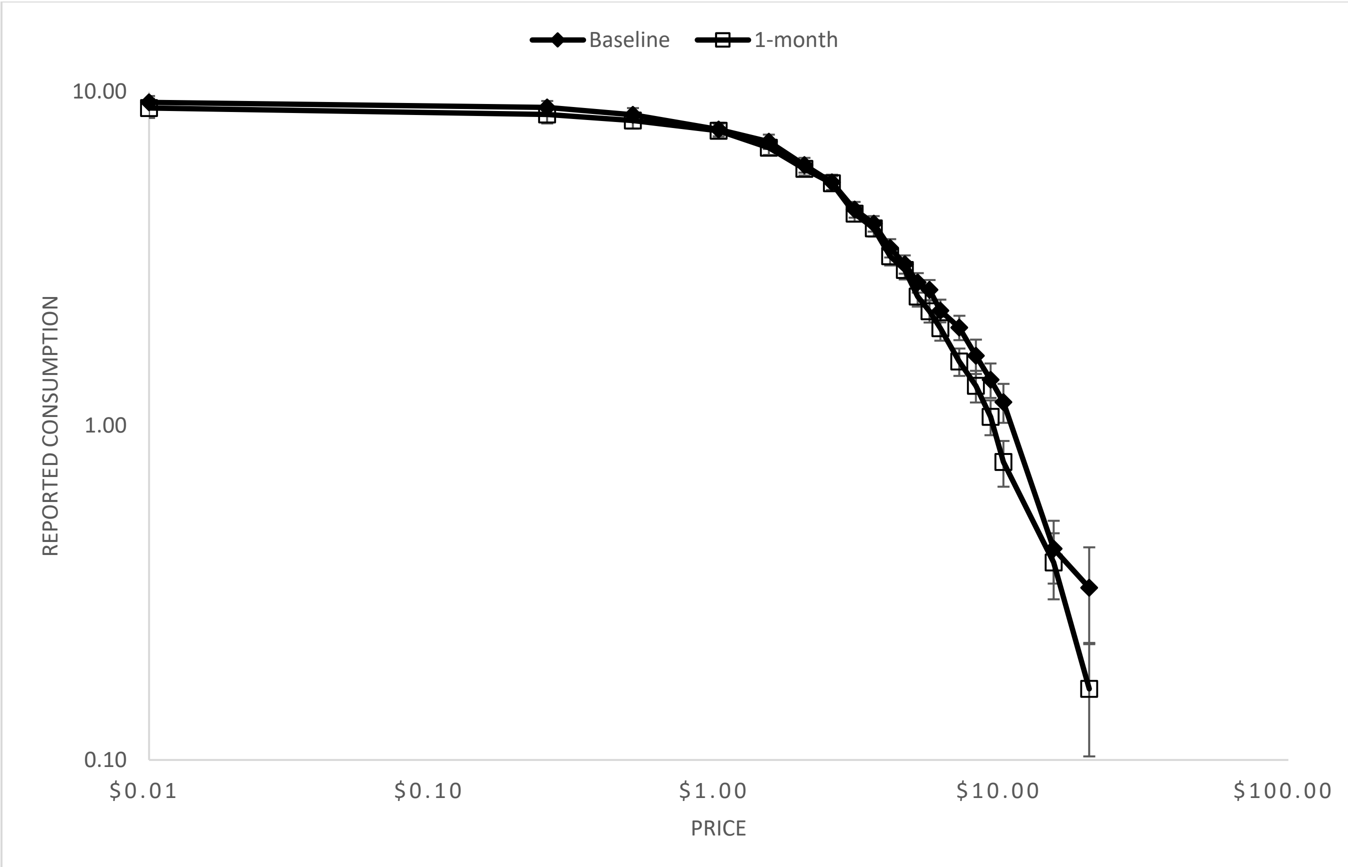

Figure 1. Demand curve for consumption of standard alcoholic drinks at baseline and 1-month. The x-axis is log-transformed price in dollars and the y-axis is the log-transformed self-reported consumption. Each data point represents the sample mean of consumption for each individual price point; error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

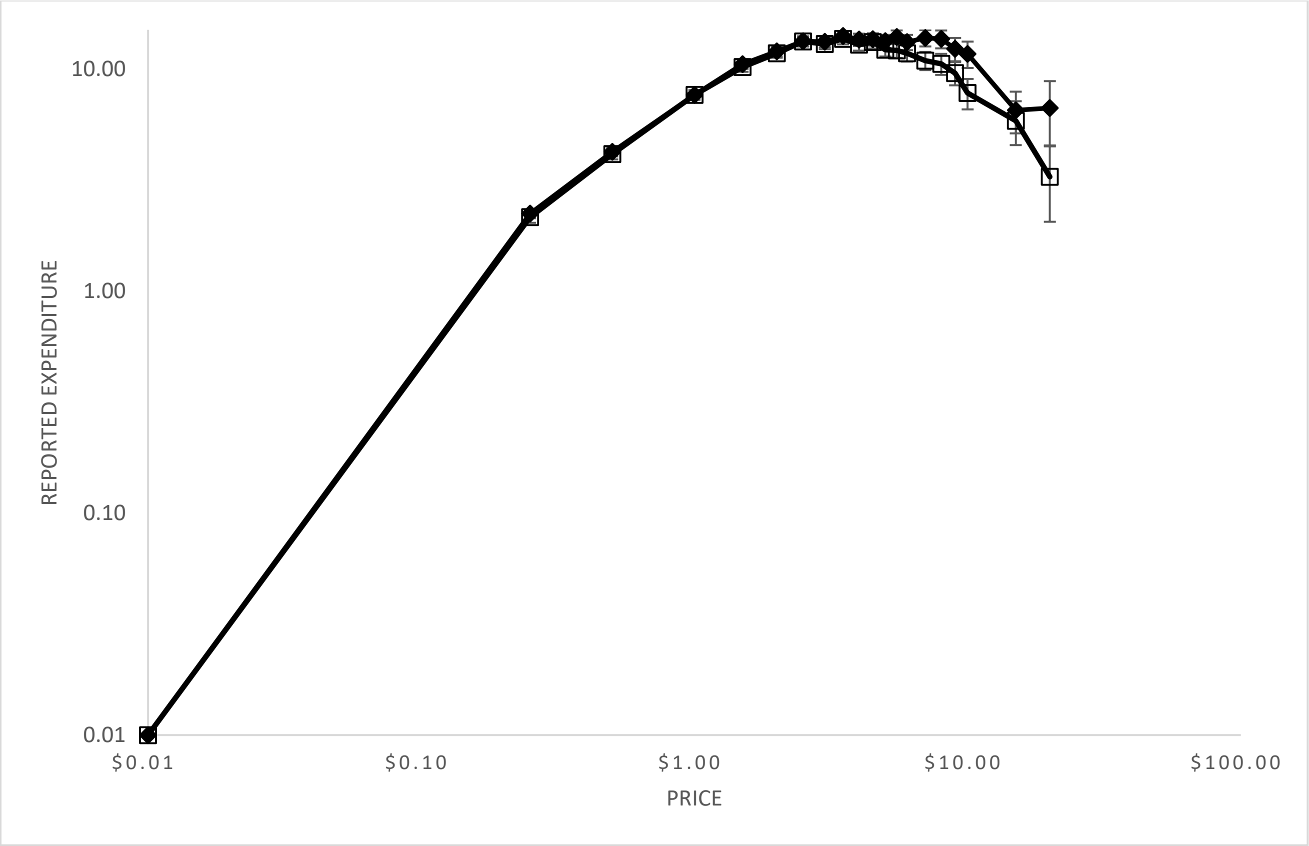

Figure 2. Demand curve for expenditure of standard alcoholic drinks at baseline and 1-month. Expenditure is calculated by multiplying price by consumption. The x-axis is log-transformed expenditure in dollars and the y-axis is the log-transformed self-reported expenditure. Each data point represents the sample mean for each individual expenditure point; error bars represent the standard error of the mean.

Hello,

The University of Memphis Institutional Review Board, FWA00006815, has reviewed and approved your submission in accordance with all applicable statuses and regulations as well as ethical principles.

PI NAME: James Murphy
CO-PI:
PROJECT TITLE: Balanced Lifestyle for Undergraduate Excellence
FACULTY ADVISOR NAME (if applicable): N/A
IRB ID: #2152
APPROVAL DATE: 8/22/2014
EXPIRATION DATE: 3/6/2015
LEVEL OF REVIEW: Expedited Modification
RISK LEVEL DETERMINATION: No more than minimal

Please Note: Modifications do not extend the expiration of the original approval

Approval of this project is given with the following obligations:

1. If this IRB approval has an expiration date, an approved renewal must be in effect to continue the project prior to that date. If approval is not obtained, the human consent form(s) and recruiting material(s) are no longer valid and any research activities involving human subjects must stop.

2. When the project is finished or terminated, a completion form must be completed and sent to the board.

3. No change may be made in the approved protocol without prior board approval, whether the approved protocol was reviewed at the Exempt, Expedited or Full Board level.

4. Exempt approval are considered to have no expiration date and no further review is necessary unless the protocol needs modification.

Approval of this project is given with the following special obligations:

Thank you,

Pamela M. Valentine
Interim Institutional Review Board Chair
The University of Memphis.

Note: Review outcomes will be communicated to the email address on file. This email should be considered an official communication from the UM IRB. Consent Forms are no longer being stamped as well. Please contact the IRB atIRB@memphis.edu if a letter on IRB letterhead is required.