High Opportunity Cost Demand as an Indicator of Weekday Drinking and Distinctly Severe Alcohol Problems: A Behavioral Economic Analysis

Keanan J. Joyner, Lidia Z. Meshesha, Ashley A. Dennhardt, Brian Borsari, Matthew P. Martens, and James G. Murphy

Introduction: Behavioral economic theory views addiction as a reinforcer pathology characterized by excessive demand for drugs relative to alternatives. Complementary to this theory, Lamb and Ginsburg (Pharmacology Biochemistry and Behavior, 164, 2018, 62) describe addiction as a behavioral allocation disorder and predict that decisions to drink under increasingly stringent constraints are a central indicator of addiction. This study used a modified demand-curve paradigm to examine alcohol demand in the context of a next-day contingency (high opportunity cost demand) as a specific indicator of a severe pattern of alcohol problems.

Methods: Participants were 370 undergraduates (61.1% female, 86.5% white, M_{age} = 18.8) reporting multiple past-month heavy drinking episodes (5/4 drinks per occasion for men/women) who completed 2 versions of an alcohol purchase task (APT), along with measures of past-month alcohol use and problems. In 1 APT (low opportunity cost), students imagined they had no next-day responsibilities, and in the other APT (high opportunity cost), they imagined having a 10:00 AM test the next day. Item-response theory analyses were used to determine mild and severe alcohol problems from the Young Adult Alcohol Consequences Questionnaire (Journal of Studies on Alcohol, 67, 2006, 169), and the most and least severe binge drinking days throughout the week.

Results: Low opportunity cost demand (β = 0.15, p = 0.02) significantly predicted beyond high opportunity cost demand for the least severe problems, and high opportunity cost demand (β = 0.17, p = 0.009) significantly predicted beyond low opportunity cost demand for the most severe problems. Similarly, low opportunity cost demand (β = 0.26, p < 0.001) was more highly associated with weekend drinking, whereas high opportunity cost demand (β = 0.21, p = 0.001) was more highly associated with weekday drinking.

Conclusions: The current results suggest high opportunity cost alcohol demand is a distinct marker of severe alcohol problems among college student heavy drinkers.

Key Words: Behavioral Economics, Alcohol Demand, Behavioral Allocation Disorder, Alcohol, Young Adult Drinking.

APPROXIMATELY 60 % of college students report drinking alcohol in the past month and 40% report at least one heavy drinking episode (5/4 drinks per occasion for men/women, respectively) in the prior 2 weeks (Substance Abuse and Mental Health Services Administration, 2014). Further, college students report experiencing a number of alcohol-related consequences including drinking and driving, risky sexual activity, poor educational outcomes, and increased rates of morbidity and mortality (Hingson et al., 2017). Despite some reductions in overall drinking in recent years (Schulenberg et al., 2018), research suggests that college students consume alcohol in greater quantities than their same-aged noncollege peers, even when considering shared genetic and family factors (Carter et al., 2010; Merrill and Carey, 2016; Slutske et al., 2004).

Behavioral Economic Theory of Addiction

According to behavioral economic theory, decisions to use alcohol and other drugs are a function of the benefit/cost ratio of substance use in relation to the benefit/cost ratios of

From the Department of Psychology (KJJ), Florida State University, Tallahassee, Florida; Center for Alcohol and Addiction Studies (LZM), Brown University School of Public Health, Providence, Rhode Island; Department of Psychology (AD, JGM), University of Memphis, Memphis, Tennessee; Mental Health Service (116B) (BB), San Francisco VA Medical Center, San Francisco, California; Department of Psychiatry (BB), University of California, San Francisco, San Francisco, California; and Department of Educational, School, and Counseling Psychology (MPM), University of Missouri, Columbia, Missouri.

Received for publication April 22, 2019; accepted September 25, 2019.

Reprint requests: James G. Murphy, PhD, Department of Psychology, University of Memphis, 400 Innovation Dr., Memphis, TN 38152; Tel.: 901-678-2630; Fax: 901-678-2579; E-mail: jgmurphy@memphis.edu

Department of Psychology (JGM), University of Memphis, Memphis, Tennessee

DOI: 10.1111/acer.14206

other available activities (Rachlin, 1997). Individuals who drink heavily may underengage in alternatives to drinking because the benefits of these activities are generally delayed. Although the value of all rewards decreases as their receipt is temporally delayed, there are individual differences in the degree that delayed rewards are discounted, and this discounting phenomenon may be a key indicator of problematic drinking (Bickel et al., 2014; Lemley et al., 2016). Generally, the rewarding effects of alcohol (e.g., acute anxiety reduction, euphoria, social facilitation) are experienced immediately compared to most alternative activities whose rewards are delayed (e.g., studying to get a good grade or completing an internship to obtain a job; Müller and Schumann, 2011). Individuals with greater discounting of delayed rewards may allocate more behavior toward immediately reinforcing activities such as consuming alcohol (MacKillop et al., 2011; Petry, 2001).

Consistent with behavioral economic theory, recent work has proposed that addiction can be conceptualized as a "behavioral allocation disorder" (BAD), such that the reward value of the drug (e.g., alcohol) exceeds that of available alternatives, causing a disproportionate level of resource allocation to alcohol-related activities compared to alcohol-free activities (Lamb and Ginsburg, 2018). One key prediction of this model is that heavy alcohol use is more likely in contexts in which alcohol is readily available and there are few constraints on use, and less likely when there are important constraints on use (e.g., social, educational, legal, or other personal consequences resulting from heavy drinking). However, although most individuals drink substantially less in the face of constraints (Berman and Martinetti, 2017; Gilbert et al., 2014; Skidmore and Murphy, 2011), many do not, and drinking that persists in the face of constraint may be especially indicative of uncontrolled and problematic drinking (Ginsburg et al., 2012; Murphy et al., 2014).

Alcohol Demand

Demand is a behavioral economic index of reward value that reflects the level of motivation or desire to possess a good or service (in this case, buying alcohol). Alcohol demand curves can be estimated from hypothetical self-reported alcohol purchase tasks (APTs; Amlung et al., 2012; Amlung and MacKillop, 2012; Murphy et al., 2009; Murphy and MacKillop, 2006) in which the participant specifies how much alcohol they would purchase and use across a range of prices. The demand curve provides a formal approach to quantifying demand by plotting consumption and expenditures related to a reinforcer as a function of price (Hursh and Silberberg, 2008). These curves can be used to quantify differences in how much participants would consume given unrestricted or free access to alcohol (intensity), how much money they would spend on alcohol (O_{max}), and the extent to which their consumption level is price sensitive (elasticity). Recent work has explored alternative quantifications of alcohol demand that utilize area-under-the-curve (AUC) functions to describe the overall degree of demand for alcohol (Amlung et al., 2015). These drug purchase tasks yield reliable and valid reward valuation indices that are correlated with laboratory-based consumption and with other indicators of problem severity among young adults, across a variety of substances (Zvorsky et al., 2019), levels of severity, and response to treatment (Aston et al., 2016; Bertholet et al., 2015; Koffarnus and Woods, 2013). Demand for alcohol is also malleable in response to a variety of contextual factors. For example, in 1 laboratory study, alcohol cues significantly increased craving and demand for alcohol relative to neutral cues (MacKillop et al., 2010; b), and another study found a similar effect for a laboratory stress induction manipulation (Amlung and MacKillop, 2014). Experimental studies also suggest that alcohol demand can be reduced by pharmacological (Bujarski et al., 2012) and behavioral interventions (Dennhardt et al., 2015).

As discussed in BAD theory (Lamb and Ginsburg, 2018), heightened price is one form of constraint placed on substance use. Indeed, it has long been known that drink price modulates drinking behavior (Babor et al., 1978), and alcohol taxes show robust epidemiological evidence of this fact (Elder et al., 2010). However, there are contextual constraints other than price that also exert significant influence on drinking decisions. Several previous studies have used modified APTs to examine the impact of next-day responsibilities on alcohol demand (e.g., the number of drinks college students would purchase if they have class the following day; Berman and Martinetti, 2017; Gentile et al., 2012; Gilbert et al., 2014; Skidmore and Murphy, 2011). The next-day responsibility paradigm can be conceptualized either as an indirect method of increasing the latent price (opportunity cost) of drinking or as a (delayed) alternative reinforcer that could serve as a substitute for drinking. This modification allows the APT to capture variability both in the price sensitivity of drinking *and* in the degree to which decisions related to drinking are sensitive to other competing demands. These studies suggest that a variety of next-day responsibilities can reduce alcohol demand (classes, work, volunteer obligations), with the largest reduction occurring for internships and course examinations occurring in the early morning the day after a drinking event (Berman and Martinetti, 2017; Gentile et al., 2012; Gilbert et al., 2014; Skidmore and Murphy, 2011). Importantly, despite strong overall reductions, there appear to be individual differences in the extent to which demand is sensitive to the presence of a next-day responsibility (Murphy et al., 2014; Skidmore and Murphy, 2011). However, no study to date has examined the possible differences in predictive utility of alcohol demand under different conditions in predicting differential types of drinking patterns and problems.

Present Study

The present study sought to test a specific tenet of BAD theory (Lamb and Ginsburg, 2018) that complements a broader behavioral economic view of addiction that suggests decisions surrounding drinking in the face of constraints are more indicative of severe problems than without competing constraints (other than drink price). We examined alcohol demand under low opportunity cost (no next-day responsibilities) and high opportunity cost (a competing next-day responsibility) conditions. The current study also examined which days of the week were indicative of severe patterns of drinking, and which alcohol problems were indicative of the greatest latent severity of alcohol problems.

Recently, Boness and colleagues (2019) demonstrated that different criteria of AUD among college student drinkers were not equivalent indicators of severity of an AUD diagnosis. This means that the severity thresholds employed using counts of DSM-5 criteria (e.g., <2 symptoms = healthy, 2 to 3 symptoms = mild, 4 to 5 symptoms = moderate, 6 + symptoms = severe) may not map well onto the *latent* severity dimension of alcohol problems (Cooper and Balsis, 2009; Lane and Sher, 2015). Using item-response theory (IRT), one can extract information about the "difficulty" of an item in relation to the total score (in this case, the difficulty parameter can be used to deduce how severe a specific AUD criterion is in relation to the total symptomatology of AUD). Relatedly, individual AUD symptoms along this severity continuum (established by the difficulty parameter identified in an IRT model) also demonstrate differential relations to broader externalizing psychopathology (McDowell et al., 2019). The implication of these findings is that individual items on an alcohol problems measure that have varying degrees of severity may relate to different psychological risk processes, partly influenced by the differential psychometric properties of the dependent variable (IRT-difficulty). Thus, the current work employed IRT analyses to determine which alcohol problems served as indicators of the most and least severe latent alcohol problems dimension.

Hypotheses. We hypothesize that: (i) consistent with prior literature (Gentile et al., 2012; Murphy et al., 2014; Skidmore and Murphy, 2011), placing an opportunity cost on drinking would reduce alcohol demand; (ii) both low opportunity cost and high opportunity cost demand would be related to overall level of drinking and alcohol problems; (iii) low opportunity cost demand would be a better predictor of lower-level ("mild") alcohol problems and drinking on the weekends (when there are typically no academic/professional next-day responsibilities); and (iv) high opportunity cost demand would be a better predictor of higher-level ("severe") alcohol problems and drinking on the weekdays (when there are typically significant next-day responsibilities, such as the test referenced in that version of the APT).

MATERIALS AND METHODS

Participants

Participants were 393 college students in their freshman or sophomore years who reported recent heavy drinking episodes and were enrolled in a larger alcohol brief intervention trial (the current paper used baseline data that were collected prior to this brief intervention; see Murphy et al., 2019 for more details). Participants were recruited from undergraduate classes or via campus-wide email solicitations at 2 large public universities. Participants were compensated $25 for completing the baseline appointment or received extra credit if enrolled in a psychology course. Participants were not seeking, nor mandated to, alcohol treatment at the time of study enrollment. Thirteen participants could not be included in the inferential analyses due to an inability to calculate their demand-curve data in one of the 2 APTs, stemming from the data being deemed as nonsystematic (specifically, exceeding threshold for reversals and AUC metrics could not be computed due to insufficient data points due to only one nonzero response)[1] according to the algorithm detailed in Stein and colleagues (2015). Additionally, 10 more participants did not have data for the relevant covariates (age and gender), and thus were dropped from inferential analyses. This resulted in a final analysis sample size of 370, who were largely female (61.1%), recruited relatively equally from each of the 2 universities (53.8%, 46.2%), and of expected age for college freshmen and sophomores (M_{age} = 18.75, SD = 1.03).

Procedure

All procedures were approved by both universities' Institutional Review Boards. To determine study eligibility, participants completed a brief screening questionnaire. Eligibility criteria included the following: (i) enrolled in school full-time in their first or second year, (ii) working less than 20 hours a week, and (iii) 2 or more heavy drinking episodes in the past month (5/4 drinks for men/women). Eligible participants completed all assessment measures during individual research appointments conducted at an on-campus research laboratory.

Measures

Alcohol Consumption. Typical weekly alcohol consumption was obtained using the Daily Drinking Questionnaire (DDQ; Collins et al., 1985). The DDQ asks participants to recall the number of drinks they consumed each day in a typical week in the past month, and responses are summed to obtain the weekly total. The DDQ is a reliable and valid measure of typical weekly drinking (Kivlahan et al., 1990). Additionally, drinks consumed on each of the 7 days of the week used to make the total typical weekly drinking score will also be separated into more specific scales based on results of the below-described IRT analyses.

Alcohol Demand. Demand metrics were collected using the APT (Murphy and MacKillop, 2006). The APT asks participants how many drinks they would purchase and consume at 17 prices ranging from $0 to $20 per drink in a hypothetical situation. The APT yields purchase estimates that are reliable (Murphy et al., 2009) and highly correlated with laboratory-based alcohol purchases (Amlung et al., 2012). In the current study, 2 APTs were administered; the first involved no next-day responsibilities (termed "low opportunity cost demand" henceforth), while the second asked participants to purchase hypothetical drinks imagining they had a test the next morning at 10:00 AM worth 25% of their grade in the class (termed "high opportunity cost demand" henceforth because there is a constraint [the next-day responsibility] placed on their drinking). While Murphy and colleagues (2009) identified 4 indices of alcohol demand using the APT, the current study opted to use one metric from each APT—the area under the curve (AUC; Amlung et al., 2015)—to reduce total the number of statistical tests conducted to help control type 1 error rate as an omnibus test of the primary hypotheses.

[1]Participants with all zero responses on the APT were assigned AUC, intensity, breakpoint, and O_{max} values of 0.

Contingent on evidence of overall demand elevation (using AUC), exploratory follow-up analyses were conducted on each of the 4 demand indices derived from the APT. These indices have shown consistent associations with alcohol use, problems, and response to treatment (Murphy et al., 2015).

Alcohol Problems. Alcohol problems were assessed using the 48-item Young Adult Alcohol Consequences Questionnaire (YAACQ; Read et al., 2006). This scale assesses a broad array of problems due to alcohol use that are most applicable to a young adult drinking context. It is widely employed in research on young adult drinking (e.g., Read et al., 2008). It displays impressive reliability ($\alpha = 0.89$, omega $[\omega]^2 = 0.89$ in the current sample) and very good criterion validity (e.g., to other alcohol problems inventories and quantity/frequency drinking measures; Read et al., 2006, 2007). Additionally, specific alcohol problems used to make the YAACQ-total score were separated into more specific scales based on results of the below-described IRT analyses. Notably, the IRT employed in the current work was *not* meant to redefine subscales of the YAACQ, but instead identify and quantify a severity dimension using an established unidimensional measure.

Data Analysis Plan

AUC values were generated using GraphPad Prism (version 6). The area under the demand curve represents total drinks purchased across all prices. The total curve area can be defined as the AUC value when the maximum consumption value across all prices is entered at each price. An AUC value for each individual can be divided by total maximum AUC to generate proportionate AUC, with larger AUC values reflecting greater demand. For a more thorough explanation of how AUC values are calculated, see Amlung and colleagues (2015). Intensity is the level of consumption when price is minimized (i.e., free). Breakpoint is the price associated with total suppression of consumption. O_{max} is the amount of maximum expenditure (product of price and consumption). Elasticity represents the sensitivity to price, for example, the rate at which consumption falls as price increases, according to an exponentiated curve (Koffarnus et al., 2015). A paired-sample *t*-test was then conducted on the low opportunity cost and high opportunity cost demand metrics to examine sample-level reductions in alcohol demand as a function of a next-day responsibility.

Outliers in the DDQ-total and YAACQ-total scores were identified using the value of the median $\pm$ 2.5 interquartile ranges, and then, outliers were winsorized to 1 unit above the highest nonoutlying value. This method was utilized due to the fact that outliers exert influence over common metrics for determining outliers, such as the mean and standard deviation, whereas outliers have less leverage over the median and interquartile ranges (Donoho and Huber, 1983). After correcting for outliers, neither the DDQ nor YAACQ-total scores exhibited significant amounts of skew or kurtosis (i.e., $\pm$ 2; Trochim and Donnelly, 2006).

Item-Response Theory Analyses

IRT is a set of methodological tools that serve to examine the psychometric properties of a measure in a very different way from classical test theory (for further IRT details, see Hambleton and Swaminathan, 2013). IRT models in the current work were implemented using the "ltm" package (Rizopoulos, 2006) in R v3.5.1 (R Core Team, 2018). One key factor for the current work is that IRT assumes that different items of a test are more or less informative for individuals at different levels of the very continuum being defined by that test, termed "theta." Thus, examining the point along the dimension of theta where items are maximally informative can yield insight into which alcohol problems are most or least severe—as indicated by the opposing ends of the "difficulty" parameter in IRT models.[3] One of the assumptions of IRT models is that the indicators are drawn from a unidimensional model. This assumption was empirically tested using a modified parallel analysis (Drasgow and Lissak, 1983), which simulates eigenvectors from unidimensional latent models with the number of indicators specified in the IRT model and compares the second eigenvalue from the simulated data to the second eigenvalue from the observed data to determine if a second factor is present.

A 1-PL IRT model was conducted on the 7-item DDQ (corresponding to the 7 days of the week). To fit a 1-PL model, number of drinks per day was dichotomized according to the standard binge episode criteria (4/5 drinks for women/men). The 2 lowest-difficulty binge drinking days were then selected to form the "DDQ-mild" scale (indicative of the days where binge drinking was most common for everyone), and the 2 highest-difficulty days were selected to form the "DDQ-severe" scale (indicative of the days where binge drinking was least common for everyone). Then, a 1-PL IRT model was conducted on the 48-item YAACQ scale. This model specifies that each item in the scale is allowed to vary freely in terms of difficulty (where along the latent dimension this item yields the most information), but the discrimination (the amount of information this item yields at the above-described difficulty level) parameter is constrained across items. The 10 lowest-difficulty items were then selected to form the "YAACQ-mild" scale, indicative of alcohol problems that are most informative for individuals low in total alcohol problems, and the 10 highest-difficulty items were then selected to form the "YAACQ-severe" scale, indicative of alcohol problems that are most informative for individuals high in total alcohol problems. Following this, the unique predictive value of low opportunity cost and high opportunity cost alcohol demand was examined in prediction of: (i) DDQ-total score, (ii) YAACQ-total score, (iii) DDQ-mild score, (iv) YAACQ-mild score, (v) DDQ-severe score, and (vi) YAACQ-severe score through use of hierarchical regressions, entering age, gender, and recruitment site as covariates in step 1 and the demand variables in step 2. Following the test of overall demand effects (using AUC), we included individual demand metrics as exploratory analyses whose long-run error rate is controlled via the false discovery rate (FDR; Benjamini and Yekutieli, 2001) to probe these effects further to understand which mechanisms of elevated demand are responsible for the observed AUC effects.[4]

[2]Recent work (McNeish, 2018) has suggested that the alpha estimate of internal consistency reliability is affected by common properties of psychological instruments, such as not meeting distributional assumptions of polychoric correlations, but because omega is based on factor-analytic techniques, it tends to be less affected by these. However, see work by Edwards and colleagues (2019) suggesting that some of these above-mentioned factors affect alpha less than many other alternatives.

[3]IRT models also yield a "discrimination" parameter, which refers to the amount of information yielded at the point along the theta dimension where an item yields maximal information (e.g., the difficulty parameter). Given that the focus of the current work is only about severity of item and not about the psychometric properties of the YAACQ itself (which have been reported elsewhere; see Read et al., 2007), a 1-parameter logistic (1-PL) model was used, which holds the discrimination parameter constant across items, only allowing them to vary in terms of difficulty.

[4]We did not have specified a priori hypotheses about differential effects of individual demand indices (intensity, breakpoint, O_{max}, and elasticity). Elasticity cannot be computed for individuals with fewer than 3 data points, so the sample size utilized for elasticity analyses will be reduced to only those individuals without all-0 responses on the high opportunity cost APT ($N = 309$).

RESULTS

Descriptive Statistics

On average, participants reported consuming 17.23 (SD = 12.31) standard drinks per week over the previous month. Participants also experienced an average of 13.23 (SD = 7.89) alcohol problems over the previous month. Alcohol demand in a low opportunity cost context (no next-day responsibilities) and alcohol demand in a high opportunity cost context (presence of a next-day responsibility) were correlated, $r = 0.61$, $p < 0.001$. A paired-sample *t*-test demonstrated a within-subjects reduction in demand for alcohol from the low opportunity cost APT ($M_{AUC} = 0.056$) to the high opportunity cost APT ($M_{AUC} = 0.024$), $t(369) = 22.09$, $p < 0.001$. This reduction was also reflected across all of the individual demand metrics: Intensity, $t(369) = 28.45$, $p < 0.001$; Breakpoint, $t(369) = 17.00$, $p < 0.001$; O_{max}, $t(369) = 10.93$, $p < 0.001$; and Elasticity, $t(308) = -3.52$, $p = 0.001$. See Fig. 1 for an illustration of the magnitude of this reduction sample-wide. Correlations among primary study variables are presented in Table 1.

Determination of Mild/Severe Drinking Days and Alcohol Problems

A 1-PL model was fit to the DDQ for each of the 7 days of the week. The modified parallel analysis indicated that the DDQ was unidimensional (second eigenvalue observed: 1.37, average of 100 simulated second eigenvalues: 2.17, $p = 0.96$). The 2 lowest-difficulty drinking days were determined using the difficulty parameter for binge drinking episodes, and these were Friday (difficulty = −0.69, $M_{drinks} = 5.95$, SD = 4.67, dichotomized endorsement rate = 71.8%) and Saturday (difficulty = −0.96, $M_{drinks} = 6.92$, SD = 5.84, dichotomized endorsement rate = 77.3%). The 2 highest-difficulty drinking days were determined using the same difficulty parameter, and these were Monday (difficulty = 3.94, $M_{drinks} = 0.28$, SD = 1.28, dichotomized endorsement rate = 1.8%) and Tuesday (difficulty = 4.36, $M_{drinks} = 0.20$, SD = 0.98, dichotomized endorsement rate = 1.6%). The total number of drinks consumed on the 2 lowest- and highest-difficulty days was summed together to form "DDQ-mild" and "DDQ-severe" variables to be used in subsequent analyses (as opposed to presence/absence of binge episodes).[5]

A 1-PL model was fit to the YAACQ for each of the 48 alcohol-related consequences. The modified parallel analysis indicated that the YAACQ was unidimensional (second eigenvalue observed: 4.08, average of 100 simulated second eigenvalues: 3.63, $p = 0.19$). The 10 lowest-difficulty items were determined using the difficulty parameter, and the probability of endorsement of the specific item for the hypothetical person at the median of the latent continuum of alcohol problems is notarized as "$P(x = 1|z = 0)$." For illustrative purposes, the 5 lowest-difficulty items were the following: "I have had a hangover (headache, sick stomach) the morning after I had been drinking," difficulty = −1.43, $P(x = 1|z = 0) = 0.80$, observed sample endorsement rate = 76.8%; "While drinking, I have said or done embarrassing things," difficulty = −1.22, $P(x = 1|z = 0) = 0.83$, observed sample endorsement rate = 77.8%; "I often drank more than I originally had planned," difficulty = −0.57, $P(x = 1|z = 0) = 0.65$, observed sample endorsement rate = 63.0%; "I have awakened the day after drinking and found that I could not remember a part of the evening before," difficulty = −0.36, $P(x = 1|z = 0) = 0.61$, observed sample endorsement rate = 59.5%; and "I have felt very sick to my stomach or thrown up after drinking," difficulty = −0.29, $P(x = 1|z = 0) = 0.55$, observed sample endorsement rate = 55.4%. The 5 highest-difficulty items were the following: "I have gotten into trouble at work or school because of drinking," difficulty = 6.50, $P(x = 1|z = 0) = 0.02$, observed sample endorsement rate = 1.9%; "I have felt like I needed a drink after I'd gotten up (that is, before breakfast)," difficulty = 4.54, $P(x = 1|z = 0) = 0.06$, observed sample endorsement rate = 7.3%; "I have been overweight because of my drinking," difficulty = 3.98, $P(x = 1|z = 0) = 0.07$, observed sample endorsement rate = 8.4%; "I have injured someone else while drinking or intoxicated," difficulty = 3.42, $P(x = 1|z = 0) = 0.03$, observed sample endorsement rate = 4.9%; and "As a result of drinking, I neglected to protect myself or my partner from a sexually transmitted disease or an unwanted pregnancy," difficulty = 3.19, $P(x = 1|z = 0) = 0.06$, observed sample endorsement rate = 8.1%. The 10 lowest (items #1, 5, 7, 8, 10, 28, 29, 36, 37, and 46) and highest (items #9, 13, 16, 19, 22, 26, 38, 41, 42, and 44) difficulty items were summed together to form "YAACQ-mild" and "YAACQ-severe" variables to be used in subsequent analyses.[6]

Daily Drinking Questionnaire

In a 2-step hierarchical regression with age, gender, and recruitment site entered in the first step, the inclusion of both low opportunity cost and high opportunity cost demand increased predictive power in prediction of typical weekly drinks (DDQ-total), $\Delta R^2 = 0.11$, $\Delta F(2, 364) = 24.83$, $p < 0.001$. The overall regression model was significant, $R^2 = 0.23$, $F(5, 364) = 21.35$, $p < 0.001$, and both low opportunity cost demand ($\beta = 0.18$, $p = 0.002$) and high

[5]The "DDQ-mild" composite correlated highly with the common quantification of the DDQ-total (the sum of all 7 days, including the days that make up the "DDQ-mild" composite), $r = 0.89$, but the "DDQ-severe" correlated substantially less, indicating more independence from the total score, $r = 0.39$.

[6]The "YAACQ-mild" composite correlated highly with the common quantification of the YAACQ-total (sum of all 48 items in the scale), $r = 0.86$, and the "YAACQ-severe" correlated with lesser magnitude, $r = 0.58$. See Table S1 for correlations among the mild and severe items sets with all subscales of the YAACQ.

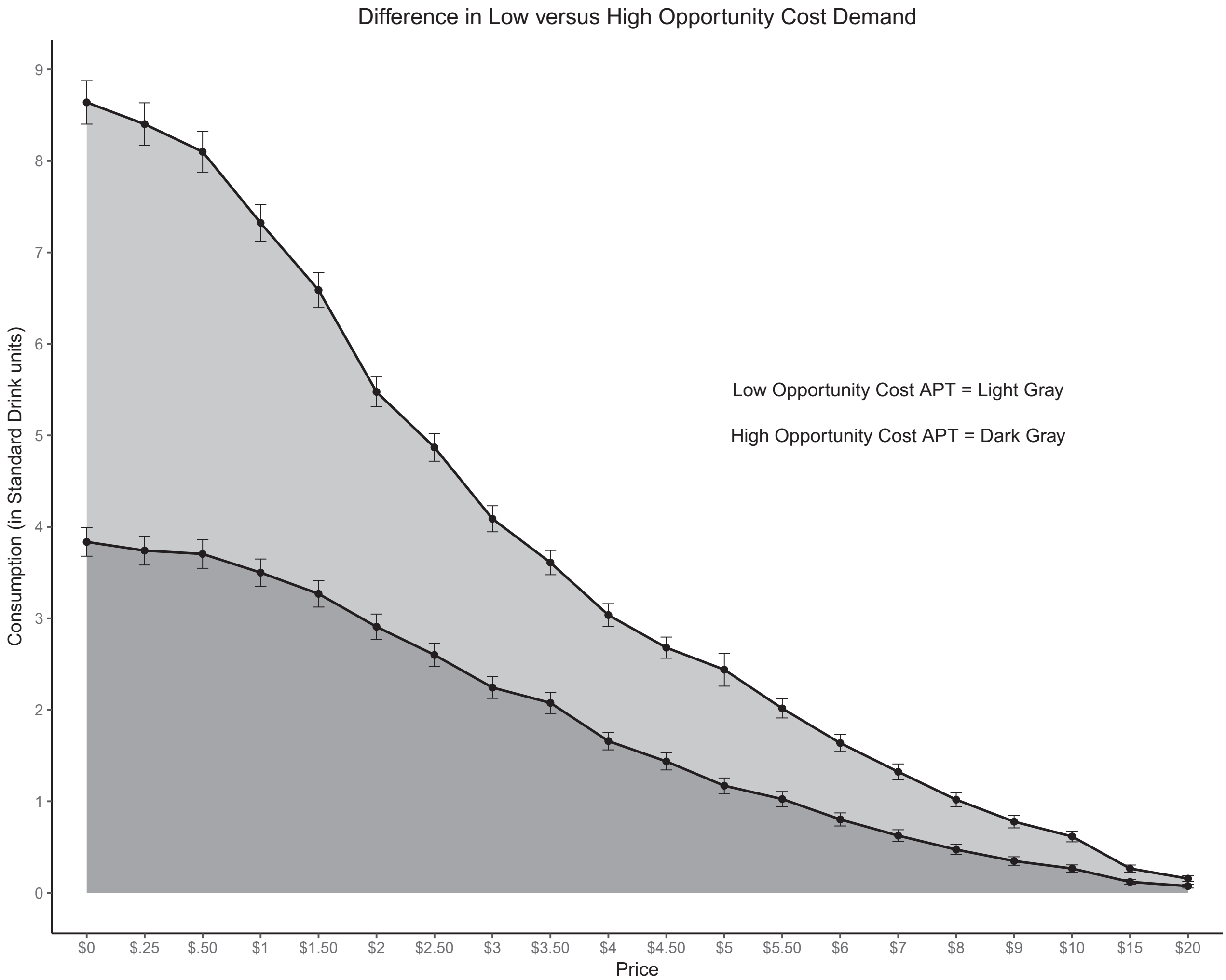

Fig. 1. Reduction in alcohol demand as a function of adding a next-day responsibility (an opportunity cost). Error bars represent the ±1 standard error of the mean.

opportunity cost demand ($\beta = 0.18$, $p = 0.002$) were significant individual predictors (Fig. 2).

This was probed further using the individual demand metrics, using the same covariates in the first step of each regression. The inclusion of both low opportunity cost and high opportunity cost intensity increased predictive power, $\Delta R^2 = 0.27$, $\Delta F(2, 364) = 81.66$, FDR $q < 0.05$, and only low opportunity cost intensity was a significant individual predictor ($\beta = 0.49$, FDR $q < 0.05$). The inclusion of both low opportunity cost and high opportunity cost breakpoint increased predictive power, $\Delta R^2 = 0.03$, $\Delta F(2, 364) = 7.42$, FDR $q < 0.05$, and only high opportunity cost breakpoint was a significant predictor ($\beta = 0.25$, FDR $q < 0.05$). The inclusion of both low opportunity cost and high opportunity cost O_{max} increased predictive power, $\Delta R^2 = 0.08$, $\Delta F(2, 364) = 18.14$, FDR $q < 0.05$, and only high opportunity cost O_{max} was a significant predictor ($\beta = 0.24$, FDR $q < 0.05$). The inclusion of both low opportunity cost and high opportunity cost elasticity increased predictive power, $\Delta R^2 = 0.03$, $\Delta F(2, 303) = 5.01$, FDR $q < 0.05$, and only low opportunity cost elasticity was a significant individual predictor ($\beta = -0.17$, FDR $q < 0.05$).

In prediction of the "DDQ-mild" composite (made up of total drinks on Friday and Saturday), the inclusion of both low opportunity cost and high opportunity cost demand significantly increased predictive power, $\Delta R^2 = 0.10$, $\Delta F(2, 364) = 21.93$, $p < 0.001$. The overall regression model was significant, $R^2 = 0.20$, $F(5, 364) = 17.87$, $p < 0.001$, and only low opportunity cost demand ($\beta = 0.26$, $p < 0.001$), but not high opportunity cost demand ($\beta = 0.08$, $p = 0.18$), was a significant individual predictor.

This was probed further using the individual demand metrics, using the same covariates in the first step of each regression. The inclusion of both low opportunity cost and high opportunity cost intensity increased predictive power, $\Delta R^2 = 0.24$, $\Delta F(2, 364) = 64.45$, FDR $q < 0.05$, and only low opportunity cost intensity was a significant predictor ($\beta = 0.48$, FDR $q < 0.05$). The inclusion of both low opportunity cost and high opportunity cost breakpoint did not increase predictive power, $\Delta R^2 = 0.01$, ΔF(2,

Table 1. Correlations and Confidence Intervals Among Primary Study Variables

	1	2	3	4	5	6	7	8	9
1. Age	–								
2. Female	0.06 [−0.04, 0.16]	–							
3. DDQ-total	0.05 [−0.05, 0.15]	−0.32** [−0.41, −0.22]	–						
4. DDQ-mild	0.02 [−0.08, 0.12]	−0.29** [−0.37, −0.19]	0.80** [0.76, 0.83]	–					
5. DDQ-severe	0.05 [−0.05, 0.15]	−0.10* [−0.20, −0.00]	0.38** [0.29, 0.47]	0.13* [0.03, 0.23]	–				
6. YAACQ-total	0.01 [−0.09, 0.11]	0.11* [0.01, 0.21]	0.36** [0.27, 0.44]	0.21** [0.11, 0.30]	0.13* [0.03, 0.22]	–			
7. YAACQ-mild	−0.01 [−0.11, 0.09]	0.13* [0.03, 0.23]	0.31** [0.21, 0.39]	0.17** [0.07, 0.26]	0.14** [0.04, 0.23]	0.86** [0.83, 0.88]	–		
8. YAACQ-severe	0.12* [0.02, 0.22]	0.00 [−0.10, 0.10]	0.29** [0.19, 0.38]	0.19** [0.09, 0.28]	0.08 [−0.02, 0.18]	0.58** [0.51, 0.64]	0.34** [0.25, 0.42]	–	
9. LOC-APT AUC	0.07 [−0.03, 0.17]	−0.07 [−0.17, 0.03]	0.30** [0.21, 0.39]	0.27** [0.17, 0.36]	0.03 [−0.07, 0.13]	0.17** [0.07, 0.27]	0.18** [0.08, 0.28]	0.21** [0.11, 0.30]	–
10. HOC-APT AUC	−0.02 [−0.12, 0.08]	−0.05 [−0.15, 0.05]	0.30** [0.21, 0.39]	0.22** [0.13, 0.32]	0.15** [0.05, 0.24]	0.19** [0.09, 0.28]	0.17** [0.07, 0.27]	0.23** [0.13, 0.32]	0.60** [0.53, 0.66]

M and SD are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation.

AUC, area under the curve; DDQ, Daily Drinking Questionnaire; HOC, high opportunity cost; LOC, low opportunity cost; YAACQ, Young Adult Alcohol Consequences Questionnaire. DDQ-mild = total drinks consumed on Friday and Saturday. DDQ-severe = total drinks consumed on Monday and Tuesday. YAACQ-mild = 10 lowest-difficulty items from an IRT model. YAACQ-severe = 10 highest-difficulty items from an IRT model.

*Indicates $p < 0.05$; **Indicates $p < 0.01$.

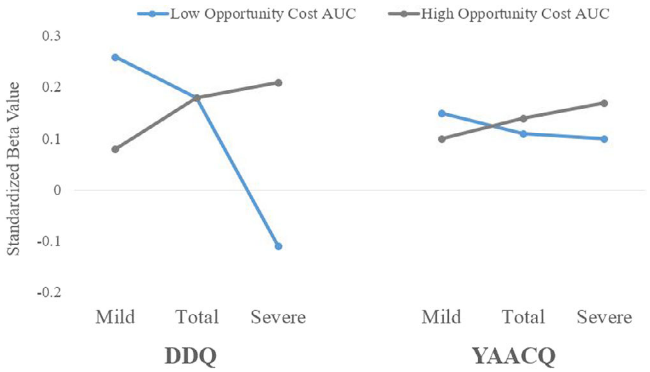

Fig. 2. Visual illustration of the predictive value of low versus high opportunity cost alcohol demand on mild, total, and severe DDQ and YAACQ scores. Standardized betas from models with predictors of age, gender, recruitment site, low opportunity cost demand, and high opportunity cost demand are plotted. For low opportunity cost demand, the unique effect is most pronounced for mild DDQ and YAACQ scores and least pronounced for severe DDQ and YAACQ scores. For high opportunity cost demand, the unique effect is most pronounced for severe DDQ and YAACQ scores and least pronounced for mild DDQ and YAACQ scores.

364) = 2.21, FDR $q > 0.05$. The inclusion of both low opportunity cost and high opportunity cost O_{max} increased predictive power, $\Delta R^2 = 0.06$, $\Delta F(2, 364) = 12.46$, FDR $q < 0.05$, and both low opportunity cost O_{max} ($\beta = 0.12$, FDR $q < 0.05$) and high opportunity cost O_{max} ($\beta = 0.17$, FDR $q < 0.05$) were significant predictors. The inclusion of both low opportunity cost and high opportunity cost elasticity increased predictive power, $\Delta R^2 = 0.03$, $\Delta F(2, 303) = 4.71$, FDR $q < 0.05$, and only low opportunity cost elasticity was a significant predictor ($\beta = -0.17$, FDR $q < 0.05$).

Conversely, in prediction of the "DDQ-severe" composite (made up of total drinks on Monday and Tuesday), the inclusion of both low opportunity cost and high opportunity cost demand significantly increased predictive power, $\Delta R^2 = 0.03$, $\Delta F(2, 364) = 5.45$, $p = 0.005$. The overall regression model was significant, $R^2 = 0.04$, $F(5, 364) = 3.25$, $p = 0.007$; however, unlike for "DDQ-mild," the effect of low opportunity cost demand was not significant ($\beta = -0.11$, $p = 0.09$), and only constrained demand ($\beta = 0.21$, $p = 0.001$) now emerged as a significant individual predictor as predictor of "DDQ-severe." Full results from the a priori regression models are presented in Table 2.

This was probed further using the individual demand metrics, using the same covariates in the first step of each regression. The inclusion of both low opportunity cost and high opportunity cost intensity increased predictive power, $\Delta R^2 = 0.02$, $\Delta F(2, 364) = 4.04$, FDR $q < 0.05$, but neither low opportunity cost nor high opportunity cost intensity was a significant individual predictor after FDR correction. The inclusion of both low opportunity cost and high opportunity cost breakpoint did not increase predictive power, $\Delta R^2 = 0.01$, $\Delta F(2, 364) = 2.45$, FDR $q > 0.05$. The inclusion of both low opportunity cost and high opportunity cost O_{max} increased predictive power, $\Delta R^2 = 0.03$, $\Delta F(2, 364) = 4.97$, FDR $q < 0.05$, and only high opportunity cost O_{max} ($\beta = 0.17$, FDR $q < 0.05$) was a significant individual predictor. The inclusion of both low opportunity cost and high opportunity cost elasticity did not increase predictive power, $\Delta R^2 < 0.01$, $\Delta F(2, 303) = 0.26$, FDR $q > 0.05$.

Young Adult Alcohol Consequences Questionnaire

Similarly, in prediction of YAACQ-total score, the inclusion of both low opportunity cost and high opportunity cost demand significantly increased predictive power, $\Delta R^2 = 0.05$, $\Delta F(2, 364) = 9.39$, $p < 0.001$. The overall regression model was significant, $R^2 = 0.07$, $F(5, 363) = 5.23$, $p < 0.001$, and low opportunity cost demand did not reach significance ($\beta = 0.11$, $p = 0.10$), but high opportunity cost demand ($\beta = 0.14$, $p = 0.03$) emerged as a significant individual predictor.

This was probed further using the individual demand metrics, using the same covariates in the first step of each regression. The inclusion of both low opportunity cost and high opportunity cost intensity increased predictive power, $\Delta R^2 = 0.12$, $\Delta F(2, 363) = 25.68$, FDR $q < 0.05$, and only low opportunity cost intensity was a significant predictor ($\beta = 0.33$, FDR $q < 0.05$). The inclusion of both low opportunity cost and high opportunity cost breakpoint increased predictive power, $\Delta R^2 = 0.02$, $\Delta F(2, 363) = 4.00$, FDR $q < 0.05$, and only high opportunity cost breakpoint was a significant predictor ($\beta = 0.18$, FDR $q < 0.05$). The inclusion of both low opportunity cost and high opportunity cost O_{max} increased predictive power, $\Delta R^2 = 0.05$, $\Delta F(2, 363) = 8.74$, FDR $q < 0.05$, and only high opportunity cost O_{max} was a significant predictor ($\beta = 0.16$, FDR $q < 0.05$). The inclusion of both low opportunity cost and high opportunity cost elasticity increased predictive power, $\Delta R^2 = 0.04$, $\Delta F(2, 302) = 7.09$, FDR $q < 0.05$, and only low opportunity cost elasticity was a significant predictor ($\beta = -0.21$, FDR $q < 0.05$).

In prediction of the "YAACQ-mild" composite, the inclusion of both low opportunity cost and high opportunity cost demand significantly increased predictive power, $\Delta R^2 = 0.05$, $\Delta F(2, 364) = 9.46$, $p < 0.001$. The overall regression model was significant, $R^2 = 0.08$, $F(5, 364) = 6.45$, $p < 0.001$; however, only low opportunity cost demand ($\beta = 0.15$, $p = 0.02$) was a significant individual predictor, and not constrained demand ($\beta = 0.10$, $p = 0.13$).

This was probed further using the individual demand metrics, using the same covariates in the first step of each regression. The inclusion of both low opportunity cost and high opportunity cost intensity increased predictive power, $\Delta R^2 = 0.09$, $\Delta F(2, 364) = 18.05$, FDR $q < 0.05$, and only low opportunity cost intensity was a significant predictor ($\beta = 0.27$, FDR $q < 0.05$). The inclusion of both low opportunity cost and high opportunity cost breakpoint increased predictive power, $\Delta R^2 = 0.02$, $\Delta F(2, 364) = 4.77$, FDR $q < 0.05$, but neither low opportunity cost nor high opportunity cost breakpoint was a significant predictor after

Table 2. Full Regression Model Results Comparing Prediction for Total Scores, Low-Difficulty Scores, and High-Difficulty Scores for Alcohol Use and Problems

	Alcohol use			Alcohol problems		
	DDQ-mild R^2 = 0.20	DDQ-total R^2 = 0.23	DDQ-severe R^2 = 0.04	YAACQ-mild R^2 = 0.06	YAACQ-total R^2 = 0.08	YAACQ-severe R^2 = 0.04
Recruitment site	β = 0.12, *p* = 0.01	β = 0.16, *p* = 0.001	β = −0.02, *p* = 0.76	β = 0.11, *p* = 0.03	β = 0.10, *p* = 0.05	β = 0.06, *p* = 0.27
Female	β = −0.29, *p* < 0.001	β = −0.30, *p* < 0.001	β = −0.11, *p* = 0.04	β = 0.15, *p* = 0.005	β = 0.11, *p* = 0.02	β = 0.05, *p* = 0.36
Age	β = 0.02, *p* = 0.72	β = 0.06, *p* = 0.21	β = 0.07, *p* = 0.18	β = −0.03, *p* = 0.60	β = 0.04, *p* = 0.40	β = 0.08, *p* = 0.13
Low opportunity cost demand (AUC)	β = 0.26, *p* < 0.001	β = 0.18, *p* = 0.002	β = −0.11, *p* = 0.09	β = 0.16, *p* = 0.01	β = 0.11, *p* = 0.08	β = 0.01, *p* = 0.89
High opportunity cost demand (AUC)	β = 0.08, *p* = 0.18	β = 0.18, *p* = 0.002	β = 0.21, *p* = 0.001	β = −0.01, *p* = 0.91	β = 0.16, *p* = 0.01	β = 0.17, *p* = 0.01

AUC, area under the curve; DDQ, Daily Drinking Questionnaire; YAACQ, Young Adult Alcohol Consequences Questionnaire. DDQ-mild = total drinks consumed on Friday and Saturday. DDQ-severe = total drinks consumed on Monday and Tuesday. YAACQ-mild = 10 lowest-difficulty items from an IRT model. YAACQ-severe = 10 highest-difficulty items from an IRT model. Total model R^2 values and individual predictor standardized betas and *p*-values are presented.

FDR correction. The inclusion of both low opportunity cost and high opportunity cost O_{max} increased predictive power, $\Delta R^2 = 0.04$, $\Delta F(2, 364) = 7.24$, FDR $q < 0.05$, and only high opportunity cost intensity was a significant predictor ($\beta = 0.16$, FDR $q < 0.05$). The inclusion of both low opportunity cost and high opportunity cost elasticity increased predictive power, $\Delta R^2 = 0.04$, $\Delta F(2, 303) = 5.96$, FDR $q < 0.05$, and only low opportunity cost elasticity was a significant predictor ($\beta = -0.19$, FDR $q < 0.05$).

Similarly, in prediction of the "YAACQ-severe" composite, the joint inclusion of low opportunity cost and high opportunity cost demand significantly increased predictive power, $\Delta R^2 = 0.06$, $\Delta F(2, 364) = 11.64$, $p < 0.001$. The overall regression model was significant, $R^2 = 0.07$, $F(5, 364) = 5.88$, $p < 0.001$, but in contrast to "YAACQ-mild," the effect of low opportunity cost demand was not significant ($\beta = 0.10$, $p = 0.11$), and only constrained demand ($\beta = 0.17$, $p = 0.008$) emerged as a significant individual predictor of "YAACQ-severe." Full results from the a priori regression models are presented in Table 2.

This was probed further using the individual demand metrics, using the same covariates in the first step of each regression. The inclusion of both low opportunity cost and high opportunity cost intensity increased predictive power, $\Delta R^2 = 0.11$, $\Delta F(2, 364) = 23.19$, FDR $q < 0.05$, and both low opportunity cost intensity ($\beta = 0.24$, FDR $q < 0.05$) and high opportunity cost intensity ($\beta = 0.16$, FDR $q < 0.05$) were significant individual predictors. The inclusion of both low opportunity cost and high opportunity cost breakpoint did not significantly increase predictive power, $\Delta R^2 = 0.01$, $\Delta F(2, 364) = 2.71$, FDR $q > 0.05$; only high opportunity cost breakpoint was a significant predictor ($\beta = 0.16$, FDR $q < 0.05$). The inclusion of both low opportunity cost and high opportunity cost O_{max} increased predictive power, $\Delta R^2 = 0.06$, $\Delta F(2, 364) = 12.73$, FDR $q < 0.05$, and only high opportunity cost O_{max} ($\beta = 0.21$, FDR $q < 0.05$) was a significant individual predictor. The inclusion of both low opportunity cost and high opportunity cost elasticity increased predictive power, $\Delta R^2 = 0.03$, $\Delta F(2, 303) = 4.05$, FDR $q < 0.05$, and only low opportunity cost elasticity was a significant predictor ($\beta = -0.16$, FDR $q < 0.05$).

DISCUSSION

In this paper, we sought to understand the association between alcohol demand under different conditions and more or less severe patterns of alcohol use and consequences. Although alcohol demand is suppressed overall by the presence of a constraint, such as a next-day responsibility, demand under different conditions may be differentially informative for specific types of drinking patterns and alcohol problems. Indeed, we observed a sample-level suppression of alcohol demand through introduction of a next-day responsibility, which suggests, in line with prior work, the presence of a competing alternative (here, a next-day responsibility) serves to reduce alcohol demand (Gentile et al., 2012; Murphy et al., 2014). Low opportunity cost and high opportunity cost demand were also highly correlated with one another ($r = 0.6$). As such, we observed that the shared variance between low opportunity cost and high opportunity cost demand was robustly related to each index of alcohol use and problems. This is consistent with a large literature on the connection between alcohol demand and alcohol use and problems (Kiselica et al., 2016).

Most importantly, the data analyses presented in this paper demonstrated that low opportunity cost and high opportunity cost alcohol demand each contain *unique* variance that is most related to different levels of severity of alcohol problems. This extends the existing literature on low opportunity cost and high opportunity cost alcohol demand (Gentile et al., 2012; Gilbert et al., 2014; Murphy et al., 2014; Skidmore and Murphy, 2011). Previous research has convincingly demonstrated that standard alcohol demand indices (which do not specify the presence or absence of next-day responsibilities) uniquely predict alcohol problem severity, including predicting dependence symptoms among young adults (Bertholet et al., 2015), adult problem drinkers (MacKillop et al., 2010), drinking and driving (Teeters and Murphy, 2015; Teeters et al., 2014), and change in drinking over time (Dennhardt et al., 2015; Murphy et al. 2015). These associations tend to be significant above and beyond drinking level and differentiate problem outcomes within samples of heavy drinkers.

However, the current results add further nuance to these consistent findings. Specifically, these data demonstrate that low opportunity cost demand (drink purchases prior to a day with no significant responsibilities) was a better predictor of less severe (and more common) alcohol problems, such as hangovers or acting impulsively while under the influence, when directly compared to high opportunity cost demand (drink purchases prior to a day with a significant responsibility). On the other hand, high opportunity cost demand was a better unique predictor of drinking happening on the weekdays (Monday and Tuesday) and of much more severe alcohol problems, such as physiological dependence and compulsivity, most indicative of an "addiction"-like state where drinking is relatively less responsive to contextual events that serve to limit drinking for most drinkers. In particular, these results succinctly validate the high opportunity cost APT (alcohol demand in the face of something important the next day), as high opportunity cost demand uniquely predicted drinking on Monday and Tuesdays—days which most college students *actually do* have classes the next day, as opposed to drinking on Friday and Saturday, which are typically free of next-day classes. Furthermore, our results differed from what was observed when analyzing data using the most common total sum scores of alcohol use and problems scales. Using total scores, both low opportunity cost and high opportunity cost demand were significant predictors, suggesting that they each contained unique variance separate from one another in prediction of alcohol use and problems. By selecting items indicative of more and less severe alcohol use and problems, whose selection was informed by the results of IRT models, we were able to provide support for the construct validity and utility of the high opportunity cost demand index.

These overall demand effects were probed further through examination of individual demand indices. No single demand index followed the exact same pattern of results as did AUC (consistent with past work demonstrating AUC to be a unique metric derived from demand curves; Amlung et al., 2015). However, intensity and O_{max} most closely followed the pattern of AUC results, suggesting overall demand effects may be driven more by amplitude of demand than persistence of demand (MacKillop et al., 2009). Furthermore, several interesting patterns for the individual demand metrics were observed and potentially shed new light on the nature of these demand indices.

Consistent with meta-analytic work (Kiselica et al., 2016), low opportunity cost intensity demonstrated the largest associations with alcohol use and problems of the demand indices, and was more closely aligned with drinking level than drinking consequences. Whereas the same meta-analysis (Kiselica et al., 2016) suggested breakpoint was less predictive of alcohol use and problems, the current work suggests specifically high opportunity cost breakpoint relative to low opportunity cost breakpoint is more predictive of both drinking level and problems. This result highlights that while overall breakpoint was reduced in the high opportunity cost APT, there was a proportional increase in variability in breakpoint under conditions of a next-day responsibility (i.e., motivation to have a single drink under maximum price and opportunity cost), and this may boost relations with alcohol use and problems. Conversely, high opportunity cost elasticity did not out-predict low opportunity cost elasticity, even in prediction of severe alcohol use and problems, diverging from other demand metrics. This suggests that low opportunity cost elasticity is already a more "difficult" indicator of alcohol demand, and adding a next-day responsibility proportionally decreases variability in elasticity due to floor effects. Thus, the current work also highlights that while correlated, demand indices from different APT versions have differential predictive value for predicting alcohol use and problems.

Clinically, alcohol demand has been linked to a variety of treatment-relevant outcomes and already has an evidence base of its clinical relevance (e.g., Bertholet et al., 2015; MacKillop et al., 2010; Teeters et al., 2014). These results add to this clinical relevance, as they indicate that among specifically alcohol-dependent populations, administering APTs including a constraint is likely to optimize the utility of the alcohol demand construct, as high opportunity cost demand better differentiates alcohol problems operating among individuals at the highest end of the latent alcohol problems continuum. Conversely, among lighter drinking populations, administering APTs without constraints is likely to optimize the utility of the alcohol demand construct in that population, as low opportunity cost demand better differentiates alcohol problems operating among individuals at the lower end of the latent alcohol problems continuum.

Additionally, the current results dovetail with Boness and colleagues (2019) findings demonstrating the difference in severity of individual items of alcohol problems measures among college students, supporting the idea that additional information can be gleaned from an item-level examination of our alcohol problems measures that is obscured by using a total sum score approach. Items relating to physiological dependence and compulsive use, for example, were shown to be most discriminatory among drinkers at the high end of theta (the latent dimension of alcohol problems defined by the IRT model). Similarly, our IRT modeling of the DDQ provided quantitative evidence for what is already intuitively accepted among those studying young adult drinking—most drinking happens in a pattern whereby heavy drinking happens on weekends in a binge-episodic pattern and alcohol is rarely consumed during weekdays. Our results suggest, then, that counting the number of drinks consumed on low-frequency drinking days (such as Monday and Tuesday) indexes more severe drinking patterns, discriminating most among those with high total alcohol consumption. While these analyses *do not* suggest that alcohol use or problems lack unidimensionality, they *do* suggest that each item included in measurements of alcohol use or problems is not equally useful for all scenarios. In particular, these results have ramifications for research being conducted where the numbers of items that can be feasibly collected are limited (such as ecological momentary assessment); researchers should carefully consider the population (such as alcohol-dependent vs. lighter drinkers) and outcome (frequent/common alcohol problems, or infrequent/more severe alcohol problems) they desire to measure, and include items that will be maximally informative for those individuals and that process specifically.

Etiologically, these findings are very much in line with addiction as a BAD theory (Lamb and Ginsburg, 2018), which predicted that decisions surrounding substance use in the face of a constraint (or at the expense of an alternative) reflect a central feature of addiction. Although both APTs measure demand as a function of some constraint (price vs. price and next-day responsibility), demand under both price and next-day responsibility constraints was the better predictor of severe alcohol use and problems rather than traditional price-constrained-only demand. While both reflect alcohol demand, due to the differing contexts in the APTs, the *process* they serve as *indicators of* changes (low opportunity cost demand: milder-use alcohol valuation; high opportunity cost demand: more severe-use alcohol valuation). Interestingly, Murphy and colleagues (2014) demonstrated that a family history of alcohol misuse predicted reduced contextual sensitivity in the same APT paradigms employed here, raising the possibility that there may be a heritable propensity implicated in high opportunity cost demand that may link specifically to more severe-use factors.

Limitations and Future Directions

Some limitations of the current data do require comment. First, the younger age (M = 18.8, SD = 1.0) of this sample may affect the generalizability of these results to other samples. Although these college students were heavy drinkers (on average, 17+ drinks per week), the contextual factors influencing college student drinking (e.g., peer influence (Borsari and Carey, 2001), availability of alcohol (Chaloupka and Weschler, 1996; Kuo et al., 2003), and the illicit status of alcohol for minors) may affect the equivalency of alcohol problems experienced by college students versus adult drinkers. Second, though the reliability and validity of the standard APT have been well established through test–retest reliability and actual alcohol consumption in a laboratory bar setting (Amlung et al., 2012; Murphy et al., 2009, respectively), the reliability of the APT including a next-day responsibility (high opportunity cost) has not yet been demonstrated. However, as previously discussed, the current work makes a strong argument for the validity of the APT including a next-day responsibility. Future work can extend these findings by an application to substances other than alcohol. Cigarette (MacKillop et al., 2008), marijuana (Aston et al., 2015), and cocaine (Bruner and Johnson, 2014) purchase tasks all exist and could similarly be adapted to include contextual constraints like the current work's application of a next-day responsibility, and other constraints, such as having to drive after drinking, have been shown to suppress demand (Teeters and Murphy, 2015). Lastly, the order of the APTs in the current work was not randomized, and as such, future work should evaluate the serial ordering effects on responses in APTs.

These results also shed light on the difficulty in predicting low–base rate psychological phenomena, such as weekday drinking and severe alcohol problems. Generally, the amount of variance explained in the severe composites (R^2 = 0.04 for both DDQ and YAACQ) was smaller than might be encountered for total scores (R^2 = 0.23 and 0.08 for DDQ and YAACQ, respectively), which is intuitive from both a statistical and theoretical standpoint. Rarer events are more difficult to predict; as such, addiction science should utilize creative insights from other psychological subfields who commonly encounter low–base rate problems like suicidality or learning disabilities through use of gated screening (e.g., Compton et al., 2010) and other techniques.

In conclusion, the current work provides novel information about alcohol demand's link to alcohol use and problems. Specifically, we found that high opportunity cost demand (reflecting sensitivity to both price and next-day responsibilities) was uniquely predictive of less common alcohol use (drinking on the weekdays) and more severe problems (such as withdrawal and foregoing alternative activities), whereas low opportunity cost demand (reflecting only price sensitivity) was uniquely predictive of more common alcohol use (drinking on weekends) and milder problems (such as bingeing and hangovers). This work is in line with behavioral economic theory of addiction and the conceptualization of addiction as a BAD.

FUNDING

This work was supported by National Institute of Health grant R01 AA020829 to James G. Murphy. Keanan J. Joyner's efforts were supported by a Ford Foundation Fellowship administered by the National Academies of Sciences, Engineering, and Medicine. Lidia Z. Meshesha's effort was funded by NIAAA (T32 AA007459).

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

Amlung MT, Acker J, Stojek MK, Murphy JG, MacKillop J (2012) Is talk "cheap"? An initial investigation of the equivalence of alcohol purchase task performance for hypothetical and actual rewards. Alcohol Clin Exp Res 36:716–724.

Amlung M, MacKillop J (2012) Consistency of self-reported alcohol consumption on randomized and sequential alcohol purchase tasks. Front Psychiatry 3:65. https://doi.org/10.3389/fpsyt.2012.00065

Amlung M, MacKillop J (2014) Understanding the effects of stress and alcohol cues on motivation for alcohol via behavioral economics. Alcohol Clin Exp Res 38:1780–1789.

Amlung M, Yurasek A, McCarty KN, MacKillop J, Murphy JG (2015) Area under the curve as a novel metric of behavioral economic demand for alcohol. Exp Clin Psychopharmacol 23:168–175.

Aston ER, Metrik J, Amlung M, Kahler CW, MacKillop J (2016) Interrelationships between marijuana demand and discounting of delayed rewards: convergence in behavioral economic methods. Drug Alcohol Depend 169:141–147.

Aston ER, Metrik J, MacKillop J (2015) Further validation of a marijuana purchase task. Drug Alcohol Depend 152:32–38.

Babor TF, Mendelson JH, Greenberg I, Kuehnle J (1978) Experimental analysis of the 'happy hour': effects of purchase price on alcohol consumption. Psychopharmacology 58:35–41.

Benjamini Y, Yekutieli D (2001) The control of the false discovery rate in multiple testing under dependency. Ann Stat 29:1165–1188.

Berman HL, Martinetti MP (2017) The effects of next-day class characteristics on alcohol demand in college students. Psychol Addict Behav 31:488–496.

Bertholet N, Murphy JG, Daeppen JB, Gmel G, Gaume J (2015) The alcohol purchase task in young men from the general population. Drug Alcohol Depend 146:39–44.

Bickel WK, Johnson MW, Koffarnus MN, MacKillop J, Murphy JG (2014) The behavioral economics of substance use disorders: reinforcement pathologies and their repair. Ann Rev Clin Psychol 10:641–677.

Boness CL, Lane SP, Sher KJ (2019) Not all alcohol use disorder criteria are equally severe: toward severity grading of individual criteria in college drinkers. Psychol Addict Behav 33:35–49.

Borsari B, Carey KB (2001) Peer influences on college drinking: a review of the research. J Subst Abuse 13:391–424.

Bruner NR, Johnson MW (2014) Demand curves for hypothetical cocaine in cocaine-dependent individuals. Psychopharmacology 231:889–897.

Bujarski S, MacKillop J, Ray LA (2012) Understanding naltrexone mechanism of action and pharmacogenetics in Asian Americans via behavioral economics: a preliminary study. Exp Clin Psychopharmacol 20:181–190.

Carter AC, Brandon KO, Goldman MS (2010) The college and noncollege experience: a review of the factors that influence drinking behavior in young adulthood. J Stud Alcohol Drugs 71:742–750.

Chaloupka FJ, Wechsler H (1996) Binge drinking in college: the impact of price, availability, and alcohol control policies. Contemp Econ Policy 14:112–124.

Collins RL, Parks GA, Marlatt GA (1985) Social determinants of alcohol consumption: the effects of social interaction and model status on the self-administration of alcohol. J Consult Clin Psychol 53:189–200.

Compton DL, Fuchs D, Fuchs LS, Bouton B, Gilbert JK, Barquero LA, Cho E, Crouch RC (2010) Selecting at-risk first-grade readers for early intervention: eliminating false positives and exploring the promise of a two-stage gated screening process. J Educ Psychol 102:327–340.

Cooper LD, Balsis S (2009) When less is more: how fewer diagnostic criteria can indicate greater severity. Psychol Assess 21:285–293.

Dennhardt AA, Yurasek AM, Murphy JG (2015) Change in delay discounting and substance reward value following a brief alcohol and drug use intervention. J Exp Anal Behav 103:125–140.

Donoho DL, Huber PJ (1983) The notion of breakdown point, in A Festschrift for Erich L. Lehmann, pp 157–184.

Drasgow F, Lissak RI (1983) Modified parallel analysis: a procedure for examining the latent dimensionality of dichotomously scored item responses. J Appl Psychol 68:363–373.

Edwards A, Joyner K, Schatschneider C (2019) A simulation study on the performance of different reliability estimation methods. https://doi.org/10.31234/osf.io/xzc52

Elder RW, Lawrence B, Ferguson A, Naimi TS, Brewer RD, Chattopadhyay SK, Toomey TL, Fielding JE; Task Force on Community Preventive Services (2010) The effectiveness of tax policy interventions for reducing excessive alcohol consumption and related harms. Am J Prev Med 38:217–229.

Gentile ND, Librizzi EH, Martinetti MP (2012) Academic constraints on alcohol consumption in college students: a behavioral economic analysis. Exp Clin Psychopharmacol 20:390–399.

Gilbert LJ, Murphy JG, Dennhardt AA (2014) A behavioral economic analysis of the effect of next-day responsibilities on drinking. Psychol Addict Behav 28:1253–1258.

Ginsburg BC, Pinkston JW, Lamb RJ (2012) The potency of fluvoxamine to reduce ethanol self-administration decreases with concurrent availability of food. Behav Pharmacol 23:134–142.

Hambleton RK, Swaminathan H (2013) Item Response Theory: Principles and Applications. Springer Science & Business Media, New York.

Hingson R, Zha W, Smyth D (2017) Magnitude and trends in heavy episodic drinking, alcohol-impaired driving, and alcohol-related mortality and overdose hospitalizations among emerging adults of college ages 18–24 in the United States, 1998–2014. J Stud Alcohol Drugs 78:540–548.

Hursh SR, Silberberg A (2008) Economic demand and essential value. Psychol Rev 115:186–198.

Kiselica AM, Webber TA, Bornovalova MA (2016) Validity of the alcohol purchase task: a meta-analysis. Addiction 111:806–816.

Kivlahan DR, Marlatt GA, Fromme K, Coppel DB, Williams E (1990) Secondary prevention with college drinkers: evaluation of an alcohol skills training program. J Consult Clin Psychol 58:805–810.

Koffarnus MN, Franck CT, Stein JS, Bickel WK (2015) A modified exponential behavioral economic demand model to better describe consumption data. Exp Clin Psychopharmacol 23:504–512.

Koffarnus MN, Woods JH (2013) Individual differences in discount rate are associated with demand for self-administered cocaine, but not sucrose. Addict Biol 18:8–18.

Kuo M, Wechsler H, Greenberg P, Lee H (2003) The marketing of alcohol to college students: the role of low prices and special promotions. Am J Prev Med 25:204–211.

Lamb RJ, Ginsburg BC (2018) Addiction as a BAD, a behavioral allocation disorder. Pharmacol Biochem Behav 164:62–70.

Lemley SM, Kaplan BA, Reed DD, Darden AC, Jarmolowicz DP (2016) Reinforcer pathologies: predicting alcohol related problems in college drinking men and women. Drug Alcohol Depend 167:57–66.

Lane SP, Sher KJ (2015) Limits of current approaches to diagnosis severity based on criterion counts: an example with DSM-5 alcohol use disorder. Clin Psychol Sci 3:819–835.

MacKillop J, Amlung MT, Few LR, Ray LA, Sweet LH, Munafò MR (2011) Delayed reward discounting and addictive behavior: a meta-analysis. Psychopharmacology 216:305–321.

MacKillop J, Murphy JG, Ray LA, Eisenberg DT, Lisman SA, Lum JK, Wilson DS (2008) Further validation of a cigarette purchase task for assessing the relative reinforcing efficacy of nicotine in college smokers. Exp Clin Psychopharmacol 16:57–65.

MacKillop J, Murphy JG, Tidey JW, Kahler CW, Ray LA, Bickel WK (2009) Latent structure of facets of alcohol reinforcement from a behavioral economic demand curve. Psychopharmacology 203:33–40.

MacKillop J, O'Hagen S, Lisman SA, Murphy JG, Ray LA, Tidey JW, McGeary JE, Monti PM (2010) Behavioral economic analysis of cue-elicited craving for alcohol. Addiction 105:1599–1607.
McDowell YE, Vergés A, Sher KJ (2019) Are some alcohol use disorder criteria more (or Less) externalizing than others? Distinguishing alcohol use symptomatology from general externalizing psychopathology. Alcohol Clin Exp Res 43:483–496.
McNeish D (2018) Thanks coefficient alpha, we'll take it from here. Psychol Methods 23:412–433.
Merrill JE, Carey KB (2016) Drinking over the lifespan: focus on college ages. Alcohol Res Curr Rev 38:103–114.
Müller CP, Schumann G (2011) Drugs as instruments: a new framework for non-addictive psychoactive drug use. Behav Brain Sci 34:293–310.
Murphy JG, Dennhardt AA, Martens MP, Borsari B, Witkiewitz K, Meshesha LZ (2019) A randomized clinical trial evaluating the efficacy of a brief alcohol intervention supplemented with a substance-free activity session or relaxation training. J Consult Clin Psychol 87:657–669.
Murphy JG, Dennhardt AA, Yurasek AM, Skidmore JR, Martens MP, MacKillop J, McDevitt-Murphy ME (2015) Behavioral economic predictors of brief alcohol intervention outcomes. J Consult Clin Psychol 83:1033–1043.
Murphy JG, MacKillop J (2006) Relative reinforcing efficacy of alcohol among college student drinkers. Exp Clin Psychopharmacol 14:219–227.
Murphy JG, MacKillop J, Skidmore JR, Pederson AA (2009) Reliability and validity of a demand curve measure of alcohol reinforcement. Exp Clin Psychopharmacol 17:396–404.
Murphy JG, Yurasek AM, Meshesha LZ, Dennhardt AA, Mackillop J, Skidmore JR, Martens MP (2014) Family history of problem drinking is associated with less sensitivity of alcohol demand to a next-day responsibility. J Stud Alcohol Drugs 75:653–663.
Petry NM (2001) Delay discounting of money and alcohol in actively using alcoholics, currently abstinent alcoholics, and controls. Psychopharmacology 154:243–250.
R Core Team (2018) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.
Rachlin H (1997) Four teleological theories of addiction. Psychon Bull Rev 4:462–473.
Read JP, Beattie M, Chamberlain R, Merrill JE (2008) Beyond the "binge" threshold: heavy drinking patterns and their association with alcohol involvement indices in college students. Addict Behav 33:225–234.
Read JP, Kahler CW, Strong DR, Colder CR (2006) Development and preliminary validation of the Young Adult Alcohol Consequences Questionnaire. J Stud Alcohol 67:169–177.
Read JP, Merrill JE, Kahler CW, Strong DR (2007) Predicting functional outcomes among college drinkers: reliability and predictive validity of the Young Adult Alcohol Consequences Questionnaire. Addict Behav 32:2597–2610.
Rizopoulos D (2006) ltm: an R package for latent variable modeling and item response theory analyses. J Stat Softw 17:1–25.
Schulenberg JE, Johnston LD, O'Malley PM, Bachman JG, Miech RA, Patrick ME (2018) Monitoring the Future National Survey Results on Drug Use, 1975–2017. Volume II, College Students & Adults Ages 19-55. Institute for Social Research, The University of Michigan, Ann Arbor.
Skidmore JR, Murphy JG (2011) The effect of drink price and next-day responsibilities on college student drinking: a behavioral economic analysis. Psychol Addict Behav 25:57–68.
Slutske WS, Hunt-Carter EE, Nabors-Oberg RE, Sher KJ, Bucholz KK, Madden PA, Anokhin A, Heath AC (2004) Do college students drink more than their non-college-attending peers? Evidence from a population-based longitudinal female twin study. J Abnorm Psychol 113:530–540.
Stein JS, Koffarnus MN, Snider SE, Quisenberry AJ, Bickel WK (2015) Identification and management of nonsystematic purchase task data: toward best practice. Exp Clin Psychopharmacol 23:377–386.
Substance Abuse and Mental Health Services Administration (2014) Results from the 2013 National Survey on Drug Use and Health: Summary of National Findings, NSDUH Series H-48, HHS Publication No. (SMA) 14-4863. Substance Abuse and Mental Health Services Administration, Rockville, MD.
Teeters JB, Murphy JG (2015) The behavioral economics of driving after drinking among college drinkers. Alcohol Clin Exp Res 39:896–904.
Teeters JB, Pickover AM, Dennhardt AA, Martens MP, Murphy JG (2014) Elevated alcohol demand is associated with driving after drinking among college student binge drinkers. Alcohol Clin Exp Res 38:2066–2072.
Trochim WK, Donnelly JP (2006) The Research Methods Knowledge Base, 3rd ed. Atomic Dog, Cincinnati, OH.
Zvorsky I, Nighbor TD, Kurti AN, DeSarno M, Naudé G, Reed DD, Higgins ST (2019) Sensitivity of hypothetical purchase task indices when studying substance use: a systematic literature review. Prev Med :105789. https://doi.org/10.1016/j.ypmed.2019.105789

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Correlations and confidence intervals among mild and severe item sets of the DDQ and YAACQ with standard YAACQ subscales.