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Interrelationships among Individual Differences in Alcohol Demand, Impulsivity, and Alcohol Misuse

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Abstract

An Alcohol Purchase Task (APT) is a novel behavioral economic measure for characterizing the incentive value of alcohol to an individual (i.e., alcohol demand). Individual differences in alcohol demand have been associated with a number of alcohol-related outcomes and the current investigation sought to extend these previous findings in a number of ways. The goals of the study were: i) to examine the relationship between alcohol demand and alcohol misuse in a large sample of community adults; ii) to examine sex differences in alcohol demand; and, iii) to examine the relationship between alcohol demand and impulsive personality traits, both in general and as moderating variables. Participants ($N = 720$; 39% female) were adult smokers who reported drinking in the last year and were recruited from the community at large. All four behavioral economic indices of demand from the APT were significantly associated with alcohol misuse, with $O_{\max}$ and intensity uniquely associated in combined analyses. Males exhibited significantly higher demand, but these differences were largely eliminated after adjusting for drinks/week and other covariates. Trait levels of urgency, sensation-seeking and lack of premeditation were significantly associated with intensity and urgency was associated with $O_{\max}$, but no moderating relationships were present. The significant relationships between aspects of impulsivity and the demand indices may signify a common process underlying disinhibition and demand for alcohol. These findings further support the relationship between indices of alcohol demand and alcohol misuse and a link between demand and impulsivity. Methodological considerations and future directions are discussed.

Keywords

Alcohol; Behavioral Economics; Purchase Task; Demand; Impulsivity

A behavioral economic approach to alcohol use disorders (AUDs) integrates concepts from psychology and economics to understand why people come to persistently overvalue and overconsume alcohol (Vuchinich & Heather, 2003; Murphy, MacKillop, Tidey, & Brazil, 2011). One important construct in a behavioral economic approach is that of alcohol

demand, referring an individual's level of motivation for alcohol at varying levels of cost (Hursh, Galuska, Winger, & Woods, 2005). A recently developed method to assess demand is an Alcohol Purchase Task (APT; Murphy & MacKillop, 2006), which characterizes the individual's relative value of alcohol as a reinforcer via estimated consumption of standard drinks at escalating levels of price. Several different indices of value can be generated from an APT, including intensity (i.e., consumption when alcohol is free), $O_{\max}$ (i.e., maximum expenditure for alcohol), breakpoint (i.e., first price suppressing consumption to zero), and elasticity (i.e., proportionate price sensitivity).

An accumulating empirical literature has implicated these indices with various aspects of alcohol use and misuse. The APT metrics have been found to correlate significantly with typical drinking behavior and alcohol use disorder severity (Murphy & MacKillop, 2006; MacKillop et al., 2010; Murphy, MacKillop, Skidmore, & Pederson, 2009), which has been paralleled in studies using purchase tasks to study the incentive value of other psychoactive drugs (Few, Acker, Murphy, & MacKillop, 2011; MacKillop et al., 2008; Murphy et al., 2011; O'Connor, Bansal-Travers, Carter, & Cummings, 2012). In a clinical context, the APT indices have been found to predict alcohol brief intervention outcomes (MacKillop & Murphy, 2007). Importantly, a recent laboratory study found that APT responses for hypothetical outcomes closely corresponded with choices involving real alcohol and money, and that estimated alcohol consumption was highly correlated with actual drinking behavior (Amlung, Acker, Stojek, Murphy, & MacKillop, 2011).

Beyond the direct relationship links between individual differences in alcohol demand and alcohol misuse, there is emerging interest in contextualizing alcohol's incentive value in relation to other variables, especially impulsive personality traits. These relationships are potentially important because significant associations between these traits and alcohol demand may reflect related processes or alternative manifestations of shared underlying neurobiological substrates. Alternatively, it is also possible that the two domains may interact together and thus conjointly contribute to risk for alcohol misuse. Two recent studies have addressed these possibilities. In the first, impulsive personality traits and alcohol demand were examined concurrently and breakpoint was found to be significantly positively associated with negative urgency (i.e., disposition to engage in rash action during high levels of negative affect) (Acker et al., 2012), which has also been associated with alcohol misuse (e.g., Cyders et al., 2009). In the second, $O_{\max}$ was found to moderate the relationship between both negative urgency and sensation seeking in relation to alcohol involvement (Smith et al., 2010). At high levels of $O_{\max}$, negative urgency and sensation seeking were positively associated with alcohol consumption and negative urgency was positively associated with alcohol related problems, whereas at low levels of $O_{\max}$, negative urgency was still significantly related to alcohol problems albeit less strongly. In addition, for individuals with high intensity of demand, these same impulsivity-related traits were significantly more closely related to alcohol use. This suggests that individuals who value alcohol highly as a reinforcer and have highly impulsive tendencies are most likely to drink excessively and experience alcohol-related consequences.

The current study sought to extend the findings in the preceding areas. Although the accumulated findings support the relevance of alcohol demand to alcohol misuse, almost all

previous studies have focused exclusively on collegiate drinkers, making it unclear to what extent the relationships similarly apply to the more general population of drinkers. Only one study has examined alcohol demand in community adults and had a relatively small sample size ($N = 61$) (MacKillop et al., 2010). Additionally, the existing studies have not systematically examined sex differences in alcohol demand due, in part, to limited sample sizes. Moreover, the relationship between indices of alcohol demand and impulsivity-related traits has been examined in only two studies, making the relationships at best tentative at this point. The current study sought to address each of these issues. First, the study examined continuous relationships between alcohol demand and alcohol misuse in a large community sample of adult drinkers, predicting that the indices of demand would be significantly associated with alcohol misuse. Second, the study systematically examined sex differences in alcohol demand, predicting that males would exhibit significantly greater alcohol demand, but that these differences would be largely accounted for by sex-related differences in drinking patterns and anthropometrics. Third, the study further investigated the relationship between indices of demand and impulsivity traits through examination of the direct associations and moderating relationships. Parallel findings to the two previous investigations on alcohol demand and impulsivity were predicted.

Method

Participants

The data are from a parent study examining the relationship between cigarette consumption and price (MacKillop et al., 2012), which had a sample of 1,124 smokers. Participants were included in the current study if they reported any alcohol use in the previous year ($N = 787$). However, 8% were subsequently excluded based on low effort (i.e., 3 contradictions on the APT, reflecting random responding, or absence of variability in responding) or missing greater than 25% of their data, leaving a final sample of 720 (39% female; 68% White; M age = 29.7). Participant characteristics are provided in Table 1.

Assessment

Comprehensive demographics were assessed including, sex, age, race, gender, income, education and other descriptive variables. Alcohol misuse was measured by the Alcohol Use Disorders Identification Test (AUDIT; Saunders, Aasland, Babor, de la Fuente, & Grant, 1993). Alcohol demand was measured by an Alcohol Purchase Task (APT), which assessed estimated alcohol consumption at 21 ascending prices: FREE, 2¢, 5¢, 13¢, 25¢, 50¢, \$1, \$2, \$3, \$4, \$5, \$6, \$7, \$8, \$9, \$10, \$15, \$20, \$25, \$30, \$35). Of note, the APT initially included 26 prices, including \$70, \$140, \$280, \$560, and \$1120. These prices were excluded from consideration because of a lack of variability in responses, excessively large intervals between prices, and market incongruence. Impulsive personality traits were assessed using the UPPS Impulsive Behavior Scale (Whiteside & Lynam, 2001). The UPPS consists of 45-items and to assess four impulsivity traits: (lack of) Premeditation, a propensity to act without considering potential consequences (Premeditation, $\alpha = .86$); Negative Urgency, a proclivity for acting on immediate cues particularly when experiencing negative affect (Negative Urgency, $\alpha = .84$); Sensation Seeking, an orientation toward engaging in high energy and thrill behaviors (Sensation Seeking, $\alpha = .88$); and (lack of) Perseverance, an

inability to follow through on tasks ($\alpha = .83$). As all participants were smokers, nicotine dependence (ND) was assessed using the Fagerström Test of Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerström, 1991).

Data Analysis

Missing single data points (among those that had < 25% total missing) on the APT were coded such that the value at the next highest price was imputed for the missing value at the lower price. For participants missing less than 25% of data points on the other assessments, missing values were imputed using multiple regression (AUDIT < .01%; UPPS = .29%). Outliers from all assessments were defined as $Z > 3.29$ and iteratively recoded as the highest non-outlying value (APT = 2.74%; AUDIT = .42%; UPPS < .01%; weight/height = .6%). AUDIT scores were log transformed to correct for positive skewness and kurtosis. With the exception of elasticity, the indices of demand were generated using an observed values approach (Murphy & MacKillop, 2006): intensity was defined as number of drinks at the lowest price (free); $O_{\max}$ was defined as the maximum expenditure on alcohol; breakpoint was observed as the first price suppressing consumption to zero. Elasticity was calculated as α in the following demand equation (Hursh & Silberberg, 2008): $\log_{10}Q = \log_{10}Q_0 + k(e^{-\alpha Q_0 C} - 1)$, where Q = consumption at the given price, Q_0 = consumption at 0, k = range of the dependent variable (drinks) in logarithmic units, C = cost (price), and α = elasticity (rate of decline in log consumption based on price increase). The overall mean performance on the APT was calculated for the best-fitting k , which was 3.0. Elasticity could not be calculated for 36 participants due to an insufficient range of responses (< 2 responses > 0).

The relationship between the indices of alcohol demand and both income and tobacco involvement were examined as potential covariates using Pearson's product-moment correlations (r). The same approach was used for the relationship between the demand indices and alcohol involvement, followed by hierarchical linear regressions including all nominally significant demand indices simultaneously. The impulsivity analyses used both zero-order correlations and moderation analyses for the candidate relationships of interest. To test for moderation, continuous variables were centered about the mean and hierarchical linear regressions were conducted for alcohol misuse as measured by the AUDIT. To avoid potential confounding, gender, income, and ND (i.e., FTND total score) were entered as covariates into the first step of each analysis. The variables subject to moderation analyses were those previously reported by Smith et al. (2010), namely, $O_{\max}$, intensity, negative urgency, and sensation seeking. To determine incremental variance provided by each variable, the UPPS subscale variables were entered in the second step of the regression and the demand were entered in the third step. Then, interaction effects between the indices of demand and impulsivity-related traits were entered in the fourth step to determine moderation. Finally, for comparisons between males and females, analysis of variance/covariance (ANOVA/ANCOVA) were used to compare the demand indices between males and females, first in unadjusted models and then incorporating AUDIT, pretax income, and FTND as covariates.

Results

Demand curves were topographically prototypic, with consumption decreasing as a function of escalating price (Figure 1) and expenditure conforming to an inverted U-shaped curve. Zero order correlations among all variables are provided in Table 2. The alcohol demand indices of $O_{\max}$, intensity, breakpoint, and elasticity were all significantly associated with AUDIT, but not income or ND (Table 2). In a hierarchical regression to account for overlap among the indices and covariates, intensity and $O_{\max}$ were both uniquely significant.

Sex differences, both unadjusted and including covariates, are in Table 3. In uncorrected analyses, significant differences were present for intensity, $O_{\max}$, and elasticity, and the largest effect size differences were present for $O_{\max}$ and intensity (with males exhibiting higher expenditure maxima and zero price drinking than females). The ANCOVAs eliminated sex differences for $O_{\max}$ and elasticity, but not intensity, although the effect size was substantially reduced.

The UPPS-P variables were significantly associated with both alcohol misuse and each other (Table 2). Contrary to prediction, breakpoint was not significantly correlated with negative urgency, although negative urgency was significantly associated with both $O_{\max}$ and intensity. In addition, intensity was significantly correlated with premeditation and sensation-seeking. Interactions of $O_{\max}$ and negative urgency ($\beta = .00$; $p = .99$) and $O_{\max}$ and sensation seeking ($\beta = -.01$; $p = .77$) with alcohol misuse were not significant. Additionally, interactions of intensity and negative urgency ($\beta = -.04$; $p = .24$) and intensity and sensation seeking ($\beta = .00$; $p = .94$) with alcohol misuse were not significant. The regression integrating the UPPS and demand variables is provided in Table 4.

Discussion

The aim of the current study was to extend the understanding of the relationship between individual differences in alcohol demand and alcohol misuse in several ways. Significant overall associations between the demand indices and alcohol misuse converge with several previous findings (Murphy & MacKillop, 2006; Murphy et al. 2009; Smith et al. 2010, Acker et al., 2012). However, the current study extended the previous findings by incorporating the indices together and clarifying that these associations were largely specific to two demand indices, intensity and $O_{\max}$, with intensity exhibiting a significant medium effect size association and $O_{\max}$ exhibiting a significant small effect size association with alcohol misuse. The consistently greater association of $O_{\max}$ and intensity with alcohol misuse suggests that it may be preferences for volumetric consumption of alcohol rather than persistence of pursuing alcohol at increasing levels of price that are the most important aspects of alcohol demand in relation to an individual's problematic alcohol use (MacKillop et al., 2009).

The second goal was to conduct a systematic examination of gender differences in alcohol demand. As predicted, compared to females, males were found to have significantly greater $O_{\max}$ and intensity, and significantly lower elasticity, however, the differences for $O_{\max}$ and elasticity were virtually eliminated, while intensity was reduced to a small effect size, after

adjusting for differences in drinking patterns and other covariates. This suggests that males estimated greater unconstrained alcohol consumption, putatively reflecting greater value of alcohol. Nonetheless, these findings largely support the hypothesis that the reinforcing value of alcohol does not substantially differ by sex when other sex-related characteristics are jointly considered.

The third goal of the study was to examine the interrelationships among alcohol demand, impulsivity-related personality traits, and alcohol misuse. Here, the predicted association between breakpoint and negative urgency was not replicated, although intensity and $O_{\max}$ were positively associated with negative urgency, or proneness to act out during periods of intense distress, and intensity was also significantly associated with (lack of) premeditation and sensation seeking. These relationships were relatively small in terms of effect size (accounting for 1-4% of the variance), but are nonetheless notable and suggest the possibility of underlying common processes, such as more general reward sensitivity. Additionally, the study sought to examine the potential moderating role of $O_{\max}$ and intensity in the relationship between impulsivity and alcohol outcomes. Here, the results did not replicate the previously reported relationships (Smith et al., 2010). Two non-mutually exclusive aspects of this sample may explain the absence of interaction effects. The first being that these interactions may be specific to young adult drinkers, as the previous study was comprised of college students and approximately three-quarters were female, whereas the current sample was a community sample with a more equal sex distribution. A second possibility is that, given the findings demonstrating negative urgency and sensation seeking are associated with smoking status and initiation (e.g., Doran et al., 2012; Trocki, Drabble, & Midanik, 2009), the range of impulsivity may have been restricted in this sample of smokers or the variable distributions may not have been normal. However, the means and standard deviations in previous studies on unselected community samples reveal generally comparable levels of sensation seeking and negative urgency to this study's sample (Bayard, Raffard, Gely-Nargeot, 2011; Whiteside, Lynam, Miller, & Reynolds, 2005) and the distributions were adequately normally distributed, suggesting that this is unlikely.

These findings should be interpreted in the context of several strengths and limitations. Strengths include a large sample comprised of individuals from the community at large. Additionally, the sample was particularly heterogeneous, with considerable variability in age, socioeconomic status, and education. However, a clear limitation is that the participants were all smokers. Although ND was consistently incorporated into the analyses and was not related to alcohol demand, this study cannot directly address the extent to which the findings apply to non-smoking drinkers. These individuals differ from drinkers who are also smokers in potentially meaningful ways, including lower consumption and fewer alcohol-related negative consequences (e.g., Friedman, Tekawa, Klatsky, Sidney, & Armstrong, 1991; Dawson, 2000). However, this limitation is mitigated somewhat by the substantial epidemiological overlap in terms of smoking and drinking (Bobo & Husten, 2000; DiFranza & Guerrera, 1990; Falk, Yi, & Hiller-Sturmhöfel, 2006). For example, the prevalence of smoking is approximately 20% higher in drinkers compared to the general population and the comorbidity of AUDs and ND is 34%, approximately three times the rate in the general population (Falk et al., 2006). A second limitation is the nature of the cross-sectional design, which meant that causal relationships between the demand indices and alcohol misuse could

not be inferred. From an etiological standpoint, elevated alcohol reinforcer value is putatively a recursive marker, presaging further escalating incentive value and alcohol misuse over time, but future studies using longitudinal designs will be necessary to address that question.

Finally, because the relationships between drinking and alcohol demand run the risk of being interpreted as being self-evident or uninformative, it is worth considering the broader significance of alcohol demand in understanding alcohol misuse. On its face, for example, a significant association between level of drinking and willingness to pay for alcohol is not very surprising. However, the goal of the APT is not to quantify the relationship between estimated drinking and financial costs in a literal sense, but to provide a systematic and multidimensional assessment of alcohol as a reinforcer to the individual. In other words, alcohol demand indices are thought to be important because they have the potential to capture important individual differences in how much a person values alcohol. In turn, this variation is intended to be leveraged to make novel and informative contributions in clinical and etiological research. For example, alcohol demand has been used to predict treatment response to a brief motivational intervention in young adults (MacKillop & Murphy, 2007), to improve the measurement of craving (MacKillop et al., 2010), and to clarify alcoholism pharmacotherapy mechanisms (Bujarski et al., 2011).

Taken together, these results converge with and extend previous findings on individual differences in alcohol demand and alcohol misuse. In a large community sample, the study found further evidence of robust relationships between indices of alcohol demand and alcohol misuse, especially for O_{max} and intensity. Furthermore, several indices of impulsivity were significantly associated with alcohol demand, although the hypothesis that intensity or O_{max} would moderate impulsivity-related traits was not supported. Sex differences in alcohol demand were present, but were largely a function of differences in drinking patterns and body size. These findings provide further support for a robust association between alcohol demand and alcohol misuse, a potential link between demand and impulsivity, and the need for longitudinal studies to disentangle the causal relationships among these variables more comprehensively.

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Figure 1.

Empirical alcohol demand curve from the Alcohol Purchase Task (APT). Estimated consumption is in standard drinks, hypothetical consumption levels are denoted with circles with respective bars representing standard errors. Corresponding demand indices derived from the APT are represented: intensity refers to consumption at zero cost; breakpoint refers to price at which consumption is zero; and elasticity (α) refers to the slope of the demand curve.

Table 1

Participant Characteristics (N =720).

Variable	<i>M</i> (SD) / % / Median
Gender (% female)	39.2%
Age	29.7 (12.0)
Ethnicity (%)	
<i>White</i>	68.2%
<i>Black/African American</i>	23.9%
<i>Asian</i>	2.8%
<i>American Indian/Alaskan Native</i>	0.6%
<i>Mixed Race</i>	3.6%
<i>Other</i>	1.0%
Education (years)	12.9 (2.1)
Income	< \$15,000
AUDIT	10.7 (7.3)

Note. AUDIT = Alcohol Use Disorders Identification Test.

Table 2
Pearson Correlations Among Alcohol Misuse, Alcohol Demand, and Impulsivity Variables

Variable	1	2	3	4	5	6	7	8	9	10
1. AUDIT	---	---	---	---	---	---	---	---	---	---
2. Intensity	.49**	---	---	---	---	---	---	---	---	---
3. O _{max}	.40**	.55**	---	---	---	---	---	---	---	---
4. Breakpoint	.24**	.20**	.67**	---	---	---	---	---	---	---
5. Elasticity	-.19**	-.29**	-.64**	-.48**	---	---	---	---	---	---
6. UPPS- <i>pre</i>	.20**	.08*	.02	.06	-.03	---	---	---	---	---
7. UPPS- <i>u</i>	.17**	.12**	.08*	.04	-.03	.17**	---	---	---	---
8. UPPS- <i>ss</i>	.08*	.10**	.04	.03	-.07	.08*	.13**	---	---	---
9. UPPS- <i>per</i>	.16**	.07	-.01	.00	-.02	.61**	.19**	.14**	---	---
10. PretaxInc	.04	.03	.03	.02	-.06	.06	-.06	.23**	.01	---
11. FTND	.00	.05	.04	-.04	.05	.00	-.13**	-.24**	.04**	-.34**

Note: AUDIT= Alcohol Use Disorders Identification Test; UPPS-*pre*= UPPS-(lack of) Premeditation; UPPS-*u*= UPPS-Negative Urgency; UPPS-*ss*= UPPS-Sensation Seeking; UPPS-*per*= UPPS-(lack of) Perseverance; PretaxInc= Pretax Income; FTND= Fagerström Test of Nicotine Dependence

* significant correlation at $p < .01$

** significant correlation at $p < .001$.

Table 3

Analyses of Variance and Covariance of Sex Differences in Alcohol Demand

	Unadjusted Model			Covariate Model (FTND, pretax income, AUDIT, weight, height)				
	Male (SEM)	Female (SEM)		Male (SEM)	Female (SEM)			
			<i>F</i>	<i>p</i>	η_p^2		<i>F</i>	<i>p</i>
Intensity	10.68 (.34)	7.79 (.42)	28.62	<.001	.04	10.04 (.35)	8.78 (.46)	3.81 .05
O_{max}	24.33 (.81)	20.50 (1.00)	8.81	.003	.01	23.30 (.86)	22.54 (1.14)	.42 .52
Breakpoint	14.23 (.50)	13.84 (.61)	.24	.63	.000	13.84 (.56)	14.53 (.74)	.44 .51
Elasticity	.004 (.000)	.005 (.000)	5.38	.02	.008	.004 (.000)	.004 (.000)	1.17 .28

Note: Male $n = 430$; Female, $n = 278$.

Table 4

Hierarchical regressions examining indices of alcohol demand and impulsivity in relation to alcohol misuse (AUDIT).

Integration of Demand Indices				Integration of Demand and Impulsivity			
	B	SEM	<i>B</i>		B	SEM	β
Step 1: $R^2 = .04$				Step 1: $R^2 = .05$			
Gender	-.14	.03	-.20**	Gender	-.16	.03	-.22**
Income	.01	.01	.04	Income	.01	.01	.05
FTND	.02	.03	.03	FTND	.01	.04	.01
Step 2: $R^2 = .21$				Step 2: $R^2 = .06$			
Gender	-.08	.02	-.12**	Gender	-.16	.03	-.22**
Income	.00	.01	.02	Income	.01	.01	.04
FTND	-.01	.03	-.01	FTND	-.02	.03	-.02
Intensity	.02	.00	.36**	UPPS- <i>pre</i>	.11	.02	.16**
Omax	.00	.00	.17**	UPPS- <i>u</i>	.09	.02	.15**
BP	.00	.00	.04				
α	5.33	4.53	-.05				
				Step 3: $R^2 = .21$			
Overall R^2	.25**			Gender	-.10	.02	-.13**
				Income	.00	.01	.01
				FTND	-.04	.03	-.04
				UPPS- <i>pre</i>	.10	.02	.15**
				UPPS- <i>u</i>	.06	.02	.09**
				Intensity	.02	.00	.33**
				O _{max}	.00	.00	.19**
				Overall R^2	.31**		

Note: UPPS-*pre*= UPPS-(lack of) Premeditation; UPPS-*u*= UPPS-Negative Urgency

* $p < .05$

SEM: standard error; AUDIT: Alcohol Use Disorders Identification Test.

**
 $p < .01$