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Reinforcer pathologies: Predicting alcohol related problems in college drinking men and women

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ABSTRACT

Background: Alcohol use in college is common, and problematic consequences of alcohol may affect college men and women differently. Approaches within behavioral economics have been used to improve our understanding of alcohol use in college students.
Methods: The current study assessed relations between college students' delay discounting, demand for alcohol, and alcohol problems as measured by the Young Adult Alcohol Consequences Questionnaire (YAACQ). In this study, 80 college drinkers completed a monetary choice questionnaire that assessed delay discounting of money, a novel beer choice questionnaire that evaluated delay discounting of beer, and an alcohol purchase task that measured demand for alcohol.
Results: Behavioral economic measures associated with the reinforcer pathologies model (i.e., demand and discounting) predicted alcohol consequences as measured by the YAACQ. For men, these significant predictor variables included money discounting, beer discounting, and intensity of alcohol demand, whereas for women money discounting and essential value were significant predictors.
Conclusions: These findings highlight the utility of the reinforcer pathologies approach for the study of alcohol use and the importance of considering gender differences in examining college drinking.

1. Introduction

Over 70% of college students report recent alcohol consumption with 35% reporting binge drinking (5+ drinks/occasion) and 13% reporting extreme binge drinking (i.e., 10+ drinks/occasion; Johnston et al., 2014). Heavy drinking increases students' risk of alcohol-related problems with health, academics, injuries, and death (White and Hingson, 2014). Gender may play an important role in college drinkers' experience. Although women's alcohol use is rising, men are more likely to binge drink (Johnston et al., 2014) and experience conspicuous alcohol-related problems (Ham and Hope, 2003; Perkins, 2002). Fewer gender differences, however, are found when broader alcohol-related consequences are assessed (Read et al., 2015, 2006). Relatedly, college men and women respond differently to alcohol use interventions (Carey et al., 2011). Such findings highlight the need to assess gender differences in alcohol-related decision making.

Problematic alcohol use relate to behavioral economic measures. Specifically, the reinforcer pathologies model (Bickel et al., 2011, 2012c, 2014; Carr et al., 2011; Jarmolowicz et al., 2013b, 2015b) posits that problematic use results from excessive valuation of the abused substance and a general inability to delay gratification.

Excessive valuation of an abused substance is reflected by *demand indices*. Alcohol purchase tasks (APT; Murphy and MacKillop, 2006) assess demand through reports of hypothetical alcohol consumption at a range of prices. Demand indices are generally derived via non-linear regression (Hursh and Silberberg, 2008). These indices include demand intensity (Q_0, consumption when alcohol is free), demand elasticity (essential value, how quickly the regression curve moves from inelastic to elastic), P_{max} (the price when demand becomes elastic), and O_{max} (maximum expenditure at P_{max}). Additionally, breakpoint is the observed price at which consumption is driven to zero. These indices comprehensively describe individuals' cost-benefit alcohol valuation.

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The APT has good test-retest reliability (Murphy et al., 2009), yields similar findings to tasks that use real alcohol (Amlung et al., 2012), and has provided insight into alcohol-related phenomena. Among college students, heavy drinkers have higher intensity of demand than light drinkers (Murphy and MacKillop, 2006), and elevated intensity is associated with alcohol use disorder symptoms (Bertholet et al., 2015). Elevated alcohol demand has been associated with greater alcohol-related risk behavior (Herschl et al., 2012), as well as depression and PTSD symptomology (Murphy et al., 2013). Demand indices are sensitive to situational variables such as next-day responsibilities (Gentile et al., 2012; Gilbert et al., 2014) and distal variables, such as a family history of drinking problems (Murphy et al., 2014). Moreover, those with higher demand consumed more alcohol after intervention (MacKillop and Murphy, 2007).

As with alcohol-related problems, college men and women differ on alcohol demand indices. Skidmore and Murphy (2011) found that men reported greater intensity of demand and higher consumption at lower prices, whereas women displayed higher P_{max} and higher breakpoints. Weekly drinking was predicted by intensity, O_{max}, and elasticity for both genders, but breakpoint was a significant predictor for women but not men (Skidmore et al., 2014).

Consistent with the reinforcer pathologies model, an inability to delay gratification – often reflected in high delay discounting rates (i.e., *k* values) – is also associated with alcohol abuse (Bickel et al., 2012b; Petry, 2001; Vuchinich and Simpson, 1998). Additionally, among drinkers, steeper money discounting is associated with greater alcohol consumption (Christiansen et al., 2012; Yankelevitz et al., 2012) and greater alcohol-related risk behavior (Rossow, 2008). Moreover, higher discounting rates are associated with earlier onset of alcohol use (Kollins, 2003), and discounting predicts later alcohol involvement during adolescence (Fernie et al., 2013). Although generally more intensive to administer, tasks assessing alcohol discounting can provide insight into alcohol problems. By finding individuals' subjective equivalence between immediate money and alcohol, researchers have demonstrated that alcohol users discount money at higher rates than controls (Odom and Rainaud, 2003; Petry, 2001), and alcohol discounting has been associated with alcohol use levels (Field et al., 2007; Yankelevitz et al., 2012).

As with demand, a number of findings suggest that discounting may differentially predict alcohol problems for men and women. Women, but not men, with a family history of paternal alcohol dependence discounted money more steeply than those without a family history (Petry et al., 2002). Yankelevitz et al. (2012) specifically assessed gender differences in alcohol discounting, demonstrating that discounting of alcohol correlated with number of drinks per sitting for women but not men.

Higher discounting tends to predate substance abuse (Audrain-McGovern et al., 2009), whereas elevated demand tends to develop with substance use (Christensen et al., 2008) and decrease with cessation (Madden and Kalman, 2010). These findings suggest that excessive discounting can be a predictor of future substance use, and elevated demand can be a marker of current substance use. Conceptually, the reinforcer pathologies model explains addictive behavior through these two methodological approaches (Bickel et al., 2014). This model suggests that addiction results from elevated reinforcer valuation, measured by demand, and high preference for the immediate consumption of that reinforcer, measured by delay discounting (Bickel et al., 2014). The interaction of these measures in alcohol use, if any, is underexplored.

These two aspects of reinforcer pathology predict food intake (Rollins et al., 2010), obesity (Epstein et al., 2014; Feda et al., 2015), and response to obesity treatment (e.g., Best et al., 2012; Rollins et al., 2010). Although demand and an impulsivity scale predicted college students' alcohol use and consequences (Smith et al., 2010) and discounting but not demand predicted heavy drinkers' alcohol use disorder symptoms (MacKillop et al., 2010), we know of no single study that used demand and discounting to predict alcohol-related consequences in college students. The present study sought to (1) test a novel beer choice questionnaire (BCQ) to easily and rapidly assess beer discounting and (2) predict alcohol-related consequences using discounting and demand.

2. Methods

2.1. Participants

Participants were college students recruited from a lower-level behavioral science class at a large midwestern university. Participants received extra credit. Only those providing complete data (N = 115) were considered for the study. Of those considered, participants were excluded from analyses for completing discounting surveys inconsistently (i.e., consistency scores under 75%; N = 11); for these participants, more than 25% of their choices on a discounting questionnaire were inconsistent with the *k* value associated with their most consistent choices, as described by Kirby and Petry (2004). Participants were also excluded for reporting no demand for alcohol (N = 15), consumption that resulted in negative alpha values (N = 3); consumption that resulted in data greater than four standard deviations beyond the remaining distribution (N = 2); or consumption inconsistent with realistic consumption (e.g., more than 25 drinks in five hours; N = 4). Participants included in data analysis did not significantly differ from excluded participants or those providing incomplete data on any demographic variables. For 80 participants included in data analysis (58 women), median age was 19.5 years (interquartile range [IQR] = 18.7, 20.64).

2.2. Procedure

Participants received a packet containing an information statement indicating institutional review board approval, a demographics form, and surveys during an in-class session.

2.2.1. Monetary choice questionnaire. The monetary choice questionnaire MCQ (Kirby et al., 1999), a discounting survey with good test-retest reliability (Kirby, 2009), was among the first two surveys in the packet. Each of 27 hypothetical choices consisted of a smaller, sooner (SS) amount of money now or a larger, later (LL) amount after a delay. Each choice corresponded to one of three magnitudes (i.e., small, medium, or large) and one of nine *k* values representing different rates of discounting. Choice order was identical across participants. Each form instructed:

> For each of the next 27 choices, please circle which hypothetical reward you would prefer: the smaller reward today, or the larger reward in the specified number of days. While you will not actually receive the rewards, pretend you will actually be receiving the amount you indicate and answer honestly.

2.2.2. Beer choice questionnaire. A novel beer choice questionnaire (BCQ) was counterbalanced across packets with the MCQ. The BCQ was identical to the MCQ, except each choice consisted of a SS number of cans of beer or a LL number of cans of beer after a delay. Choice amounts were proportional to the MCQ, and were calculated using a money-to-beer equivalency value obtained during a prior in-class poll (e.g., number of cans worth $100; see Table 1). The mean (N = 178) was 107.23 cans and the median was 100 cans. To present rounded values, 105 cans were used as the BCQ equivalency value.

Table 1
Summary of Monetary and Beer Choice Questionnaires.

	Money			105 Can Equivalency Value for Beer					
Order	Immediate		Delayed	Immediate		Delayed	Delay	k	Rank	Size
13	$34	or	$35	36 cans of beer	or	37 cans of beer	186 days	.00016	1	S
1	$54	or	$55	57 cans of beer	or	58 cans of beer	117 days	.00016	1	M
9	$78	or	$80	82 cans of beer	or	84 cans of beer	162 days	.00016	1	L
20	$28	or	$30	29 cans of beer	or	32 cans of beer	179 days	.00040	2	S
6	$47	or	$50	49 cans of beer	or	53 cans of beer	160 days	.00040	2	M
17	$80	or	$85	84 cans of beer	or	89 cans of beer	157 days	.00040	2	L
26	$22	or	$25	23 cans of beer	or	26 cans of beer	136 days	.0010	3	S
24	$54	or	$60	57 cans of beer	or	63 cans of beer	111 days	.0010	3	M
12	$67	or	$75	70 cans of beer	or	79 cans of beer	119 days	.0010	3	L
22	$25	or	$30	26 cans of beer	or	32 cans of beer	80 days	.0025	4	S
16	$49	or	$60	52 cans of beer	or	63 cans of beer	89 days	.0025	4	M
15	$69	or	$85	72 cans of beer	or	89 cans of beer	91 days	.0025	4	L
3	$19	or	$25	20 cans of beer	or	26 cans of beer	53 days	.0060	5	S
10	$40	or	$55	42 cans of beer	or	58 cans of beer	62 days	.0060	5	M
2	$55	or	$75	58 cans of beer	or	79 cans of beer	61 days	.0060	5	L
18	$24	or	$35	25 cans of beer	or	37 cans of beer	29 days	.016	6	S
21	$34	or	$50	35 cans of beer	or	53 cans of beer	30 days	.016	6	M
25	$54	or	$80	57 cans of beer	or	84 cans of beer	30 days	.016	6	L
5	$14	or	$25	15 cans of beer	or	26 cans of beer	19 days	.041	7	S
14	$27	or	$50	28 cans of beer	or	53 cans of beer	21 days	.041	7	M
23	$41	or	$75	43 cans of beer	or	79 cans of beer	20 days	.041	7	L
7	$15	or	$35	16 cans of beer	or	37 cans of beer	13 days	.10	8	S
8	$25	or	$60	26 cans of beer	or	63 cans of beer	14 days	.10	8	M
19	$33	or	$80	35 cans of beer	or	84 cans of beer	14 days	.10	8	L
11	$11	or	$30	11 cans of beer	or	32 cans of beer	7 days	.25	9	S
27	$20	or	$55	21 cans of beer	or	58 cans of beer	7 days	.25	9	M
4	$31	or	$85	32 cans of beer	or	89 cans of beer	7 days	.25	9	L

Table showing choices on the MCQ (first set of shaded columns) and BCQ (second set of shaded columns), with BCQ values determined by an equivalency value of 105 beers worth $100. The first column presents the order of choice presentation. The shaded columns feature the hypothetical choices between the smaller, sooner amount available now or the larger, later amount available after the delay specified in the following column. The next column presents the *k* value, and then its corresponding rank. The final column describes the magnitude of the values offered for that choice (S = Small, M = Medium, L = Large).

2.2.3. Alcohol purchase task. An alcohol purchase task (APT) version validated by Murphy and MacKillop (2006) was modified to include two higher prices. Participants were instructed:

> Imagine that you and your friends are at a bar from 9 P.M. to 2 A.M. to see a band. The following questions ask how many drinks you would purchase at various prices. The available drinks are standard size beer (12oz), wine (5 oz), shots of hard liquor (1.5 oz), or mixed drinks with one shot of liquor. Assume that you did not drink alcohol before you went to the bar and will not go out after.

Participants responded to 16 fill-in-the-blank questions, asking "How many drinks would you have if they were X?" with X increasing across successive questions (i.e., free, $0.25, $0.50, $1.00, $1.50, $2.00, $2.50, $3.00, $4.00, $5.00, $6.00, $7.00, $8.00, $9.00, $10.00, $12.00).

2.2.4. Young adult alcohol consequences questionnaire. Participants completed the Young Adult Alcohol Consequences Questionnaire (YAACQ; Read et al., 2006), a 48-item questionnaire with demonstrated construct validity (Skidmore et al., 2014) and internal validity and test-retest reliability (Read et al., 2006). The YAACQ assesses problematic alcohol-related consequences across eight domain subscales: social and interpersonal functioning, academic/occupational functioning, risky behavior, impaired control, poor self-care, diminished self-perception, blackout drinking, and physiological dependence. The YAACQ assessment consisted of a three-page questionnaire that instructed:

> Below is a list of things that sometimes happen to people either during, or after they have been drinking alcohol. Next to each item below, please mark an "X" in either the YES or NO column to indicate whether that item describes something that has happened to you in the past year.

2.3. Data analysis

2.3.1. Delay discounting. Each of the 27 choices on either discounting form corresponded to a *k* value. Three choices were presented per *k* value, one each for small, medium, and large magnitudes of money or beer. A freely available Excel-based calculator developed by Kaplan et al. (2014) was used to calculate an overall *k* value and a *k* value for each of the three magnitudes of each commodity (see Kaplan et al., in press, for a discussion). This calculator determined an overall *k* value and a *k* value for each magnitude using the method described by Kirby et al. (1999). These *k* values were then log transformed to correct for distribution. Log-transformed *k* values for both discounting tasks, however, were non-normal according to a Komogorov-Smirnov test of normality ($p < 0.001$) so nonparametric alternatives were performed for these statistical tests. These tests included the Mann-Whitney for between-group differences, the Wilcoxon for paired-samples tests, and Spearman's Rho for correlations.

Table 2
Gender Differences on YAACQ, Discounting, and Demand.

Scale	Women		Men		*Z*	*p*
	Median	IQR	Median	IQR		
YAACQ Total	10.5	4, 18	19.5	5.75, 26	−2.10	0.053
Social/Interpersonal	2	1, 3	2.5	1, 4.25	−1.56	0.165
Impaired Control	1	.75, 2	1.5	1, 3	−1.20	0.305
Self-Perception	0	0, 2	0	0, 2.25	−0.483	0.573
Self-Care	1	0, 3	1	0, 4.25	−1.89	0.079
Risky Behavior	**1.5**	**0, 3**	**3.5**	**1, 5**	**−2.67**	**.010**
Academic/Occupational	0	0, 2	1	0, 3	−1.73	0.109
Physiological Dependence	**0**	**0, 1**	**1**	**0, 2**	**−3.36**	**.001**
Blackout Drinking	3	1, 5.25	4.5	3, 6	−1.74	0.117
LN(k) Money	−4.63	−5.99, −3.66	−4.14	−5.55, −3.66	−1.252	0.287
Small	−4.61	−5.55, −3.44	−3.68	−5.55, −3.44	−0.360	0.848
Medium	−4.63	−6.45, −3.66	−4.15	−5.54, −3.66	−1.246	0.291
Large	−5.55	−6.45, −4.63	−4.63	−6.45, −4.37	−1.598	0.155
LN(k) Beer	−4.14	−4.706, −2.75	−4.14	−5.09, −2.52	−0.068	0.955
Small	−3.66	−4.63, −2.75	−3.66	−3.92, −2.58	−0.437	0.665
Medium	−4.15	−4.63, −2.75	−4.63	−5.55, −2.53	−0.021	0.994
Large	−4.63	−5.55, −2.75	−4.63	−5.55, −2.75	−0.048	0.959
Essential value	0.47	.29, 0.62	0.42	.60, 0.89	−1.53	0.070
Intensity	**8**	**5.75, 10**	**11**	**9.5, 15**	**−3.37**	**.001**
Breakpoint	**6**	**5, 9**	**8.5**	**6.25, 9.75**	**−2.01**	**.042**
P_{max}	4.23	2.67, 6.29	4.34	2.99, 5.78	−0.565	0.734
O_{max}	11.85	7.30 15.66	14.02	9.85, 20.75	−1.53	0.070

Presents median scores and interquartile ranges (IQR) for women (left column) and men (middle column) with *Z* scores and significance values (right column). Shown are scores on the subscales of the YAACQ, log transformed *k* values for discounting of beer and money, and demand indices. Higher scores on the YAACQ represent greater self-reported problematic consequences from alcohol use. Significant differences between genders are indicated by bold font.

2.3.2. APT. Data from the APT were analyzed using Hursh and Silberberg's (2008) exponential model of demand:

$$\log Q = \log Q_0 + k(e^{-\alpha[Q_0 \cdot C]} - 1)$$

in this model, *Q* represents consumption (drinks purchased) as a function of price (*C*; US$ per drink). A measure of demand intensity, Q_0 was each participant's observed peak consumption when the commodity was free (zero price). A scaling constant, *k*, reflected the number of log-units comprising the range of consumption. An observed group *k* of 1.9 was calculated by dividing the mean maximum consumption by the mean minimum consumption and log transforming. An empirically derived measure of demand elasticity, α was calculated in GraphPad Prism version 6. The price at which consumption was first suppressed was each participant's breakpoint. Additional demand indices, including P_{max}, O_{max}, the essential reinforcing value of alcohol (EV), were determined using a freely available Excel-based calculator (Kaplan and Reed, 2014). All indices were non-normally distributed according to a Komogorov-Smirnov test of normality ($p < 0.001$) so nonparametric alternatives were performed for statistical tests. These tests included the Mann-Whitney for across group differences and Spearman's Rho for correlations.

2.3.3. YAACQ. Participants' "yes" responses to all YAACQ questions were summed. Participants were categorized as high-risk drinkers (i.e., YAACQ total ≥16; Read et al., 2015) or low/moderate-risk drinkers. Additionally, items corresponding to each domain were summed to calculate each subscale score. YAACQ scores were not normally distributed ($p < 0.01$), so nonparametric tests were used.

2.3.4. Regression models. Multiple linear regression models were developed for the YAACQ scales on which at least half of participants reported 1 or more consequences in that domain, resulting in six total models. For each scale, we developed a single model using discounting of money, discounting of beer, alcohol EV, alcohol intensity, and gender as predictor variables. In addition, interaction variables were assessed, including the interaction of money discounting and EV, as well as the interaction of gender with each behavioral economic variable. Significant interaction terms were reported (see Table 3), whereas nonsignificant interaction terms were not reported (data available upon request).

3. Results

3.1. Delay discounting

The left panel of Fig. 1 displays mean *k* values for each magnitude of money (open circles) and beer (closed circles). Overall, participants discounted delayed beer more steeply than delayed money ($Z = -4.187$, $p < 0.001$). This between commodity difference was observed across small ($Z = -3.192$, $p = 0.001$), medium ($Z = -2.362$, $p = 0.017$), and large ($Z = -3.837$, $p < 0.001$) magnitudes of these commodities. Although men discounted beer more than money overall ($Z = -2.430$, $p = 0.013$) and at small magnitudes ($Z = -3.011$, $p = 0.001$), no differences were observed for men across medium ($Z = -0.978$, $p = 0.348$) or large magnitudes ($Z = -1.539$, $p = 0.132$). Women discounted delayed beer at significantly greater rates than delayed money overall ($Z = -3.567$, $p < 0.001$) and across small ($Z = -2.126$, $p = 0.033$), medium ($Z = -2.059$, $p = 0.039$), and large magnitudes ($Z = -3.405$, $p < 0.001$). No between-gender differences were found on money or beer discounting (see Table 2). The right panel of Fig. 1 shows participants' proportions of choices for SS beer relative to LL beer (open circles) and SS money relative to LL money (closed circles) for the overall sample (top panel), men (middle panel), and women (bottom panel). At smaller *k* values (0.00016–0.0010), the proportion of SS money choices was not different from the proportion of SS beer choices. Overall, a larger proportion of SS beer choices was observed relative to money, beginning at *k* value 0.0025 ($p = 0.02$) and continuing across all successively larger *k* values. A similar trend was observed for women, with the proportions of SS beer choices relative to money different at six of nine *k* values. For men, significantly greater proportions of SS beer choices relative to money were observed only at a *k* of 0.041 ($p = 0.008$) Thus, overall participants' proportion of SS reward

Table 3
Multiple Linear Regression Models.

	YAACQ Total						Social/Interpersonal Subscale					
	LN(k) Money	LN(k) Beer	EV Alcohol	Intensity Alcohol	Gender	Gender × LN(k) Beer	LN(k) Money	LN(k) Beer	EV Alcohol	Intensity Alcohol	Gender	Gender × LN(k) Beer
B	2.305	−0.568	3.226	0.286	3.586	−3.805	0.338	−0.105	−0.170	0.100	0.192	−0.404
SE	0.732	0.610	2.723	0.227	2.308	1.245	0.120	0.100	0.447	0.037	0.379	0.204
β	0.376	−0.109	0.122	0.138	0.161	−0.355	0.347	−0.127	−0.041	0.303	0.054	−0.237
t	3.151	−0.930	1.185	1.259	−1.553	−3.056	2.816	−1.046	−0.382	2.678	0.506	−1.976
p	0.002	0.355	0.240	0.212	0.125	0.003	0.006	0.299	0.704	0.009	0.614	0.052
	$R^2 = 0.307$, $p < 0.001$						$R^2 = 0.259$, $p < 0.001$					

	Impaired Control Subscale						Self-Care Subscale					
	LN(k) Money	LN(k) Beer	EV Alcohol	Intensity Alcohol	Gender	Gender × LN(k) Beer	LN(k) Money	LN(k) Beer	EV Alcohol	Intensity Alcohol	Gender	Gender × LN(k) Beer
B	0.341	−0.070	−0.280	0.043	0.255	−0.500	0.272	−0.076	0.278	−0.023	0.966	−0.619
SE	0.113	0.095	0.422	0.035	0.358	0.193	0.165	0.137	0.614	0.051	0.520	0.281
β	0.384	−0.093	−0.073	0.142	0.079	−0.322	0.220	−0.073	0.052	−0.056	0.214	−0.286
t	3.008	−0.739	−0.663	1.215	0.713	−2.588	1.652	−0.555	0.453	−0.456	1.857	−2.208
p	0.004	0.463	0.509	0.228	0.478	0.012	0.103	0.581	0.652	0.650	0.067	0.030
	$R^2 = 0.206$, $p = 0.008$						$R^2 = 0.137$, $p = 0.088$					

	Risky Behavior Subscale						Blackout Drinking Subscale					
	LN(k) Money	LN(k) Beer	EV Alcohol	Intensity Alcohol	Gender	Gender × LN(k) Beer	LN(k) Money	LN(k) Beer	EV Alcohol	Intensity Alcohol	Gender	Gender × LN(k) Beer
B	0.434	−0.022	0.315	0.052	0.949	−0.590	0.444	−0.167	1.276	0.078	0.330	−0.334
SE	0.141	0.117	0.523	0.044	0.444	0.239	0.175	0.146	0.652	0.054	0.553	0.298
β	0.374	−0.023	0.063	0.132	0.225	−0.291	0.317	−0.141	0.212	0.164	0.065	−0.136
t	3.085	−0.190	0.603	1.183	2.139	−2.463	2.537	−1.145	1.957	1.429	0.597	−1.121
p	0.003	0.850	0.549	0.241	0.036	0.016	0.013	0.256	0.054	0.157	0.553	0.266
	$R^2 = 0.283$, $p < 0.001$						$R^2 = 0.240$, $p = 0.002$					

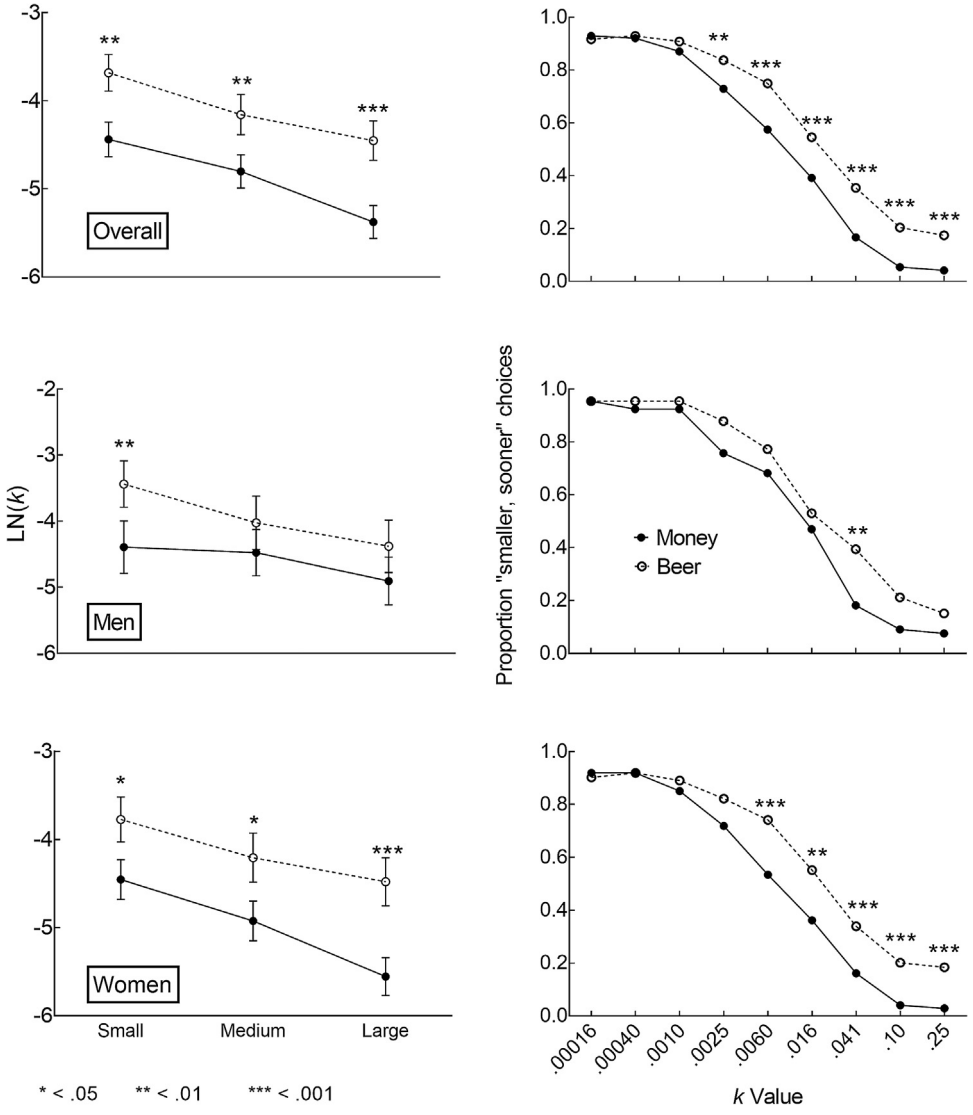

Fig. 1. Beer and Money Discounting.
The left panels show mean natural log *k* values of money (closed circles) and beer (open circles) at small, medium, and large magnitudes of reward. Error bars show the standard error of the mean. Top panel shows overall data, while the middle panel shows men's data and the bottom panel shows women's' data. The right panel shows proportion of choices for the smaller, sooner reward relative to the larger, later reward at each untransformed *k* value of the MCQ and BCQ. Each proportion includes the participants' responses to three questions from each of the discounting questionnaires for beer (open circles) and money (closed circles). Top panel shows data for the entire sample, the middle figure shows men's data, and the bottom panel shows women's data. ($^{*}p < 0.05$ $^{**} < 0.01$ $^{***}p < 0.001$)

choices was similar for beer and money at smaller *k* values, in which there was less difference in amount between the SS reward relative to LL reward. In contrast, at larger *k* values, participants made a greater proportion of choices for SS beer relative to SS money; these choices at larger *k* values correspond to choices in which there was a larger difference in amount between the SS reward relative to LL reward.

Fig. 2 illustrates the correlation between participants' delay discounting rates of money and beer. Natural log *k* values representing these two rates of discounting were significantly correlated overall ($r = 0.49$, $p < 0.001$), as well as for men ($r = 0.79$, $p < 0.001$) and women ($r = 0.39$, $p = 0.002$).

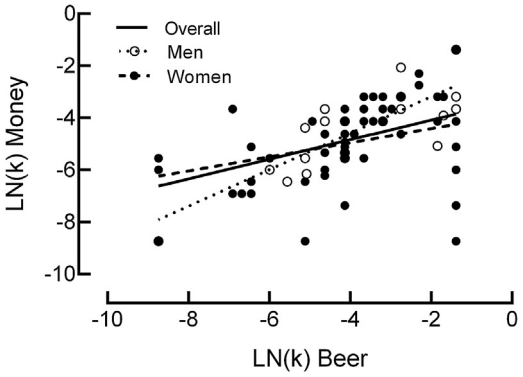

Fig. 2. Correlation Between Discounting of Beer and Discounting of Money.
Graph showing the correlation between log transformed *k* values for discounting of beer and discounting of money for men (open circle; dotted line), women (closed circle; dashed lines), and the overall correlation (solid line).

3.2. APT

Most behavioral economic measures of demand were significantly correlated (data available upon request), except intensity and breakpoint. Intensity and O_{max} were perfectly rank-order correlated (i.e., Spearman's Rho). Fig. 3 depicts the mean number of

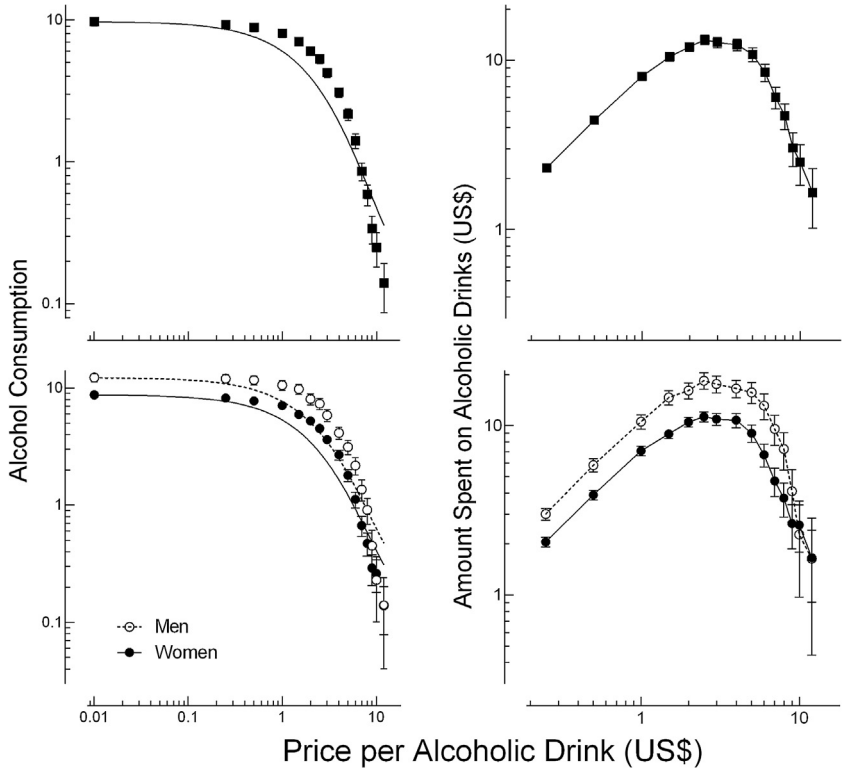

Fig. 3. Alcohol Consumption and Spending as a Function of Price.
Right panels show reported consumption as a function of increases in unit price for the overall group (top, right panel) and separately (bottom, right panel) for men (open circles) and women (closed circles). Left panels show amount spent on alcoholic drinks as a function of increases in unit price for the overall sample (top, left panel) and separately for men and women (bottom, left panel).

drinks consumed as a function of price for the overall sample (top, left panel) and for men (open circles) and women (closed circles) separately (bottom, left panel). Consumption decreased as price increased. The right panels show spending on alcoholic beverages as a function of price overall (top, right panel) and separately (bottom, right panel) for men (open circles) and women (closed circles). There were no gender differences on EV, P_{max}, or O_{max} (see Table 2), but men reported higher intensity and breakpoint. Men also reported greater consumption and output at prices through $6, but men and women's consumption and output converged at prices from $7 to $12.

To examine relations between discounting of money and beer and demand indices, demand indices were analyzed across median-split groups of high and low discounters (see Fig. 4). Groups were divided by money discounting (MD = −4.50; left panels) and beer discounting (MD = −4.14; right panels). Results are depicted for the overall group (top panel), men (middle panel), and women (bottom panel). High money discounters (closed circles) reported greater intensity ($Z = 2.67$, $p = 0.007$), EV ($Z = 2.97$, $p = 0.003$), and O_{max} ($Z = 2.97$, $p = 0.003$) relative to low discounters; no differences were observed in breakpoint or P_{max}. High money discounters reported greater consumption at prices from $0 through $6. There were no significant differences between high and low beer discounters on demand indices or consumption at any price.

3.3. YAACQ

Participants reported a median of 10.5 alcohol-related consequences on the YAACQ (IQR = 4, 18). Overall, 40% of participants were classified as high-risk drinkers. Relative to low/moderate-risk drinkers, high risk drinkers discounted money at greater rates ($Z = -3.076$, $p = 0.002$) and reported higher intensity ($Z = -2.936$, $p = 0.003$), EV ($Z = -3.767$, $p < 0.001$), and O_{max} ($Z = -3.767$, $p < 0.001$); no differences were found on beer discounting ($Z = -0.376$, $p = 0.710$), breakpoint ($Z = -0.680$, $p = 0.501$), or P_{max} ($Z = -1.606$, $p = 0.108$). Among men, 54.5% were high-risk drinkers, and among women, 34.5% were high-risk drinkers. These proportions were not significantly different ($\chi^2 = 2.675$, $p = 0.128$). Relative to low/moderate-risk women, high-risk women discounted money at greater rates ($Z = -3.362$, $p = 0.001$) and reported higher intensity ($Z = -2.330$, $p = 0.020$), EV ($Z = -3.371$, $p = 0.001$, and O_{max} ($Z = -3.371$, $p = 0.001$). No significant differences were observed between high-risk and low/moderate-risk men on any behavioral economic measures. Overall, men reported more alcohol-related consequences than women only on risky behavior and physiological dependence subscales (see Table 2).

3.4. Regression models

A single multiple linear regression model was developed for the YAACQ total and each of five subscales. Behavioral economic measures predicted scores on the YAACQ overall scale and four subscales (see Table 3); money discounting and intensity were significant predictors. Of the interactions assessed (money discounting × EV and gender × behavioral economic variables), only the interaction of beer discounting and gender was significant, and this effect was found in models for the YAACQ total and two subscales.[1]

[1] Income and a reinforcer pathologies interaction variable (mean-centered LN(k) money × mean-centered EV) were entered as predictor variables in hierarchical regression models. This interaction was nonsignificant, and these models are not reported.

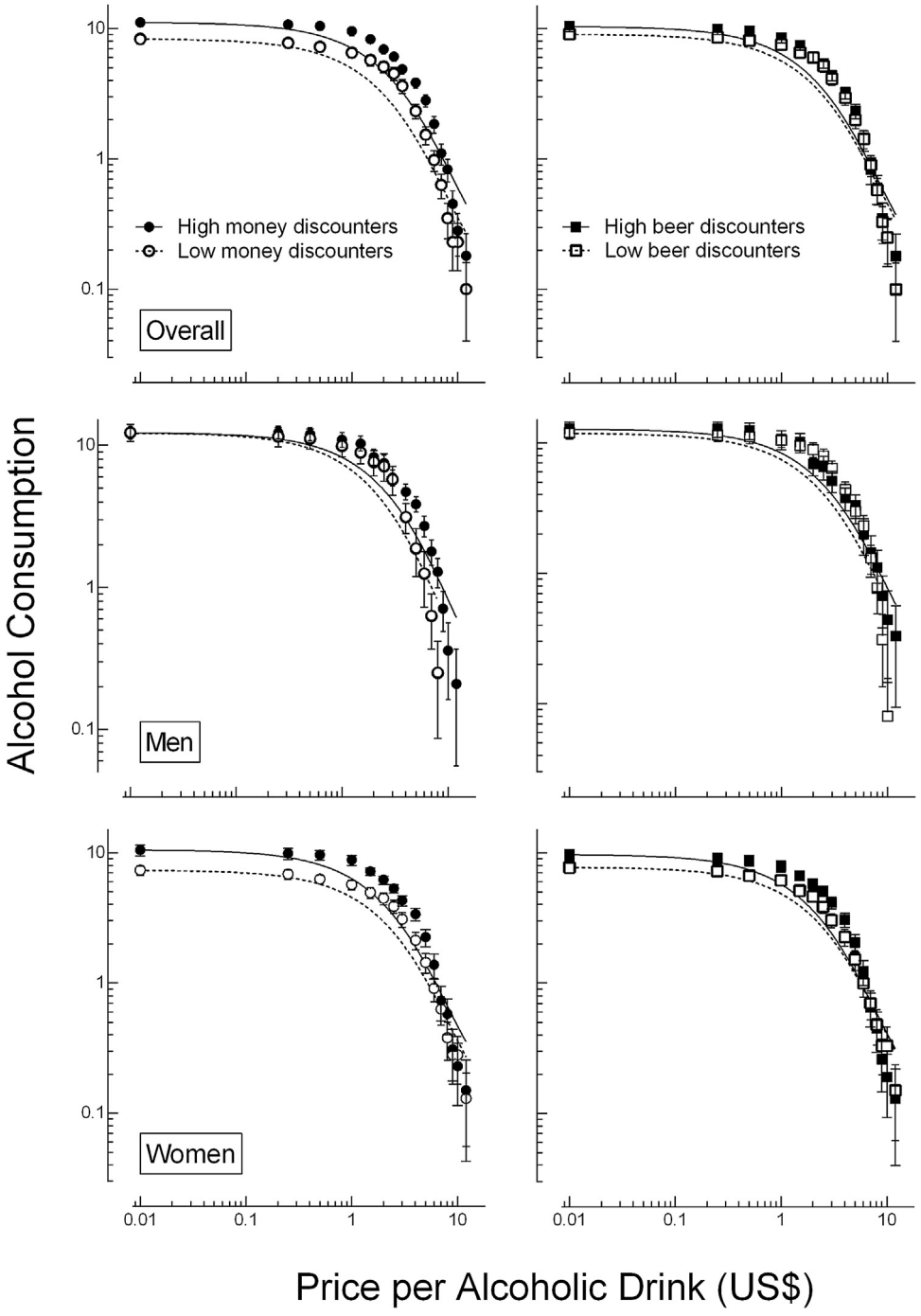

Fig. 4. Participants' Demand by Median Split.
Demand curves for participants divided by median discounting scores for money (left panels; circles) and beer (right panels; squares). Top panels show median split data for all participants. The middle panels show men's' median split data, while the bottom panel shows median split data for women. High discounters (beer < −4.14, N = 40; money < −4.50, N = 40) are depicted by closed symbols while low discounters (beer ≥ −4.14, N = 40; money ≥ −4.50, N = 40) are depicted by open symbols.

4. Discussion

As in prior studies, demand from the APT was well described by the exponential demand model (Mean $R^2 = 0.84$, SEM = 0.014; Hursh and Silberberg, 2008), individuals discounted beer more rapidly than money (Odum and Rainaud, 2003; Petry, 2001; Yankelevitz et al., 2012), and discounting (Yankelevitz et al., 2012) and demand (Skidmore et al., 2014) predicted alcohol-related problems. Similar to research integrating discounting and relative reinforcing value (Best et al., 2012; Epstein et al., 2014; Feda et al., 2015; MacKillop et al., 2010; Rollins et al., 2010), we used discounting and demand measures in a model predicting alcohol consequences. We would like to make four additional points regarding the current data.

First, behavioral economic measures from the reinforcer pathologies model predicted YAACQ total score and four subscales. Significant variables across these models included discounting of money, intensity, gender, and the interaction of beer discounting with gender. These findings extend previous research that using discounting (Yankelevitz et al., 2012) or demand (Skidmore et al., 2014) to account for college students' alcohol use. As with obesity (Best et al., 2012; Feda et al., 2015; Rollins et al., 2010) and

alcohol use disorders (MacKillop et al., 2010), behavioral economic variables within the reinforcer pathologies framework accounted for alcohol-related consequences. In this sample of college students, discounting and demand did not interact; instead these two variables accounted for non-orthogonal portions of the variance in predicting alcohol-related consequences. Although the interaction of discounting and demand was not a significant predictor of any alcohol-related consequences in the regression models, individuals with higher rates of discounting did report greater demand for alcohol (see Fig. 4). Consistent with previous research showing that money discounting tends to carry the most predictive power when compared to a number of other variables (Moody et al., 2013), money discounting was predictive of alcohol-related consequences across all significant models. Similar to previous findings (Skidmore et al., 2014), intensity was a significant predictor of alcohol-related consequences on the social/interpersonal subscale.

Second, gender differences were found on alcohol consequences and demand indices. Gender was a significant predictor for the YAACQ risky behavior subscale with men tending to score higher on this subscale. The interaction of beer discounting and gender was a significant predictor of the YAACQ total and the subscales of impaired control, risky behavior, and self-care; however, the self-care subscale regression model as a whole was not significant ($p = 0.088$). Higher beer discounting amongst males was associated with lower scores on the YAACQ total and the three subscales with a significant interaction. Conclusions based on these data, however, must be tempered because only the correlation between beer discounting and the YAACQ total scale was significant for men; relations between the YAACQ subscales and beer discounting were not significant for men. For women, none of these correlations were significant. Future research should examine these relations further. College men had higher intensity of demand than women and higher demand for alcohol at lower prices (Skidmore and Murphy, 2011; Skidmore et al., 2014). This may reflect that men require more alcohol than women to reach similar blood alcohol concentrations due to differences in body mass and metabolism (Nolen-Hoeksema, 2004). In this sample, however, men and women did not vary on other demand indices; the reason for this discrepancy is not clear. Although Read et al. (2006) reported YAACQ gender differences only on the self-care subscale, the men in our sample reported having experienced more consequences on the risky behavior and physiological dependence subscales.

Third, the present study debuted a novel variant of the MCQ modified to examine beer discounting. Much like other between-commodity comparisons (Bickel et al., 1999; Coffey et al., 2003; Jarmolowicz et al., 2013a, 2014, 2015a; Madden et al., 1997; Petry, 2001), this approach determined the subjective equivalence between money and beer and generated a delay discounting assessment of equally valued options. As with prior comparisons alcohol was discounted more rapidly than money (Petry, 2001), and these differences were significant across six of nine k values assessed, demonstrating the BCQ's sensitivity. Consistent with previous research comparing discounting of money and other commodities (Odum, 2011), rates of beer discounting from the novel beer discounting questionnaire were highly correlated with rates of discounting of money (see Fig. 2), demonstrating that this questionnaire-based approach yields functionally similar results as the more intensive titration procedures often used (Bickel et al., 1999; Coffey et al., 2003; Madden et al., 1997; Petry, 2001).

Lastly, future research can address limitations of the current study. The sample in the current study was predominantly women (73%), reflecting the composition of behavioral science classes. These uneven sample sizes may limit interpretation of the findings, although robust gender differences were seen on several measures and in regression models. Future studies should recruit a balanced sample of men and women. This study also solicited information only on the primary dependent variable of interest, participants' alcohol-related consequences as measure by the YAACQ; data about levels of alcohol consumption were not collected. Future studies should examine how behavior economic measures relate to both alcohol-related consequences and alcohol use. The current study used a novel BCQ that crowd-sourced a money/beer equivalency value from a class-wide poll. Although data obtained from the BCQ correspond well with previous findings on alcohol discounting (Odum and Rainaud, 2003; Yankelevitz et al., 2012), future studies should use individualized beverages (i.e., not all students prefer beer) and equivalency values (cf., Jarmolowicz et al., 2015a). We were unable to develop predictive models for some subscales of the YAACQ because those consequences were seldom reported. Future studies could examine behavioral economic predictors of these subscales using a larger sample. The current study also utilized hypothetical rather than real rewards, but tasks utilizing hypothetical rewards are common in behavioral economics (Fantino and Stolarz-Fantino, 2013), and their correspondence with tasks providing real rewards has been shown in both demand (Amlung et al., 2012) and discounting paradigms (Johnson and Bickel, 2002).

This study used behavioral economic demand and discounting from the reinforcer pathologies model (Bickel et al., 2012a, 2011, 2014; Carr et al., 2011; Jarmolowicz et al., 2015b) to predict alcohol-related consequences. Delay discounting of alcohol and money, demand for alcohol, and alcohol-related consequences were examined in a sample of college drinkers. Regression models based on behavioral economic measures predicted alcohol-related problems, and significant predictors included money discounting, intensity, and the interaction of beer discounting and gender.

Conflict of interest

None.

Role of funding source

Nothing declared.

Contributors

David Jarmolowicz, Derek Reed, and Brent Kaplan contributed to the design of this project. David Jarmolowicz, Derek Reed, and Alexandria were involved in data collection. All authors participated in data analysis and manuscript preparation, and all authors have approved the final version of the manuscript.

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