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Relative Reinforcing Efficacy of Alcohol Among College Student Drinkers

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The construct of relative reinforcing efficacy (RRE) is central to many laboratory and theoretical models of drug abuse, but it has not been widely measured in applied clinical research contexts. The authors used a simulated alcohol purchase task to measure RRE in a sample of 267 college student drinkers. Participants reported their alcohol consumption across a range of prices, and their responses were well-described by a regression equation that has been used to construct demand curves in drug self-administration studies. Several measures of relative reinforcing efficacy were generated, including breakpoint, intensity of demand, elasticity, P_{max} (price at which response output is maximized), and O_{max} (maximum alcohol expenditures). Demand for alcohol was inelastic across the initial range of prices but became elastic as price increased. Students who reported recent heavy drinking reported significantly greater intensity of demand, O_{max}, and breakpoint. These results provide initial support for the validity of the RRE indices generated with the alcohol purchase task. These results also provide empirical support for programs that attempt to reduce alcohol abuse by eliminating low-cost access to alcohol.

Keywords: demand curves, college drinking, behavioral economics, relative reinforcing efficacy, prevention

Behavioral economic theory conceptualizes drug abuse as a state in which the reinforcing efficacy of drugs is high relative to the reinforcing efficacy of available nondrug reinforcers (Bickel, Madden, & Petry, 1998; Carroll & Campbell, 2000; Higgins, Heil, & Plebani-Lussier, 2003; Rachlin, 2000; Redish, 2004; Vuchinich & Heather, 2003). Drug abusers generally consume large quantities of drugs, organize their behavior around obtaining and consuming drugs, and allocate a significant proportion of their economic resources toward purchasing drugs (Tucker, Vuchinich, & Rippins, 2002). Relative reinforcing efficacy (RRE) is central to many laboratory and theoretical accounts of drug abuse (Bickel, Marsch, & Carroll, 2000; Hursh, 2000; Rachlin, 2000; Vuchinich & Heather, 2003), but it has not been widely studied in applied research and treatment contexts.

Bickel et al. (2000) defined RRE as a “theoretical construct designed to integrate the diverse phenomena related to the strengthening effects of reinforcement into a more general property of behavior” (p. 45). Laboratory measures of RRE include peak response rate generated by a drug reinforcer, breakpoint obtained from progressive ratio schedules, and proportional choice for a drug versus an alternative reinforcer. Drugs that produce higher peak response rates and breakpoints and greater relative preference have greater reinforcing efficacy than do drugs with lower values on these parameters. Laboratory researchers have used these measures of RRE to determine a drug’s abuse liability and to examine the influence of pharmacological or environmental manipulations on drug consumption (Bickel, DeGrandpre, & Higgins, 1995; Higgins, Bickel, & Hughes, 1994; Hursh, 2000; Hursh & Winger, 1995).

Bickel et al. (2000) noted that RRE is not a homogeneous phenomenon and suggested that demand curves provide several distinct measures of reinforcement (Bickel et al., 2000; Jacobs & Bickel, 1999; Hursh & Winger, 1995). Demand refers to the quantity of a good that is purchased and consumed at a given price, and demand curves plot consumption of a good across a range of prices. Output functions plot behavioral output or expenditures at each price. Research conducted with a variety of drugs and subject populations demonstrates that drug consumption decreases with increasing price, which is accurately described by the following regression equation (Hursh, Raslear, Shurtleff, Bauman, & Simmons, 1988):

$$\ln C = \ln L + b(\ln P) - aP, \quad (1)$$

where C is consumption at unit price of P, L is the price intercept, and b and a represent the regression slope and the acceleration, respectively. Quantitative analyses of demand curves reveal variability in several demand parameters, including maximum levels of consumption at low prices (intensity of demand), maximum levels of operant responding

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(output) maintained by a drug (O_{max}), and the degree to which consumption declines with increasing price (elasticity of demand).

Although high RRE for drugs can be inferred from general features of drug abuse (i.e., high rates of consumption and drug-seeking behavior), only a few studies have directly examined RRE as a feature of human drug abuse (Correia & Carey, 1999; Jacobs & Bickel, 1999; Murphy, Correia, Colby, & Vuchinich, 2005; Petry & Bickel, 1998; Tucker et al., 2002). The most direct method of measuring RRE is a laboratory self-administration paradigm (Higgins et al., 1994). However, drug self-administration research is costly and time consuming, and it can be ethically dubious with some populations. An alternative approach to measuring RRE with human participants is to measure actual patterns of behavior or resource allocation as they occur in the natural environment. For example, several investigators have used reinforcement survey instruments such as the Pleasant Events Schedule (MacPhillamy & Lewinsohn, 1982) to measure behavioral allocation and enjoyment from substance use relative to substance-free activities (Correia, Carey, Simons, & Borsari, 2003; Murphy et al., 2005). Similarly, relative monetary allocation to substance use versus savings has been used as an index of RRE (Tucker et al., 2002). Preliminary results using these measures suggest that RRE may be a novel index of strength of preference for drugs that predicts changes in use over time and response to intervention (Murphy et al., 2005; Tucker et al., 2002).

A second approach to measuring RRE is to use tasks that are modeled after laboratory drug self-administration procedures but that use hypothetical rather than real outcomes (Griffiths, Rush, & Puhala, 1996; Jacobs & Bickel, 1999; Petry & Bickel, 1998, 1999). These simulation tasks present participants with choices between drug and monetary amounts that are analogous to the choices participants would make in a laboratory drug administration procedure and yield precise quantitative measures of participants' choices (Jacobs & Bickel, 1999). Simulation procedures have been widely used in experimental economics (Camerer & Hogarth, 1999) and in behavioral economic studies of addiction. For example, over 20 published studies provide strong support for the reliability, validity, and utility of the hypothetical delayed reward discounting task with a variety of human populations (see Green & Myerson, 2004, for a review).

Evidence also supports the validity of RRE simulation measures that are based on choices between drug and monetary amounts (Griffiths et al., 1996). Jacobs and Bickel (1999) developed a simulation measure that generates demand curves for heroin and cigarettes. Opioid-dependent outpatient participants completed a questionnaire measure that assessed their consumption of heroin, cigarettes, and heroin and cigarettes concurrently across 15 different prices. Participants' hypothetical drug purchases decreased as a positively decelerating function of price, and Equation 1 provided an excellent fit to participants' data. The relative intensity of demand for cigarettes versus heroin in the alone condition predicted preference between the two drugs in the concurrent condition. In addition, measures of intensity of demand and elasticity of demand provided unique information. Most participants showed greater intensity of demand for cigarettes than for heroin; however, as price increased, heroin purchases decreased less rapidly, indicating that their demand for heroin was less elastic than was their demand for cigarettes. These results suggest that demand curves provide multiple unique measures of RRE (Bickel et al., 2000). The fact that the hypothetical price manipulations impacted reported consumption in the same manner as actual price manipulations provides support for the validity of the demand simulation measure.

The RRE measures generated by demand curves may have utility in clinical and applied research settings (Petry & Bickel, 1998). Individual differences in consumption and expenditures on a simulated drug purchase task might capture important variability in the extent to which individuals overvalue a substance. Although it is possible to obtain actual reports of drug use and expenditures in the natural environment, advantages of simulation tasks include the ability to control for contextual influences on consumption through the use of a standard scenario and the ability to model aspects of consumption that would be difficult to capture using naturalistic patterns of drug use and expenditures (Jacobs & Bickel, 1999).

In the present study, we examined the RRE of alcohol among college student drinkers. Approximately 40% of U.S. college students engage in regular heavy drinking and are at high risk for alcohol-related problems (O'Malley & Johnston, 2002). We measured RRE using a simulated alcohol purchase task (APT) that was modeled after Jacobs and Bickel's (1999) hypothetical demand curve procedure. In the APT, participants are asked to indicate how many drinks they would purchase and consume during a hypothetical drinking scenario. Participants estimate their consumption across 14 drink prices (range = \$0–\$9). Thus, the task allowed us to examine students' reported maximum alcohol consumption, maximum alcohol expenditures, and elasticity of demand for alcohol while controlling for the influence of contextual variables through the use of a uniform drinking scenario. Our specific goals in the study were fourfold. First, we sought to evaluate the adequacy of Equation 1 for describing college drinkers' self-reported alcohol consumption in a hypothetical drinking scenario. Second, we examined the generated indices of RRE (e.g., breakpoint, intensity of demand, elasticity of demand, P_{max} [price at which response output is maximized], and O_{max}) in reference to each other and to measures of alcohol use. Third, we examined the divergent validity of the indices of RRE by comparing subsamples of participants with different levels of drinking. Finally, we attempted to provide descriptive data on the impact of specific drink prices on students' reported heavy episodic drinking (four or more drinks for women and five or more drinks for men per episode; Wechsler, Kuo, Lee, & Dowdall, 2000).

Method

Participants

Participants were 267 undergraduates (76% women) from a large public Southeastern university who reported drinking on a weekly basis. Participants' mean age was 20.11 years ($SE = 0.09$), and they reported drinking an average of 14.33 ($SE = 0.72$) drinks per week. Participants reported an average of 1.70 ($SE = 0.09$) heavy drinking episodes per week and a mean of 5.19 ($SE = 0.25$) alcohol-related problems in the preceding month. Participants were compensated for participating with extra credit in psychology or communications courses.

Procedure

All procedures were approved by the university's institutional review board, and all participants completed informed consent forms prior to participating in the study. Participants completed all the study measures (described below) in group administrations.

Measures

Daily Drinking Questionnaire (DDQ). The DDQ (Collins, Parks, & Marlatt, 1985) is a seven-item measure of an individual's alcohol consumption during a typical week during the past month. A widely used measure of drinking, the DDQ has been shown to have good psychometric properties (Kivlahan, Marlatt, Fromme, Coppel, & Williams, 1990; Miller et al., 1998). The number of drinks per week and heavy drinking episodes were calculated via the DDQ.

Rutgers Alcohol Problem Inventory (RAPI). Alcohol-related problems were assessed using the RAPI, which has demonstrated good reliability and internal consistency and has been validated for use in young adults (White & Labouvie, 1989). This version of the RAPI assessed the occurrence of 23 alcohol-related problems over the prior 30 days. Scale range was from 0 to 23.

APT. The APT was based on Jacobs and Bickel's (1999) procedure and assessed a number of metrics of RRE.

Prior to completing the APT, participants were provided with the following instructional set:

> 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 (12 oz), 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 were then asked "How many drinks would you consume if they were ____ each?" at the following 14 costs: $0 (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, and $9.00.

The APT generated five RRE metrics: (a) breakpoint, (i.e., the first price at which consumption is zero), (b) intensity of demand (i.e., consumption at the lowest price), (c) elasticity of demand (the sensitivity of alcohol consumption to increases in cost), (d) P_{max} (another index of elasticity), and (e) O_{max} (maximum alcohol expenditures). For three of these measures, intensity, P_{max}, and O_{max}, the APT generated both observed and empirically derived values. Observed values were estimated by directly examining performance on the APT, whereas the empirically derived values were derived using values generated by Equation 1. Finally, the APT also generated a multiple correlation value, reflecting the percentage of variance accounted for by Equation 1, which provides an index of the adequacy of the fit of the model to the data.

Statistical Analyses

Breakpoint was defined as the first increment of cost at which no alcohol would be consumed. Participants who reported that they would drink at the highest price increment were assigned a breakpoint at the highest price ($9.00). *Intensity—observed* was defined as free-access consumption (consumption when drinks were free). P_{max}*—observed* was defined as the price associated with the maximum total expenditure (O_{max}). O_{max}*—observed* was defined as the greatest expenditure for an alcohol purchase (i.e., maximum output).

The derived demand metrics were generated by fitting the self-reported demand curves to the following equation (Hursh et al., 1988):

$$\ln C = \ln L + b(\ln P) - aP, \tag{2}$$

where C is predicted consumption at a unit price of P, L is the price intercept, and parameters b and a determine the slope and acceleration, respectively, of the resulting function. Nonlinear regression generated a multiple correlation value, reflecting percentage of variance accounted for by the equation. Consistent with Jacobs and Bickel (1999), when fitting the data to Equation 1, we replaced consumption values of 0 with an arbitrarily low but nonzero consumption value of 0.01, which is necessary for the logarithmic transformation in Equation 1.

Intensity—derived was defined as the empirically generated price intercept L. P_{max}*—derived* was determined using the a and b parameters of Equation 1:

$$P_{max} = (1 + b)/a \tag{3}$$

O_{max}*—derived* was calculated by multiplying P_{max}—derived by the predicted consumption at P_{max}.

The a and b parameters from Equation 1 were used to determine the elasticity of demand at each price (e):

$$e = b - aP. \tag{4}$$

Overall elasticity of demand (*elasticity*) was determined by calculating the mean of the individual price elasticities (Hursh & Winger, 1995).

We used SPSS Version 11.5 nonlinear regression to fit Hursh et al.'s (1988) demand curve equation to the data and for all other analyses. The RRE metrics were examined for distribution normality and outliers. All the variables were relatively normally distributed, although intensity—derived, P_{max}—derived, and O_{max}—derived had small numbers of outliers (5, 1, and 2, respectively) when we used the criterion of a standard (z) score of 3.29 as a cutoff (Tabachnick & Fidell, 2001). Because these values were established as valid data points, we followed the recommendation of Tabachnick and Fidell (2001) and recoded them as being one unit greater than the highest nonoutlier value. This resulted in normal distributions for all RRE metrics.

Results

Adequacy of the Model

Figure 1 depicts the mean number of drinks that participants reported that they would consume at 14 different

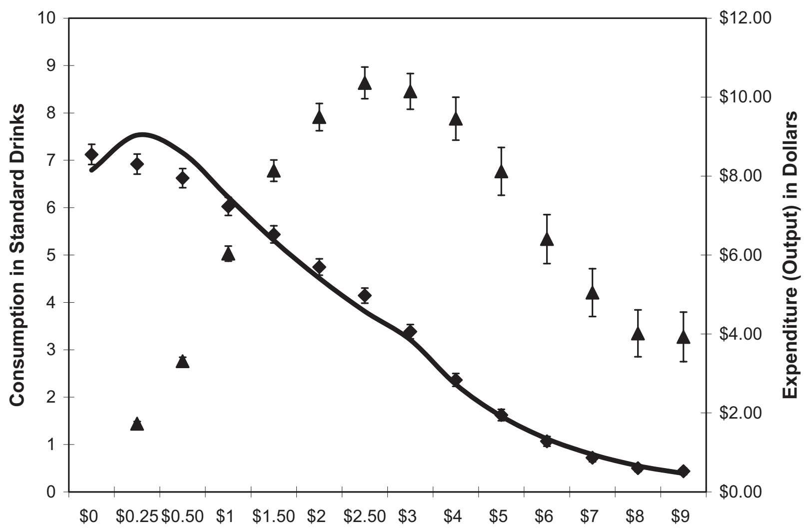

Figure 1. Means and standard errors (represented with error bars) for self-reported consumption of standard alcoholic drinks (left axis) and expenditures (response output; right axis) at 14 levels of price. Consumption is represented with diamonds and expenditures are represented with triangles. Predicted consumption values ($R^2 = .995$) generated by Equation 1 are represented as a line. Values are presented in actual units rather than the logarithmic units that are conventional in economics for interpretational clarity.

prices, the predicted consumption generated by Equation 1, and the response output (expenditure) associated with each price. As expected, alcohol consumption exhibited a decelerating trend in response to price increases and response output conformed to an inverted U-shaped function. Hursh et al.'s (1988) demand curve equation provided a good fit for all individual data (median $R^2 = .85$, interquartile range = .81–.89, total range = .56–.98, mean $R^2 = .84$, $SE = .005$) and an excellent fit for the aggregated data ($R^2 = .995$). Although no accepted criterion for adequacy of fit for Equation 1 exists, the model provided a good fit for all participants using a criterion that Reynolds and Shiffbauer (2004) suggested for curve fits obtained in a delayed reward discounting task ($R^2 \geq .30$). Alcohol RRE metrics for the total sample are presented in Table 1. Because the fitted curve slightly overestimated consumption at low prices, we evaluated an alternative model that constrained the b parameter (i.e., $b < 0$). However, this alternative model diminished goodness of fit and still overestimated consumption at low prices, so we retained Equation 1, which has shown robust generality across multiple studies (Hursh, 2000). The overestimate may be due to the inelastic demand observed across the initial price increments (i.e., $0, $0.25, $0.50).

Table 1
Means and Standard Errors for the Alcohol Relative Reinforcement Efficacy (RRE) Metrics for the Total Sample (n = 267)

RRE metric	*M*	*SE*	Range
Breakpoint	6.22	0.13	0.25–9.00
Intensity—observed	7.12	0.21	1.50–20.00
Intensity—derived	16.73	0.83	0.01–60.20
P_{max}—observed	3.73	0.11	0.00–9.00
P_{max}—derived	5.14	0.28	−0.50–26.94
O_{max}—observed	13.50	0.64	0.00–99.00
O_{max}—derived	5.92	0.31	0.01–31.29
Elasticity	−1.01	0.03	−1.72–−0.02

Relations Among Relative Reinforcing Efficacy Metrics

Pearson's product–moment correlation was calculated among the metrics (see Table 2). On the basis of the 28 correlations generated, a Bonferroni correction was used to reduce the significant p value to .002. As anticipated, large-magnitude positive associations were evident between the observed and derived versions of the same RRE metric. In addition, large-magnitude positive associations were evident between the conceptually related metrics of breakpoint, P_{max}, and elasticity, which all reflect sensitivity of demand to increases in price. Unexpectedly, derived intensity of demand was negatively correlated with elasticity.

Relationships Between RRE Metrics and Alcohol Use

Pearson's product–moment correlation was calculated for each of the alcohol demand metrics and the number of drinks per week, the number of heavy drinking episodes per week, and RAPI score, as shown in Table 3. On the basis of the 24 correlations, a Bonferroni correction was used to reduce the significant p value to .002. Moderate positive associations were evident between all three measures of alcohol use and breakpoint, both measures of intensity, and

Table 2
Correlations Among Relative Reinforcement Efficacy (RRE) Metrics

RRE metric	1	2	3	4	5	6	7	8
1. Breakpoint	—							
2. Intensity—observed	.25**	—						
3. Intensity—derived	.20**	.54**	—					
4. P_{max}—observed	.71**	.07	.03	—				
5. P_{max}—derived	.66**	.17*	−.21**	.72**	—			
6. O_{max}—observed	.57**	.56**	.36**	.52**	.69**	—		
7. O_{max}—derived	.69**	.59**	.32**	.58**	.77**	.93**	—	
8. Elasticity	.82**	.04	−.21**	.72**	.86**	.54**	.66**	—

Note. A Bonferroni correction reduced the significant *p* value to .002.
* $p < .002$. ** $p < .001$.

both measures of O_{max}. P_{max}—derived was positively correlated with the number of drinks per week and the number of heavy drinking episodes per week, but these correlations were not significant at the alpha-adjusted *p* value.

Relative Reinforcing Efficacy in Heavy Drinkers and Light Drinkers

To examine the RRE of alcohol at different levels of drinking, we segregated the sample on the basis of the self-reports of weekly heavy drinking episodes. Participants who reported at least one weekly heavy drinking episode were designated *heavy drinkers* and participants who reported no weekly episodes of heavy drinking were designated *light drinkers*. Heavy drinkers reported drinking an average of 18.34 (SE = 0.85) standard drinks per week. Light drinkers reported drinking an average of 4.46 (SE = 0.31) standard drinks per week.

Performance for each subsample on the RRE metrics is presented in Table 4 and the respective demand curves and output functions are depicted in Figure 2. Equation 1 provided a good fit to the data for both heavy (median = .86, interquartile range = .81–.90, mean R^2 = .85, SE = .005) and light drinkers (median = .84, interquartile range = .78–.87, mean R^2 = .83, SE = .008). Equation 1 provided an excellent fit to the aggregated data for both heavy and light drinkers (R^2s = .995 and .994, respectively).

Given the variable correlations between the demand metrics (Huberty & Morris, 1989), we used univariate ANOVAs to examine drinker group differences on each RRE metric (see Table 4). A Bonferroni correction was used to reduce the significance level to .01. There were significant group differences on breakpoint, intensity—observed, intensity—derived, O_{max}—observed, and O_{max}—derived. As anticipated, all significant differences reflected greater RRE for alcohol in the heavy drinkers. There were nonsignificant trends in the same direction for P_{max}—observed (p = .06), P_{max}—derived (p = .05), and elasticity (p = .07).

Impact of Drink Price on Heavy Drinking

To examine the effects of specific drink prices on heavy drinking, we calculated the proportion of participants who reported that they would engage in a heavy drinking episode by increments of price (see Figure 3). The sample prevalence of heavy drinking was highly sensitive to changes in price between the $1.00 and $6.00 range. Whereas approximately 85% of participants reported that they would engage in a heavy drinking episode if alcohol were $0.50 or less per drink, the percentages decreased to 37% and 13% at drink prices of $3.00 and $5.00, respectively.

Table 3
Correlations Among Relative Reinforcement Efficacy (RRE) Metrics and Measures of Alcohol Use

RRE metric	Drinks/ week	Heavy drinking episodes/week	RAPI
Breakpoint	.21**	.24**	.16†
Intensity—observed	.70**	.61**	.48**
Intensity—derived	.40**	.39**	.27**
P_{max}—observed	.06	.08	−.02
P_{max}—derived	.13†	.14†	.07
O_{max}—observed	.45**	.42**	.24**
O_{max}—derived	.44**	.40**	.23**
Elasticity	.06	.09	.04

Note. RAPI = Rutgers Alcohol Problem Inventory. A Bonferroni correction reduced the significant *p* value to .002.
† $p < .05$. ** $p < .001$.

Discussion

In this study, we examined the relationship between alcohol consumption and drink price among college students. Participants' reported consumption on a simulated APT conformed to a quantitative model that has accurately described the relation between response requirement and drug consumption in laboratory research (Hursh, 2000; Hursh et al., 1988). These results provide further evidence for the generality of this equation. Demand for alcohol was initially inelastic across low prices but became highly elastic as price increased (see Figure 1). Specifically, mean consumption was approximately 7 drinks when price was $0.25 or less per drink and remained high (5 or more drinks) at prices up to $1.50 per drink, then decreased linearly as price increased. Mean consumption decreased by approximately 1.5

Table 4
Means, Standard Errors, and ANOVA Results for the Drinker Group Comparisons on the Alcohol Relative Reinforcement Efficacy (RRE) Metrics

	Sample				
	Heavy drinkers (n = 189)		Light drinkers (n = 78)		
Demand variable	*M*	*SE*	*M*	*SE*	F(1, 267)
Breakpoint	6.58**	0.15	5.34	0.23	19.67**
Intensity—observed	8.16**	0.24	4.60	0.25	75.13**
Intensity—derived	19.60**	1.04	9.77	0.92	32.34**
P_{max}—observed	3.87	0.14	3.40	0.17	3.62
P_{max}—derived	5.49	0.35	4.30	0.43	3.82†
O_{max}—observed	15.63**	0.82	8.33	0.69	29.31**
O_{max}—derived	6.98**	0.39	3.32	0.36	31.13**
Elasticity	−0.98	0.03	−1.08	0.04	3.29

Note. Heavy drinking status was based on self-report of at least one episode of heavy drinking (four drinks per episode for women and five drinks per episode for men) per week. Familywise Bonferroni error corrections were made for the seven comparisons, reducing the significant alpha level to .01. ANOVA = analysis of variance.
† $p < .05$. ** $p < .001$.

standard drinks per dollar price increase in the $1.00 to $4.00 price range. Average consumption was less than 2.5 standard drinks when drink price was $4.00 and less than 1 standard drink at prices greater than $6.00. The output function conformed to the inverted U-shape that is generally observed in laboratory self-administration studies (Bickel et al., 1995). Participants' reported expenditures on alcohol increased sharply with initial price increases, reached asymptote at approximately $3.00 per drink, and diminished thereafter (see Figure 1).

The sample prevalence of self-reported heavy drinking was also extremely sensitive to drink price (see Figure 3). These data suggest that the availability of low-cost alcohol at college bars and parties is a substantial risk factor for heavy drinking. Our results are relevant to prevention programs that attempt to reduce college alcohol abuse by eliminating low-cost access to alcohol (DeJong & Langford, 2002; Weitzman, Nelson, Lee, & Wechsler, 2004). It is assumed that the availability of inexpensive alcohol at fraternity parties or college bars contributes to the high rates of

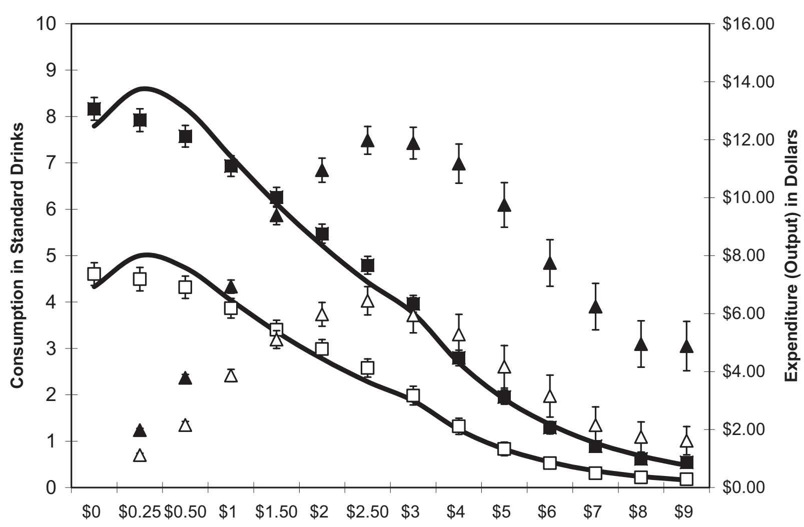

Figure 2. Means and standard errors (represented with error bars) for self-reported consumption of standard alcoholic drinks (left axis) and expenditures (response output, right axis) at 14 levels of price for heavy and light drinkers. Consumption is represented with squares and expenditures are represented with triangles; filled symbols represent heavy drinkers and unfilled symbols represent light drinkers. Predicted values generated by Equation 1 are represented as lines (for heavy drinkers, R^2 = .995; for light drinkers, R^2 = .994).

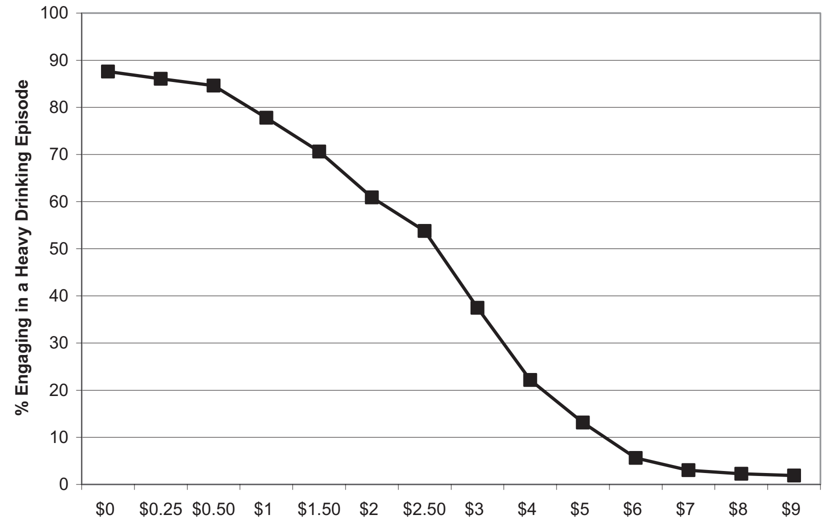

Figure 3. Percentage of participants who reported that they would engage in a heavy drinking episode (four or more drinks for women and five or more drinks for men) at 14 levels of price.

heavy drinking among college students, and although some epidemiological studies support this contention (Saffer & Chaloupka, 1999; Wechsler et al., 2000), this study is the first to collect precise data on students' reported consumption patterns across a range of drink prices. College bars routinely offer specials where drinks can be purchased for $1.00 or less or where students can drink an unlimited amount of alcohol over a specified time frame for a nominal fee. These findings suggest that these drink specials directly increase the likelihood of heavy drinking and alcohol-related problems and concur with the notion that they should be targeted as part of comprehensive alcohol abuse prevention programs (DeJong & Langford, 2002; Weitzman et al., 2004).

An advantage of a demand curve analysis of substance use is its capacity to generate multiple indices of RRE (Bickel et al., 2000). In this study, the measures of breakpoint, intensity of demand, and O_{max} exhibited the strongest correlations with measures of alcohol use and problems. Moreover, these indices exhibited divergent validity among levels of drinking. Compared with students who were lighter drinkers, students who were heavy drinkers reported higher breakpoint values, greater intensity of demand, and greater peak expenditures on alcohol (O_{max}). The RRE indices of P_{max} and elasticity of demand were less strongly associated with alcohol use. There was, however, some evidence that the consumption patterns of heavy drinkers are less sensitive to increases in drink price. P_{max}—derived scores were positively correlated with heavy drinking, but this difference did not reach statistical significance after the Bonferroni adjustment. Similarly, in the drinker group comparisons, although there were no group differences on P_{max} and elasticity, the direction of the effects suggested greater price sensitivity for lighter drinkers. It is interesting to note that there were significant differences on breakpoint, which was highly correlated with P_{max} and elasticity and also reflects sensitivity of consumption to price. The fact the RRE indices showed consistent directional relations to drinking but differences in the strength of the relations is consistent with Bickel et al.'s (2000) conclusion that RRE is a heterogeneous phenomenon. Although P_{max} and elasticity were not strongly associated with drinking in this sample, these indices may predict other aspects of drinking behavior, such as resistance to change or response to intervention.

Future research is needed to address the utility of these RRE measures with college drinkers and other substance-abusing samples. RRE may be useful in assessing emerging substance abuse in populations such as college students or adults with mild to moderate substance use problems. For example, although approximately 40% of college students are heavy drinkers, several features of college drinking make it difficult to measure the severity of students' alcohol consumption for purposes of predicting the course of drinking or identifying students in need of treatment. First, students' drinking patterns tend to be highly variable and subject to contextual influences (Clapp, Reed, Holmes, Lange, & Voas, in press; Del Boca, Darkes, Greenbaum, & Goldman, 2004), which limits the utility of measures of consumption that are based on a student's drinking pattern during a given week or month of college. Second, the interpretation of alcohol-related negative consequences such as hangovers, arguments, and regretted experiences can be problematic because these events could reflect a lack of drinking experience rather than an incipient drinking problem (Kahler, Strong, Read, Palfai, & Wood, 2004). Finally, because many college students have a very brief drinking history, dependence symptoms are either extremely uncommon (e.g., withdrawal, alcohol-related medical problems) or difficult to interpret (e.g., tolerance, efforts to control drinking). Thus, there is a need for innovative and theoretically informed measures of problem severity to complement existing measures, and RRE may be useful in this regard (Murphy et al., 2005). An advantage of the APT used in this study is that it provides a clean measure of demand for alcohol that controls for the myriad contextual influences on drinking patterns in the natural environment.

This study had several limitations that could be addressed in future research. Because we did not have a nationally representative sample of college students, we cannot directly assess the generality of these findings to the larger population of U.S. college students. Future research should use this measure in other student populations or in a nationally representative sample of students. Another limitation of this study is that even at the highest price increment, some participants continued to report that they would drink. This likely diminished the demand curve fit to an extent and underestimated breakpoint in a small number of participants. Future simulation studies should refine the procedures to include a higher maximum drink price. A final limitation is that the simulated APT used in this study assessed reported alcohol consumption in one scenario: an evening at a bar that spanned a 5-hr period. Although this drinking context is certainly not unusual for college students, future research could examine other drinking scenarios to determine if these findings are robust across contexts. Simulation tasks could also manipulate other relevant contextual variables, such as the availability of alternative substance-free leisure activities or the presence of next-day responsibilities such as tests or employment, to more closely mimic the environment in which students make decisions regarding whether and how much to drink (Murphy, Barnett, & Colby, 2006). Such simulation research could be an efficient and inexpensive way to model the impact of potential prevention strategies.

To conclude, in this study, we used a simulated APT to provide bridges between basic research on drug self-administration and both the expression of RRE in human alcohol use and applied prevention questions about the impact of drink price on heavy episodic drinking. The results revealed that Hursh et al.'s (1988) demand curve equation provided a good fit for human self-reported alcohol use, that a number of RRE metrics mapped onto alcohol use variables, and that heavy episodic drinking is highly price sensitive. These findings lay the groundwork for future work that examines whether these procedures can model other aspects of substance use and could be used to identify young adults at risk for developmentally persistent substance abuse.

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