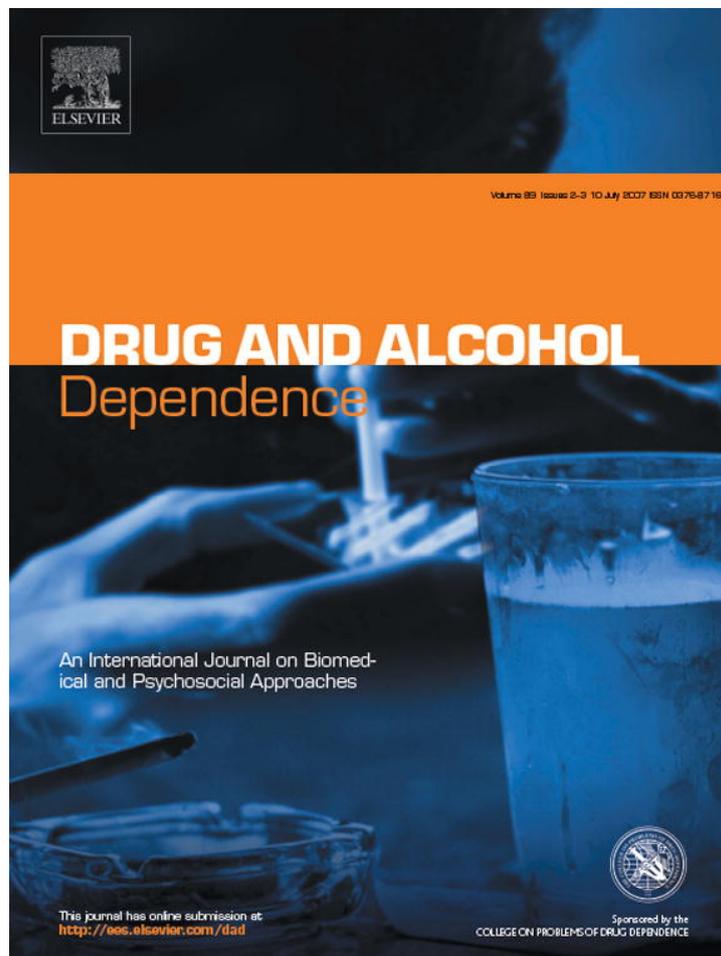


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A behavioral economic measure of demand for alcohol predicts brief intervention outcomes

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Abstract

Considerable basic and clinical research supports a behavioral economic conceptualization of alcohol and drug dependence. One behavioral economic approach to assess motivation for a drug is the use of demand curves, or quantitative representations of drug consumption and drug-reinforced responding across a range of prices. This study used a hypothetical alcohol purchase task to generate demand curves, and examined whether the resulting demand curve parameters predicted drinking outcomes following a brief intervention. Participants were 51 college student drinkers (67% female; 94% Caucasian; drinks/week: $M = 24.57$, $S.D. = 8.77$) who completed a brief alcohol intervention. Consistent with predictions, a number of demand curve indices significantly predicted post-intervention alcohol use and frequency of heavy drinking episodes, even after controlling for baseline drinking and other pertinent covariates. Most prominently, O_{max} (i.e., maximum alcohol expenditure) and breakpoint (i.e., sensitivity of consumption to increasing price) predicted greater drinking at 6-month post-intervention follow-up. These results indicate that a behavioral economic measure of alcohol demand may have utility in characterizing the malleability of alcohol consumption. Moreover, these results support the utility of translating experimental assays of reinforcement into clinical research.

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1. Introduction

Behavioral economic models of alcohol and drug dependence view substance dependence as an acquired state in which the relative reinforcement from a substance remains high compared to other available reinforcers, despite the negative physical and psychosocial consequences of continued use (Ainslie and Monterosso, 2003; Herrnstein and Prelec, 1992; Rachlin, 1997, 2000; Vuchinich and Tucker, 1988, 1996). This approach is supported by an extensive empirical literature, with evidence that addictive substances act as potent reinforcers in both infrahuman and human laboratory research, and that substance use is substantially influenced by the presence of alternative reinforcers or the degree of effort necessary to obtain a drug (for reviews, see Bigelow, 2001; Higgins et al., 2004). Similarly, beyond the lab-

oratory, substance use has been demonstrated to inversely vary with the availability of substance-free rewards (Correia et al., 2003; Murphy et al., 2006; van Etten et al., 1998; Vuchinich and Tucker, 1988, 1996). In addition, behavioral economic theories of addiction have been able to explain core addictive phenomena, such as impulsive decision-making and loss of control over substance use (Bickel and Marsch, 2001).

Despite a strong theoretical and empirical foundation, there has been relatively little translation of the existing experimental measures of reinforcement into clinical contexts. The lack of translational research is regrettably common in behavioral science (Onken and Bootzin, 1998; National Advisory Mental Health Council Behavioral Science Workgroup, 2000) and is unfortunate in this case because these measures might provide unique information on strength of preference for drugs that cannot be gleaned from existing measures (Murphy and MacKillop, 2006; Tucker et al., 2006). Behavioral economics defines the relative level of preference for a substance as its *relative reinforcing efficacy*, which in laboratory settings is typically quantified by the amount of behavior (e.g., lever presses, money, time) allocated to gain access to the substance (e.g., Bickel et al.,

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1997; Higgins et al., 1994; Griffiths et al., 1996; Willner et al., 1995). Several preliminary studies with human participants have developed brief measures of the relative reinforcing efficacy of a substance use that can be administered in clinical settings and can therefore facilitate translational research (Correia et al., 1998; Jacobs and Bickel, 1999; Vuchinich and Tucker, 1996).

Three recent prospective studies suggest that naturalistic measures of drug reinforcement can predict changes in alcohol use over time (Murphy et al., 2005; Tucker et al., 2002, 2006). In two studies of natural recovery from alcohol dependence, Tucker et al. (2002, 2006) assessed the proportion of discretionary income allocated to alcohol in alcohol dependent individuals prior to a quit attempt and found that greater proportionate allocation (putatively reflecting greater relative reinforcement) predicted relapse, even though relapsers and non-relapsers reported similar alcohol consumption prior to the quit attempt. Similarly, Murphy et al. (2005) found that a measure of substance-related reinforcement relative to total reinforcement (reinforcement ratio; Correia et al., 1998) that was derived from Herrnstein's (1970) Matching Law incrementally predicted post-intervention drinking following a single-session intervention for college drinkers. However, it is important to note that relative reinforcing efficacy appears to be a heterogeneous construct (Bickel et al., 2000), with related but nonetheless distinct facets, and it is not clear whether such macrocosmic measures of financial or behavioral allocation clearly capture or differentiate between multiple aspects of reinforcement.

To more directly address whether facets of relative reinforcing efficacy may predict clinical outcomes, the current study examined indices of reinforcement derived from a novel behavioral economic measure as predictors of treatment outcome in a previously published randomized clinical trial (Murphy et al., 2004). Heavy drinking college students completed an alcohol purchase task (APT) prior to receiving a single-session alcohol intervention and multiple indices of reinforcement derived from the APT were examined as potential predictors of alcohol use at the 6-month post-intervention follow-up. Purchase tasks can be used to generate demand curves (e.g., Jacobs and Bickel, 1999; Murphy and MacKillop, 2006), or quantitative representations of self-reported drug consumption and drug-reinforced responding (i.e., expenditure) across a range of prices. Such demand curves can in turn be used to generate several indices of alcohol-related reinforcement (Hursh, 2000), such as maximum level of alcohol consumption at low cost (intensity of demand), maximum level of alcohol expenditure (O_{\max}), and several measures that reflect the degree to which consumption declines with increasing price (breakpoint, P_{\max} , and elasticity of demand). Greater relative reinforcement from alcohol at baseline was predicted to be associated with greater weekly drinking and frequency of heavy drinking (5/4 drinks in an episode in men/women; Wechsler et al., 2000) after the intervention, both independently and incrementally beyond several covariates. Because these data came from a larger dataset from which a previous report detailed the predictive validity of a behavioral economic resource allocation measure (Murphy et al., 2005), the reinforcement ratio measure used in that analysis was included as a covariate. To contribute to the larger question of clarify-

ing the relationship among measures of reinforcement (Bickel et al., 2000; Johnson and Bickel, 2006), it was also compared to performance on the APT.

2. Methods

2.1. Participants

Potential participants were recruited through an extra-credit screening available to undergraduate students enrolled in psychology and communications courses at a large public university in the Southeastern United States. After completing an informed consent form approved by the university Institutional Review Board, student volunteers ($n = 331$) completed the screening questionnaires in exchange for 1-h of course extra-credit. The majority (77.6%) of screened students were women, which is consistent with enrollment patterns in psychology and communications courses. The screening packet contained the assessment measures described below. Individuals ($n = 67$) who were in the upper 20% of the weekly drinking distribution for their gender were invited to participate in the intervention component of the study. Research assistants contacted eligible participants by phone and described the study procedures. Students were told that they would receive 1-h of extra research credit for their participation in a brief alcohol intervention, and could earn \$15.00 for completing a 6-month follow-up assessment.

There were 54 students who qualified for the study and agreed to participate. The remaining participants ($n = 13$) either could not be contacted (i.e., did not return phone calls) or missed two or more intervention appointments. Participants were randomized to one of two brief intervention conditions that included personalized drinking feedback (PDF). PDF interventions are designed to motivate students to decrease levels of alcohol consumption and to avoid alcohol-related negative consequences (Larimer and Cronce, 2002; Murphy et al., 2001). The goal of the intervention aspect of the study was to compare the efficacy of PDF delivered during a motivational interviewing counseling session (Miller and Rollnick, 2002) to PDF delivered without a counseling session (see Murphy et al., 2004 for more details about the interventions and outcomes).

All participants were contacted at 6-month follow-up and were assessed for alcohol use using the same measures as baseline (described below). Of the original 54 participants, 51 (94%) participated in the follow-up. The mean age of the participants was 20.00 years (S.D. = 1.22, range = 19–25); 67% were female, 94% were Caucasian (2% Asian, 2% African-American, 2% "other"), 75% were sophomores or juniors, and 53% belonged to a fraternity or sorority. Prior to the intervention, participants reported an average of 24.57 (S.D. = 8.77) total drinks/week and 3.02 (S.D. = 1.09) heavy drinking episodes per week on the daily drinking questionnaire (DDQ; Collins et al., 1985). Participants reported an average of approximately 8 ($M = 7.98$, S.D. = 4.24) negative consequences associated with drinking in the last month on the Rutgers Alcohol Problem Index (RAPI). No formal diagnostic assessment was conducted on the participants. Additional information on the participants is provided in Murphy et al. (2004).

2.2. Measures

2.2.1. Daily drinking questionnaire (DDQ). Total drinks/week and weekly heavy drinking episodes were assessed with the DDQ (Collins et al., 1985), which has been used frequently with college students and is highly correlated with self-monitored drinking reports (Kivlahan et al., 1990). A heavy drinking episode was defined as 5/4 or more drinks in an episode for men/women, respectively (Wechsler et al., 2000).

2.2.2. Alcohol purchase task (APT). Reinforcement from alcohol was assessed using an APT (Murphy and MacKillop, 2006), which is a simulation measure that assesses self-reported alcohol consumption and financial expenditure across a range of drink prices. It is modeled after previous hypothetical purchase tasks (Jacobs and Bickel, 1999), which were developed to represent a progressive-ratio operant schedule (Hodos, 1961).

The task included the following instructions:

"Imagine that you and your friends are at a bar from 9pm to 2am 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 (5oz), shots of hard liquor (1.5oz), 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 to respond to the following question “How many drinks would you consume if they were _____ each,” at the following 14 costs: zero (free), \$.25, \$.50, \$1, \$1.50, \$2, \$2.50, \$3, \$4, \$5, \$6, \$7, \$8, and \$9.

Facets of reinforcement from alcohol were determined by examining the demand curves generated by the APT. Demand curves were estimated by fitting each participant’s reported consumption across the range of prices to Hursh et al.’s (1988) demand curve equation:

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

where C is the predicted consumption at a unit price of P , L the price intercept, and parameters b and a determine the slope and acceleration of the resulting function, respectively. Nonlinear regression was used to generate an R^2 value, reflecting percentage of variance accounted for by the equation. Consistent with Jacobs and Bickel (1999), when fitting the data to Eq. (1), zero values were replaced by an arbitrarily low but nonzero value of .01, which is necessary for the logarithmic transformations.

The APT generated five reinforcement metrics: (1) breakpoint (first price at which alcohol consumption is zero); (2) intensity of demand (alcohol consumption at the lowest price); (3) O_{\max} (output maximum, or maximum financial expenditure on alcohol); (4) P_{\max} (price maximum, or price at which expenditure is maximized); (5) elasticity of demand (sensitivity of alcohol consumption to increases in cost). Breakpoint was defined as the first increment of cost at which no alcohol was purchased; participants who reported that they would drink at the highest price increment were assigned a breakpoint at the highest price (\$9). Intensity was defined as reported consumption at zero cost. O_{\max} was defined as the algebraically determined maximum expenditure, and P_{\max} was defined as the price at which O_{\max} was reached. The a and b parameters from Eq. (1) were used to determine the elasticity of demand at each price:

$$e = b - aP \quad (2)$$

Overall elasticity of demand across the curve (hereafter simply referred to as elasticity) was defined as the mean of the individual price elasticities (Hursh and Winger, 1995; Jacobs and Bickel, 1999).

2.2.3. Proportional reinforcement from substance use relative to other activities. Participants’ relative proportion of substance-related reinforcement over the last month was assessed using a modified version of the Adolescent Reinforcement Survey Schedule (ARSS; Murphy et al., 2005). Participants rated their frequency of engagement in and enjoyment from a number of social, academic, family, leisure, and dating activities. Frequency ratings ranged from 0 (zero times per week) to 4 (more than once per day), and enjoyment ratings ranged from 0 (unpleasant or neutral) to 4 (extremely pleasant). The frequency and enjoyment rating for each of the 45 activities were multiplied to obtain a cross-product score (range = 0–16), which reflects reinforcement derived from the activity (Correia et al., 2003). The measure assessed each activity twice, distinguishing between when the activity was substance-related and when it was substance-free. This permitted us to compute substance-related and substance-free reinforcement scores, and calculate the ratio of substance-related reinforcement to total reinforcement, i.e., substance-related total/(substance-free total + substance-related total). The substance-related reinforcement ratio ranges from 0 to 1, with higher scores indicating a greater proportion of reinforcement from substance-related activities relative to substance-free activities (Correia et al., 1998).

2.3. Data analysis

All pre-intervention data were examined for distribution normality and modified as necessary (Tabachnick and Fidell, 2001). Eq. (1) was initially examined in terms of the adequacy of model fit to the pre-intervention demand for alcohol, as indexed by the R^2 values generated for the overall dataset and participants’ individual data; median and interquartile ranges are provided for the latter. Breakpoint, intensity of demand, O_{\max} , and P_{\max} were generated via observed

values or algebraic derivations.¹ Eqs. (1) and (2) were used to generate elasticity of demand. Pearson’s product-moment correlation (r) was used to examine associations among the continuous measures. Of note, because elasticity is measured in negative units, with greater negative values reflecting greater price sensitivity, positive correlations between elasticity and other variables reflect a relationship such that as elasticity approaches zero (inelastic demand), increases are also evident in the other variable, and vice versa.

The principal analyses to determine the predictive strength of the pre-intervention indices of reinforcement were conducted using two methods. First, simple regressions were conducted to assess the predict utility of the indices independent of any other variables. Regressions were conducted between the pre-intervention reinforcement metrics and the two primary intervention outcome variables: drinks/week and frequency of heavy drinking (Murphy et al., 2004). Second, a more stringent test of the incremental predictive utility of the variables was conducted using hierarchical multiple regression with the same dependent variables. Based on gender differences in alcohol use and inherent associations between pre-intervention alcohol use and post-intervention use, both variables were entered into an initial block as covariates. Although no effect of conducting PDF in the context of a motivational interview was evident in the clinical trial (Murphy et al., 2004), treatment condition was also included in an initial block to account for the different procedures. Finally, because reinforcement ratio was found to predict treatment outcome in a previous analysis with this sample (Murphy et al., 2005), it was also entered as a covariate to determine the unique contribution of the APT indices. Although regression is a correlational statistic, these associations are referred to as predictive because pre-intervention RRE metrics were examined in reference to post-intervention alcohol use 6 months later.

3. Results

3.1. Baseline considerations, model adequacy, and concurrent relations among variables

Drinks/week was square-root transformed to correct for positive skewness and kurtosis; no other variables required transformations. The demand data topographically conformed to expectations: alcohol consumption exhibited a decelerating curve in response to escalating price and expenditure exhibited the characteristic inverted U-shaped curve (see Fig. 1). Eq. (1) provided an excellent fit to the aggregated data, $R^2 = .996$, and provided a very good fit to the individual participant data, median $R^2 = .86$ (IQR = .81–.90). Correlations among all continuous indices revealed a number of significant associations, as indicated in Table 1. The varying signs and magnitudes of associations among the multiple metrics of the APT did not suggest a single underlying latent variable. Particularly high correlations were evident between elasticity, breakpoint, and P_{\max} , and high correlations were evident between O_{\max} and all of the other reinforcement indices. The reinforcement ratio exhibited significant, albeit modest, positive correlations with drinks/week and heavy drinking episodes, and a trend-level positive association with intensity of demand but no other APT indices. Indices generated from the APT were largely uncorrelated with the alcohol use variables, with the exception of intensity of demand.

¹ Intensity, O_{\max} , and P_{\max} can also be derived using Eq. (1) (see Jacobs and Bickel, 1999; Murphy and MacKillop, 2006), however, the observed and derived parameters are very highly correlated and data from our laboratory suggest that the observed parameters are more reliable than the derived values (J. Murphy, unpublished data). Therefore, we elected to only use observed parameters.

Table 1
Pearson product-moment (r) correlations among the continuous measures prior to the intervention

	BP	O_{max}	P_{max}	I	E	RR	D/W	HD	RAPI
Behavioral economic measures									
Breakpoint (BP)	1								
O_{max}	.56***	1							
P_{max}	.63***	.60***	1						
Intensity (I)	.04	.49***	.01	1					
Elasticity (E)	.91***	.61***	.73***	-.01	1				
Reinforcement ratio (RR)	.12	.07	-.07	.23†	.02	1			
Alcohol use measures									
Drinks/week (D/W)	.11	.18	.04	.44***	.05	.31*	1		
Heavy drinking (HD)	.00	.12	-.01	.114	.01	.27†	.71***	1	
Rutgers alcohol problem inventory (RAPI)	.08	-.17	-.19	.18	.00	.41**	.33*	.13	1

† $p \leq .10$; * $p \leq .05$; ** $p < .01$; *** $p \leq .001$.

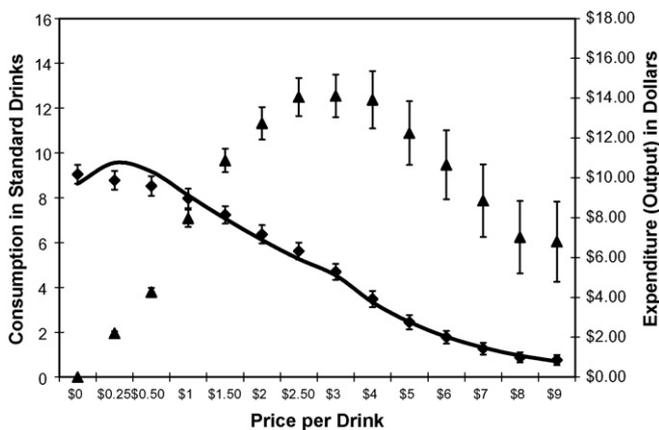


Fig. 1. The alcohol demand curve as generated by the alcohol purchase task. The X-axis presents the increments of the price, with the associated values directly above the price increment between the hatch marks. Self-reported consumption is depicted in filled diamonds and the resulting expenditure is depicted in filled triangles; means and standard errors are provided for both consumption and expenditure. Predicted consumption using Hursh et al.'s (1988) demand equation is depicted as a continuous line ($R^2 = .996$).

3.2. Associations between facets of pre-intervention reinforcement from alcohol and post-intervention alcohol use

The primary intervention outcomes are described in Murphy et al. (2004). Most relevant to the current study, within-subjects

analyses of variance found significant effects of the intervention on drinks/week ($F [1, 47] = 9.91, p < .01$) and frequency of heavy drinking ($F [1, 47] = 7.33, p < .01$), both of which were decreases of medium effect size magnitude. These results are consistent with previous studies of brief interventions that include personalized feedback (e.g., Carey et al., 2006; White et al., 2006). However, there were no significant differences between the two intervention conditions ($p > .20$).

Significant independent associations between the reinforcement indices and drinks/week were evident for all of the indices, ranging from modest associations of marginal statistical significance to large magnitude, highly significant associations. These associations are provided in Table 2. In terms of incremental prediction using the specified covariates, as anticipated, the covariate model (gender, pre-intervention weekly alcohol use, treatment assignment, reinforcement ratio) was significantly associated with post-intervention weekly drinking ($R^2 = .54$; $F [4, 44] = 13.44, p < .001$). Coefficient estimates indicated that pre-intervention drinking ($\beta = .45, p < .001$), gender ($\beta = -.33, p < .01$) and reinforcement ratio ($\beta = .21, p < .05$) were significant predictors, but treatment assignment ($\beta = .01, p > .90$) was not. In terms of the pre-intervention APT metrics, O_{max} , P_{max} , breakpoint, and elasticity all significantly predicted unique variance in post-intervention weekly alcohol use (see Table 2), although intensity of demand did not. The significant reinforcement indices increased the variance accounted for between 5% and 9%, with O_{max} increasing the R^2 by the greatest amount;

Table 2
Prediction of post-intervention drinks/week by alcohol purchase task (APT) reinforcement indices both independently and incrementally beyond a covariate model (gender, drinks/week, treatment condition, and reinforcement ratio)

APT metric	Independent model			Covariate model		
	R^2	F (d.f. = 1, 49)	β	ΔR^2	ΔF (d.f. = 1, 45)	β
Breakpoint	.11	6.02	.33*	.06	6.45	.24*
O_{max}	.24	15.47	.49***	.09	11.36	.33**
P_{max}	.06	3.18	.25†	.05	5.31	.22*
Intensity	.26	16.89	.51***	.01	1.31	.14
Elasticity	.10	5.18	.31*	.06	7.21	.25**

For the independent model, values reflect individual simple regressions. For the covariate model, values for each variable reflect individual hierarchical multiple regressions with the variable of interest entered following the covariate model. The ΔR^2 value represents the increase in variance accounted for beyond the covariate model (covariate $R^2 = .54$). † $p \leq .10$; * $p \leq .05$; ** $p \leq .01$; *** $p < .0005$.

Table 3

Prediction of post-intervention heavy drinking (i.e., $\geq 5/4$ drinks per occasion for men/women) by alcohol purchase task (APT) reinforcement indices both independently and incrementally beyond a covariate model (gender, heavy drinking, treatment condition, and reinforcement ratio)

APT metric	Independent model			Covariate model		
	R^2	F (d.f. = 1, 49)	β	ΔR^2	ΔF (d.f. = 1, 45)	β
Breakpoint	.11	5.93	.33*	.11	7.51	.33**
O_{\max}	.11	5.96	.33*	.06	4.10	.27*
P_{\max}	.05	2.43	.22	.04	2.78	.21 [†]
Intensity	.04	2.08	.20	.01	0.56	.12
Elasticity	.06	3.35	.25 [†]	.06	3.85	.24 [†]

For the independent model, values reflect individual simple regressions. For the covariate model, values for each variable reflect individual hierarchical multiple regressions with the variable of interest entered following the covariate model. The ΔR^2 value represents the increase in variance accounted for beyond the covariate model (covariate $R^2 = .26$). [†] $p \leq .10$; * $p \leq .05$; ** $p \leq .01$.

the combined models for the significant indices accounted for between 59% and 63% of the total variance in post-intervention drinks/week.

In terms of heavy drinking episodes, only breakpoint and O_{\max} were significantly associated with post-intervention heavy drinking, with elasticity exhibiting a trend level association. Associations for all of the reinforcement indices are provided in Table 3. In terms of incremental predictive power, the covariate model (gender, pre-intervention heavy drinking episodes, treatment assignment, and reinforcement ratio) was significantly associated with post-intervention heavy drinking episodes ($R^2 = .26$; $F [4, 45] = 3.96$, $p < .05$), with coefficient estimates indicating a significant association with pre-intervention heavy drinking episodes ($\beta = .47$, $p < .005$), but not gender, reinforcement ratio, or treatment assignment ($ps > .45$). Breakpoint and O_{\max} significantly predicted unique variance in post-intervention weekly heavy drinking and both elasticity and P_{\max} were marginally significant predictors (see Table 3). The significant reinforcement indices increased the variance accounted for between 4% and 11%, with breakpoint increasing the R^2 by the greatest amount; the combined models for the significant indices accounted for between 30% and 37% of the total variance in post-intervention heavy drinking episodes.

4. Discussion

This study used alcohol reinforcement indices derived from a demand curve to predict alcohol use following a brief intervention. Consistent with previous studies (Jacobs and Bickel, 1999; Murphy and MacKillop, 2006), the APT generated demand curves that topographically conformed to previous human and infrahuman studies and Hursh et al.'s (1988) demand equation provided a very good fit to the data. Moreover, as hypothesized, a number of the facets of reinforcement predicted weekly alcohol consumption and heavy drinking at the 6-month post-intervention follow-up assessment. Participants who at baseline reported greater maximum expenditure (i.e., O_{\max}) for alcohol and lower price sensitivity (i.e., breakpoint, P_{\max} , and elasticity) reported greater follow-up weekly drinking. Moreover, these variables did so both independently and beyond a stringent group of covariates that accounted for a substantial proportion of the variance. These indices of strength of preference for alcohol are

consistent with well-established laboratory paradigms for determining reinforcer value (Bickel et al., 2000) and provide unique information that is not typically included in clinical or clinical research contexts. These results complement previous research indicating that behavioral and money allocation-based measures of reinforcement can predict changes in alcohol use (Murphy et al., 2005; Tucker et al., 2002, 2006), and support the notion that indices of alcohol reinforcement derived from basic behavioral economic research may have clinical utility.

As anticipated, the various reinforcement indices derived from the APT showed varying degrees of overlap and independence. These results are consistent with Bickel et al.'s (2000) proposal that reinforcement is a heterogeneous construct. For example, intensity of demand and O_{\max} reflect different facets of reinforcement – initial demand for alcohol versus maximum expenditure for alcohol – and were not surprisingly uncorrelated in this study. In contrast, breakpoint and elasticity have considerable conceptual overlap, both reflecting sensitivity to the price of alcohol, and were highly correlated. Of note, taking the empirical correlations among the metrics into account, it is likely that although O_{\max} and breakpoint were most prominently associated with follow-up drinking, there was considerable shared variance among the reinforcement measures.

An additional aspect of the associations among the measures used in the study that warrants discussion is the relationship between the demand curve reinforcement metrics and both the pre-intervention alcohol use variables and the reinforcement ratio. In reference to alcohol use variables, only intensity of demand exhibited a significant correlation with drinks/week, which may seem counterintuitive, and is, in fact, in contrast to a previous validation study of the APT where significant correlations were observed between the APT metrics and alcohol use (Murphy and MacKillop, 2006). However, because that study used a large sample with highly variable drinking habits and the current study specifically recruited participants who were heavy drinkers, it seems likely that the lack of associations may have been a result of the restricted range of alcohol consumption at baseline (all participants were in the upper 20% of the screening sample drinking distribution). In contrast, at follow-up, as a result of the differential effects of the intervention or other naturalistic influences, there was greater variability in alcohol consumption, permitting the emergence of the significant

associations. Moreover, the lack of associations between alcohol use and the demand metrics at baseline demonstrates that despite only modest associations with traditional measures of alcohol use or problems, the APT nevertheless appeared to capture unique information about the malleability of an individual's drinking.

Similarly, the demand curve indices of reinforcement were largely uncorrelated with the measure of relative substance-related behavioral allocation and enjoyment (reinforcement ratio), and predicted unique variance beyond that measure. This was important for distinguishing the incremental utility of using a demand curve approach in predicting clinical outcome beyond a previously demonstrated index of reinforcement. As noted above, the pattern of considerable variability of the associations among the demand indices and with the reinforcement ratio again supports the notion that there is no superordinate measure of drug reinforcement, but that reinforcement value or efficacy is a heterogeneous phenomenon, composed of related, but independent, elements (Bickel et al., 2000; Johnson and Bickel, 2006).

In demonstrating that facets of a demand curve predict treatment outcome, these findings have a number of clinical implications. The APT provided a quantitative index of the sensitivity of consumption to increasing costs, which may parallel or portend an important feature of substance dependence – use despite escalating consequences – and may serve as a useful complement to traditional measures of dependence or alcohol-related problems. A second advantage of the APT is that many of its indices are implicit (e.g., O_{\max} , elasticity), which may reduce the probability of self-serving response bias. As such, these indices appear to capture useful aspects of reinforcement that are not highly associated with pure quantity/frequency measures. This is exemplified by the differential associations in predicting drinks/week by intensity of demand, O_{\max} , and breakpoint when considered independently and as part of the larger model. Intensity, which was moderately correlated with drinks/week at baseline, was a significant predictor of post-intervention drinks/week independently, but had a limited incremental contribution when baseline drinks/week was included in the larger model. In contrast, O_{\max} and breakpoint were negligibly associated with drinks/week at baseline, but uniquely predicted drinking at follow-up.

One potential application of these findings is to use demand curve metrics to determine the appropriate level of intervention necessary to reduce substance use. For example, individuals with low elasticity of demand for alcohol might require more intensive interventions than individuals with highly elastic demand for alcohol. This information could be used to guide treatment assignment, especially in college and university settings where the rates of heavy drinking exceed the available treatment resources (Borsari and O'Leary Tevyaw, 2005), creating the need for additional discrimination. The APT might also be useful in titrating levels of intervention for reinforcement-based treatments. In an effort to minimize costs and disseminate contingency management interventions, recent studies have attempted to determine the differential effects of "lean" and "rich" contingency management schedules (e.g., Correia et al.,

2005; Petry et al., 2004) and the pre-intervention responses on a substance purchase task might be related to the magnitude of contingent reinforcement necessary for positive treatment effects. Alternatively, demand curve indices may be related to other parameters of contingency management (e.g., reinforcement schedule, immediacy of reinforcement; Stitzer and Petry, 2006). Each of these possibilities represent promising future applications of purchase tasks.

There are a number of limitations to this study. First, the APT was a hypothetical task and thus subject to the limitations of self report (Nisbett and Wilson, 1977; Wilson and Dunn, 2004). Although there is evidence that hypothetical purchase tasks parallel the findings of operant behavioral tasks (Jacobs and Bickel, 1999), as well as reported behavior outside of the laboratory (Murphy and MacKillop, 2006), it is nonetheless possible that the findings may have been different if alcohol demand was assessed using actual alcohol purchases and consumption. A second limitation to the study was that participants' income levels were not assessed, which might have been related to performance on the APT, or to post-intervention alcohol use. Although this issue cannot be addressed in the context of the current study, recently collected data in a similar sample of undergraduate drinkers ($n=37$) found a significant association between personal income and elasticity, but none of the other demand metrics (J. Murphy, unpublished data). Therefore, it seems unlikely that the current findings would be substantially influenced by participants' income.

Despite the preceding caveats, the current study nonetheless provides data supporting the predictive validity of experimental indices of reinforcement from alcohol in a clinical context. Several demand metrics predicted post-intervention drinking, revealing that high levels of alcohol expenditure and relative insensitivity to the escalating cost of alcohol were associated with greater alcohol use following treatment. These findings support the broad hypothesis that substance-related reinforcement is meaningfully related to treatment outcome and suggest that experimental measures of reinforcement may have clinical utility, especially in triaging individuals to different levels of care.

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