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Reliability and Validity of a Demand Curve Measure of Alcohol Reinforcement

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Recent clinical research suggests that several self-report behavioral economic measures of relative reinforcing efficacy (RRE) may show utility as indices of substance abuse problem severity. The goal of the present study was to evaluate the reliability and validity of the Alcohol Purchase Task (APT), a RRE measure that uses hypothetical choices regarding alcohol purchases at varying prices (demand curves) to generate several indices of alcohol-related reinforcement. Participants were 38 college students who reported recent alcohol consumption. Both the raw alcohol purchase/consumption values and several of the computed reinforcement parameters (intensity & O_{max}) showed good to excellent 2-week test–retest reliability. Reinforcement parameters derived from both a linear-elasticity (Hursh, Raslear, Bauman, & Black, 1989) and an exponential (Hursh & Silberberg, 2008) demand curve equation were generally less reliable, despite the fact that both equations provided a good fit to participants' reported consumption data. The APT measures of demand intensity (number of drinks consumed when price = 0), O_{max}(maximum expenditure), and elasticity (α) were correlated with weekly drinking, alcohol-related problems, and other self-report RRE measures (relative discretionary monetary expenditures toward alcohol and/or relative substance-related activity participation and enjoyment). Demand intensity was uniquely associated with problem drinking in a regression model that controlled for weekly consumption. These results provide support for the reliability and validity of the RRE indices generated with the APT.

Keywords: addiction, alcohol, behavioral economics, demand, reinforcement

Behavioral economic theories of addiction view substance dependence as an acquired state in which the relative reinforcement (i.e., utility, value) from a substance remains persistently high compared to other available options (e.g., Loewenstein, 1996; Rachlin, 1997; Vuchinich & Heather, 2003). This perspective is supported by an extensive empirical literature of both laboratory and naturalistic findings. Addictive substances act as potent reinforcers in laboratory research, but consumption is nonetheless sensitive to the presence of alternative reinforcers and the degree of effort necessary to obtain a drug (Higgins, Heil, & Plebani-Lussier, 2004; Vuchinich & Tucker, 1988). Similarly, when substance use is assessed beyond the laboratory it has been found to be inversely related to the availability of substance-free rewards (Correia, Carey, Simons, & Borsari, 2003; Murphy, Correia, & Barnett, 2007; van Etten, Higgins, Budney, & Badger, 1998), and, in clinical settings, treatments that focus on providing competing reinforcement for abstinence from substance use are highly efficacious (Petry et al., 2006).

Within this behavioral economic framework, relative reinforcing efficacy (RRE, also referred to as relative reinforcing value) is a central construct, referring to the behavior-strengthening or behavior-maintaining properties of a drug or a specific dose of a drug (Bickel, Marsch, & Carroll, 2000). In the context of empirical laboratory research, RRE can be quantified by the amount of behavior (e.g., lever presses, money, time) allocated to gain access to the substance (Higgins et al., 2004). These methods have demonstrated utility in preclinical research aimed at assessing the abuse liability of drugs or response to an experimental manipulation (Hursh & Silberberg, 2008), but have limited clinical utility because they often require multiple laboratory sessions (e.g., to assess drug consumption across a range of response costs) and can be ethically questionable in certain samples (e.g., treatment-seeking individuals) (Jacobs & Bickel, 1999). Several investigators have devel-

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oped more time- and cost-efficient measures of RRE that can be administered in clinical settings and can therefore facilitate the translational research necessary to fully evaluate the utility of behavioral economic concepts such as RRE (Jacobs & Bickel, 1999; Little & Correia, 2006; Murphy, Correia, & Barnett, 2007; Tucker, Roth, Vignolo, & Westfall, 2009; Tucker, Vuchinich, Black, & Rippins, 2006). Three general types of measures have been developed, hypothetical purchase tasks, personal expenditure allocation, and relative behavioral allocation/enjoyment. All three are derived from basic laboratory measures of RRE and measure some element of behavioral or monetary allocations to substance use. Several studies suggest that these RRE measures may assess clinically meaningful individual differences in strength of desire for substance use.

Hypothetical purchase tasks are one promising means of measuring RRE. A purchase task is a self-report measure that assesses an individual's estimated substance consumption during a specified time period (e.g., one day or evening) and across an escalating series of prices (Jacobs & Bickel, 1999; MacKillop et al., 2008; Murphy & MacKillop, 2006). For example, the initial question may assess drug or alcohol purchases at zero cost per drink, cigarette, or other substance consumption unit, with subsequent questions gradually increasing in price up to a level at which purchases (and consumption) are drastically suppressed (e.g., $9 for a standard drink). The reported purchases can then be used to generate an individual's demand curve for the substance, or a quantitative representation of their estimated consumption (and expenditures) across an array of prices. This in turn provides a number of indices of RRE including demand intensity (number of drinks consumed when price = 0), O_{max}(maximum expenditure), P_{max} (the price at which demand become elastic), breakpoint (the price which completely suppresses consumption), and elasticity (the rate of decrease in consumption as a function of price).

Jacobs and Bickel (1999) initially examined the validity of cigarette and heroin purchase tasks in a sample of nicotine- and heroin-dependent individuals and found that as price increased, self-reported consumption decreased, that the associated expenditure exhibited the characteristic inverted U-shaped curve, and that the data conformed with a quantitative model (Hursh et al., 1989) used in previous drug administration studies that examined RRE via observable behavior. More recently, Murphy and MacKillop (2006) validated an alcohol purchase task (APT) in a large sample of drinkers recruited from a college population, similarly finding that self-reported consumption decreased as a function of increasing price, that expenditure exhibited an inverted U-shaped curve, and that the Hursh et al. (1989) equation accounted for over 90% of the variance in the demand curve. MacKillop and Murphy (2007) found that several demand curve RRE indices predicted drinking reductions following a brief intervention in heavy drinking college students. In particular, participants with greater baseline (pretreatment) O_{max} and breakpoint values reported greater drinking at follow-up even in models that controlled for baseline drinking. These initial studies suggest that purchase tasks may be both time- and cost-efficient methods for assessing RRE, and that they may have clinical utility as an index of strength of desire for substances that is not redundant with simple reports of typical consumption (Murphy et al., 2007; Tucker et al., 2006).

However, as with any novel assessment measure, the use of purchase tasks for assessing indices of RRE as clinically relevant individual difference variables requires a thorough evaluation of the reliability and validity of the measure. Purchase tasks have been used previously to assess consumption over a typical day (Jacobs & Bickel, 1999; Murphy & MacKillop, 2006), with the implicit assumption that the measure is gauging fairly stable individual differences in RRE. In the current study, the test–retest reliability of an APT was empirically assessed over a 2-week period to examine this assumption. We predicted that the demand curve RRE indices derived from the APT reflect fairly stable levels of preference for alcohol and would therefore exhibit high test–retest reliability.

In addition to the reliability analysis, we sought to further evaluate the convergent validity of the APT measures of RRE by determining the extent to which they are related to two other RRE indices that have recently been shown to predict changes in alcohol use over time (Murphy, Correia, Colby, & Vuchinich, 2005; Tucker, Vuchinich, & Rippins, 2002; Tucker et al., 2006). In two studies of natural recovery from alcohol dependence, Tucker et al. (2002, 2006) assessed the proportion of discretionary income allocated to alcohol (relative to savings) in alcohol-dependent individuals prior to a quit attempt and found that greater proportional allocation (putatively reflecting greater relative reinforcement) predicted relapse, even though relapsers and nonrelapsers 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 that was derived from Herrnstein's (1970) Matching Law incrementally predicted postintervention drinking following a single-session intervention for college drinkers. Drinkers with greater proportional activity participation and enjoyment related to substance use reported greater follow-up drinking, even in models that controlled for baseline drinking levels. Thus, all three general categories of naturalistic RRE indices—hypothetical purchase tasks, personal expenditure allocation, and relative behavioral allocation/enjoyment—have demonstrated initial clinical utility. Although RRE appears to be a heterogeneous construct (Bickel et al., 2000), with related but nonetheless distinct facets (Mackillop et al., 2009), it was hypothesized that the APT measures of RRE would exhibit convergent validity via significant associations with other RRE indices. It was further hypothesized that greater alcohol RRE would be associated with greater levels of alcohol use and problems. A final goal of this study was to compare the goodness of fit and reliability of the original Hursh et al. (1989) linear-elasticity demand curve equation and the exponential demand curve equation more recently developed by Hursh and Silberberg (2008). The equations make similar predictions regarding the impact of price on consumption but the exponential equation has the advantage of generating a single elasticity parameter (α) which is standardized and independent of reinforcer magnitude.

Method

Procedures

All procedures were approved by each university's institutional review board, and all participants provided informed consent prior to participating in the study. Participants were 38 undergraduate students (50% female; 84% Caucasian, Mean age = 19.92, *SD* = 1.68, range = 18–26) recruited via newspaper advertisements from several colleges and universities in a city in the northeastern United States. Participants were part of a larger study examining the relations between behavioral economic variables and substance abuse and were eligible to participate if they reported past-month heavy drinking or drug use. All participants reported past-month alcohol consumption. Individual assessment sessions took place in private rooms in the campus library or student center. A randomly selected subset of 17 participants completed a second APT administration exactly 14 days after the initial assessment. Participants received $40 for completing the initial assessment session and $20 for completing the reliability assessment.

Participants

Participants averaged 12.55 (*SD* = 10.82, range = 1–42) drinks per week. Most participants (92%) reported one or more past month heavy drinking episode (5/4 drinks in an occasion for men/women; *M* = 5.81 past month episodes, *SD* = 5.5). Participants reported an average of 8.97 (*SD* = 4.91) past year alcohol-related problems including drinking and driving, missing class or work due to drinking/hangovers, and experiencing a blackout (reported by 45%, 42%, and 63% of the sample, respectively). Although participants were not seeking treatment and did not complete formal diagnostic interviews, their drinking patterns were generally consistent with an alcohol abuse diagnosis. A little more than half of participants (55.3%) also reported past-year illicit drug use. Participants were all full-time students of varied class standings (23.7% Freshman, 34.2% Sophomores, 28.9% Juniors and 13.2% Seniors).

Measures

Alcohol consumption and expenditures. Alcohol use was measured with a 28-day Timeline Followback interview (TLFB), a widely used and reliable measure of alcohol use (Sobell & Sobell, 1995). For each day, the number of standard drinks and any drug and alcohol-related expenditures were recorded. These data were used to generate measures of average drinks per week and past-month drug and alcohol-related expenditures (Tucker et al., 2006).

Alcohol-related problems. The Young Adult Alcohol Problems Screening Test (YAAPST; Hurlbut & Sher, 1992) is a 37-item measure that assesses frequency of alcohol problems over the past year. The YAAPST was developed for use with college students and has demonstrated strong internal consistency (Hurlbut & Sher, 1992). For the purposes of this study, each item was dichotomized (0 = did not happen, 1 = happened), and items were summed to derive a total score for past-year alcohol problems.

RRE Indices

Hypothetical alcohol purchases. The APT presents a hypothetical party scenario and asks participants how many drinks they would purchase and consume at 14 different prices (Murphy & MacKillop, 2006). The APT includes the following instructions:

In the questionnaire that follows we would like you to pretend to purchase and consume alcohol. Imagine that you and your friends are at a party on a weekend night from 9:00 p.m. until 2:00 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 domestic beers (12 oz.), wine (5 oz.), shots of hard liquor (1.5 oz.), or mixed drinks containing one shot of liquor. Assume that you did not drink alcohol or use drugs before you went to the party, and that you will not drink or use drugs after leaving the party. You cannot bring your own alcohol or drugs to the party. Also, assume that the alcohol you are about to purchase is for your consumption only. In other words, you can't sell the drinks or give them to anyone else. You also can't bring the drinks home. Everything you buy is, therefore, for your own personal use within the 5 hour period that you are at the party. Please respond to these questions honestly, as if you were actually in this situation.

Participants were then asked, "How many drinks would you consume if they were ___ each?" at 14 prices ranging from $0 (free) to $3.00 increasing by 50-cent increments, and $3.00 to $9.00 increasing by $1.00 increments.

Reported consumption is then plotted as a function of price; expenditures at each price are computed by multiplying reported consumption by price. The resulting demand and expenditure curves yield several RRE indices which can be observed directly from the consumption or expenditure data (referred to as observed RRE parameters), including consumption when drinks are free (intensity of demand), maximum alcohol expenditure (O_{max}), the price at which demand becomes elastic (P_{max}, which is also the price associated with O_{max}), and the first price at which consumption is completely suppressed (breakpoint). Participants who reported that they would drink at the highest price increment were assigned a breakpoint at the highest price ($9).

In addition to observing the aforementioned RRE indices from the raw alcohol consumption and expenditure data, demand curves were fit to the alcohol consumption responses for each participant using two nonlinear regression equations. These equations can generate estimates of elasticity of demand, which cannot be observed from raw data, as well as estimates of intensity, O_{max} and P_{max} (referred to as derived RRE parameters). Equation 1 (Hursh et al., 1989) is a linear-elasticity equation which has been widely used in both laboratory research and several previous simulated demand curve studies. Equation 2 is an exponential equation first described by Hursh and Silberberg (2008). We fit both equations in order to compare them on goodness of fit (R^2) and the reliability of their respective RRE parameters.

In Equation 1: $\ln C = \ln L + b (\ln P) - aP$, C is consumption at unit price of P, L is consumption at $p = 0$, and a and b represent the regression slope and the acceleration, respectively. The logarithmic transformation of price and consumption is conventional in economics for scalar equivalence. Consistent with Jacobs and Bickel (1999), when fitting the data to Equation 1, zero values were replaced by an arbitrarily low but nonzero value of .01, which is necessary for the logarithmic transformations. Intensity was defined as the empirically generated price intercept, L. P_{max} was determined using the a and b parameters of Equation 1: $P_{max} = (1 + b)/a$. O_{max} was calculated by multiplying P_{max} 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: $e = b - aP$. Overall elasticity of demand across the curve was defined as the mean of the individual price elasticities (Jacobs & Bickel, 1999), with greater negative values reflecting greater price sensitivity (elasticity).

In Equation 2: $\ln Q{:} = \ln Q_{max} + k\,(e^{-\alpha P} - 1)$, Q is the quantity consumed, k specifies the range of the dependent variable (alcohol consumption) in natural logarithmic units, and α specifies the rate of change in consumption with changes in price (elasticity). The value of k (3.8 in the present study) is constant across all curve fits. Individual differences in elasticity are thereby scaled with a single parameter (α) which is standardized and independent of reinforcer magnitude. Larger α values reflect greater price sensitivity (elasticity). Demand curves were fit according to the Hursh and Silberberg (2008) guidelines using the calculator provided on the Institute for Behavioral Resources website (www.ibrinc.org/ibr/centers/bec/BEC_demand.html). Intensity was defined as the empirically generated price intercept Q_{max} O_{max} was defined as the predicted maximum expenditure generated from Equation 2 and P_{max} was the price associated with O_{max}.

Relative Behavioral Allocation and Enjoyment

The Adolescent Reinforcement Survey Schedule-Substance Use Version (ARSS-SUV; Murphy et al., 2005) provides a measure of past-month activity participation and enjoyment related to substance-related and substance-free activities. Participants were provided with a list of 54 activities and instructed to rate the frequency of participation and enjoyment associated with each of these activities during the previous 30 days. Frequency ratings ranged from 0 (0 times in the past 30 days) to 4 (more than once a day). Enjoyment ratings range from 0 (unpleasant or neutral) to 4 (extremely pleasant). Participants completed all items twice; once for activities that took place when they were using alcohol or drugs and once for substance-free activities. Cross-product scores (range 0–16), reflecting reinforcement derived from these activities, were obtained by multiplying frequency and enjoyment ratings separately for substance-free and substance-related activities (Correia & Carey, 1999). The RRE index, derived from Herrnstein's (1970) matching law, is a ratio obtained by dividing the total substance-related reinforcement by the sum of the total substance-related and substance-free reinforcement scores. Larger values reflect greater proportional reinforcement derived from substance-related activities (greater RRE). Previous research has indicated that reinforcement surveys provide reliable estimates of participation in rewarding activities and have been shown to be consistent with observer reports and subsequent behavior choice (MacPhillamy & Lewinsohn, 1982).

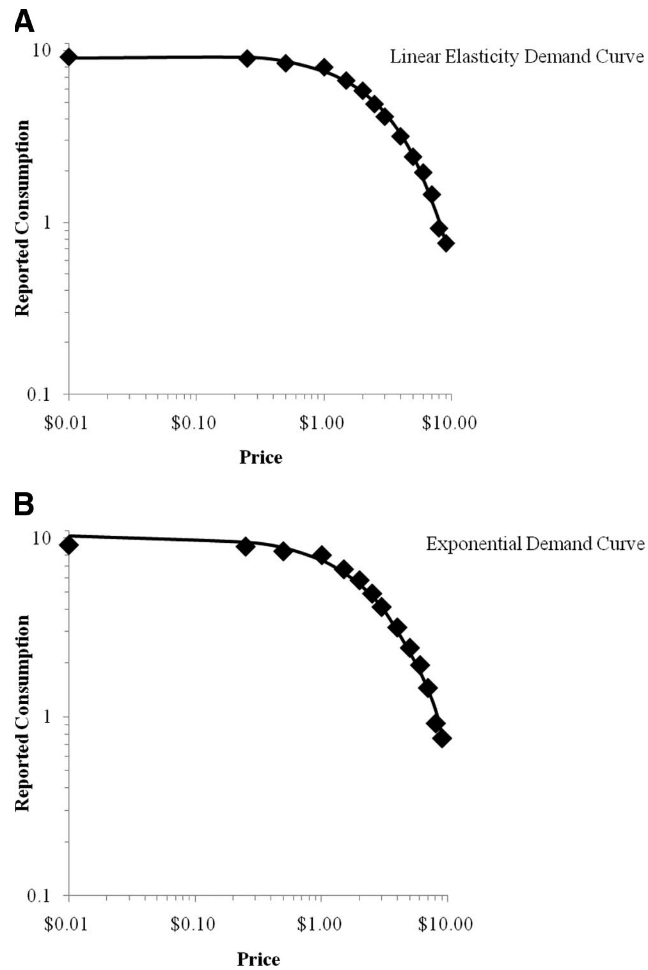

Figure 1. Mean alcohol demand curves for all 38 participants at Time 1. Mean consumption values are represented with diamonds. Predicted consumption values generated by the Linear-Elasticity (Equation 1, Panel A) and Exponential (Equation 2, Panel B) equations are represented as lines. Both equations provided an excellent fit to the aggregate date (R^2s = .997 and .992, respectively). Data are provided in conventional log—log units for proportionality. Zero price and consumption are replaced by 0.01 to permit logarithmic units.

Relative Discretionary Expenditures on Substance Use

The discretionary expenditure measure developed by Tucker and colleagues (2002, 2006) was based on proportional discretionary expenditures allocated to alcohol relative to savings in samples of middle class adults. However, because our participants were college students, who typically have income levels that preclude substantial savings, our discretionary expenditure index was calculated by dividing past-month drug and alcohol expenditures (collected during the TLFB interview) by past-month discretionary income estimates. Larger values reflected greater proportional discretionary expenditures toward substance use and greater RRE. Discretionary income was measured with an item which asked students to estimate the amount of money available to spend for nonessential items (e.g., clothing, CDs, entertainment, alcohol, eating in restaurants, going to the movies, etc.), excluding money budgeted for essentials, such as rent, school books, gasoline, utility bills, and groceries in the past month.

Results

Distributional Properties and Demand Curve Model Accuracy

Alcohol consumption exhibited a decelerating trend in response to price increases and both the Hursh et al. (1989) linear-elasticity and the Hursh and Silberberg (2008) exponential equations provided a good fit to individual participant responses ($N = 38$, mean $R^2 = .85$, median $R^2 = .86$, range = .70–.99 and mean $R^2 = .82$, median = .86, range = .56–.99, respectively) and an excellent fit to the aggregate data (R^2s = .997 and .992, respectively). Figure 1 shows the mean consumption levels and model fits for Equations 1 and 2 for all 38 participants who completed the

Table 1
Two-Week Test–Retest Means and Reliability Coefficients for the Alcohol Purchase Task

	Consumption values on the alcohol purchase task					
	Time 1		Time 2			
	Mean	*SD*	Mean	*SD*	Pearson's *r*	*t*-test result
Free	7.53	3.86	7.82	4.99	.89***	NS
$.25	7.41	3.91	7.65	4.97	.89***	NS
$.50	6.76	3.90	7.53	5.00	.91***	NS
$1.00	6.41	4.05	6.41	4.12	.90***	NS
$1.50	5.82	4.23	5.47	4.03	.91***	NS
$2.00	5.00	3.28	4.59	3.76	.88***	NS
$2.50	4.00	3.45	4.12	3.92	.79***	NS
$3.00	3.24	2.82	3.24	2.99	.85***	NS
$4.00	2.65	2.60	2.71	2.76	.84***	NS
$5.00	2.00	2.18	1.88	2.18	.87***	NS
$6.00	1.76	2.14	1.41	1.73	.84***	NS
$7.00	1.18	1.63	.82	1.55	.83***	NS
$8.00	.69	1.08	.65	1.32	.76***	NS
$9.00	.56	.96	.59	1.28	.71**	NS
	RRE indices generated from the alcohol purchase task					
	Mean	*SD*	Mean	*SD*	Pearson's *r*	*t*-test result
	Observed parameters					
Intensity	7.53	3.86	7.82	4.99	.89***	NS
P_{max}	4.26	2.01	3.71	1.84	.67**	NS
O_{max}	13.79	11.67	13.09	10.59	.90***	NS
Breakpoint	7.09	2.03	6.44	2.34	.81***	NS
	Parameters derived from Hursh et al. (1988) equation					
Intensity	13.78	7.62	14.87	12.06	.64**	NS
Elasticity	−.85	.42	−.94	.43	.68**	NS
P_{max}	5.62	4.13	5.19	3.88	.58*	NS
O_{max}	9.28	12.13	8.88	11.75	.64**	NS
	Parameters derived from Hursh & Silberberg (2008) equation					
Intensity	15.98	8.80	13.60	5.25	.64**	NS
Elasticity	.008	.006	.01	.008	.75**	NS
P_{max}	2.93	3.15	2.09	1.93	.66**	NS
O_{max}	12.12	12.29	9.11	10.50	.84**	NS

Note. $N = 17$. NS = not significant at $p < .05$.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$ (two tailed tests).

initial baseline assessment. Although there is no accepted criterion for adequacy of demand curve fit (cf. Johnson & Bickel, 2008), the model provided a good fit for all participants using a criterion that Reynolds and Schiffbauer (2004) suggested for curve fits obtained in a delayed reward discounting task ($R^2 \geq .30$). The distributional proprieties of the RRE and drinking indices were evaluated for normality prior to data analysis. The derived intensity and elasticity parameters (from Equation 1 and 2) and the discretionary expenditure indices were square root transformed to correct for positive skewness and kurtosis; no other variables required transformation.

Alcohol Purchase Task Reliability Analysis

Raw consumption values. Table 1 shows mean reported APT consumption values across the two administrations, paired sample *t* test results, and Pearson correlations for the 17 participants who completed the retest administration. Mean reported consumptions and expenditure values across the 14 drink prices are plotted in Figure 2; there were no significant differences in group level consumption means across the two administrations (see Table 1). Consumption values across the two administrations were highly correlated (Pearson's *r* values ranged from .71–.91, M = .85, all $ps < .002$). The highest prices ($8 and $9) had the lowest reliability coefficients (*r*s = .76 and .71, respectively).

RRE parameters. There were no significant differences in group levels RRE index means across the two administrations (see Table 1). Observed intensity of demand and O_{max} were the most reliable RRE indices (*r*s = .89 and .90, respectively). Observed breakpoint and the elasticity and O_{max} parameters derived from Equation 2 showed acceptable reliability (*r*s = .81, .75, and .84, respectively). P_{max} observed, all of the indices derived from Equation 1, and the intensity and P_{max} indices derived from Equation 2 were less reliable (*r*s = .58–.68).

Relations Among RRE Indices

We conducted a series of correlations to assess the relations among the various RRE indices among all 38 participants who completed the baseline assessment. To minimize the number of correlations, and because of the reliability outcomes, we included APT observed rather than derived parameters in these analyses. Elasticity cannot be observed so we included the more reliable elasticity parameter derived from Equation 2. The ARSS relative behavioral allocation index, TLFB discretionary expenditures index, APT O_{max} and APT intensity indices were all correlated (see Table 2). Elasticity was correlated with the TLFB discretionary expenditures index and with all of the other APT indices. The APT breakpoint, and P_{max} indices were correlated with each other and with elasticity but not with the other RRE indices.

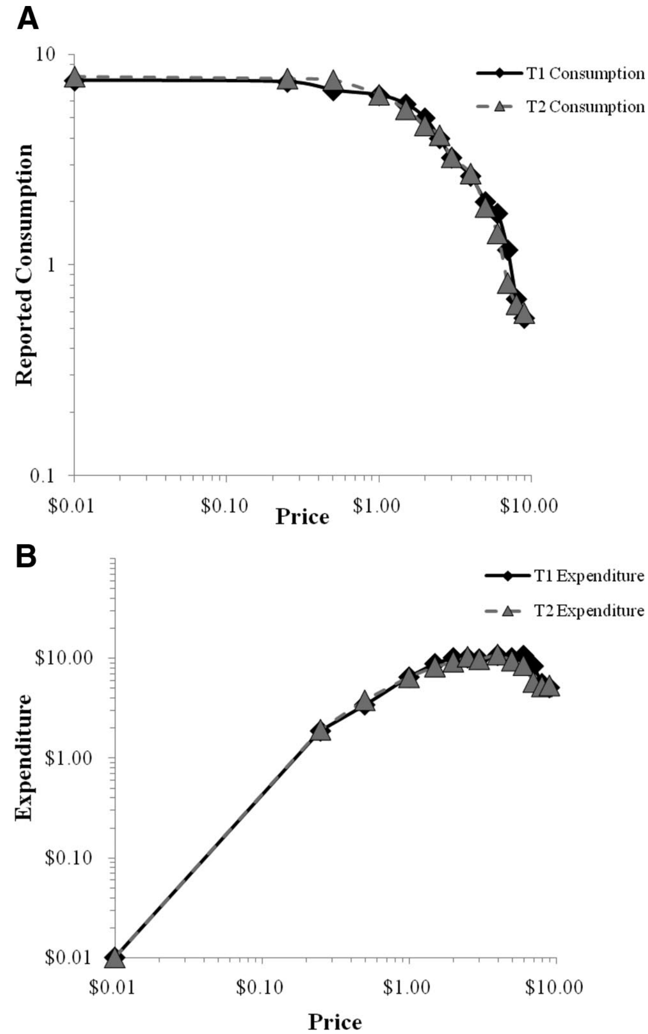

Figure 2. Mean alcohol demand and expenditure curves for Time 1 and Time 2 Alcohol Purchase Task administrations (N = 17). The retest period was exactly 2 weeks. Panel A provides alcohol demand and Panel B provides associated expenditure (reported consumption × price). Data are provided in conventional log—log units for proportionality. Zero price and consumption are replaced by 0.01 to permit logarithmic units. There were no significant differences between mean consumption values across the two administrations for any of the 14 drink prices (see Table 1 for *t* test results).

Relations Among RRE Indices and Drinking Measures

The ARSS relative behavioral allocation index, TLFB discretionary expenditures index, APT O_{max} APT elasticity, and APT intensity indices were significantly correlated with weekly drinking (see Table 2)[1]. The ARSS and APT O_{max} elasticity, and intensity indices were correlated with alcohol-related problems. In hierarchical regression models that

[1] The elasticity parameter derived from the Hursh et al. (1989) linear-elasticity equation was not correlated with any drinking measures or with the ARSS or discretionary expenditure RRE measures.

Table 2
Relations Among RRE and Drinking Measures

Measure	Drinks per week	Alcohol problems	ARSS-RR	Discretionary expenditures	Intensity	O_{max}	Elasticity	Breakpoint	P_{max}
Drinks per week	—	$.60^{**}$	$.43^{**}$	$.46^{**}$	$.72^{**}$	$.56^{**}$	$-.46^{**}$	.14	−.07
Alcohol Problems		—	$.31^{\dagger}$	.16	$.63^{**}$	$.46^{**}$	$-.32^{*}$	.03	.16
ARSS-RR			—	$.32^{\dagger}$	$.34^{*}$	.27	−.16	−.06	−.20
Discretionary Expenditures				—	$.43^{**}$	$.45^{**}$	$-.44^{**}$	.25	.05
Intensity					—	$.66^{**}$	$-.61^{**}$	.21	−.01
O_{max}						—	$-.84^{**}$	$.58^{**}$	$.43^{**}$
Elasticity							—	$-.81^{**}$	$-.56^{**}$
Breakpoint								—	$.75^{**}$
P_{max}									—

Note. $N = 38$.
† $p < .07$ (two tailed tests). * $p < .05$. ** $p < .01$.

controlled for weekly drinking,[2] only APT intensity was uniquely associated with levels of alcohol problems ($\beta = .44$; $\Delta R^2 = .10$; $t = 2.37$, $p < .03$) (see Table 3). Participants with greater intensity of demand for alcohol reported more alcohol problems, even after taking into account their level of drinking.

Discussion

The present results contribute to a growing literature supporting the reliability and validity of the APT as a self-report behavioral economic measure of the RRE of alcohol. Reported alcohol consumption on the APT conformed to quantitative models that have accurately described drug reinforced responding and consumption in laboratory research (Hursh & Silberberg, 2008). Consumption was high at low prices and decreased steadily as price increased. Both the linear-elasticity and the exponential demand curve equations provided good fits to participant data. Both the raw data associated with the APT (participants' hypothetical alcohol purchases across 14 drink prices) and two of the RRE parameters derived from the APT (intensity and O_{max}) were highly reliable over a 2-week period. The RRE indices derived from the demand curve equations were generally less reliable, although the exponential elasticity and O_{max} RRE indices showed acceptable reliability.

More generally, these results provide support for the application of the behavioral economic construct of RRE—measured using approaches derived from basic laboratory research—to the analyses of human substance abuse. Previous research suggests that the three general categories of RRE indices (hypothetical purchase tasks, personal expenditure allocation, and relative behavioral allocation/enjoyment) examined in the present study predict changes in drinking over time (MacKillop & Murphy, 2007; Murphy et al., 2005; Tucker et al., 2002; 2006; 2009). The current results suggest that these RRE indices are related, but not redundant, and may thus provide unique information on the potency or persistence of drug reinforcement. Not surprisingly, the APT indices were generally highly correlated, with the strongest associations between the measures that all reflect the price sensitivity of consumption (O_{max}, elasticity, P_{max}, and breakpoint) (MacKillop et al., 2009). However, the fact that the RRE measures of intensity and O_{max}, derived from a hypothetical purchase task, were significantly correlated with the RRE indices derived from two very distinct measures (actual past-month proportional discretionary expenditures toward substance use and relative substance-related behavioral allocation/enjoyment) is consistent with the idea that RRE is a heterogeneous yet meaningful construct related to the reinforcing value of substance use (Bickel et al., 2000).

The APT reflects level of consumption or resource allocation toward alcohol (akin to a single reinforcer lab paradigm), while the relative substance-related behavioral allocation/enjoyment and discretionary expenditure measures reflect the comparative value of alcohol versus other activities (akin to a choice based lab paradigm). Several of the RRE indices (discretionary expenditure and relative substance-related behavioral allocation/enjoyment, elasticity, intensity, O_{max}) were significantly associated with levels of drinking and or alcohol problems; this is consistent with the behavioral economic hypothesis that greater RRE (measured using three distinct approaches) predicts greater substance use and problems (Vuchinich & Heather, 2003). In regression models that controlled for weekly drinking levels, intensity predicted levels of problems. Perhaps individuals with high demand for alcohol tend to drink, in spite of experiencing consequences which would typically serve to limit drinking. This may portent an escalating pattern of drinking consistent with alcohol dependence. However, these regression analyses were somewhat underpowered and should be interpreted cautiously and do not suggest that intensity is necessary the most important RRE index, especially in light of the fact that previous research suggests that all of the RRE indices *except intensity* have predicted changes in drinking over time (MacKillop & Murphy, 2007; Murphy et al., 2005; Tucker et al., 2006). Thus, although there have only been a few naturalistic studies of RRE, and there is clearly a need for continued research to investigate the potentially unique utility of the various RRE indices in

[2] We tested alternate regression models that included income and gender but these covariates did not change the results.

Table 3
RRE Indices as Predictors of Alcohol-Related Consequences[1]

	B	*SE*	β	*t*	ΔR^2
ARSS-RR	3.16	6.46	.08	.49	.01
Discretionary income percentage	−1.92	2.01	−.15	−.96	.02
Demand intensity	2.79	1.18	.44	2.37*	.10
O_{max}	.07	.06	.17	1.07	.02
Elasticity	−7.88	21.85	−.06	−.36	.01
Breakpoint	−.12	.30	−.05	−.39	.01
P_{max}	−.27	.30	−.12	−.89	.01

Note. $N = 38$.
[1] Each regression model included weekly drinking as a covariate.
* $p < .05$ (two-tailed tests).

predicting various clinically relevant elements of substance abuse, the extant literature provides initial support for the construct validity, clinical utility, and reliability of RRE as an individual difference measure of strength of preference for alcohol. Although our results support Hursh and Silberberg's (2008) proposal that elasticity provides an important index of the essential value of a drug, these results do not support the *superiority* of elasticity relative to the other RRE indices.

The present study is the first to evaluate the reliability of the APT, a novel behavioral economic index of RRE that has previously demonstrated clinical utility in predicting response to intervention. This is also the first study to evaluate the task relative to three other commonly used naturalistic RRE indices. Taken together, the current study supports the validity of the APT, both in terms of its reliability and its relationship to alcohol use and problems and other RRE indices. Simulation measures such as the APT are useful for translating constructs that form the basis for compelling theoretical and laboratory models of excessive substance use into variables that can be measured in the natural environment (Bickel et al., 2000). Despite these strengths, the present study also has several weaknesses including a relatively small sample size and a short retest period. Future research should evaluate the stability of the APT over longer timeframes and with clinical samples (e.g., individuals seeking treatment for drug or alcohol dependence). In addition, these findings should not be overinterpreted to suggest that the RRE of alcohol as measured this way is immutable. Rather, the current results suggest that performance on the APT was generally reliable when assessed under neutral conditions with no known intervening changes or manipulations. Clinical interventions or laboratory manipulations such as alcohol administrations would in fact be hypothesized to change the RRE of alcohol (MacKillop & Murphy, 2007).

This study was also limited by the substance use criterion measures—alcohol use and problems. Although these are widely used to gauge alcohol problem severity they may not measure other clinical phenomenon that might be more closely related to the RRE construct (e.g., strength of desire for alcohol as measured by persistence of drinking despite treatment or increasing personal, health, or financial costs). Future research should continue to investigate the clinical utility of these RRE indices.

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