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Further examination of the temporal stability of alcohol demand☆

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ABSTRACT

Demand, or the amount of a substance consumed as a function of price, is a central dependent measure in behavioral economic research and represents the relative valuation of a substance. Although demand is often utilized as an index of substance use severity and is assumed to be relatively stable, recent experimental and clinical research has identified conditions in which demand can be manipulated, such as through craving and stress inductions, and treatment. Our study examines the 1-month reliability of the alcohol purchase task in a sample of heavy drinking college students. We also analyzed reliability in subgroup of individuals whose consumption decreased, increased, or stayed the same over the 1-month period, and in individuals with moderate/severe Alcohol Use Disorder (AUD) vs. those with no/mild AUD. Reliability was moderate in the full sample, high in the group with stable consumption, and did not differ appreciably between AUD groups. Observed indices and indices derived from an exponentiated equation (Koffarnus et al., 2015) were generally comparable, although P_{max} observed had very low reliability. Area under the curve, O_{max} derived, and essential value showed the greatest reliability in the full sample (rs = 0.75–0.77). These results provide evidence for the relative stability over time of demand and across AUD groups, particularly in those whose consumption remains stable.

1. Introduction

Behavioral economics frames substance misuse as behavioral choices made in the context of environmental constraints (Bickel et al., 1995). A demand curve analysis plots consumption of a given drug across a range of prices and is a central dependent measure in behavioral economic research. Demand curves prototypically exhibit steady consumption at low prices with decreasing levels of consumption as price increases (Lhachimi et al., 2012; Mackillop et al., 2012b; Skidmore and Murphy, 2011; Wagenaar et al., 2009). Further, demand curves produce multifaceted information about the reinforcing properties of a substance which are theorized to characterize degree of motivation to consume a substance (Bickel et al., 2000). Psychopharmacology researchers initially used demand curve analyses to examine differences in abuse liability across various drugs as well as the impact of environmental manipulations on drug demand (Hursh et al., 2005; Hursh and Winger, 1995; Ko et al., 2002), and more recently human researchers have used demand curves to measure individual differences in drug reward valuation (Murphy and MacKillop, 2006).

1.1. Hypothetical purchase tasks

Human substance demand studies in laboratories are often time-consuming and costly, and ethical guidelines prohibit the examination of high consumption amounts. Consequently, researchers have developed hypothetical purchase tasks (HPTs) to assess reported demand for alcohol (MacKillop et al., 2010a; Murphy and MacKillop, 2006; Skidmore and Murphy, 2011), marijuana (Aston et al., 2016, 2015; Collins et al., 2014; Metrik et al., 2016), cigarettes (Field et al., 2006; Mackillop et al., 2012b; MacKillop and Tidey, 2011), prescription drugs (Pickover et al., 2016), and other illicit drugs (Jacobs and Bickel, 1999) in situations where it would be impractical to estimate demand based on actual laboratory drug consumption/purchases. Individuals are asked how much of a given substance they would purchase and consume across a series of escalating prices, and consumption is plotted as a function of price to create a demand curve. The measure produces nine values found using two approaches: four that can be observed directly from plotting consumption and expenditure values (intensity, breakpoint, O_{max}-observed, P_{max}-observed; Murphy and MacKillop, 2006), and five that are derived from regression equations that model consumption as a function of price (elasticity, Q_0, P_{max}-derived, and O_{max}-derived, and essential value). Intensity refers to consumption

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when cost is zero; Q_0 is intensity derived. Breakpoint refers to the price when consumption reaches zero. O_{max} is the maximum expenditure, or the highest amount spent on the reinforcer, and P_{max} is the price at which O_{max} is reached. Both P_{max} and O_{max} are found using the observed and derived methods. Elasticity refers to the sensitivity of demand to changes in price, and was traditionally derived using an exponential equation described by Hursh and Silberberg (2008). This equation has recently been modified to allow for the inclusion of zero into the curve fits by raising both sides to the power of 10 (Koffarnus et al., 2015):

$$Q = Q_0 * 10^{k\ (e\ -\alpha P - 1)} \tag{1}$$

Where Q = quantity consumed, k = the range of the dependent variable (standard drinks) in logarithmic units, P = price, and α = elasticity of demand. O_{max}-derived is the predicted maximum expenditure from the equation and P_{max}-derived is the price associated with O_{max}. The new equation avoids poor model fits due to exclusion of zeros in the equation (Yu et al., 2014). Area under the curve (AUC) refers to individual's total reported consumption across all prices (Amlung et al., 2015), represented by the total amount of geometric area under the demand curve. AUC may be statistically redundant with O_{max} (r = 0.92; Amlung et al., 2015). AUC is calculated by drawing lines from each data point on the curve to the x-axis, creating a series of trapezoids. Each trapezoid can be represented by the following equation:

$$(\chi^2 - x^1)\ [(y^1 + y^2)/2] \tag{2}$$

Where x^1 and χ^2 are successive prices, and y^1 and y^2 are the respective consumption values of the prices (Amlung et al., 2015). While other indices of demand provide partial information about the construct, AUC may provide a global picture of demand since it encompasses much of each metric in the final outcome (Amlung et al., 2015). AUC is different from elasticity in that it accounts for both the slope at which price decreases and the intercept at which it begins, while elasticity only represents the slope. Similarly, essential value (EV) represents a global index of valuation, is inversely proportional to elasticity (α), and accounts for k to allow for comparison between studies (Hursh, 2014). EV is calculated using the following formula:

$$\text{EV} = 1/(100 \times \alpha \times \text{k}^{1.5}) \tag{3}$$

Where α = elasticity of demand and k = range of possible consumption (Hursh, 2014). Factor analytic studies have revealed that the HPT metrics correspond to two heterogeneous aspects of demand – amplitude and persistence (MacKillop et al., 2009; Skidmore et al., 2014) – which may be equally important in understanding the valuation of a substance. Intensity and O_{max} form a factor labeled amplitude – the amount consumed and spent – and elasticity, breakpoint, O_{max} and P_{max} form a factor labeled persistence – sensitivity of consumption to changing price. Demand estimates generated from HPTs correlate highly with *in vivo* purchase tasks (Amlung and MacKillop, 2015; Amlung et al., 2012), suggesting strong validity for the self-report task.

1.2. Demand as an index of substance problem severity

The introduction of the HPT allowed investigators to examine how individual differences in demand predict future consumption, response to treatment or other manipulations, and substance use severity. For example, multiple studies have observed associations between demand metrics and alcohol use, with intensity and O_{max} demonstrating the most robust associations (Bertholet et al., 2015; Skidmore et al., 2014). In addition to consistent relations with consumption, elevated demand has exhibited relationships with problematic alcohol use (Bertholet et al., 2015; Skidmore et al., 2014). In a sample of 267 college students, Murphy and MacKillop (2006) found that heavy drinkers had significantly higher levels of intensity, breakpoint and O_{max} than light drinkers. Murphy et al. (2009) extended these findings by demonstrating that intensity predicted alcohol problems after controlling for consumption, suggesting that elevated demand may function as an unique index of severity; AUC was also uniquely predictive of alcohol problems in a sample of heavy drinking college students (Amlung et al., 2015). Elevated demand is also associated with alcohol use disorder (Bertholet et al., 2015; MacKillop et al., 2010a), and demand predicts brief alcohol intervention outcomes (MacKillop and Murphy, 2007). Similarly, elevated demand has been related to problematic use of cigarettes, marijuana, prescription opiates, and cocaine as well (Aston et al., 2016, 2015; Bruner and Johnson, 2014; Chase et al., 2013; Collins et al., 2014; Pickover et al., 2016; Vincent et al., 2016).

1.3. Stability of demand

Despite the strong empirical evidence linking alcohol demand to alcohol misuse, further research is required to increase understanding of the construct as an individual difference measure, and in particular its relative degree of stability versus malleability. Surprisingly, questions about the stability of demand still exist. Although demand has demonstrated stability over short periods of time (1–2 weeks; Few et al., 2012; Murphy et al., 2009) and is frequently used as an individual difference variable, other studies indicate that demand can be manipulated in a number of different conditions. Understanding the conditions in which demand is relatively stable versus those in which it fluctuates is important to enhancing its theoretical and clinical utility.

Two reliability studies of HPTs have demonstrated strong stability over short time periods. Murphy et al. (2009) found good to excellent test-retest reliability for several indices of demand over a two-week period in a sample of 38 college student drinkers. Specifically, observed indices of intensity and O_{max}-observed were very stable (rs = 0.89 and 0.90, respectively), breakpoint and elasticity (derived from Hursh and Silberberg, 2008) were also stable (rs = 0.81 & 0.75), and P_{max}-observed was slightly less stable (r = 0.67). In the same study, the test-retest reliability of the derived values of intensity (Q_0), O_{max}, and P_{max} (rs = 0.64–0.84) were lower than the observed (rs = 0.67–0.90). Similar patterns emerged when testing the reliability of a cigarette purchase task. Evaluated over a one-week period, correlation coefficients obtained from a sample of 11 smokers recruited from the community were of a higher magnitude; intensity and O_{max}-observed still exhibited the strongest reliability, followed by elasticity and breakpoint (rs = 0.99, 0.95, 0.88, and 0.76; Few et al., 2012). Derived intensity, O_{max}, and P_{max} were not evaluated in this study (Fig. 1 and 2).

The greater reliability of the amplitude indices – intensity and O_{max}-observed – suggests stronger stability for that factor, although composite scores of indices have not been directly examined. Both studies only included relatively small sample sizes (i.e., 38 and 11), and temporal stability has only been examined to two weeks. Further, more severe clinical samples may demonstrate different reliability coefficients for demand (Murphy et al., 2009). Individuals with more severe levels of alcohol use may report higher, more consistent levels of motivation for alcohol, in part due to internal motives, and thus less malleable demand. In contrast, the stability of alcohol demand for lighter drinkers may be more contingent upon environmental changes.

Despite strong reliability evidence in the above studies, behavioral economics posits that changes in one's environment could influence demand for alcohol. For example, craving, which can be understood as an acute increase in an individual's valuation of a drug (Loewenstein, 1999), increases demand for alcohol (MacKillop et al., 2010a,b) and other drugs (Acker and MacKillop, 2013; Mackillop et al., 2012a), suggesting that it is sensitive to dynamic state changes in desire to drink associated with craving. Research has also documented the influence of stress on demand, such that stress inductions cause increases in the valuation of alcohol (Amlung and MacKillop, 2014; Owens et al., 2015; Rousseau et al., 2011), consistent with research examining the robust association between alcohol-related problems and stress (Tripp et al.,