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Abstract

The use of drug purchase tasks to measure drug demand in human behavioral pharmacology and addiction research has proliferated in recent years. Few studies have systematically evaluated the stimulus-selectivity of drug purchase tasks to demonstrate that demand metrics are specific to valuation of or demand for the commodity under study. Stimulus-selectivity is broadly defined for this purpose as a condition under which a specific stimulus input or target (e.g., alcohol, cigarettes) is the primary determinant of behavior (e.g., demand). The overall goal of the present study was to evaluate the stimulus-selectivity of drug purchase tasks. Participants were sampled from the crowdsourcing platform Amazon.com's Mechanical Turk (mTurk). Participants either completed alcohol and soda purchase tasks (Experiment 1; N = 139) or cigarette and chocolate purchase tasks (Experiment 2; N = 46) and demand metrics were compared to self-reported use behaviors. Demand metrics for alcohol and soda were closely associated with commodity-similar (e.g., alcohol demand and weekly alcohol use), but not commodity-different (e.g., alcohol demand and weekly soda use) variables. A similar pattern was observed for cigarette and chocolate demand, but selectivity was not as consistent as for alcohol and soda. Collectively, we observed robust selectivity for alcohol and soda purchase tasks and modest selectivity for cigarette and chocolate purchase tasks. These preliminary outcomes suggest that demand metrics adequately reflect the specific commodity under study and support the continued use of purchase tasks in substance use research.

Keywords: Behavioral Economics; Demand; Chocolate; mTurk; Soda

Public Health Significance: Drug purchase tasks are used to understand drug demand and provide insight into treatment response. Few studies have systematically evaluated the specificity of demand metrics to the commodity under study (i.e., stimulus-selectivity). This study demonstrated that demand in alcohol and cigarette purchase tasks as well as non-drug soda and chocolate purchase tasks was generally stimulus-selective, thereby supporting the continued use of these tasks in behavioral research.

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J.C. Strickland and W.W. Stoops developed the study concept and data collection measures. Data were collected by J.C. Strickland. J.C Strickland performed the data analysis and interpretation under the guidance of W.W. Stoops. J.C. Strickland drafted the initial manuscript and W.W. Stoops provided critical reviews. Both authors read and approved the final version of the manuscript for submission.

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Stimulus-Selectivity of Drug Purchase Tasks: A Preliminary Study Evaluating Alcohol and Cigarette Demand

The merger of theoretical perspectives and methodologies from behavioral economics and operant theory has resulted in numerous advances in addiction science (Bickel, Johnson, Koffarnus, MacKillop, & Murphy, 2014; Bickel, Marsch, & Carroll, 2000; Hursh, 1984). One prominent example of this interdisciplinary approach is the application of consumer demand theory to drug-taking behavior. Demand curves allow researchers to graphically represent drug consumption across variations in price and are used to generate metrics thought to underlie drug use and reinforcement (Hursh & Roma, 2013). A widely used method for evaluating economic demand in humans is the hypothetical purchase task. Demand curves are generated with these purchase tasks by asking participants to report hypothetical consumption of a good (e.g., alcohol) across a range of prices (e.g., $0.01, $1.00, $10.00/drink). This methodology is particularly appealing because of its temporal reliability (e.g., Few, Acker, Murphy, & MacKillop, 2012; Murphy, MacKillop, Skidmore, & Pederson, 2009), cost and time efficiency, and adaptability for populations with whom drug self-administration or other typical measures of drug use are not ethically or practically feasible (e.g., patients in residential treatment; participants with contraindications to drug administration).

Alcohol and cigarettes are the most commonly studied commodities in drug purchase task research, likely due to their legal status, widespread use, and relevance for other substance use and mental health conditions (Degenhardt, Hall, & Lynskey, 2001; Grant & Harford, 1995; McKay, Alterman, Rutherford, Cacciola, & McLellan, 1999). Alcohol and cigarette purchase tasks have been largely successful, with consistent relationships observed between demand metrics and measures of drug use and misuse (see reviews in Bickel et al., 2014; MacKillop, 2016). These studies have also demonstrated that alcohol and cigarette purchase tasks are sensitive to state-level changes in drug demand, such as those following stress-induction, withdrawal, or cue presentation (e.g., Amlung & MacKillop, 2014; MacKillop et al., 2012; Owens, Ray, & MacKillop, 2015). Although the clinical relevance of drug demand is still under investigation, preliminary evidence suggests that demand metrics may help identify behavioral mechanisms underlying effective interventions (Bujarski, MacKillop, & Ray, 2012; McClure, Vandrey, Johnson, & Stitzer, 2013; but see Schlienz, Hawk, Tiffany, O'Connor, & Mahoney, 2014) or function as prognostic variables predicting treatment success (MacKillop & Murphy, 2007; Madden & Kalman, 2010; Murphy et al., 2015).

The use of purchase tasks in human behavioral pharmacology and addiction research has grown in recent years given these promising clinical findings and the numerous benefits that purchase tasks may offer. As applied research utilizing purchase tasks has proliferated, however, so has the continued need for methodological and parametric evaluation of these procedures. Certainty in capturing the essential aspects of demand that purchase tasks are purported to measure relies on such research concerning measurement reliability, validity, and fidelity.

Several studies have demonstrated the psychometric properties of purchase tasks, including their test-retest reliability, construct validity, and incremental validity (e.g., Few et al., 2012; MacKillop et al., 2008; Murphy et al., 2009; Murphy, MacKillop, Tidey, Brazil, & Colby, 2011). One area that has received less attention is the systematic study of stimulus-selectivity. Stimulus-selectivity for this purpose is broadly defined as a condition under which a specific stimulus input or target (e.g., alcohol, cigarette) is the primary determinant of behavior (e.g., demand) (Powell, Honey, & Symbaluk, 2013). In the context of cognitive-behavioral research, stimulus-selectivity implies that the stimulus presented during a task determines behavior as opposed to a general propensity to respond without respect to specific contextual determinants. Purchase tasks, as typically utilized, are thought to determine commodity specific demand (e.g., cigarette valuation in the cigarette purchase task). If behavior is stimulus-selective then responses should reflect only the value of or demand for that commodity under study. However, it is possible that responses could represent an overall valuation for reinforcers without regard to the commodity under study. Although domain-general outcomes and a related hypo- or hyper-valuation of reinforcement may be important for understanding reinforcer sensitivity as it relates to drug use, this generalized responding weakens the fidelity of purchase tasks for specifically measuring demand for particular drug commodities.

Little research has focused on and systematically evaluated the stimulus-selectivity of purchase task metrics. A recent study included purchase tasks for six common non-drug commodities (e.g., toilet paper, vacation packages) across a range of price densities (Roma, Hursh, & Hudja, 2016). Differences in and the rank order of demand metrics across and within commodity manipulations were generally consistent with the commodity under purchase, supporting the notion that the commodity was the primary determinant of purchasing behavior (i.e., that the task was stimulus selective). To our knowledge, only one study has simultaneously examined demand for a drug (i.e., cigarettes) and non-drug (i.e., chocolate) commodity to establish this selectivity within the context of behavioral pharmacology and addiction research (Chase, MacKillop, & Hogarth, 2013). Chocolate demand in that study was not associated with nicotine dependence, thereby providing preliminary support for the stimulus-selectivity of the purchase task metrics. However, the relationship between cigarette demand and chocolate use was not measured, preventing the reciprocal interpretation of stimulus-selectivity.

The overall purpose of the present study was to provide a preliminary evaluation of the stimulus-selectivity of drug purchase tasks. Participants either completed alcohol and soda purchase tasks (Experiment 1) or cigarette and chocolate purchase tasks (Experiment 2) and demand metrics were compared to self-reported use behaviors. Demand was predicted to closely associate with commodity-similar variables (e.g., alcohol demand to weekly alcohol use), but not with commodity-dissimilar ones (e.g., alcohol demand to weekly soda use). Such commodity-similar associations would support stimulus-selectivity by demonstrating that the commodity under study is the primary determinant of choice and behavior.

Experiment 1 Methods

Participants and Procedures

Participants were recruited from Amazon.com's Mechanical Turk (mTurk), a crowdsourcing platform that provides cost-effective and efficient sampling of diverse populations. All surveys were completed on the Qualtrics (Provo, UT) platform. Data were collected as a part of a larger study on choice and drug-related cues. Participants were required to have an approval rating of 95% or higher on at least 100 mTurk tasks, currently reside in the United States, and be 18 years of age or older to view the parent studies. Previous research in substance-using populations has documented a close correspondence between laboratory and online crowdsourced outcomes, supporting the validity of the approach (e.g., Johnson, Herrmann, & Johnson, 2015; Strickland, Bolin, Lile, Rush, & Stoops, 2016). Participants were compensated $0.05 for completion of a screener survey and up to a $2.50 bonus for completion of the full survey. Bonus amounts varied in the parent study depending on the number of tasks completed; however, participants were not informed of total payment until the end of the survey to ensure that differential payment did not influence experimental outcomes. All participants provided informed consent via electronic confirmation. The University of Kentucky Institutional Review Board approved all procedures, including the consent process.

Participants qualified if they endorsed current alcohol and current soda use (n = 166; no time period of consumption other than "current" was specified). Several attention checks were used to identify inattentive or non-systematic participant data. These checks included: 1) comparison of age and sex responses at the start and end of the survey, 2) recall of a single digit number presented halfway through the survey that participants were instructed to remember and enter at the end of the survey, 3) an item that instructed participants to select a specific response (i.e., "Select 'A Little Bit'"), and 4) an item asking participants if they had been attentive and thought their data should be included. Nineteen participants were removed for failing one or more attention checks included to ensure participant engagement and response fidelity. Eight additional participants were removed due to non-systematic demand data (see Purchase Tasks below). This resulted in a final analyzed sample of 139 participants. See Table 1 for demographic and alcohol/soda use variables.

Measures

Purchase Tasks. An alcohol purchase task (Murphy et al., 2009) and novel soda purchase task were used to evaluate demand. Participants were asked to imagine a typical day over the last month when they would drink alcohol (or soda) and to indicate the hypothetical number of alcoholic drinks (i.e., one preferred brand US standard drink) or sodas (i.e., one preferred brand 12 oz serving of soda) they would purchase at 16 monetary increments ranging from $0.00 to $140/drink, presented sequentially (full range: $0.00 [free], $0.01, $0.05, $0.13, $0.25, $0.50, $1.00, $2.00, $3.00, $4.00, $5.00, $6.00, $11.00, $35.00, $70.00, $140.00/unit). This price range was selected to accommodate the elastic and inelastic portion of the demand curves for a wide range of commodities. This range was also within those used in other purchase task literature, including studies conducted with alcohol (e.g., Bujarski et al., 2012; MacKillop et al., 2010) and cigarettes (e.g., MacKillop et al., 2008; Wilson, Franck, Koffarnus, & Bickel, 2016). Participants were instructed that they could only get drinks from this source, could not stockpile them, and would have to consume all purchases in a single day. All choices were hypothetical and participants completed the tasks in a fixed order of the alcohol purchase task before soda purchase task. See Supplementary Materials for example instructions.

Alcohol and Soda Use Behaviors. Participants completed questions evaluating drug use and other health behaviors (e.g., “How many alcoholic drinks do you typically have in a week”, “How many days per week do you typically drink soda?”). Corresponding measures were evaluated or computed for alcohol and soda use. Quantity-frequency measures included: 1) number of drinks per week (one US standard alcohol or one 12 oz serving of soda) and 2) number of drinking days per week. Three severity measures were also calculated based on Substance Abuse and Mental Health Services Administration (SAMHSA) and National Institute on Alcohol Abuse and Alcoholism (NIAAA) guidelines (National Institute on Alcohol Abuse and Alcoholism, 2016): 1) endorsement of a past month heavy use day (i.e., 5/4 or more drinks in a single day for men/women), 2) “heavy” drinking (i.e., 5 or more heavy drinking days/month), and 3) “at risk” drinking (i.e., more than 14/7 drinks/week or 5/4 or more drinks/typical occasion for men/women). All severity measures were dichotomously coded. Although these guidelines were developed for alcohol use and may not directly reflect heavy soda drinking criteria or at-risk soda consumption, corresponding variables were computed for soda variables to provide analogous comparisons and decrease the likelihood that the observed pattern of results was due to systematic differences in the measures used for each commodity.

Data Analysis

Non-systematic curves were identified according to standardized criteria (see Stein, Koffarnus, Snider, Quisenberry, & Bickel, 2015). Specifically, demand curves were examined for frequent price-to-price consumption increases, reversals from zero consumption, and increased consumption with increased price as well as for extreme consumption (i.e., greater than 100 drinks in a single day). Price elasticity and intensity were generated using the exponentiated demand equation:

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

where Q = consumption; Q_0 = derived intensity of demand (consumption at zero price); k = a constant that denotes log consumption range (*a priori* set to 2); C = the price of the commodity; and α = derived elasticity of demand. The exponentiated model is a recently developed and validated equation that provides superior modeling for zero consumption values (Koffarnus, Franck, Stein, & Bickel, 2015; Strickland, Lile, Rush, & Stoops, 2016). Model adequacy was evaluated by R^2 values and the relationship between derived intensity and reported “free” consumption. We focused our analyses on derived intensity and elasticity metrics to reduce type I error due to repeated testing and given that the latent structure of alcohol and cigarette demand is fully captured by demand intensity and elasticity (Bidwell, MacKillop, Murphy, Tidey, & Colby, 2012; MacKillop et al., 2009). However, one derived measure (i.e., breakpoint or the price at which consumption dropped to zero) was also included. Breakpoint may intuitively differ from intensity and elasticity and its inclusion allowed for comparison between the selectivity of derived and observed values. Demand variables showed skew that was corrected by log-transformation prior to analysis. Pearson bivariate correlations were used to explore the relationship between alcohol and soda demand and use measures. The relationship between individual difference variables (i.e., age, sex, race, college education, and body mass index [BMI]) and commodity demand was also evaluated using bivariate correlations. A secondary analysis by mixed drink preferences was conducted by dividing participants into mixed drink favoring (i.e., rated Quite a Bit or Very Much on a mixed drink likability scale; n = 61) and non-favoring (rated Not at All, A Little Bit, or Moderately on a mixed drink likability scale; n = 78) groups. Demand curves were generated using GraphPad Prism 6.0f (GraphPad Software, Inc., La Jolla, CA). All other analyses were conducted in SPSS Statistics 22 (IBM; Armonk, NY) with $\alpha = 0.05$.

Experiment 1 Results

Response Topography and Model Fit

Figure 1 depicts alcohol and soda demand fit to mean (SEM) values using the exponentiated model. Demand was characterized by prototypic decreases in consumption with increases in unit price. The exponentiated model provided an excellent fit to mean alcohol and soda demand as well as to individual data (see Figure 1). Model derived and observed intensities were also closely associated for alcohol (r = .95) and soda (r = .96) demand providing further support for model adequacy.

Individual Differences in Alcohol and Soda Demand

Correlations between demand variables and age, sex, race, and BMI were not statistically significant (*r* values = -.16 to .16). Having a college education was modestly associated with lower soda demand intensity ($r = -.27$, $p = .001$) and higher alcohol breakpoints ($r = .19$; $p = .03$).

Association Between Alcohol and Soda Demand

Correlations between alcohol and soda demand intensity ($r = .21$, $p = .01$), elasticity ($r = .42$, $p < .001$), and breakpoint ($r = .49$, $p < .001$) were all statistically significant.

Association Between Alcohol and Soda Consumption Measures

Only the cross-commodity relationship between endorsement of “more than 14/7 drinks/week or 5/4 or more drinks per typical occasion” was significant ($r = .20$; $p = .02$). All other cross-commodity consumption variables were not significantly related (*r* values = .02 to .12).

Alcohol and Soda Demand in Relation to Use Behavior

Table 2 contains correlations between demand metrics and use measures. Correlations between alcohol demand and alcohol use variables were generally statistically significant and medium-to-large in effect size. For example, greater alcohol demand intensity was associated with more alcoholic drinks per week and days drinking per week as well as endorsement of severity measures (e.g., 5/4 or more drinks in a single day for men/women). The exception to this trend was alcohol breakpoint, which showed less robust and one non-significant association with alcohol use variables. A similar pattern of statistically significant associations was observed for soda demand and soda use variables.

Alcohol and soda demand showed excellent selectivity to the stimulus-related use variables, with no significant associations observed between alcohol demand and soda use and only one significant association between soda demand and alcohol use (soda breakpoint and alcoholic drinks per week; $r = .22$).

Analysis by mixed drink favorability group revealed a more robust cross-commodity correlation for demand intensity in the mixed drink non-favoring group (Favoring: Intensity r = .07; Elasticity r = .39; Breakpoint r = .52; Non-Favoring: Intensity r = .31; Elasticity r = .46; Breakpoint r = .46). Commodity-similar consumption correlations were generally similar between the two groups, with the exception of alcohol demand elasticity. Alcohol elasticity was not correlated with any alcohol consumption variables in the mixed drink favoring group (see Supplemental Table). Importantly, no systematic differences for commodity-different correlations were observed, with a similar pattern of small and generally non-significant associations detected in both subgroups (only four significant correlations were observed, three of which involved the breakpoint measure; significant r values < .27).

Experiment 1 Summary

The primary aim of Experiment 1 was to demonstrate the stimulus-selectivity of alcohol and soda purchase tasks for measuring alcohol and soda demand, respectively. Modest correlations were observed for corresponding cross-commodity demand metrics (e.g., demand elasticity for soda and alcohol) suggesting that some overlap does exist in purchasing tendencies. This similarity in demand is consistent with the idea that reinforcer sensitivity may reflect shared neurobiological and environmental risk factors related to alcohol and soda use (e.g., both may be associated with chronic stress or elevated discounting; Bickel, Jarmolowicz, Mueller, Koffarnus, & Gatchalian, 2012; Sinha, 2008; Spillman, 1990). However, metrics from each task showed a consistent and robust association with commodity-similar use variables (e.g., alcohol demand elasticity and weekly alcohol use), but not with commodity-different ones (e.g., alcohol demand elasticity and weekly soda use). Derived demand measures (i.e., demand intensity and elasticity) generally showed a more robust and selective relationship with consumption measures than the observed variable studied here (i.e., breakpoint; see General Discussion for more details). Taken together, these discriminating associations support stimulus-selectivity by showing that the stimulus or commodity under question was the primary determinant of behavior.

We observed a mostly consistent pattern of effects when participants were divided by mixed drink preferences. The exception to this trend was the lack of significant associations between alcohol elasticity and alcohol use variables in the mixed drink favoring group. Previous research has demonstrated an association between alcohol demand and combined alcohol and caffeine use as well as the unique contribution of this alcohol combination to alcohol misuse (Amlung et al., 2013). Such findings highlight the need for further study of this potentially important individual difference for alcohol use behaviors. It is important to note that we used an indirect measure of mixed drink usage (i.e., ratings of likability for mixed drinks), and therefore recommend that future research use prospective designs to evaluate the potential contribution of mixed drink use to economic demand and related variables.

In Experiment 2, a sample of individuals reporting daily cigarette use was evaluated. The aim of Experiment 2 was to replicate previous findings showing no relationship between chocolate demand and nicotine dependence variables (Chase et al., 2013). We also wanted to extend these findings by using an alternative sampling method (i.e., in-laboratory screening versus online crowdsourcing) as well as by evaluating the reciprocal relationship between cigarette demand and a chocolate use behavior.

Experiment 2 Methods

Participants and Procedures

Experimental procedures were identical to those reported for Experiment 1. Briefly, participants were sampled from mTurk and required to report daily cigarette use and any chocolate use (no time period specified) to qualify for this analysis (n = 66). Although data were collected as a part of a series of parent studies on choice and drug-related cues, no participants evaluated in Experiment 1 were also included in Experiment 2 (i.e., independent samples were included in each experiment reported here). Seven participants were removed for failing one or more attention and/or fidelity checks and 13 additional participants were removed due to non-systematic demand data, as described in Experiment 1. This resulted in a final sample size of 46 participants. See Table 2 for demographics and cigarette/chocolate use variables for Experiment 2.

Measures

Purchase Tasks. Cigarette and chocolate purchase tasks instructions and price range/densities were identical to those described in Experiment 1. Hypothetical cigarettes were quantified as one preferred brand cigarette (e.g., Chase et al., 2013; MacKillop et al., 2008). Hypothetical chocolate was quantified as one Hershey Kiss size chocolate candy. This commodity size was selected given its similarity to the commodity used in a previous chocolate purchase task (Chase et al., 2013; Cadbury Dairy Milk Chocolate Bars) and its relevance for a United States sample. Participants completed the purchase tasks in the fixed order of cigarette purchase task before chocolate purchase task.

Cigarette and Chocolate Use Variables. Cigarette and chocolate use variables were collected as a part of a health and drug use history questionnaire. Cigarette use variables included cigarettes smoked per day and the Fagerström test for Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerström, 1991). The only chocolate use variable collected was typically chocolate consumed per occasion, operationalized as the number of Hershey Kiss size chocolate candies.

Data Analysis

Data analysis and evaluation of demand curves was identical to Experiment 1. All analyses were conducted using GraphPad Prism 6.0f (GraphPad Software, Inc., La Jolla, CA) and SPSS Statistics 22 (IBM; Armonk, NY) with $\alpha = 0.05$.

Experiment 2 Results

Response Topography and Model Fit

Figure 2 depicts cigarette and chocolate demand fit to mean (SEM) values using the exponentiated model. Demand was characterized by prototypic decreases in consumption with increases in unit price. The exponentiated model provided an excellent fit to mean cigarette and chocolate demand as well as to individual data (see Figure 2). Model derived and observed intensities were also closely associated for cigarette (r = .96) and chocolate (r = .93) demand providing further support for model adequacy.

Individual Differences in Cigarette and Chocolate Demand

Correlations between cigarette and chocolate demand variables and age, race, education, and BMI were not statistically significant (r values = -.27 to .21). Cigarette breakpoints were higher for men (r = .35), but no sex differences were observed for chocolate breakpoints or other demand intensity or elasticity values.

Association Between Cigarette and Chocolate Demand

Correlations between cigarette and chocolate demand intensity (r = .35; p = .02), elasticity (r = .40; p = .01), and breakpoint (r = .43; p = .003) were all statistically significant.

Association Between Cigarette and Chocolate Consumption Measures

Chocolate use was not significantly related to usual cigarettes per day (r = -.06) or FTND scores (r = .01).

Cigarette and Chocolate Demand in Relation to Use Behavior

Table 4 contains correlations between demand metrics and cigarette and chocolate use behaviors. Correlations between cigarette demand intensity and usual cigarettes per day (r = .39) and FTND scores (r = .52) were statistically significant and medium-to-large in effect size. Cigarette demand elasticity was associated with cigarette use variables in the expected direction, but these correlations were not statistically significant. Cigarette breakpoint was not related to cigarette use variables. Chocolate demand intensity, but not elasticity or breakpoint, was significantly associated with the chocolate use variable (i.e., typical amount of chocolate eaten per occasion).

Cigarette and chocolate demand showed acceptable selectivity to the stimulus-related use variables. Specifically, chocolate demand intensity was modestly associated with cigarette use variables, but these relationships were not statistically significant. Cigarette demand values were not associated with chocolate use.

Experiment 2 Summary

The primary aim of Experiment 2 was to replicate and extend previous research evaluating the stimulus-selectivity of cigarette and chocolate purchase tasks. Similar to Experiment 1, moderate correlations were observed for corresponding cross-commodity demand metrics (e.g., demand elasticity for cigarette and chocolate). Satisfactory stimulus-selectivity was obtained, with significant associations observed between some commodity-similar variables and non-significant associations observed between commodity-different variables. However, the selectivity of these relationships was not as consistent as those observed for alcohol and soda demand. For example, the relationship between cigarette demand elasticity and cigarette use frequency and severity was not statistically significant (but see Bidwell et al., 2012; MacKillop et al., 2008; Strickland et al., 2016b for similar results). The correlations between chocolate demand intensity and cigarette use variables, although not statistically significant, were also modest in size (*r* values of .23 to .28).

It is unclear why selectivity for these cigarette and chocolate purchase tasks was less robust than for the alcohol and soda tasks in Experiment 1, but several explanations are plausible. First, the chocolate purchase task described a very specific commodity (i.e., one Hershey Kiss size candy). Participants were instructed that they could substitute this with an alternative, but similarly sized, chocolate. However, the exactness of this commodity may have made it difficult for participants to adequately imagine their typical purchasing behavior. This potential problem with the task parameters may also explain why we observed a relatively high proportion of non-systematic data in Experiment 2 (although note that comparable exclusion rates were described in previous research; Chase et al., 2013). Cigarettes and chocolate are also not directly comparable with respect to cost or time to consume. We used chocolate as the non-drug commodity in Experiment 2 to facilitate comparisons with previous research (Chase et al. 2013). Cigarettes and chocolate also share many of the same hedonic and purchasing qualities (e.g., typically purchased as a larger “pack” and consumed as distinct units) that should have helped improve the equivalence between these items. Second, the sample was relatively small especially compared to Experiment 1. Observations obtained from a larger sample may have provided better estimation of the association between demand and use outcomes. We should note that the magnitude of the relationships observed here are similar to those reported in other studies in the demand literature, including in one of the original validation studies of the cigarette purchase task (e.g., MacKillop et al., 2008). Nevertheless, the small sample size makes the results from Experiment 2 preliminary and in need of replication in additional studies. Third, we only evaluated a single, coarse measure of chocolate use and did not have a battery of frequency and severity measures as in Experiment 1. Future research including alternative measures of chocolate use would help determine if additional measures could help clarify this discrepancy. Fourth, it is possible that the relative decrement in stimulus-selectivity observed in Experiment 2 could be due to demographic differences. Comparisons of demographics between Experiments 1 and 2’s participants did not reveal statistically significant differences; however, there was trend towards a greater percentage of participants with a college education in Experiment 1 (p = .06; all other comparisons p values > .13). These differences reflect, in part, the populations typically studied using alcohol and cigarette purchase tasks. Specifically, Experiment 1 included a sample reporting a range of alcohol use behaviors (from light to heavy use), whereas Experiment 2 was a sample more narrowly defined as daily cigarette users. Future research could focus on other cigarette-using populations (e.g., non-daily “chippers” or social cigarette users) to evaluate if sampling a range of cigarette use behaviors helps reveal improved stimulus-selectivity. These possibilities withstanding, the observation that stronger and more consistent relationships were observed between commodity-similar than dissimilar items provides modest support for the stimulus-selectivity of the cigarette and chocolate purchase tasks as described here.

General Discussion

The overall purpose of this study was to evaluate the stimulus-selectivity of drug purchase tasks. To this end, participants completed purchase tasks for drug (i.e., alcohol or cigarettes) and non-drug comparators (i.e., soda or chocolate). Stimulus-selectivity was defined as consistent relationships between commodity-similar and not commodity-different variables. This stimulus-selectivity was examined in a double-dissociative manner by measuring demand and use behaviors for both drug and non-drug commodities. We observed robust selectivity for alcohol and soda purchase tasks and modest selectivity for cigarette and chocolate purchase tasks. These findings indicate that demand metrics likely reflect the value of or demand for only the commodity under study. Taken together, our results reinforce the fidelity of drug purchase tasks for specifically evaluating valuation of the commodity under study and support their continued use in behavioral pharmacology and addiction research.

Stimulus-selectivity was generally more consistent and robust for the equation derived (i.e., demand intensity and elasticity) than graphically observed (i.e., breakpoint) measures. This outcome suggests that model derived variables may provide a more stimulus-selective measure of demand, potentially because these metrics are generated using data encompassing the entire curve rather than from a single point (e.g., the breakpoint location). However, we must note that we did not make specific *a priori* hypotheses about observed and derived variables so these differences should be taken as preliminary and future research conducted to test this observation.

Although some discrepancies were observed, our findings are generally consistent with the outcomes reported by Chase and colleagues (2013) for cigarette and chocolate demand and extend them in at least three ways. First, we collected data using a soda purchase task and compared those metrics to data from an alcohol purchase task. Alcohol purchase tasks are one of the most widely used in the research literature making this generalization an important one (MacKillop, 2016). Alcohol is also commonly evaluated in the context of other substance use and mental health disorders given its association with drug use relapse and psychiatric comorbidities (e.g., Degenhardt et al., 2001; McKay et al., 1999), highlighting the importance of its study for a variety of health behaviors.

Second, we provided explicit evidence for stimulus-selectivity by comparing demand in a reciprocal and comprehensive manner (i.e., drug demand to non-drug consumption and vice versa). These comparisons also supported the construct validity of the novel soda purchase task used in Experiment 1. Future studies in addiction science and other health fields (e.g., nutrition) could utilize this soda purchase task to investigate soda demand as it relates to other health-related outcomes (e.g., obesity and diet). The chocolate purchase task could prove equally useful in health psychology and related fields, although further research is needed to refine and validate this task (see Experiment 2 Summary).

Finally, we collected data using online crowdsourcing as opposed to sampling methods typically used in the university laboratory setting (e.g., Chase et al., 2013; Murphy et al., 2009; but see Koffarnus et al., 2015). The use of this novel sampling method supports the generalizability of stimulus-selectivity across diverse experimental settings and populations. Importantly, alcohol and cigarette demand generally correlated with consumption variables in a way that was similar to previous studies using in-person, laboratory techniques (e.g., MacKillop et al., 2008; Murphy et al., 2009). These finding adds to the growing literature demonstrating a close correspondence between data obtained using laboratory and online methods (e.g., Johnson et al., 2015; Strickland et al., 2016a). This demonstration is important because the use of complementary in-laboratory and online studies provides an effective and efficient opportunity for the replication of experimental findings across diverse settings and samples.

Several limitations must be considered. First, these analyses were conducted as a secondary evaluation of data collected in a parent series of studies. The variables available for studying commodity use frequency and severity were therefore limited in breadth and depth. This was a particular concern for chocolate use for which only one use variable was available. Second, a consistent price density and range was used for each purchase task. Although this range was consistent with those used in other purchase task studies (e.g., Jacobs & Bickel, 1999; MacKillop et al., 2010), more recently researchers have elected to remove extreme prices from the price range (e.g., Murphy et al., 2015). Similarly, although the specific instructions used in these tasks were similar to those used elsewhere, they did differ in some respects from some studies evaluating the psychometric properties of alcohol and cigarette demand (e.g., framing the event as a weekend party versus as a “typical day” here; Murphy et al., 2009). Nevertheless, the high density of prices in the initial portion of the range likely provided sufficient coverage across the elastic and inelastic portions of the demand curve and allowed for accurate estimation of demand intensity and elasticity.

Third, the order of completion was not randomized and all participants completed drug purchase tasks prior to non-drug purchase tasks. Few studies have evaluated demand across multiple commodities, and those that exist either have not clearly indicated if counterbalancing was used or, if it was, if an order effect was observed (e.g., Chase et al., 2013; Jacobs & Bickel, 1999; Pickover, Messina, Correia, Garza, & Murphy, 2016; Strickland et al., 2016b). One of these studies was completed by our research laboratory and included both cigarette and alcohol purchase tasks. Analysis of these data for possible order effects indicated that order of completion (i.e., alcohol before cigarette purchase task or vice versa) did not influence the magnitude of alcohol or cigarette demand intensity or elasticity observed in that study (data not reported in the original report; Strickland et al. 2016b). The use of repeated and specific instructions prefacing each purchase task could have also lessened the potential for order effects. Namely, participants were provided a detailed overview of the commodity available prior to completion in each task to ensure awareness of the operational parameters. Nevertheless, future studies should include a randomized order to test if order of completion influences the stimulus-selectivity of purchase tasks.

Fourth, soda and chocolate were chosen as the non-drug comparators for alcohol and cigarettes given general similarities in use topography, qualitative appearance, and typical serving size. Our focus was on unhealthy commodities given that these items were expected to show the closest relationship with drug demand and provide a more rigorous test of stimulus-selectivity than healthier consumables (e.g., fruit). We attempted to equate all commodities in some respect by allowing participants to purchase their “preferred brands”. However, differences in the type (e.g., gin, beer, regular, diet), container (e.g., glass, can), and brand (e.g., Coca Cola®, Pepsi®) used may have influenced decision-making. Nevertheless, such variation is inherent to the stimulus qualities and selectivity of commodity purchase tasks to the item under question and as such should not be considered problematic for the present study. We also did not consider the status of soda and chocolate as economic substitutes or complements for alcohol or cigarettes, respectively. A recent study suggests that fast food items are not economic substitutes for cigarettes, whereas cigarettes are a modest complement for food (Murphy, Owens, Sweet, & MacKillop, 2016). It is unlikely that substitutes or complements affected the pattern of results reported here given that all purchase tasks were completed as independent commodities without reference to other drug or non-drug items. However, these economic mechanisms are a critical area for future research given their importance for the allocation of behavior away from undesired drug use to desired alternatives activities. Fifth, drug use could not be biologically verified and experimental control was not guaranteed in the online setting. We used several techniques to help increase data quality (e.g., attention checks) and, as noted above, demand and consumption correlations were generally consistent with the previous literature. Finally, we must emphasize that these analyses represent a preliminary study of the stimulus-selectivity of drug purchase tasks given the limited scope and small sample size in Experiment 2. Future research is needed to replicate these and other experimental findings to support the validity of drug purchase tasks across a variety of experimental conditions (e.g., study setting; drug and non-drug commodity types) and populations (e.g., recreational users; treatment-seeking participants).

Despite these limitations, the current study provides preliminary evidence supporting the stimulus-selectivity of commonly used drug purchase tasks. As the use of drug purchase tasks in behavioral research proliferates, it is critical that research continue to address the reliability, validity, and fidelity of these procedures. Such methodological and parametric studies will help reinforce the capacity of purchase tasks and econometric analyses for revealing behavioral mechanisms underlying drug-taking behavior and help encourage the use of best practice methods in health and addiction science.

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Table 1

Experiment 1 Participant Demographics and Alcohol/Soda Use Behaviors

	Median/%	IQR
Demographics		
Age	31	26–39
Male	45.3%	
White	74.8%	
College Education	64.0%	
BMI	26.1	23.0–32.7
Alcohol Use		
Drinks/Week	4	1–10
Days/Week	2	1–3
Past Month Day with ≥5/4 Drinks	59.0%	
≥5 Past Month Days with ≥5/4 Drinks	20.1%	
>14/7 Drinks/Week or ≥5/4 Drinks/Usual Occasion	40.3%	
Soda Use		
Drinks/Week	3	1–10
Days/Week	2	1–7
Past Month Day with ≥5/4 Drinks	23.7%	
≥5 Past Month Days with ≥5/4 Drinks	10.8%	
>14/7 Drinks/Week or ≥5/4 Drinks/Usual Occasion	23.7%	

Note. IQR = interquartile range; BMI = body mass index; all divided criteria (e.g., 5/4) refer to separate criteria for men/women, respectively

Table 2

Association Between Demand and Alcohol and Soda Use Measures

	Alcohol					Soda				
	Drinks/ Week	Days/ Week	Past Month Day with ≥5/4 Drinks	≥5 Past Month Days with ≥5/4 Drinks	>14/7 Drinks/ Week or ≥5/4 Drinks/ Usual Occasion	Drinks/ Week	Days/ Week	Past Month Day with ≥5/4 Drinks	≥5 Past Month Days with ≥5/4 Drinks	>14/7 Drinks/ Week or ≥5/4 Drinks/ Usual Occasion
Alcohol										
Q_0	**.48**	**.39**	**.52**	**.44**	**.48**	<.01	.06	.05	.06	.08
α	**-.28**	**-.31**	**-.29**	**-.21**	**-.32**	.04	.04	.03	.02	.03
BP	**.20**	**.18**	**.17**	.10	**.17**	-.09	-.09	-.05	-.07	-.12
Soda										
Q_0	.04	-.01	.01	-.05	<.01	**.52**	**.45**	**.57**	**.43**	**.50**
α	-.09	-.07	-.03	.05	-.06	**-.43**	**-.39**	**-.39**	**-.34**	**-.43**
BP	**.22**	.08	.10	.02	.12	**.30**	**.30**	**.24**	**.17**	**.30**

Note. Q_0 = demand intensity from the exponentiated demand equation; α = demand elasticity from the exponentiated demand equation; BP = breakpoint; all divided criteria (e.g., 5/4) refer to separate criteria for men/women, respectively. **Bold** = statistically significant correlation.

Table 3

Experiment 2 Participant Demographics and Cigarette/Chocolate Use Behaviors

	Median/%	IQR
Demographics		
Age	34	28-42
Male	54.3%	
White	80.4%	
College Education	47.8%	
BMI	27.7	23.8-34.2
Cigarette Use		
CPD	10	6-19
FTND	4	1-6
Chocolate Use		
Chocolate/Occasion	4	3-6

Note. IQR = interquartile range; BMI = body mass index; CPD = cigarettes/day; FTND = Fagerström Test for Nicotine Dependence.

Table 4

Association Between Demand and Cigarette and Chocolate Use Measures

	Cigarettes		Chocolate
	CPD	FTND	Chocolate/ Occasion
Cigarettes			
Q_0	**.52**	**.39**	.01
α	-.17	-.21	.05
BP	.01	.06	-.02
Chocolate			
Q_0	.23	.28	**.32**
α	.08	-.01	-.17
BP	-.06	<.01	-.01

Note. Q_0 = demand intensity from the exponentiated demand equation; α = demand elasticity from the exponentiated demand equation; BP = breakpoint; CPD = cigarettes/day; FTND = Fagerström Test for Nicotine Dependence. **Bold** = statistically significant correlation.

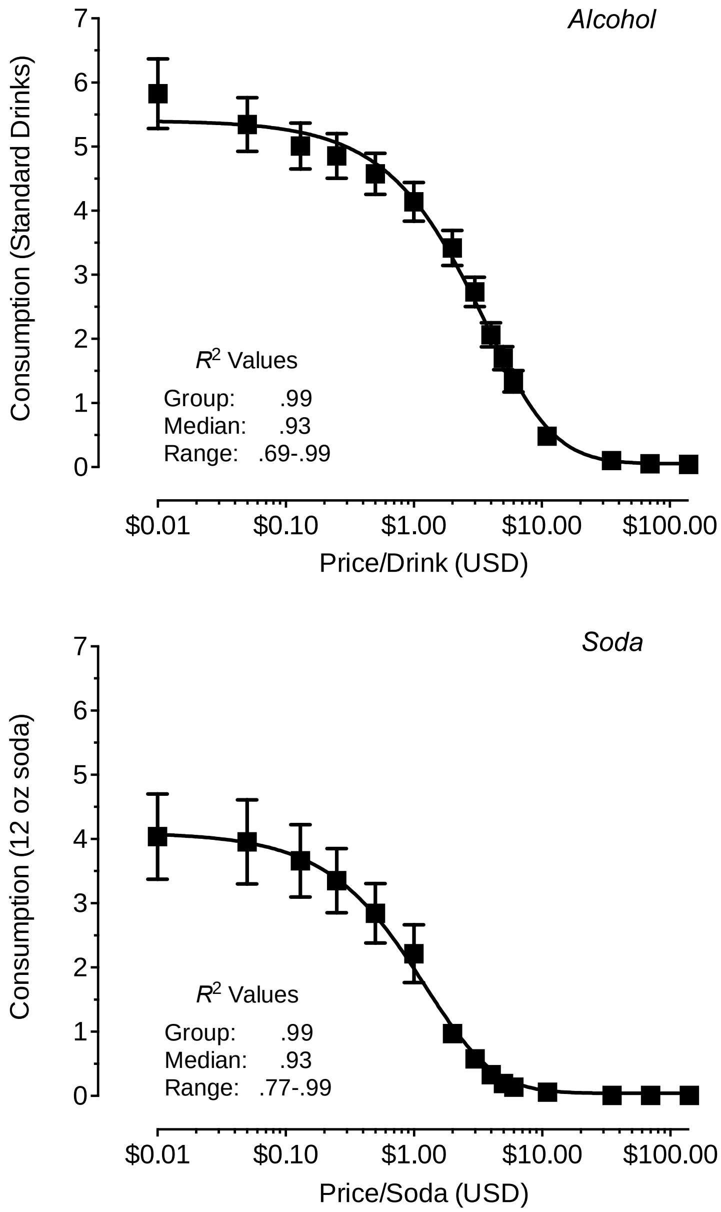

Figure 1. Economic demand for alcohol (top panel) and soda (bottom panel). Participants (n = 139) completed commodity purchase tasks in which hypothetical alcohol (one US standard drink) or soda (one 12 oz soda) were available. Price varied in United States dollars (USD). Plotted are mean (SEM) group data on a log-linear axis fit using the exponentied model. Also included are group R^2 values for model fit as well as median and ranges for individual data.

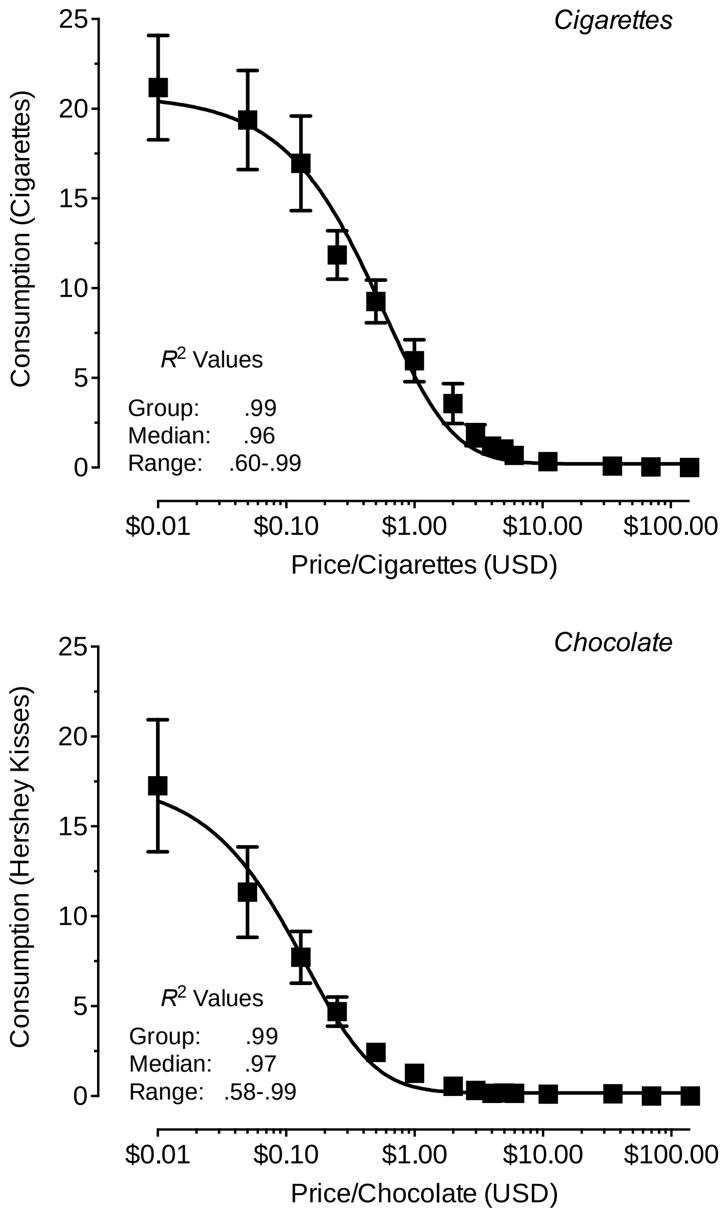

Figure 2. Economic demand for cigarettes (top panel) and chocolate (bottom panel). Participants (n = 46) completed commodity purchase tasks in which hypothetical cigarettes (one preferred brand cigarette) or chocolate (one Hershey Kiss size chocolate) were available. Price varied in United States dollars (USD). Plotted are mean (SEM) group data on a log-linear axis fit using the exponentied model. Also included are group R^2 values for model fit as well as median and ranges for individual data.