Brief Report

Temporal Stability of a Cigarette Purchase Task

Lauren R. Few, M.S.,¹ John Acker, B.A.,¹ Cara Murphy, B.S.,¹ & James MacKillop, Ph.D.^{1,2}

¹ Department of Psychology, University of Georgia, Athens, GA

² Center for Alcohol and Addiction Studies, Brown University, Providence, RI

Corresponding Author: James MacKillop, Ph.D., Department of Psychology, University of Georgia, Athens, GA 30602, USA.

Telephone: 706-542-3033; E-mail: jmackill@uga.edu

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Abstract

Introduction: Cigarette purchase tasks (CPTs) are relatively new behavioral economic assessments that efficiently quantify motivation for tobacco by assessing how much an individual values cigarettes. This is achieved by assessing estimated cigarette consumption at escalating levels of price per cigarette and generating several measures of motivation from the resulting demand curve. The temporal stability of the indices generated from a CPT has not been examined to date and was the focus of the current study.

Methods: Participants were 11 moderately heavy smokers from the community who completed CPTs and other measures on 2 occasions 1 week apart. The CPT indices of the relative value of cigarettes were (a) intensity (i.e., consumption under minimal cost), (b) $O_{\max}$ (i.e., maximum expenditure for cigarettes), (c) breakpoint (i.e., first price suppressing consumption to 0), and (d) elasticity (i.e., proportionate price sensitivity).

Results: Demand for cigarettes was initially insensitive to price changes (inelastic) but became increasingly sensitive (elastic) as prices increased. Correlations between the demand indices at both administrations were very high magnitude and statistically significant ($r_s = .76-.99$, $p_s < .001$), and no significant within-subjects differences were present.

Conclusions: These findings provide initial support for the temporal stability of motivation for tobacco as measured by a CPT. Future studies with larger samples and timeframes will be important to verify these findings.

Introduction

Smoking remains a major source of morbidity and mortality in the United States and worldwide (Mokdad, Marks, Stroup, & Gerberding, 2004; World Health Organization, 2008). One major determinant of tobacco consumption is the cost of cigarettes. For example, at the population level, health economic studies have revealed that cigarette taxation substantially influences consumption (e.g., Levy, Chaloupka, & Gitchell, 2004),

and at the level of the individual smoker, behavioral economic studies have similarly revealed that the costs of cigarettes substantially affect consumption (e.g., Johnson & Bickel, 2006).

Within behavioral economics, individual demand curve analysis is one methodology to quantify the relative value of commodities, including cigarettes. This refers to examining the relationship between a person's consumption of a commodity and its cost. As prices increase, demand typically decreases at a relatively low rate initially but then becomes more precipitous at higher prices, finally terminating altogether. Importantly, several indices of motivation can be generated from demand curves (Hursh & Silberberg, 2008; Murphy & MacKillop, 2006). For example, the start and the finish of the demand curve are referred to as intensity and breakpoint. Intensity is defined as consumption at zero or minimal cost, whereas breakpoint is defined as the first price that fully suppresses consumption to zero. In addition, a demand curve can be used to generate a measure of expenditure, termed $O_{\max}$ (i.e., maximum expenditure across prices), and a measure of overall price sensitivity, termed elasticity (i.e., the proportional slope of the demand curve or, more simply, how responsive the individual is to increases in price). Together, these indices provide a multidimensional assessment of an individual's relative value of cigarettes.

A recent approach for conducting demand curve analysis is the use of a cigarette purchase task (CPT), which assesses individuals' estimated consumption of cigarettes at varying levels of price. This typically starts at zero or very low prices and escalates to very high prices. A CPT permits relatively rapid detailed assessment of consumption for a wide array of prices and facilitates examining individual variation in cigarette demand as a potentially relevant determinant of smoking and nicotine dependence. The benefits of this approach are its time- and cost-efficiency and capacity for highly detailed data collection. In contrast, in vivo laboratory assessments of demand can be limited by participant and experimenter burden, small sample size requirements, limited price options, and potential ethical issues in clinical populations (Jacobs & Bickel, 1999; MacKillop et al., 2008).

Although only a small number of studies using self-report purchase tasks have been published, the data so far are promising.

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Jacobs and Bickel (1999) initially validated purchase tasks for cigarettes and heroin in a group of nicotine- and heroin-dependent individuals, finding prototypic decreases in consumption as a function of price. Moreover, demand indices have been found to be significantly associated with both cigarette consumption and nicotine dependence in young adult smokers (MacKillop et al., 2008) and adolescent smokers (Murphy, MacKillop, Tidey, Brazil, & Colby, 2011). These findings complement recent studies on individual differences in alcohol demand that revealed similar associations with alcohol use, alcohol misuse, and alcohol treatment response (MacKillop & Murphy, 2007; MacKillop et al., 2009, 2010; Murphy & MacKillop, 2006).

Despite the growing literature supporting the utility of a CPT, there have been no studies examining the temporal stability of demand data from a CPT. This is an important aspect of psychometric validation, but stability over an interim of presumably stable conditions also has significant implications for the application of this measure in clinical and research settings. For example, the CPT could be utilized to examine the impact of intervening factors that may affect smoking motivation, such as the presence of smoking-related cues, nicotine withdrawal, behavioral and pharmacological smoking cessation treatments, and public health education efforts. If, however, a CPT is generally temporally unstable, the utility of the measure in these applications would be substantially undermined. To address this, the current study is an initial investigation of CPT temporal stability in a community sample of adult smokers over a 1-week period. Other behavioral economic measures have been found to be stable over time (e.g., Baker, Johnson, & Bickel, 2003; Ohmura, Takahashi, Kitamura, & Wehr, 2006; Simpson & Vuchinich, 2000; Takahashi, Furukawa, Miyakawa, Maesato, & Higuchi, 2007), and one previous study has reported high test-retest reliability of an alcohol purchase task (APT; Murphy, MacKillop, Skidmore, & Pederson, 2009). Therefore, we predicted that CPT indices of demand would also exhibit high short-term temporal stability from Time 1 (T1) to Time 2 (T2).

Methods

Participants

Eleven participants (9 men and 2 women) were recruited from the community using newspaper advertisements and flyers. Inclusion criteria were (a) age 18–65 years, (b) 5+ cigarettes/day (i.e., regular smokers), and (c) 8th+ grade education (i.e., adequate literacy). Participants were on average 36.5 years old ($SD = 11.2$) and were primarily of White race (82% White, 9% Black, and 9% Asian). They were moderate-to-heavy smokers ($M = 22.3$ cigarettes/day, $SD = 7.5$), which was confirmed via expired carbon monoxide (CO; T1 $M = 19.82$, $SD = 12.50$; T2 $M = 19.64$, $SD = 11.56$). The participants were generally of low annual income: 73% <\$15,000, 9% \$15,000–\$30,000, 9% \$30,000–\$45,000, and 9% \$45,000–\$60,000.

Procedures

Participants completed two in-person assessments in a small group format one week apart. Assessments comprised questionnaire packets, and participants provided breath samples for CO assessment via a PiCO+ Smokerlyzer (Bedfont Scientific, Limited). Participants received \$15 compensation for each

session. All aspects of the study were approved by the University of Georgia's Institutional Review Board.

Measures

Demographic variables were assessed by questionnaire. Cigarette consumption and nicotine dependence were assessed using the Fagerström Test for Nicotine Dependence (FTND; Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991). Cigarette demand was assessed using a CPT (Jacobs & Bickel, 1999; MacKillop et al., 2008), which used the following instructional set: "Imagine a TYPICAL DAY during which you smoke. The following questions ask how many cigarettes you would consume if they cost various amounts of money. The available cigarettes are your favorite brand. Assume that you have the same income/savings that you have now and NO ACCESS to any cigarettes or nicotine products other than those offered at these prices. In addition, assume that you would consume cigarettes that you request on that day; that is, you cannot save or stockpile cigarettes for a later date. Be sure to consider each price increment carefully." Estimated cigarette consumption was assessed at 73 prices from \$0 to \$10. Prices increased in 1¢ increments from zero cost to 50¢, 4¢ increments to \$1, and \$1 increments thereafter; an exception was a 2¢ increase from 98¢ to \$1. These prices were intended to provide maximum resolution at prices below, above, and around the current market price. Equivalent prices per pack were provided immediately to the right of prices per cigarette to ensure that participants were aware of the extrapolated prices.

Data Analysis

All demand curves were individually examined, and all raw data and computed values were examined for outliers and distribution normality. Indices of demand were generated using an "observed values" approach, which uses raw values (MacKillop et al., 2008; Murphy & MacKillop, 2006), and nonlinear regression of an exponential model of elasticity. Specifically, for observed values, intensity was defined as consumption at zero price, $O_{\max}$ was defined as the maximum amount of money allocated to cigarettes, and breakpoint was defined as the first price that suppressed consumption to zero. Elasticity was derived as the α parameter from Hursh and Silberberg's (2008) exponential demand equation:

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

where Q = consumption at a given price; Q_0 = maximum consumption (consumption at zero or minimal price); k = a constant across individuals that denotes the range of consumption values in log powers of 10, in this case, a constant of 4; C = the cost of the commodity (price); and α = the derived demand parameter reflecting the rate of decline of consumption in standardized price (Hursh & Silberberg, 2008). Reliability was determined by examining correlations between demand indices using Pearson's r and paired-samples t tests, comparing T1 with T2. Bivariate correlations were also computed between demand indices and both FTND scores and cigarettes per day (i.e., C/D). A conventional significance level of $\alpha < .05$ was used for all analyses.

Results

The exponential demand curve equation provided a very good fit to the overall mean data (T1 $R^2 = .91$; T2 $R^2 = .96$) and a good

fit on an individual subject level (T1 mean $R^2 = .77$ [SD] = 0.14; mean R^2 T2 = .75 [SD] = 0.10)). Aggregate demand curves at both timepoints are provided in Figure 1 along with individual demand data for three representative subjects, which were determined by the median and interquartile ranges of the R^2 values. From T1 to T2, statistically significant and high magnitude correlations were present for all demand indices, C/D, and FTND ($ps < .001$), and no significant t test differences were present, presented in Table 1. All demand indices were strongly correlated with both FTND scores and C/D in the expected direction, with the exception of breakpoint (Table 1). Individual subject data are available from the last author upon request.

Discussion

The purpose of the current study was to further validate a CPT as a time- and cost-efficient assessment of the relative value of cigarettes by examining its temporal stability in a community sample of adult smokers. As predicted, the indices of demand exhibited high levels of reliability. High magnitude and statistically significant test-retest correlations were present, reflecting

large proportions of overlapping variance, with all demand indices meeting psychometric conventions for good-to-excellent test-retest reliability. Demand indices also correlated with nicotine dependence, smoking rate, and each other in patterns that were generally consistent with previous findings (MacKillop et al., 2008; Murphy et al., 2011), albeit with some differences, such as negative associations for breakpoint. In addition, some associations fell short of statistical significance because of the small sample size.

This is the first study to examine test-retest reliability of a CPT (to our knowledge) and provides important support for the previous studies using a CPT by suggesting that the observed relationships would be expected to be robust over time. Moreover, these findings converge with another recent study reporting high temporal stability of an APT (Murphy et al., 2009) and other behavioral economic decision-making tasks (Baker et al., 2003; Ohmura et al., 2006; Takahashi et al., 2007). Both the current study and the previous APT study found the highest reliability coefficients for intensity and O_{max} , although the breakpoint and elasticity coefficients were acceptable. With regard to elasticity, this is probably because the α parameter is a derived

Figure 1. Cigarette demand at prices from \$0 to \$10 per cigarette at two timepoints, one week apart. Panel A provides means for all participants ($N = 11$), and topographical indices of demand are provided for clarity. Intensity refers to consumption at minimum cost (\$0), elasticity refers to the proportionate relationship between consumption and price, and breakpoint refers to the price that suppresses consumption to zero; O_{max} refers to maximum expenditure allocated to the commodity and is not presented. Panels B, C, and D provide the individual data for three participants reflecting demand modeling fits at the lower, middle, and upper points of the exponential model fit interquartile range ($R^2 = .65$, $.77$, and $.86$, respectively). For proportionality, the data are presented in $\log_{10} - \log_{10}$ coordinates, with zero values depicted as trivial nonzero values.

Table 1. Means, Correlation Coefficients, and Paired-Samples *t* Tests Between Time 1 (T1) and Time 2 (T2)

Variable	T1 <i>M</i> (<i>SE</i>)	T2 <i>M</i> (<i>SE</i>)	<i>r</i> _{T1-T2}	<i>t</i>	1.	2.	3.	4.	5.
1. C/D	25.0 (2.24)	24.8 (2.39)	.81***	0.13	–				
2. FTND	6.64 (0.69)	6.73 (0.62)	.95***	–0.43	.67*	–			
3. Intensity	38.18 (6.58)	37.27 (6.62)	.99***	1.00	.66*	.56†	–		
4. <i>O</i> _{max}	7.65 (1.15)	8.37 (1.60)	.95***	–1.19	.88***	.53†	.85***	–	
5. Breakpoint	0.58 (0.08)	0.89 (0.26)	.76**	–1.50	–.30	–.57†	–.12	–.14	–
6. Elasticity	0.008 (.001)	0.009 (.001)	.88***	–0.34	–.85**	–.33	–.56	–.79**	.36

Note. C/D = cigarettes/day; FTND = Fagerström Test for Nicotine Dependence. Correlations among the same variables use raw values for T1 and T2; correlations among different variables use mean values between T1 and T2.

†*p* < .10. **p* < .05. ***p* < .01. ****p* < .001.

value and although the exponential model provides a very good fit to the data, it is almost always imperfect (i.e., $R^2 < 1.0$), making the coefficient less likely to be stable over time. However, as the only demand index that empirically quantifies demand across the aggregated choices, it is quite distinct from the other indices and may provide important incremental information.

A notable area not addressed in the current study or previous studies has been the relationship between demand indices and biomarkers of nicotine dependence. As purchase tasks depend on self-reported estimates, it is all the more important to examine and establish their relationship to objective indicators of smoking involvement, including CO and other biomarkers such as cotinine. Although CO was collected in the current study, it is relatively sensitive to recency of exposure, which was not controlled, and the CO assessment took place at varying times during the session. Taken together, these factors invalidated systematic considerations of CO in relation to the demand indices, but this is clearly a priority for future studies.

There are also several limitations to the current study that similarly point to priorities for future studies. Chief among these are the use of a relatively small sample and a relatively brief interval between the first and second assessment. With regard to the former, small sample size particularly pertains to the correlations beyond those pertaining to test–retest reliability. Here, substantial caution should be exercised because even large associations fell short of statistical significance at times and the small sample size may have substantially influenced the findings. With regard to the latter, future studies validating the test–retest reliability of the CPT over longer periods of time will be important. In addition, most assessments exhibit some decrement in reliability as time intervals increase, even for putatively long-standing characteristics, such as personality (e.g., Block & Block, 2006). This is expected to be the case for purchase tasks also, but the more important question is how much decrease in reliability takes place. Determining the stability of cigarette demand over longer periods of time and factors that affect its stability is a necessary step for further validation of a CPT approach.

There are, of course, limits to the importance of test–retest reliability data for a measure, such as a CPT. On the one hand, robust short-term temporal stability is important for the validity of the measure, but on the other, motivation for smoking is known to fluctuate over time. As such, temporal stability when

all other things are equal provides the boundary conditions for arguably more important applications, such as examining the factors that change demand, including simple fluctuations over time, pharmacological or psychosocial interventions, or environmental factors, such as tax changes, health education messages, and even environmental tobacco cues. In other words, a larger goal of validating the temporal stability of a CPT is in the service of applying this approach more widely in clinical and research settings.

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Declaration of Interests

None declared.

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