Nicotine & Tobacco Research, 2016, 531–537
doi:10.1093/ntr/ntv233
Original investigation
Advance Access publication October 24, 2015

Original investigation

Predictive Validity of a Cigarette Purchase Task in a Randomized Controlled Trial of Contingent Vouchers for Smoking in Individuals With Substance Use Disorders

James Mackillop PhD[1,2,3], Cara M. Murphy MS[2,3], Rosemarie A. Martin PhD[2], Monika Stojek MS[3], Jennifer W. Tidey PhD[2], Suzanne M. Colby PhD[2], Damaris J. Rohsenow PhD[2,4]

[1]Peter Boris Centre for Addictions Research, McMaster University/St. Joseph's Healthcare Hamilton, Hamilton, ON, Canada; [2]Center for Alcohol and Addiction Studies, Brown University, Providence, RI; [3]Department of Psychology, University of Georgia, Athens, GA; [4]Research Service, Providence Veterans Affairs Medical Center, Providence, RI

Corresponding Author: Damaris J. Rohsenow, PhD, Center for Alcohol and Addiction Studies, School of Public Health, Box G-S121-5, Brown University, Providence, RI 02912, USA. Telephone: 401-863-6648; Fax: 401-863-6697; E-mail: Damaris_Rohsenow@brown.edu

Abstract

Introduction: A cigarette purchase task (CPT) is a behavioral economic measure of the reinforcing value of smoking in monetary terms (ie, cigarette demand). This study investigated whether cigarette demand predicted response to contingent monetary rewards for abstinence among individuals with substance use disorders. It also sought to replicate evidence for greater price sensitivity at whole-dollar pack price transitions (ie, left-digit effects).

Methods: Participants (N = 338) were individuals in residential substance use disorder treatment who participated in a randomized controlled trial that compared contingent vouchers to noncontingent vouchers for smoking abstinence. Baseline demand indices were used to predict number of abstinent days during the 14-day voucher period (after the reduction lead-in) and at 1 and 3 months afterward.

Results: Demand indices correlated with measures of smoking and nicotine dependence. As measured by elasticity, intensity and O_{max}, higher demand significantly predicted fewer abstinent exhaled carbon monoxide readings during voucher period for individuals in the noncontingent vouchers condition. Breakpoint exhibited a trend-level association with abstinent exhaled carbon monoxide readings. Demand indices did not predict abstinence in the contingent vouchers group, and did not predict abstinence at 1- and 3-month follow-ups. Left-digit price transitions were associated with significantly greater reductions in consumption.

Conclusions: The association of cigarette demand with smoking behavior only in the group for whom abstinence was not incentivized indicates that CPT assesses the value of smoking more than the value of money per se and that vouchers counteract the effects of the intrinsic reinforcing value of cigarettes. Results provide initial short-term evidence of predictive validity for the CPT indices.

Implications: This study provides the first evidence of the validity of the CPT for predicting early response to brief advice for smoking cessation plus nicotine replacement in smokers with substance dependence. However, demand for cigarettes did not predict voucher-based treatment

response, indicating that incentives serve as a powerful motivator not to smoke that acts in opposition to the intrinsic reinforcing value of cigarettes and that the indices reflect the value of smoking more than the value of money per se.

Introduction

Individuals with substance use disorders (SUD) continue to smoke at higher rates than the general population.[1–3] Interventions using voucher-based contingencies have improved outcomes in nicotine, marijuana, opiate, cocaine, alcohol, and polydrug treatments.[4] Contingent voucher (CV) treatments have been effective for reducing smoking cessation among individuals in treatment for SUDs.[5,6] Smokers with SUD who were provided with CV for low levels of exhaled carbon monoxide (CO) versus noncontingent vouchers (NV) had a higher percentage of CO readings indicating abstinence and, when combined with motivational interviewing, were more likely to be abstinent for a year.[6]

An important moderator of the effectiveness of a CV program is its monetary value.[4] Accordingly, it is important to understand the factors that may influence sensitivity to voucher reinforcement. Response to vouchers for smoking abstinence was predicted by nicotine dependence and intolerance for smoking withdrawal discomfort,[7] but the reinforcing value of smoking has never been studied as a predictor. This is important because the value of the voucher is putatively a function of both its value and the value of cigarettes as reinforcers.

Behavioral economics is the discipline that has most sought to understand and categorize individual preferences between substances and monetary alternatives.[8] One method involves studying demand for cigarettes using a hypothetical cigarette purchase task (CPT) that measures estimated cigarette consumption at escalating prices.[9] Individuals with greater demand for cigarettes report smoking more cigarettes each day.[10–12] and generally are less sensitive to changes in cigarette price, so price increases should be less influential in changing smoking behavior.[13] CV incentive programs increase the cost of smoking by introducing a financial opportunity cost in the form of the voucher with monetary value, making indices of tobacco demand logical predictors of CV response. In adolescents, motivation to change smoking behavior was not associated with indices of demand cross-sectionally,[11] but no studies have prospectively examined the extent to which demand for cigarettes influences an individual's ability to successfully quit smoking. Demand may be an important patient-treatment matching variable if it can predict who will be able to abstain from smoking, especially in the context of CV-based interventions which rely on individuals making choices between cigarettes and money.

The primary goal of this study was to investigate whether cigarette demand as assessed by a CPT would predict response to CVs for smoking abstinence. Smokers in treatment for SUD were randomized to receive either CV based on abstinence for 14 days after a 5-day reduction period or NV for 19 days.[14] Biochemically-verified tobacco abstinence was assessed both during the voucher period and 1 and 3 months afterward. We predicted that tobacco demand would be inversely related to abstinence in both conditions (ie, lower demand associated with higher levels of abstinence), but that this relationship would be of greater magnitude for those in the CV condition. In that case, individuals for whom the reinforcing value of smoking is substantially reduced by financial costs would be expected to be more sensitive to the higher response cost of giving up the financial incentives. A secondary goal was to replicate evidence of previously reported "left-digit" effects,[13] or disproportionately large reductions in consumption as pack prices reach the next whole dollar amount.

Methods

Participants

Participants were 338 smokers recruited from two inner-city state-funded residential SUD treatment programs. Inclusion criteria included being at least 18 years old, meeting diagnostic[15] criteria for SUD, and smoking at least 10 cigarettes per day for the past 6 months. Participants did not need to be motivated to quit smoking. Exclusion criteria were current smoking cessation treatment, hallucinating or delusional, current suicidality, terminal illness, or inability to understand informed consent. No participants were in substance withdrawal. Both programs were abstinence-oriented and used the 12-step model to provide substance education. While smoking was allowed outside during breaks and smoking cessation was not addressed by the programs directly, staff at both facilities were supportive of the smoking intervention research. Average length of stay in residential treatment was 120 days (SD = 82 days). Programs differed in duration of treatment, $t(337) = 8.08$, $P < .05$. One program (64% of sample) had average length of stay of 89 days (SD = 23 days). The second program (36% of sample) had average length of stay of 174 days (SD = 113 days).

Procedures

All procedures were approved by the university Institutional Review Board. Participants provided informed consent then completed pretreatment assessment. Participants received four sessions of brief advice designed to motivate smoking cessation and 8 weeks of transdermal nicotine replacement therapy, and were randomized within each site to either 19 days of CV or NV. Vouchers were redeemable for merchandise certificates at local stores. Individuals in the CV group could earn vouchers for reductions from baseline CO levels using CO measured once each morning during a 5-day lead-in period ($2 per for a 25% reduction, $4 for 50% reduction, and $6 for a 75% or greater reduction). Afterward, for 14 days, participants earned vouchers for each of two daily CO readings not more than 6 ppm. Voucher values ranged from $3 to $16.50/each, increasing on an escalating scale for consecutive abstinent readings with a total possible earning of $433. When individuals missed a CO reading or CO readings were more than 6 ppm, the voucher value was reset to the lowest value,[16] but would reset to the highest previously achieved value after three consecutive CO readings not more than 6 ppm. Individuals assigned to NV were paid for providing breath samples, regardless of CO level, on the same schedule. The value of the vouchers in the NV condition ($304) was selected to be equivalent to the average daily payment received in a CV group in an unpublished prior study.

Follow-up assessments of smoking cessation completed 1 and 3 months after start of treatment were conducted away from the

treatment facility whenever possible and were only completed if the participant's breath alcohol content was less than 0.02 g%.

Measures

Demographic Information

This included age, gender, marital status, education, ethnicity, and race.

Baseline Smoking and Nicotine Dependence

Fagerström Test of Nicotine Dependence[17] is a 6-item measure of nicotine dependence scored 0–10. Daily cigarette consumption over the 7 days prior to the assessment was also collected with this instrument. CO levels were assessed via a Bedfont Micro Smokerlyzer.

Smoking Abstinence at Follow-Up

Participants provided self-reported 7-day point prevalence abstinence status at 1 and 3 months which was verified by CO ≤ 8 ppm.

Cigarette Purchase Task

A CPT[9,10] assesses estimated cigarette consumption in a typical day at various escalating prices. The version used was adapted from MacKillop et al.[10] with 41 prices ranging from $0 to $35 and using the same instructional set. Prices began at no cost (free) and increased by 2 cents (USD) to 50 cents per cigarette, increased by 10 cents to $1 per cigarette, increased by $1 to $5 per cigarette and increased by $5 to $35 per cigarette. Associated pack prices were presented to the right of the individual cigarette prices.

Data Analysis Approach

Four indices of cigarette demand were generated from the CPT including: (1) intensity: number of cigarettes consumed at zero price; (2) O_{max}: the maximum amount of money allocated to cigarettes; (3) breakpoint: the first price that suppressed cigarette consumption to zero; and (4) elasticity: overall proportionate price sensitivity (P_{max} was not analyzed since it is approximately collinear with breakpoint.[10,11]). Elasticity was derived using the following equation $\log_{10}Q = \log_{10}Q_0 + k(e^{-\alpha Q_0 C} - 1)$, where Q = consumption at a given price (with zeroes set to 0.01), Q_0 = consumption at zero/minimal price, k = a constant across individuals, in this case 3, that denotes the range of consumption values in log powers of 10, α = the derived demand parameter reflecting the rate of decline of consumption in standardized price, and C = the cost (price) of the commodity.[18] Indices of demand were log transformed to improve skewness and kurtosis. Intercorrelations among demand indices were examined to check for multicollinearity. All other variables were normally distributed except number of days abstinent during the (14-day) voucher period which was log transformed for analyses. Outliers for price level data and demand indices were defined as Z >3.29 and were Winsorized to one unit above the next highest value.[19]

Pearson correlations examined the relationship between CPT demand indices and baseline smoking-related variables. Regression analyses investigated whether demand indices predicted number of days abstinent during the voucher period. Since participants randomized to the CV condition (n = 172) are provided monetary incentives for abstinence during the 14-day voucher period, the ability of the CPT to predict abstinence was analyzed separately for participants in the CV condition versus the NV (n = 166) condition. To test whether demand indices predicted point prevalence abstinence at 1 and 3 months follow-up, logistic regression was conducted using all participants after entering voucher condition and the interaction of demand index of interest by voucher condition to control for effects of voucher condition on outcome. Analyses of point prevalence abstinence followed intent to treat principles which retain all participants randomized to treatment and count any participants with missing values, except those known to have died, as smokers according to clinical research guidelines with this population.[20] The number of participants in analyses included n = 338 at 1-month follow-up and n = 335 at 3-month follow-up (due to three deaths). One-month follow-up interviews were completed for 94% (n = 320) of the sample, and 3-month follow-up interviews were completed for 86% (n = 291) of the sample. Baseline Fagerström Test of Nicotine Dependence score was evaluated as a potential covariate if significantly associated with outcome.

Within the band of prices that had sufficient price resolution to permit examination of left-digit transitions (ie, $0 to $0.50/cigarette), left digit effects were examined using one-way two-level analysis of variance comparing average changes at non-left-digit transitions (ie, price changes that did not include a whole dollar pack price change; eg, $4.40 to $4.80 per pack) to left-digit price transitions (ie, price changes that included a whole dollar pack price change; eg, $4.80 to $5.20 per pack).

Results

Participant Characteristics

Participant characteristics, smoking, and demand indices are displayed in Table 1. Regarding SUDs, 68% of participants met criteria for alcohol dependence, 56% for cocaine dependence, 47% for

Table 1. Baseline Participant Characteristics: Mean (*SD*), Median, or Percentage

	Full sample	CV	NV
N	338	172	166
Male	68%	66%	69%
Race			
White/Caucasian	86%	85%	87%
Black/African American	10%	11%	9%
Asian/Pacific Islander	<1%	0%	<1%
American Indian	2%	4%	<1%
Multi-racial	1%	0%	2%
Married or cohabiting	11%	10%	12%
Annual household income			
$0–$9999	59%	61%	57%
$10 000–$29 999	26%	23%	29%
$30 000–$49 999	9%	9%	9%
≥$50 000	6%	7%	5%
Age	37.6 (10.0)	37.9 (10.1)	37.4 (10.0)
Years education	12.1 (2.2)	12.2 (2.0)	12.1 (2.2)
Cigarettes/d	19.5 (7.4)	20.0 (8.0)	19.0 (6.7)
FTND	5.9 (1.9)	5.9 (1.8)	6.0 (2.0)
CPT breakpoint	$5.26 (9.0)	$6.09 (10.0)	$4.40 (7.8)
CPT O_{max}	$16.74 (15.6)	$17.61 (17.1)	$15.83 (14.0)
CPT intensity	30.0 (14.9)	29.7 (14.9)	30.3 (15.1)
CPT elasticity	0.02 (0.03)	0.02 (0.03)	0.02 (0.03)
% Heavy drinking days	39.0 (38.8)	40.9 (38.9)	37.1 (37.6)
% Other drug days	54.2 (39.9)	55.6 (40.7)	52.6 (39.0)

CPT = Cigarette Purchase Task; CV = contingent vouchers group; FTND = Fagerström Test of Nicotine Dependence total score; NV = noncontingent vouchers group.

opiate dependence, and 28% for marijuana dependence. There were no significant differences between individuals in the CV and NV groups on any baseline characteristics or number of days of nicotine replacement therapy use.

Preliminary Analyses

The demand equation provided an acceptable fit to the data (median R^2 = 0.86, IQR = 0.78–0.90, see Figure 1). Correlations between the CPT indices and smoking related-variables were in expected directions (Table 2). There were no significant relationships between any indices of tobacco demand and income (*r*s = –0.3 to –0.11). There were no significant relationships between Fagerström Test of Nicotine Dependence and number of days abstinent during the voucher period (*r* = –0.05) or point prevalence abstinence at 1-month (*r* = –0.02) or 3-month (*r* = –0.09) follow-up. Therefore, income and nicotine dependence were not included as covariates in regression models.

Predicting Smoking Abstinence During and After Treatment

During the 14-day abstinence period, participants in the CV condition had significantly more smoking abstinent days (*M* = 6.99, *SD* = 5.73) than did participants in the NV condition (*M* = 3.11, *SD* = 4.65), *t*(336) = 6.48, *P* < .001. Regression analyses investigating whether demand indices predicted number of days abstinent during the voucher period for participants in the CV group were not statistically significant (βs = –0.05 to 0.01, *P*s = .48 to .93). In the NV condition, three indices of demand significantly predicted abstinence during the voucher period: higher baseline intensity, higher O_{max}, and lower elasticity predicted less abstinence (Table 3).

Confirmed 7-day point prevalence abstinence was 8.6% (*n* = 29 of 338) at 1 month and 4.2% (14 of 335, three people died) at 3 months. Demand for cigarettes was not significantly predictive of abstinence outcomes at either time point (all *P*s > .26).

Left-Digit Pack Price Effects

Changes in price-level estimated consumption exhibited considerable heterogeneity in magnitude of changes in estimated consumption, but with notably higher decreases during left-digit transitions (Figure 2). A significant difference was present between changes across non-left-digit transitions and left-digit transitions (F[1, 337] = 103.57, P < .001, η_p^2 = 0.23), reflecting a threefold higher reduction in consumption following a left-digit transition (*M* = –0.33 [standard error of the mean [*SEM*] = 0.03] vs. *M* = –1.02 [*SEM* = 0.06]). Based on the pattern of observed changes in Figure 2, left-digit effects were further subdivided into those that traversed a whole dollar price change (eg, $4.80 to $5.20 per pack) and those that were exact left-digit changes (eg, $5.60 to $6 per pack), landing on a new whole dollar amount, and a further three-level analysis of variance was conducted. A significant omnibus effect was present (F[1, 337] = 75.51, P < .001, η_p^2 = 0.25), with follow-up *t* tests revealing significant differences between all three groups. Interestingly, the exact left-digit transitions exhibited threefold larger reductions compared to the traversing left-digit changes (*M* = –0.50 [*SEM* = 0.06]

Table 2. Baseline Correlations of Cigarette Purchase Task Demand Indices and Related Variables

	Breakpoint	O_{max}	Elasticity	FTND	Cigs/d
Intensity	0.14*	0.40**	–0.34**	0.44**	0.54**
Breakpoint		0.75**	–0.91**	0.07	0.02
O_{max}			–0.88**	0.27**	0.23**
Elasticity				–0.23*	–0.17*
FTND					0.45**

FTND = Fagerström Test of Nicotine Dependence 17 total score.
*P < .01; **P < .001.

Table 3. Number of Abstinent Days During the Voucher Period in Each Condition as Predicted by Baseline Demand Indices

	Voucher period			
	β	sr^2	F(1, 164)	P
Noncontingent vouchers condition				
Intensity	–0.15	0.02	3.80	.05
Breakpoint	–0.15	0.02	3.67	.06
O_{max}	–0.15	0.02	3.90	.05
Elasticity	0.19	0.04	5.99	.02
Contingent vouchers condition				
Intensity	–0.04	<0.001	0.21	.65
Breakpoint	–0.007	<0.001	0.009	.93
O_{max}	–0.03	<0.001	0.17	.68
Elasticity	0.02	<0.001	0.09	.77

Abstinent days based on two carbon monoxide readings indicative of abstinence; sr^2 indicates percentage of variance accounted for by the predictor.

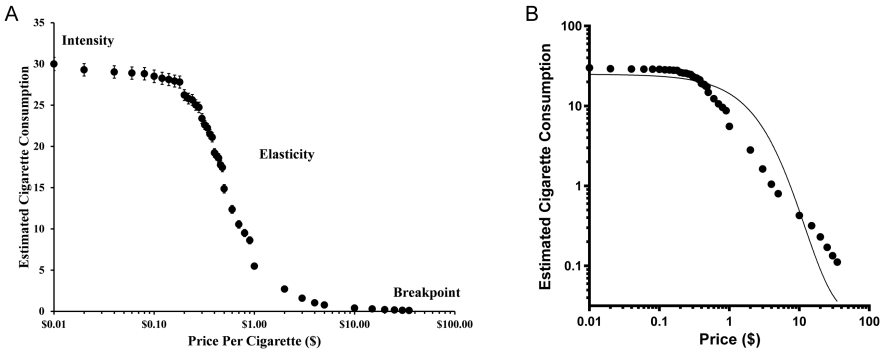

Figure 1. Baseline demand curve of estimated cigarette consumption across prices. Zero price is represented by $.01 as zero values cannot be depicted in logarithmic terms. Panel A presents the demand curve with an untransformed y-axis to present the absolute values and standard errors. Intensity of demand refers to consumption at zero price; elasticity refers to proportionate price sensitivity across escalating prices; breakpoint refers to the price at which consumption is suppressed to zero. Panel B presents log–log coordinates for proportionality and the derived exponential function.

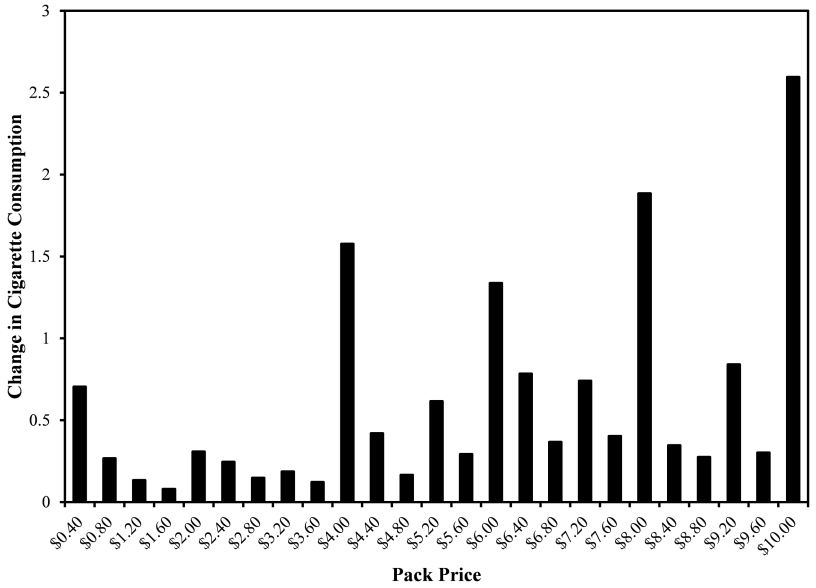

Figure 2. Changes in estimated cigarette consumption at price transitions from $.40 to $10/pack.

vs. $M = -1.54$ [$SEM = 0.11$]). Thus, reductions in consumption were generally larger during whole dollar pack price transitions but at a much larger magnitude in the presence of exact left-digit transitions.

Discussion

We had predicted that demand for cigarettes would predict abstinence over time in general but with a stronger relationship in the CV versus NV condition. Cigarette demand significantly predicted abstinence over time, but only in the NV condition. Three indices were important determinants of failure to abstain: higher baseline intensity, higher $O_{max,}$ and lower elasticity predicted less abstinence. Breakpoint, in the predicted direction, missed significance. Previous research suggests that O_{max} and intensity aggregate to form an Amplitude factor,[21] reflecting how much an individual wants to smoke or spend (y-axis of the demand curve). Thus, it appears that higher volumetric valuation of cigarettes at baseline is an important determinant of likelihood of abstaining from smoking during treatment in the absence of competing reinforcers.

The absence of an association in the CV group is somewhat surprising but has implications for understanding the nature of what the CPT is characterizing and for predicting response to voucher-based interventions. A CPT can be interpreted in two complementary ways: first as a measure of the reinforcing value of cigarettes using money as a proxy for response cost from a behavioral perspective, and second as a measure of sensitivity to the financial costs of cigarettes from an economic and more literal perspective. The prediction that a CPT will predict CV response is predicated more on the latter interpretation than the former. The absence of a significant relationship does not support the economic perspective, suggesting that the CPT is better thought of as capturing the reinforcing value of smoking using the currency of money as a proxy (universal reinforcer), not in terms of the direct relationship between money per se and cigarettes. From this perspective, the voucher condition actually eliminated the observed predictive relationship by serving as a powerful external motivator not to smoke that acted in opposition to the intrinsic reinforcing value of cigarettes. The conclusion that the CPT is relatively unrelated to specific financial contingencies is further supported by the absence of associations between demand indices and income, even in this very low income population.

Collectively, these findings can be interpreted as providing some initial support for the validity of the CPT as a predictor of short-term smoking cessation for smokers given brief advice and nicotine replacement therapy without vouchers, albeit with effect sizes that are small (2%–4% of variance). These findings clearly do not support the use of a purchase task for predicting response to voucher-based interventions. Instead, measures that more narrowly and explicitly capture the value of money to the individual may be necessary, such as an operant progressive ratio task in which an effortful behavioral response garners monetary reinforcement.

The significant associations did not persist into follow-up. Narrowly interpreted, this suggests that demand indices had short-term predictive validity in the control condition but were not predictive over longer periods of time. However, a number of considerations pertaining to the follow-up outcomes should be noted. First, the prevalence of abstinence was very low at follow-up in general, restricting range. Second, all individuals were residing in treatment during the voucher period but were not necessarily still doing so during follow-up time points. As such, the participants were likely to have an array of challenges that are not typical of smokers in general attempting smoking cessation. Third, other unmeasured factors influence longer term abstinence, including motivation,[7] intolerance for discomfort of abstinence,[7] perceived barriers to smoking cessation,[22] and these variables may have substantially influenced smoking after the initial period. None of these factors fundamentally alters the patterns of findings or interpretation, but the highly multifarious potential determinants of outcome among individuals with SUDs collectively set a "high bar" for successfully predicting response over time. Consistent with this, nicotine dependence was also not significantly associated with follow-up outcomes in this study.

A secondary goal of the study was to replicate the pattern of left-digit effects observed previously in a general community sample of smokers. The pattern of larger magnitude decreases at left-digit pack price transitions reproduces and extends the earlier findings.[13] From

a policy standpoint, this suggests that increases in tobacco taxes that extend though whole dollar prices will have disproportionately large impact. However, the current findings add an interesting nuance also. The magnitude of decreases was significantly smaller when pack price transitions were not to exact whole dollar values, but traversed the next whole dollar value. This appears to be an example of a "precision effect," in which the consumer is more oriented to final values in the price of a commodity.[23] In this case, the participants' attention appears to have been drawn to the decimal values for the traversing price changes and, in the presence of zero decimals, drawn to the whole number value for the exact left-digit changes. However, this conjecture will require direct empirical testing in future studies.

The current findings should be considered within the context of study limitations. First, the results may be specific to smokers in inner-city treatment programs for SUD. Second, participants were not recruited based on motivation to quit smoking and it is possible that demand for cigarettes could predict higher rates of long-term abstinence at follow-up in individuals with greater motivation to quit smoking. Third, all participants received nicotine replacement therapy throughout the voucher period and it is not clear whether this could have influenced the predictive relationships. Finally, although previous studies have indicated that there is high correspondence between performance on hypothetical and actual purchase tasks,[24] it is possible that results would differ if the actual contingencies were in place.

To conclude, this study sought to use behavioral economics to understand responsiveness to CV and NV in smokers with SUDs. For individuals receiving smoking brief advice with NVs, baseline levels of demand for cigarettes predicted abstinence during the voucher period. However, contrary to predictions, that relationship was not present for individuals who were provided incentives for abstinence. The predictive validity in the condition with brief advice and NV is similar to previous research on demand for alcohol which found that demand indices predicted drinking outcome following an brief intervention,[25] but this is the first known study to have a similar conclusion with regard to demand for cigarettes predicting abstinence within treatment. More broadly, these findings support the utility of a using a behavioral economic approach to understand nicotine dependence and highlight the continuing need to identify variables that predict treatment response to voucher-based interventions.

Funding

This work was supported in part by the National Institute on Drug Abuse (grant 1R01 DA023995 to DJR) and a Senior Career Research Scientist Award from the Department of Veterans Affairs (to DJR). JM is the holder of the Peter Boris Chair in Addictions Research at McMaster University, which partially supported his role. The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs.

Declaration of Interests

None declared.

Acknowledgments

Grateful appreciation is expressed to Suzanne Sales for her data analyses and to the staff of The Providence Center and of Gateway Healthcare, Inc. Preliminary results were presented at the annual meeting of the Research Society on Alcoholism, San Francisco, CA, June 27, 2012.

References

1. Richter KP, Ahluwalia HK, Mosier MC, Nazir N, Ahluwalia JS. A population-based study of cigarette smoking among illicit drug users in the United States. *Addiction*. 2002;97(7):861–869. doi:10.1046/j.1360-0443.2002.00162.x.
2. Lasser K, Boyd JW, Woolhandler S, Himmelstein DU, McCormick D, Bor DH. Smoking and mental illness: a population-based prevalence study. *JAMA*. 2000;284(20):2606–2610. doi:10.1001/jama.284.20.2606.
3. Goodwin RD, Sheffer CE, Chartrand H, et al. Drug use, abuse, and dependence and the persistence of nicotine dependence. *Nicotine Tob Res*. 2014;16(12):1606–1612. doi:10.1093/ntr/ntu115.
4. Lussier JP, Heil SH, Mongeon JA, Badger GJ, Higgins ST. A meta-analysis of voucher-based reinforcement therapy for substance use disorders. *Addiction*. 2006;101(2):192–203. doi:10.1111/j.1360-0443.2006.01311.x.
5. Sigmon SC, Patrick ME. The use of financial incentives in promoting smoking cessation. *Prev Med*. 2012;55(suppl):S24–S32. doi:10.1016/j.ypmed.2012.04.00.
6. Rohsenow DJ, Tidey JW, Martin RA, et al. Contingent vouchers and motivational interviewing for cigarette smokers in residential substance abuse treatment. *J Sub Abuse Treat*. 2015;55:29–38. doi:10.1016/j.jsat.2015.02.010.
7. Rohsenow DJ, Tidey JW, Kahler CW, Martin RA, Colby SM, Sirota AD. Intolerance for withdrawal discomfort and motivation predict voucher-based smoking treatment outcomes for smoker with substance use disorders. *Addict Behav*. 2015;43:18–24. doi:10.1016/j.addbeh.2014.12.003.
8. Bickel WK, Johnson MW, Koffarnus MN, MacKillop J, Murphy JG. The behavioral economics of substance use disorders: reinforcement pathologies and their repair. *Annu Rev Clin Psycho*. 2014;10:641–677. doi:10.1146/annurev-clinpsy-032813-153724.
9. Jacobs EA, Bickel WK. Modeling drug consumption in the clinic via simulation procedures: demand for heroin and cigarettes in opioid-dependent outpatients. *Exp Clin Psychopharm*. 1999;7(4):412–426. doi:10.1037/1064-1297.7.4.412.
10. MacKillop J, Murphy JG, Ray LA, et al. Further validation of a cigarette purchase task for assessing the relative reinforcing efficacy of nicotine in college smokers. *Exp Clin Psychopharm*. 2008;16(1):57–65. doi:10.1037/1064-1297.16.1.57.
11. Murphy JG, Mackillop J, Tidey JW, Brazil LA, Colby SM. Validity of a demand curve measure of nicotine reinforcement with adolescent smokers. *Drug Alcohol Depen*. 2011;113(2):207–214. doi:10.1016/j.drugalcdep.2010.08.004.
12. Few LR, Acker J, Murphy C, MacKillop J. Temporal stability of a cigarette purchase task. *Nicotine Tob Res*. 2012;14(6):761–765. doi:10.1093/ntr/ntr222.
13. MacKillop J, Few LR, Murphy JG, et al. High-resolution behavioral economic analysis of cigarette demand to inform tax policy. *Addiction*. 2012;107(12):2191–2200. doi:10.1111/j.1360-0443.2012.03991.x.
14. Rohsenow DJ, Tidey JW, Martin RA, Colby SM, Monti PM. Voucher-based Smoking Treatment with Nicotine Replacement and Motivational Advice for Smokers in Substance Treatment. Poster Presented at 15th Annual Meeting of the Society for Research on Nicotine and Tobacco Europe; September, 2014; Santiago de Campostela, Spain.
15. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. 4th ed. Washington, DC: American Psychiatric Association; 2000. doi:10.1176/appi.books.9780890423349.
16. Higgins ST, Budney AJ, Bickel WK, Foerg FE, Donham R, Badger GJ. Incentives improve outcome in outpatient behavioral treatment of cocaine dependence. *Arch Gen Psychiat*. 1994;51(7):568–576.
17. Heatherton TF, Kozlowski LT, Frecker RC, Fagerström KO. The Fagerström Test for nicotine dependence: a revision of the Fagerström Tolerance Questionnaire. *Brit J Addict*. 1991;86(9):1119–1127. doi:10.1111/j.1360-0443.1991.tb01879.x.
18. Hursh SR, Silberberg A. Economic demand and essential value. *Psychol Rev*. 2008;115(1):186–198. doi:10.1037/0033-295X.115.1.186.

19. Tabachnick BG, Fidell LS. *Using Multivariate Statistics*. 5th ed. Boston, MA: Allyn & Bacon; 2007.
20. Hughes JR, Keely JP, Niaura RS, Ossip-Klein DJ, Richmond RL, Swan GE. Measures of abstinence in clinical trials: issues and recommendations. *Nicotine Tob Res*. 2003;5(1):13–25. doi:10.1093/ntr/5.1.13.
21. MacKillop J, Murphy JG, Tidey JW, Kahler CW, Ray LA, Bickel WK. Latent structure of facets of alcohol reinforcement from a behavioral economic demand curve. *Psychopharmacology*. 2009;203(1):33–40. doi:10.1007/s00213-008-1367-5.
22. Martin RA, Sales SM, Rohsenow DJ. Barriers to quitting smoking among substance dependent patients in treatment predicts outcome. Poster presented at the annual meeting of the Society for Research on Nicotine and Tobacco; March 13–16, 2013; Boston, MA.
23. Janiszewski C, Uy D. Anchor precision influences the amount of adjustment. *Psychol Sci*. 2008;19(2):121–127. doi:10.1111/j.1467-9280.2008.02057.x.
24. Amlung MT, Acker J, Stojek MK, Murphy JG, MacKillop J. Is talk "cheap"? An initial investigation of the equivalence of alcohol purchase task performance for hypothetical and actual rewards. *Alcohol Clin Exp Res*. 2012;36(4):716–724. doi:10.1111/j.1530-0277.2011.01656.x.
25. MacKillop J, Murphy JG. A behavioral economic measure of demand for alcohol predicts brief intervention outcomes. *Drug Alcohol Depen*. 2007;89(2):227–233. doi:10.1016/j.drugalcdep.2007.01.002.