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The Experimental Tobacco Marketplace I: Substitutability as a Function of the Price of Conventional Cigarettes

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Abstract

Introduction: Behavioral economic studies of nicotine product consumption have traditionally examined substitution between two products and rarely examined substitution with more products. Increasing numbers of tobacco products available for commercial sale leads to more possible cross-product interactions, indicating a need to examine substitution in more complex arrangements that closely mirror the tobacco marketplace.

Methods: The experimental tobacco marketplace (ETM) is an experimental online store that displays pictures, information, and prices for several tobacco products. Smokers were endowed with an account balance based on their weekly tobacco purchases. Participants then made potentially real purchases for seven (Experiment 1) or six (Experiment 2) tobacco/nicotine products under four price conditions for conventional cigarettes while prices for other products remained constant. Smokers returned 1 week later to report tobacco/nicotine use and return unused products for a refund.

Results: In Experiment 1 ($n = 22$), cigarette purchasing decreased as a function of price. Substitution was greatest for electronic cigarettes and cigarillos and significant for electronic cigarettes. Experiment 2 ($n = 34$) was a replication of Experiment 1, but with cigarillos unavailable in the ETM. In Experiment 2, cigarette purchases decreased as a function of price. Substitution was robust and significant for electronic cigarettes and Camel Snus.

Conclusions: The ETM is a novel, practical assay that mimics the real-world marketplace, and functions as a simple research tool for both researchers and participants. Across the two experiments the product mix in the ETM altered which products functioned as substitutes suggesting complex interactions between purchasing and product availability.

Implications: This article adds a novel method of collecting purchasing data that mimics real world purchasing to the existing literature. The ETM is a practical avenue by which to study both hypothetical and potentially real purchasing.

Introduction

In recent years, the variety of tobacco products has exploded attesting to the need for research to inform tobacco regulatory control. One important feature not adequately addressed by current tobacco regulatory control is how consumption and purchasing of a given tobacco product may be influenced by the constellation of alternative

tobacco products available in a complex marketplace (eg, electronic cigarettes, chewing tobacco). An important challenge is to identify methods that would forecast the impact of regulatory change on consumption patterns and/or consumer preference. Behavioral economics provides such methods to examine how various commodities may interact to impact the purchasing behavior of tobacco consumers.[1,2]

Behavioral economics provides a means to understand the type and degree of interaction between commodities (eg, substitution, complementarity[3]). Substitution is defined as an increase in the consumption of a product at a constant cost with the increasing price of an alternative commodity. For example, as the price of conventional cigarettes in a human laboratory study is increased, the consumption of nicotine gum increases even though its price remains constant.[4] Substitution defines one end of a continuum of interactions between commodities with complementarity at the other end of that continuum. The consumption of a complement decreases as the price of an alternative commodity increases. For example, the consumption of coffee has been shown to decrease with increasing cigarette prices, even though the price of coffee remained constant.[5] Between these two extremes is independence, which occurs when changes in the price of one commodity have little or no effect on consumption of another constantly priced commodity. For example, in a study where smokers completed response requirements to obtain concurrently available money and cigarette puffs, independence between commodities was found; that is, as cigarette consumption decreased with increasing price, the amount of money earned remained stable.[6] Overall, these interactions may enhance or diminish the ability to achieve the tobacco control goals of reducing the consumption of a particular product.[3]

Current tasks investigating cigarette and alternative product consumption and purchasing typically investigate two or three products.[4,7] For example, substitution was well illustrated in a study of nicotine gum, standard cigarette, and denicotinized cigarette consumption in smokers.[7] When standard cigarette prices (ie, effort to obtain the consumable product) were increased and both denicotinized cigarettes and nicotine gum were available at a constant price, consumption of both of the latter products increased, thus demonstrating that denicotinized cigarettes and nicotine gum functioned as substitutes for standard cigarettes. However, using such laboratory studies to measure a greater number of products concurrently would add a considerable number of sessions and, as a result, would increase both the cost and participant burden. Research in this area would benefit from developing a methodology to examine a larger number of nicotine and tobacco products without the additional cost or burden associated with a large number of sessions.

A recent scientific advance in the study of obesity and other nutrition-related research has been to establish experimental supermarkets where multiple products are available with prices controlled by the experimenter.[8] These novel arrangements permit the examination of price effects and can quantify the degree of substitution or complementarity across a large number of products under conditions that more closely approximate naturalistic settings. For example, Epstein et al.[9] examined the effects of taxing (increasing price) less healthy foods and subsidizing (decreasing price) of more healthy foods purchased by mothers. They found that taxing less healthy food reduced caloric intake and proportion of the calories from fat, while increasing the amount of protein consumed. Subsidizing healthier foods did not change the macronutrient profile of foods purchased, but increased caloric intake.

In sum, understanding how the introduction of novel products interacts with the other available products in an already complex tobacco market is among the most critical phenomenon for estimating the consequences of market changes, such as the introduction of novel products or regulation. To facilitate this goal and provide a procedure that can efficiently provide such estimates, we developed the experimental tobacco marketplace (ETM), a virtual store that offers a wide range of individual tobacco and nicotine products where product descriptions and prices can be manipulated. In Experiment 1, cigarillos were included as an alternate product in the ETM. In a second experiment, cigarillos were removed to investigate substitutability when only noncombustible products were available as alternatives.

Experiment 1

Methods

Participants

Participants (n = 22) were recruited from the Roanoke, VA community via fliers looking for daily cigarette smokers to participate in a tobacco products study, social media advertisements for cigarette smokers, and referrals. To meet eligibility criteria, participants must have been at least 18 years of age, met *DSM-IV*[10] criteria for tobacco dependence, been daily cigarette smokers (10–40 cigarettes/d) who did not report use of other nicotine products in the 30 days prior to enrollment in the study on a modified Timeline Follow Back,[11] provided a breath carbon monoxide sample greater than or equal to 10 parts per million, and provided their written informed consent. Individuals who were pregnant or lactating or had plans to move out of the area prior to being able to complete the study were ineligible to participate.

Participants were 54% female; 73% white and 23% African American; had a mean age of 39.9 (SD = 11.62); had a mean of 13.34 (SD = 2.64) years of education; and had a mean monthly income of $591.46 ($SD$ = $494.81). The median monthly income was $641.00 with an interquartile range from $112.50 to $920.30. Based on the Timeline Follow Back,[11] participants smoked 23.13 (SD = 10.16) cigarettes per day in the 30 days preceding study participation and had a mean score 6.95 on the Fagerström Test for Nicotine Dependence.[12]

Procedures

The Virginia Tech Institutional Review Board approved all policies and procedures. Participants first completed a screening questionnaire to determine eligibility. If eligible, participants attended an initial session where consent was given, breath carbon monoxide was measured, and a series of questionnaires including the Fagerström Test for Nicotine Dependence and *DSM-IV* and -5[10,13] questions were completed. Two experimental sessions followed. The first session included the ETM purchasing procedure (described below) and measures of nicotine craving. One week later a follow-up session to determine consumption of study and nonstudy products occurred where participants reported the number products consumed and returned any unused products for a refund.

Account Balance

Account balance was calculated based on average weekly number of cigarettes smoked multiplied by $0.25, which is approximately the local market price per cigarette and has been previously shown

to produce purchase amounts most similar to consumption prior to the experiment.[14] The balance was then added to the account for purchasing nicotine products.

Experimental Marketplace Sessions

Participants were seated in front of a computer to access the ETM. The ETM website was created and maintained with WordPress (version 3.93, https://wordpress.org/) and WooCommerce (version 2.1.12, https://woothemes.com/woocommerce/) software. The seven following products were available to participants in the units and at the prices (determined by local average price) indicated: their usual brand of cigarettes (packs, varied based on price condition, 19.6 mg of nicotine), Blu disposable electronic cigarettes (single count, $10.00, Lorillard Tobacco Company, Greensboro, NC, 20 mg of nicotine), winterchill flavor Camel Snus (15-pouch tins, $2.89 each, R.J. Reynolds, Winston-Salem, NC, 27.75 mg of nicotine), classic flavor Skoal dip (16.8-oz tins, $4.54 each, US Smokeless Tobacco Company, Richmond, VA, 62.4 mg of nicotine), white ice mint flavor Nicorette 4-mg nicotine gum (20-count packages, $16 each, McNeil Consumer Healthcare, Fort Washington, PA, 80 mg of nicotine), mint flavor Nicorette 4-mg nicotine lozenges (20-count packages, $12 each, McNeil Consumer Healthcare, Fort Washington, PA, 80 mg of nicotine), and Swisher Sweet cigarillos (single count, $1 each, Swisher International Group, Jacksonville, FL, 150 mg of nicotine). Participants were encouraged to browse the selection of products before they added any number of each product desired to their shopping cart, but total purchases could not exceed their account balance. The products were presented in an array where each product price was clearly displayed along with an image of the product (including participants' usual cigarette brand) including traditional labeling and branding information. A description of the nicotine content (determined by nicotine content listed on package or averages of reports from brand sources) in each product accompanied the image in a product description area displayed when an individual item was viewed or clicked. Participants were asked to make 1 week's worth of nicotine-product purchases under four randomly ordered price conditions ($0.12, $0.25, $0.50, and $1.00 per cigarette) for their usual brand of cigarettes. The prices for the other products remained constant across all four conditions. After all purchasing conditions were completed, one was randomly selected. Any remaining account balance and products purchased at that condition (ie, the actualized condition) were then provided by the experimenter for the participant to use over the next week.

Data Analysis

GraphPad Prism 6 (La Jolla, CA) was used for all data analysis. Packs of cigarettes purchased in each cost condition were transformed to the corresponding amount of nicotine per unit. The cigarette purchasing data was log transformed with asymmetric error and to calculate own-price elasticity, the mean number of mg of nicotine purchased across the four price conditions was fit to the equation:

$$\log Q = \log Q_0 + k\left(e^{(-a(Q_0 * C))} - 1\right) \quad (1)$$

where C is the cost of the reinforcer, Q is cigarette consumption, Q_0 represents demand intensity (the cigarette consumption level at no cost), k equals the span of the function in logarithmic units, and α denotes demand elasticity.[15] The free parameter k was fitted as a parameter common across experiments (k = 2.024). To calculate the price that supported the most expenditure, P_{max}, the fitted parameters were inserted into the first derivative of Equation 1 and evaluated at a slope equal to −1. O_{max}, the amount of money spent at P_{max}, was obtained by multiplying consumption by price at P_{max}. To verify, these values were also derived from Kaplan and Reed's[16] automated calculator. For purchase data, Q_0 and α were not calculated for individual participants because only four unit prices assessed, which were too few to reliably fit an equation with two free parameters. Multiple methods were compared to determine the best case to detect differences in cigarette demand between experiments: (1) Log transformed group mean data with asymmetric error were fit to Equation 1; (2) Zero consumption values were converted to nonzero integers by adding both 0.1 and 0.01 followed by log transformation and then fit to Equation 1. Neither method resulted in statistically significant differences and the results are reported using method 1, which produced the lowest probability value.

Units of alternate products purchased were converted to mg of nicotine using the nicotine content reported in the Methods. The data did not fit to Hursh and Roma's[1] cross-price elasticity equation. Thus, a linear regression was performed on the group mean data with fixed-priced commodity data as a function of the log-transformed unit prices to determine substitution magnitude, or cross-price elasticity. Results are reported for slopes that are statistically different from zero.

Results

Cigarette Demand in the ETM

Figure 1 depicts cigarette and alternate product demand in mg of nicotine where demand for cigarettes decreased as unit price of conventional cigarettes increased. When mean cigarette nicotine equivalence data were fit to Equation 1, the R^2 value was 0.991. The measure of elasticity, the α value, was 0.0033 and initial consumption, Q_0, was 241.50 units. P_{max} was $0.35 and O_{max} was $27.19.

Substitution for Cigarettes in the ETM

Importantly, three participants did not purchase any alternate products in any price condition. Figure 1 depicts the fitted cigarette demand curve and purchasing for each of the constant price alternatives. At the two highest conventional cigarette unit prices, purchasing was greatest for cigarillos and electronic cigarettes. The linear regression to determine cross-price elasticity indicated no statistical difference from zero for a majority of the available constant-priced products (Table 1). The slope of the electronic cigarettes function was the only product slope significantly different from zero [F(1, 86) = 7.73, P = .007; slope = 9.698]. Table 2 reports the percent of participants that purchased each commodity and the corresponding range of units purchased.

Consumption at Follow-up

Four participants underestimated weekly cigarette consumption and returned individual cigarettes (range 5–20) purchased during their experimental session and two alternate products were returned (one cigarillo and one electronic cigarette). Fourteen participants reported consumption of nonstudy individual cigarettes (range 2–80). Three of these participants used nonstudy provided cigarillos in addition to cigarettes. Panel A of Figure 2 depicts the correlation between the number of cigarettes distributed (ie, purchased in the

actualized condition) as a percentage of baseline use (determined by the Timeline Follow Back) and number of nonstudy cigarettes used as a proportion of baseline use was not significant (r = −0.33, P = .13), indicating no difference in outside study purchases based on amount distributed.

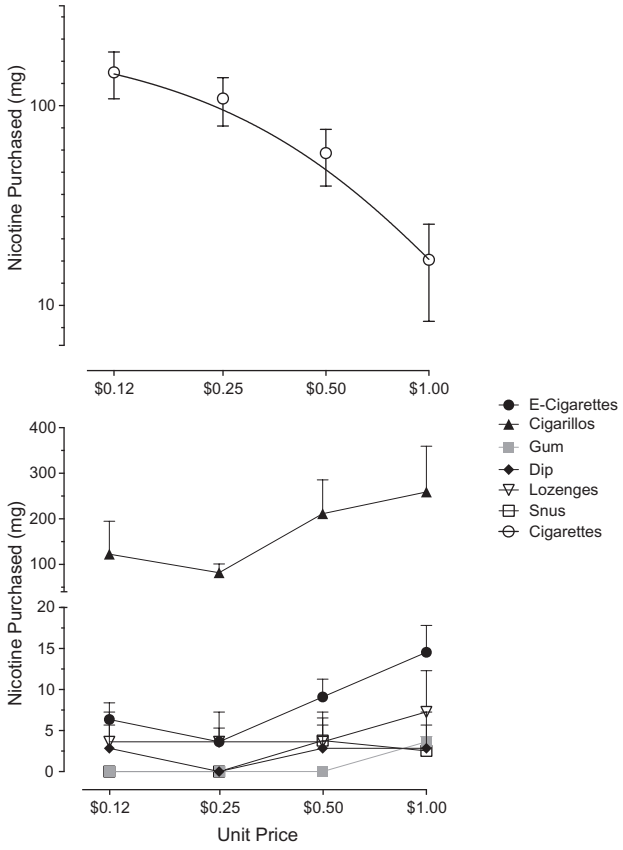

Figure 1. Individual cigarette demand and raw alternative product data from Experiment 1 represented in mg of nicotine purchased. Demand for cigarettes decreased as a function of cigarette price. Purchasing of cigarillos (P = .08) and electronic cigarettes (P = .003) increased as price of cigarettes increased.

Experiment 2

Methods

Participants

Recruitment procedures for this experiment were identical to Experiment 1 recruitment. Participants (n = 34) were 56% female, 47% white, and 53% African American; had a mean age of 40.3 (SD = 12.92); had mean 12.38 (SD = 1.56) years of education; and a mean monthly income of $554.32 ($SD$ = $580.21). The median monthly income was $190.00 with an interquartile range from $189.00 to $825.00. Based on the Timeline Follow Back,[11] participants smoked 19.91 (SD = 5.86) cigarettes per day in the 30 days proceeding study participation and scored a mean of 6.29 on the Fagerström Test for Nicotine Dependence.[12]

Procedures

Procedures for both experiments were almost identical with the exception that, in the ETM, cigarillos were available for purchase in Experiment 1 and were not available in Experiment 2. Data analyses were identical in both experiments. To determine differences in demand curves for cigarette purchasing, a nonlinear regression F test in GraphPad Prism (La Jolla, CA) was performed with k fitted as a shared parameter across the two experiments (k = 2.024).

Results

Cigarette Demand in the ETM

Figure 3 depicts cigarette and alternate product demand in mg of nicotine where demand for cigarettes decreased as unit price of conventional cigarettes increased. When mean individual cigarette data were fit to Equation 1, the R^2 value was 0.997. The resulting own-price elasticity (α value) was 0.0039, Q_0 was 277.3 units, P_{max} was $0.26, and O_{max} was $23.01. No statistical difference was present between cigarette demand curves from each experiment [F(1, 3) = 5.57, P = .099].

Substitution for Cigarettes in the ETM

Importantly, six participants did not purchase alternate tobacco products at any price condition. Figure 3 also represents the alternate constant-priced product purchases in Experiment 2 converted to mg of nicotine purchased. Electronic cigarettes and Camel Snus

Table 1. Statistics From the Linear Regressions Performed to Determine Cross-Price Elasticity

	Slope/cross-price elasticity	95% confidence intervals	Model R2	F test	P
Experiment 1					
Electronic cigarettes	9.698	2.751 to 16.64	0.08246	7.729	.0067*
Snus	3.700	−1.039 to 8.440	0.02734	2.417	.1237
Dip	0.8828	−6.213 to 7.979	0.0007	0.06138	.8049
Nicotine lozenges	3.533	−8.052 to 15.12	0.00427	0.3688	.5453
Nicotine gum	3.533	−1.728 to 8.794	0.02037	1.788	.1847
Cigarillos	174.5	−42.75 to 391.7	0.02889	2.558	.1134
Experiment 2					
Electronic cigarettes	14.34	7.070 to 21.62	0.1003	14.94	.0002*
Snus	22.06	0.9933 to 43.12	0.03048	4.212	.0421*
Dip	3.601	−1.575 to 8.776	0.01369	1.859	.1750
Nicotine lozenges	10.70	−0.5383 to 21.93	0.02533	3.482	.0642
Nicotine gum	−1.598	−8.274 to 5.078	0.00164	0.2201	.6397

Degrees of freedom for Experiment 1 = (1, 86) and Experiment 2 = (1, 134).

*Statistically significant P values reported for slopes significantly different than zero.

Table 2. Percent of Participants in Each Experiment Purchasing Each Commodity and the Range of Units Purchased by Those Participants

	Percent purchasing at each price condition				Range of units purchased at each price condition			
	0.12	0.25	0.50	1.00	0.12	0.25	0.50	1.00
Experiment 1 (n = 22)								
Cigarettes	95.4	100	86.4	59	0–16	1–13	0–6	0–3
Electronic cigarettes	31.8	18.2	45.4	54.5	0–1	0–1	0–1	0–2
Snus	0	0	9	9	0–0	0–0	0–2	0–1
Dip	4.5	0	4.5	4.5	0–1	0–0	0–1	0–1
Nicotine lozenges	4.5	4.5	4.5	9	0–1	0–1	0–1	0–1
Nicotine gum	0	0	0	4.5	0–0	0–0	0–0	0–1
Cigarillos	13.6	18.2	36.4	36.4	0–8	0–5	0–7	0–10
Experiment 2 (n = 34)								
Cigarettes	100	97	76.5	50	1–14	0–10	0–5	0–2
Electronic cigarettes	17.6	23.5	35.3	52.9	0–1	0–1	0–3	0–3
Snus	2.9	5.9	17.6	23.5	0–3	0–2	0–11	0–9
Dip	0	0	2.9	5.9	0–0	0–1	0–1	0–1
Nicotine lozenges	2.9	2.9	5.9	14.7	0–1	0–1	0–1	0–2
Nicotine gum	5.9	0	2.9	2.9	0–1	0–0	0–1	0–2

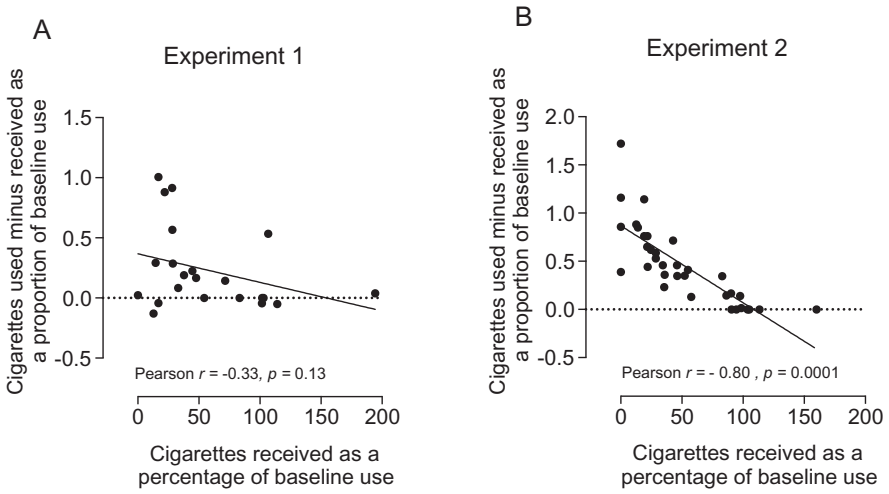

Figure 2. Consumption of cigarettes received minus used as a proportion of baseline associated with cigarettes received as a percentage of baseline consumption. The correlation in Experiment 1 (Panel A) was not significant. The correlation in Experiment 2 (Panel B) was significant (P = .0022) indicating participants that received fewer cigarettes than typically consumed were more likely to obtain combustible tobacco products outside of the experimental tobacco marketplace (ETM).

functioned as substitutes for conventional cigarettes at the two highest unit prices. The linear regressions to determine cross-price elasticity revealed two alternative products that were significantly different from zero (Table 1). Electronic cigarettes [$F(1, 134) = 14.94$, $P = .0002$; slope = 14.34] and Camel Snus [$F(1, 134) = 4.21$, $P = .042$; slope = 22.06] functioned as substitutes for conventional cigarettes.

Consumption at Follow-up

One participant did not complete the follow-up session thus follow-up session data is reported for 33 participants whereas data was included for the purchase session data for all 34 participants. No cigarettes were returned for a refund, indicating no underestimation of weekly cigarette consumption in this sample. Two participants returned electronic cigarettes, one returned a package of nicotine lozenges, and a portion of a Camel Snus tin was returned. Twenty-eight participants reported consumption of nonstudy individual cigarettes (range 3–240). Panel B of Figure 2 depicts the correlation between the number of cigarettes distributed (ie, purchased in the actualized condition) as a percentage of baseline cigarette use and the number of nonstudy cigarettes used as a proportion of baseline consumption. This correlation was significant ($r = –0.80$, $P = .0001$) indicating that participants who received a number of cigarettes approximate to or greater than normal consumption were less likely to consume nonstudy provided products and those participants who received fewer cigarettes than typically consumed were more likely to consume products obtained outside of the study. Comparison of the slopes between Experiments 1 and 2 revealed significant differences [F (1, 52) = 10.35, P = .0022], indicating that the availability of cigarillos is the ETM was related to the likelihood of participants purchasing out of study products.

Discussion

The current study found that, in the ETM, demand for cigarettes decreased as unit cost increased and elasticity of cigarette demand was no different when cigarillos were included in the ETM than when not included. In Experiment 1, as the price of cigarettes increased the greatest consumption occurred with cigarillos and electronic

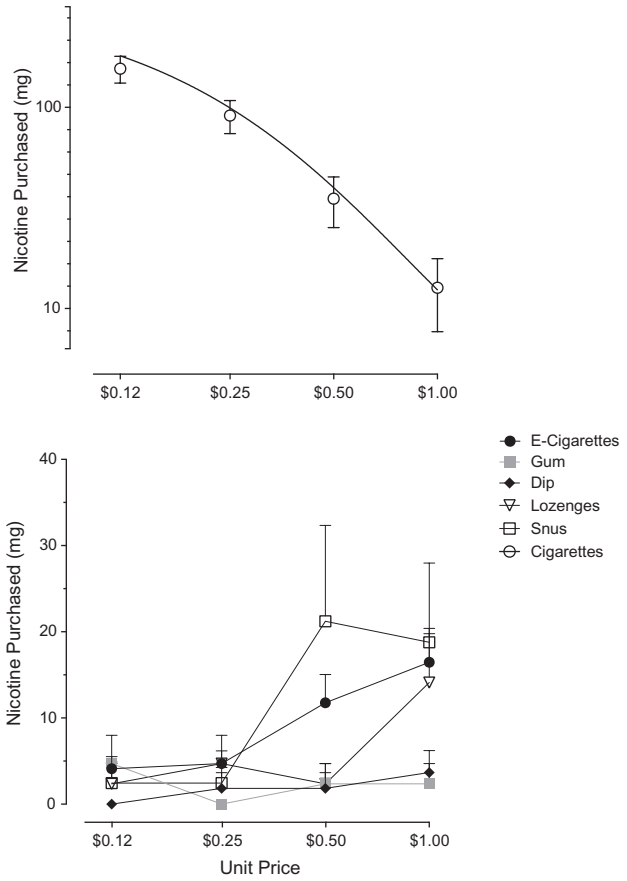

Figure 3. Individual cigarette demand and raw alternative product data from Experiment 2 represented in mg of nicotine purchased. Demand for cigarettes decreased as a function of cigarette price. Purchasing of Camel Snus ($P = .04$), electronic cigarettes ($P = .0002$) and, to a smaller extent, nicotine lozenges ($P = .06$) increased as price of cigarettes increased.

cigarettes. Although cigarillos had the greatest slope, the variability observed across participants rendered that slope not statistically different from zero. Conversely, electronic cigarettes had a lower slope and that slope was statistically different from zero (Table 1 and Figure 1). In Experiment 2, as the price of cigarettes increased, consumption of electronic cigarettes and Camel Snus was the greatest with slopes statistically different from zero and thus, indicative of substitution. Camel Snus had the greatest slope, albeit with more variability than electronic cigarettes. Although substitution occurred in both experiments, clearly the magnitude of the effect was modest.

Cigarette demand in human self-administration is one of the most widely investigated areas of behavioral economics[17] and, in cigarette smokers, consumption has consistently been shown to decrease as unit price increases.[4,6] Similar results have also been reported in econometric studies.[17,18] In this experiment, cigarette demand approximated the demand curves demonstrated in the prior studies. Moreover, cigarette demand was not altered by the presence or absence of cigarillos in the ETM across the two experiments.

In Experiment 1, cigarillos were the alternate product most often purchased by participants. Removal of this product in Experiment 2 rendered electronic cigarettes the most often purchased alternate product. In addition, exclusion of cigarillos from the ETM resulted in a slope indicative of substitution for Camel Snus, which failed to meet substitution criteria in Experiment 1. This observation suggests that the presence or absence of a particular product in the ETM can, in part, determine the interactions that occur among the available products.[19] This complex interaction of alternate product availability and resulting consumption would be difficult to model in traditional behavioral economic methods involving choice between, at most, three products.

The ETM is a novel, practical assay that mimics the real-world marketplace, and functions as a simple research tool for both researchers and participants. Fewer numbers of experimental sessions and shorter session duration are required compared to other behavioral economic investigations (eg, self administration) and the ETM lends itself to a broader range of potential applications. For example, to help prospectively estimate the effects of policies that may decrease tobacco consumption, product labeling or other stimuli associated with the product, dose, flavor, or concurrent availability of alternate products and cigarette and other product prices, availability, and associated descriptions could be manipulated.

Some limitations of this study must be acknowledged. First, the sample size was small and more robust findings may have resulted with more participants. Second, the ETM is a novel procedure and future investigations should evaluate the differences in purchasing behavior between the ETM and other purchase task varieties. Nonetheless, previous comparisons of purchase tasks have found concordance among procedures involving hypothetical and potentially real rewards[20] although these comparisons were not with an online marketplace. Third, participants were not regular users of alternate tobacco products prior to their purchasing session and may have never sampled the alternate products. Participants with prior experience either naturalistically or through a study-provided sampling period may influence the alternate products that are purchased and future investigations should determine the influence of sampling history. Fourth, if we had included an additional cigarette price condition that was sufficiently high to completely suppress cigarette purchasing then we may have seen more robust substitution.

Fifth and finally, the data from consumption at follow-up suggest (1) that participants often consumed all the products they purchased including purchasing additional products and breaking study protocol, (2) that the ETM, presumed to be a closed economy, instead functioned as an open economy. Thus, in both experiments when the prices of conventional cigarettes increased resulting in decreased consumption, participants compensated with nonstudy combustible tobacco products (mostly cigarettes), consistent with a previous report,[14] and (3) the presence or absence of cigarillos in the ETM is related to purchasing of nonstudy provided cigarettes. Significant differences between the slopes indicate that when cigarillos were available in the ETM, participants were less likely to break study protocol by purchasing outside products, likely a result of high levels of substitution with cigarillos in Experiment 1. However, when additional combustible products were not available in the ETM, participants were more likely to break study protocol and purchase outside products. Perhaps, an adjunctive purchasing session prior to the follow-up session would have eliminated the need to purchase nonstudy products and rendered the ETM closer to a closed economy.

Behavioral economic methodologies to assess cigarette consumption have evolved over the last several decades. The earliest procedures were based on those use in animal self-administration studies and extended to the human laboratory.[5] These self-administration studies required many sessions with long durations and could only conveniently compare consumption of a few products. The next step in this evolution entailed a questionnaire measuring self-reported

consumption of cigarettes at prices ranging from free to $100.00 per cigarette referred to as the hypothetical purchase task.[21–23] More recently, participants purchased conventional cigarettes at various prices in the laboratory for use in their daily life permitting interactions with real world circumstances.[14,20] The ETM is the next step in the evolution of this methodology to study reinforcer demand and substitution in an ever more naturalistic context. Where the evolution of this method may lead is beyond the scope of this article, but may be important for the future study of the behavioral economics of tobacco product consumption.

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Declaration of Interests

None declared.

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References

1. Hursh SR, Roma PG. Behavioral economics and empirical public policy. *J Exp Anal Behav*. 2013;99(1):98–124. doi:10.1002/jeab.7.
2. 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 Psychol*. 2014;10:641–677. doi:10.1146/annurev-clinpsy-032813-153724.
3. Bickel WK, DeGrandpre RJ, Higgins ST. The behavioral economics of concurrent drug reinforcers: a review and reanalysis of drug self-administration research. *Psychopharmacology (Berl)*. 1995;118(3):250–259. doi:10.1007/BF02245952.
4. Shahan TA, Odum AL, Bickel WK. Nicotine gum as a substitute for cigarettes: a behavioral economic analysis. *Behav Pharmacol*. 2000;11(1):71–79. doi:10.1097/00008877-200002000-00008.
5. Bickel WK, Hughes JR, Degrandpre RJ, Higgins ST, Rizzuto P. Behavioral economics of drug self-administration. *Psychopharmacology (Berl)*. 1992;107(2–3):211–216.
6. Johnson MW, Bickel WK. The behavioral economics of cigarette smoking: the concurrent presence of a substitute and an independent reinforcer. *Behav Pharmacol*. 2003;14(2):137–144. doi:10.1097/01.fbp.0000063266.43827.42.
7. Johnson MW, Bickel WK, Kirshenbaum AP. Substitutes for tobacco smoking: a behavioral economic analysis of nicotine gum, denicotinized cigarettes, and nicotine-containing cigarettes. *Drug Alcohol Depend*. 2004;74(3):253–264. doi:10.1016/j.drugalcdep.2003.12.012.
8. Epstein LH, Jankowiak N, Nederkoorn C, Raynor HA, French SA, Finkelstein E. Experimental research on the relation between food price changes and food-purchasing patterns : a targeted review 1 – 4. *Am J Clin Nutr*. 2012;95(4):789–809. doi:10.3945/ajcn.111.024380.1.
9. Epstein LH, Dearing KK, Roba LG, Finkelstein E. The influence of taxes and subsidies on energy purchased in an experimental purchasing study. *Psychol Sci*. 2010;21(3):406–414. doi:10.1177/0956797610361446.
10. American Psychiatric Association. *Diagnostic and Manual of Mental Disorders*. 4th ed. text rev. Washington, DC: American Psychiatric Association; 2000. doi:10.1176/appi.books.9780890423349.
11. Sobell LC, Sobell MB. Timeline Follow-back. In: Litten RZ, Allen JP, eds. *Measuring Alcohol Consumption: Psychosocial and Biochemical Methods*. Totowa, NJ: Humana Press; 1992. doi:10.1007/978-1-4612-0357-5.
12. Fagerstrom KO, Kunze M, Schoberberger R, et al. Nicotine dependence versus smoking prevalence: comparisons among countries and categories of smokers. *Tob Control*. 1996;5(1):52–56. doi:10.1136/tc.5.1.52.
13. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. 5th ed. Washington, DC: American Psychiatric Association; 2013.
14. Koffarnus MN, Wilson AG, Bickel WK. Effects of experimental income on demand for potentially real cigarettes. *Nicotine Tob Res*. 2015;17(3):292–298.
15. Hursh SR, Silberberg A. Economic demand and essential value. *Psychol Rev*. 2008;115(1):186–198. doi:10.1037/0033-295X.115.1.186.
16. Kaplan BA, Reed DD. Essential Value, Pmax, and Omax Automated Calculator [spreadsheet Application]. 2014. http://hdl.handle.net/1808/14934. Accessed June 28, 2015.
17. Chaloupka F. Macro-social influences: the effects of prices and tobacco-control policies on the demand for tobacco products. *Nicotine Tob Res*. 1999;1(1):105–109. doi:10.1080/14622299050011681.
18. Chaloupka FJ, Warner KE. The economics of smoking. In: Culyer A, Newhouse J, eds. *Handbook of Health Economics*. Vol. 1. Philadelphia, PA: Elsevier; 2000:1539–1627.
19. Smith TT, Sved AF, Hatsukami DK, Donny EC. Nicotine reduction as an increase in the unit price of cigarettes: a behavioral economics approach. *Prev Med (Baltim)*. 2014;68:23–28. doi:10.1016/j.ypmed.2014.07.005.
20. Wilson AG, Franck CT, Koffarnus MN, Bickel WK. Behavioral economics of cigarettes purchases: within subject comparison of real, potentially real, and hypothetical cigarettes [published online ahead of print July 17, 2015]. *Nicotine Tob Res*. 2015;1–7. doi:10.1093/ntr/ntv154.
21. Jacobs EA, Bickel WK. Modeling drug consumption in the clinic using simulation procedures: demand for heroin and cigarettes in opioid-dependent outpatients. *Exp Clin Psychopharmacol*. 1999;7(4):412–426. doi:10.1037/1064-1297.7.4.412.
22. 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 Psychopharmacol*. 2008;16(1):57–65. doi:10.1037/1064-1297.16.1.57.
23. Murphy JG, MacKillop J. Relative reinforcing efficacy of alcohol among college student drinkers. *Exp Clin Psychopharmacol*. 2006;14(2):219–227. doi:10.1037/1064-1297.14.2.219.