Estimating Uptake for Reduced-nicotine Cigarettes Using Behavioral Economics

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Objectives: Lowering the nicotine content in combustible cigarettes may be a viable strategy for reducing dependence and toxin exposure. Understanding how marketing and education may affect initial uptake is an important avenue of inquiry prior to any policy change. There has yet to be an investigation of how framing reductions in nicotine may affect intentions to purchase and consume these cigarettes using the behavioral economic framework. **Methods:** Participants from Amazon Mechanical Turk completed several tasks, including the Cigarette Purchase Task and Experimental Tobacco Marketplace, under conditions in which a new, reduced-nicotine cigarette alternative is the only cigarette available. **Results:** Cigarette purchasing was largely unaffected by stated nicotine concentration, but lower concentrations suggested the potential of small estimated compensatory purchasing. Exposure to a narrative detailing how others have perceived the negative subjective effects of lower nicotine cigarettes (eg, less satisfaction) significantly reduced the perceived value of cigarettes. **Conclusions:** These results suggest information about nicotine content alone is unlikely to reduce initial uptake without accompanying narratives about the effects of this reduced-nicotine content.

Key words: behavioral economics; nicotine reduction; cigarette purchase task; experimental tobacco marketplace; demand; cigarettes; humans
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Cigarette smoking is the leading preventable cause of death in the United States (US)[1] and incurs more than $300 billion in healthcare costs annually.[2] Understanding the variables that maintain cigarette use, especially the role of nicotine,[3] is an important avenue of inquiry that informs tobacco/nicotine control policies aimed at reducing smoking.[4] Research shows that substantial reductions in nicotine content in tobacco cigarettes can result in lower exposure to toxins and reduce dependence.[5,6] Towards this end, the Family Smoking Prevention and Tobacco Control Act, passed in 2009, expanded the purview of the US Food and Drug Administration (FDA) to allow broader policy implementation. The FDA has expressed interest in investigating the potential policy effects of reducing nicotine content in cigarettes and also has released an Advanced Notice of Proposed Rulemaking related to nicotine content reductions.[7]

Emerging research suggests that some smokers misunderstand the role of nicotine in terms of health risks[8] and addictiveness of reduced-nicotine cigarettes.[9,10] For example, some smokers inaccurately attribute smoking-related diseases such as asthma and lung cancer to nicotine.[11–14] Thus, smokers who hold these incorrect risk perceptions

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might be less likely to reduce smoking if they believe reduced-nicotine cigarettes are less harmful.[9] Likewise, smokers may be less likely to switch to safer nicotine alternatives (eg, nicotine replacement therapies) if they believe reduced-nicotine cigarettes can be used as a smoking cessation product.[10] Indeed, research suggests greater perceived nicotine content is associated with greater perceived risk and harm.[8] To date, few studies have assessed relationships between risk perceptions and subsequent smoking behavior of reduced-nicotine cigarettes.[8,15] In one study,[15] researchers found that after viewing an unaltered, company-created smoking advertisement for a reduced-nicotine cigarette before smoking the cigarette, participants perceived the reduced-nicotine cigarette as safer than conventional cigarettes; however, neither participants' beliefs nor subjective ratings of reduced-nicotine cigarettes directly affected smoking behavior. Rather, an interaction between subjective ratings and beliefs was associated with subsequent smoking, with lower subjective ratings and greater false beliefs associated with greater smoking. Pacek et al[8] also found that smokers' perceptions of nicotine content, but not actual nicotine content, were positively associated with perceptions of harm. To date, this research has focused largely on risk perceptions under conditions where reduced-nicotine cigarettes are conveyed (or perceived) as very low, low, moderate, and high. Although the primary goal of a reduced-nicotine policy would be to reduce actual smoking behavior, considerations and prospective methods for how the general public may react to such a policy are important.[16]

Apart from assessing perceptions of reduced-nicotine cigarettes, which is an important avenue of inquiry for a sweeping public policy initiative, several studies have examined the abuse liability of these cigarettes using methods from behavioral economics.[17–21] The Cigarette Purchase Task (CPT), one rapid assay to model cigarette demand,[22,23] allows for a quick determination of cigarette value and price sensitivity by asking respondents to estimate the number of cigarettes they would purchase and consume at a range of escalating monetary prices. Whereas risk perceptions may be a useful indicator of subsequent smoking behavior, the CPT also may be used to prospectively estimate purchasing and use based on product descriptions.[24]

Research investigating the effects of reduced-nicotine cigarettes on behavioral economic demand has done so only *after* participants experience the cigarettes and research suggests that substantial levels of cigarette smoking continues for at least 6 weeks following a switch to reduced-nicotine cigarettes.[5] Any policy change that would limit the amount of nicotine in cigarettes would likely be announced prior to cigarette smokers sampling the reduced-nicotine cigarettes[15] and messaging that hastens reductions in smoking after this policy change may dramatically reduce overall cigarette exposure. Therefore, the purpose of the current study was to address how current cigarette smokers' intentions to purchase reduced-nicotine cigarettes might be affected by various ways of describing the nicotine content in these cigarettes compared to the amount of nicotine in their usual-brand cigarettes. Across 3 experiments, our main research question was how the framing of nicotine concentration in a new type of cigarette affected 2 key aspects of behavioral economic demand: intensity (purchasing under unrestricted cost) and elasticity (purchasing sensitivity to price; ie, cigarette valuation). These 2 demand measures provide insight into how smokers might perceive and respond (via their purchasing intentions) to a nicotine reduction policy. Although some research suggests individuals misunderstand the role of nicotine in cigarettes related to health risks, based on previous in-lab research examining reduced-nicotine cigarettes and behavioral economic measures, we hypothesized that reductions in nicotine would be associated with reductions in demand intensity and elasticity. We also investigated how participant demographic variables related to these behavioral economic measures.

Experiment 1 evaluated the effects of a stated concentration, framed as a nicotine percentage. Experiment 2 attempted to replicate the results of Experiment 1 when framing nicotine percentage as a reduction from participant's usual-brand cigarette. Finally, Experiment 3 examined the effects of an undesirable narrative description of the subjective effects of reduced-nicotine cigarettes. In all 3 experiments, we also examined the effects of nicotine concentration on alternative product purchasing in the Experimental Tobacco Marketplace – an online, simulated virtual marketplace; however, we observed few direct effects of nicotine framing on other product purchasing. For openness and trans-

parency, we include methods, analyses, and results related to these procedures in the Supplemental Information (https://osf.io/ebqr8/) but do not discuss the results here.

EXPERIMENT 1 METHODS

Participants

Participants recruited from Amazon Mechanical Turk (mTurk) had to: (1) reside in the US; (2) have a task approval rate of ≥90%; (3) have completed ≥50 approved tasks; and (4) report current smoking on a brief qualification test. Overall, 496 workers participated in the experiment, which required approximately 24 minutes. Participants were paid $3.00 for completing the experiment (mean realized hourly wage of $7.54).

Procedures

All tasks were administered via Qualtrics Research Suite (www.qualtrics.com). Participants first completed an abbreviated Timeline Followback[25] (for use in the Experimental Tobacco Marketplace), followed by a baseline CPT[22] for their usual-brand cigarettes. Participants reported the number of cigarettes they would purchase and consume at 16 ascending prices. Participants were presented with general instructions and constraints (eg, imagine you have the same income/savings as you do now) used in previous CPT research[26] (see Supplemental Information for details; https://osf.io/ebqr8/).

After completing the baseline CPT, participants were randomly assigned to one of 6 groups differing with respect to cigarette nicotine concentration associated with a new type of cigarette, referred to as a percentage of nicotine compared to their usual-brand cigarette. Nicotine concentrations included 100% (current market control), 60%, 30%, 15%, 8%, and 2%. These specific percentages (except 60%) were chosen because they approximately match the nicotine contents of investigational cigarettes used in previous and ongoing reduced-nicotine research studies (RTI SPECTRUM Cigarettes, 22nd Century). Participants read a vignette that described a new type of cigarette on the market available from the participants' usual brand manufacturer, hereafter termed the variable-nicotine cigarette (see Supplemental Information for the full vignette; https://osf.io/ebqr8/). Below the instructions, participants were required to type the percentage amount of nicotine and answer a multiple-choice attending question to proceed through the remainder of the task. Participants then completed another CPT for the variable-nicotine cigarette. The instructions and price sequence were identical except for one assumption that stated: "The available cigarettes are the new cigarettes with **XX%** the amount of nicotine compared to the old cigarettes," where "**XX**%" was one of the nicotine percentages listed above associated with random group assignment. The experiment ended with the Experimental Tobacco Marketplace, followed by the Fagerström Test of Cigarette Dependence[27] (FTCD) and general demographics.

Data Analysis

All data analyses were conducted in R Statistical Software Version 3.3.2.[28] Participant characteristics (sex, education, employment, age, number of cigarettes smoked per day, FTCD) were compared across groups using either chi-square test of independence or one-way ANOVA. Responses on both CPTs were examined for systematic responding per 3 criteria that are typically indicative of inattention or misunderstanding of the task: trend (ie, invariant or ascending demand curves), as well as bounce and reversal from zero criteria (variable or inconsistent purchasing).[29] Individual datasets failing at least one of the criteria (N = 22; 4.4% of full sample) were removed from the demand analyses. Additionally, 5 participants reported smoking >100 cigarettes in one day on the Timeline Followback and were removed from all analyses. For the demand tasks, we applied an exponentiated function[30] based on the exponential demand[31] equation using the *beezdemand* package in R:[32]

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

where Q represents cigarettes purchased, Q_0 (ie, intensity) is the estimated number of cigarettes purchased at free price, k is a weighting parameter signifying the range of consumption in logarithmic units, α is the rate of change in elasticity across the entire curve (ie, elasticity), and C is the price per cigarette. For all experiments, we used a value of 2.54 for k (calculated as a shared parameter across all datasets[33]).

We logarithmically transformed elasticity prior to regression analyses (no changes were made to intensity), then flagged outliers for intensity and elasticity if they exceeded 3.29 SDs,[34] and excluded them for the relevant analyses. Using multiple regression, we examined the effects of concentration amount on intensity and elasticity. Based on statistically significant intercorrelations of various measures, we included several demographic variables in the multiple regression to: (1) examine the relations between these variables and demand measures, and (2) isolate the potential effects of concentration amount on demand measures. Partial eta squared (η_p^2) is reported and was obtained using the *sjstats* package.[36] *Post hoc* comparisons of marginal means between groups were accomplished using the *emmeans* package,[37] with Holm-Bonferroni[35] adjustments and weighted cell means.

EXPERIMENT 1 RESULTS

Demographics

The second column of Table 1 displays overall participant demographics for Experiment 1 (Table S1 in the Supplemental Information [https://osf.io/ebqr8/] displays demographics among the concentration groups). We did not observe any statistically significant differences in demographic variables across the 6 groups. Spearman rank-order correlations between income, age, cigarettes per day, FTCD, and demand measures are reported in Table S2.

Effects of Concentration on Cigarette Demand.

Equation 1 provided an excellent fit to the data (Mdn R^2 = .97, IQR = .96, .98) resulting in a median elasticity (α) of 0.0101 (IQR = 0.0056, 0.0191) and median intensity (Q_0) of 20.30 (IQR = 10.73, 25.99). Twenty participants (4% of the full sample) displayed intensity values exceeding 3.29 SDs and were excluded along with 2 participants who reported "other" for their sex (when examining the effect of a categorical variable such as sex, a small group size [N = 2] may otherwise obfuscate meaningful main effects), and one participant who did not report income.

Table 2 depicts the F-statistic and corresponding (effect size) associated with each predictor variable used in the multiple linear regression models across all 3 experiments. We observed no differences across groups in derived baseline CPT intensity (see top third of Table 2) while controlling for sex, income, age, cigarettes per day, and FTCD score. A statistically significant effect of concentration was found for derived variable-nicotine CPT intensity when controlling for baseline intensity and the aforementioned demographic variables. *Post hoc* comparisons of marginal means of variable-nicotine CPT intensity revealed participants in the 100% framing group estimated purchasing fewer cigarettes if they were free compared to the other concentration groups (see Table S3 for all *post hoc* comparisons). No differences in estimated purchasing were found between any of the other concentration groups – that is, participants reported purchasing more cigarettes, but increases in purchasing were not systematically related to nicotine concentration.

Several participant demographic variables were significantly related to CPT intensity. With all else in the model being equal, males reported greater baseline CPT intensity (b = 4.48, SE = 1.48) compared to females, and older age was associated with lower baseline CPT intensity (b = -0.15, SE = 0.007). Additionally, cigarettes smoked per day (b = 0.91, SE = 0.12) and FTCD score (b = 0.92, SE = 0.38) significantly positively predicted baseline CPT intensity. Sex (men reporting 2.25 more cigarettes) and cigarettes per day (b = 0.25, SE = 0.09) were significantly associated with variable-nicotine CPT intensity.

Eight participants had elasticity values exceeding 3.29 SDs and were excluded from the elasticity analysis. No differences in either baseline or variable-nicotine CPT elasticity were observed (Table 2) when controlling for demographic variables, suggesting reductions in nicotine concentration did not significantly affect cigarette price sensitivity, the primary measure of cigarette valuation. In terms of participant demographics, both cigarettes smoked per day and FTCD score significantly predicted baseline CPT elasticity in the expected direction; that is, greater number of cigarettes smoked per day (b = -0.034, SE = 0.008) and higher FTCD scores (b = -0.113, SE = 0.027) predicted *lower* elasticity values and thus, higher cigarette valuation.

EXPERIMENT 1 DISCUSSION

The primary aim of Experiment 1 was to determine whether the stated concentration of nicotine

Table 1
Experiments 1-3 Overall Demographics

	Experiment 1 (N = 491)	Experiment 2 (N = 212)	Experiment 3 (N = 178)
Variable (Mean [SD])			
Age (years)	36.63 (10.77)	34.57 (9.98)	34.73 (9.12)
Cigarettes Smoked/Day	14.60 (8.49)	14.49 (8.95)	14.66 (6.92)
FTCD[a]	4.34 (2.46)	4.22 (2.63)	4.32 (2.32)
Variable (N [%])			
Sex			
Women	287 (58.5)	121 (57.1)	79 (44.4)
Men	202 (41.1)	91 (42.9)	99 (55.6)
Other	2 (0.4)	0 (0)	0 (0)
Education*			
Less than High School	3 (0.6)	2 (0.9)	0 (0)
High School/GED	67 (13.6)	30 (14.2)	27 (15.2)
Some College	165 (33.6)	67 (31.6)	49 (27.5)
2-Year College Degree (Associates)	84 (17.1)	28 (13.2)	32 (18.0)
4-Year College Degree (BA, BS)	128 (26.1)	70 (33.0)	58 (32.6)
Master's Degree	34 (6.9)	12 (5.7)	9 (5.1)
Professional Degree (MD, JD, DDS, DVM, PsyD)	4 (0.8)	1 (0.5)	3 (1.7)
Doctorate (PhD, DSc, EdD, DFA)	6 (1.2)	2 (0.9)	0 (0)
Employment			
Employed	395 (80.4)	168 (79.2)	163 (91.6)
Unemployed	85 (17.3)	42 (19.8)	0 (0)
Retired	11 (2.2)	2 (0.9)	15 (8.4)
User Type			
Cigarette Only	302 (61.5)	147 (69.3)	115 (64.6)
Cigarette & ENDS[b] Only	82 (16.7)	41 (19.3)	42 (23.6)
Cigarette & NRT[c] Only	40 (8.1)	7 (3.3)	6 (3.4)
Cigarettes & > 1 Product	67 (13.6)	17 (8.0)	15 (8.4)

Note.
***Only significant difference detected for Experiment 2, p = .020.**
a: FTCD: Fagerström Test of Cigarette Dependence
b: ENDS: Electronic Nicotine Delivery System
c: NRT: Nicotine Replacement Therapy

in a novel, variable-nicotine cigarette would be related systematically to demand for cigarettes. To our knowledge, this is the first investigation looking at hypothetical outcomes as they relate to different cigarette nicotine concentrations.

Given the literature examining cigarette demand for reduced-nicotine cigarettes, we had originally hypothesized that demand would be related to concentration amount. On the contrary, we did not find parametric differences in either demand intensity or elasticity as a function of concentration amount suggesting the stated percentage of nicotine does not appreciably affect cigarette valuation. Interestingly, we found participants exposed

Table 2
Multiple Regression Predicting Cigarette Purchase Task Intensity and Elasticity

	Baseline CPT[a] Intensity	Variable Nicotine CPT Intensity	Baseline CPT Elasticity	Variable Nicotine CPT Elasticity
Regression Term	**F (η_p^2)**	**F (η_p^2)**	**F (η_p^2)**	**F (η_p^2)**
		Experiment 1		
Intercept	11.27* (.03)	9.27* (.02)	276.23* (.38)	0.66 (.00)
Concentration	1.19 (.01)	7.65* (.08)	0.73 (.01)	0.77 (.01)
BL Intensity/Elasticity		659.04* (.60)		998.77* (.69)
Sex	9.12* (.02)	4.09* (.01)	0.09 (.00)	1.69 (.00)
Income	0.76 (.00)	3.60 (.01)	0.06 (.00)	0.82 (.00)
Age	4.82* (.01)	1.87 (.00)	3.40 (.01)	0.44 (.00)
Cigarettes/Day	61.84* (.12)	7.17* (.02)	17.97* (.04)	0.87 (.00)
FTCD[b]	5.69* (.01)	0.15 (.00)	17.56* (.04)	2.63 (.01)
		Experiment 2		
Intercept	9.51* (.05)	0.45 (.00)	121.69* (.39)	0.48 (.00)
Amount	0.02 (.00)	7.60* (.04)	4.38* (.02)	1.50 (.01)
Frame	0.13 (.00)	0.44 (.00)	0.11 (.00)	0.27 (.00)
BL Intensity/Elasticity		12.19* (.06)		178.02* (.50)
Sex	0.17 (.00)	0.02 (.00)	0.08 (.00)	0.97 (.01)
Income	0.49 (.00)	0.01 (.00)	2.69 (.01)	1.04 (.01)
Age	2.75 (.02)	1.28 (.01)	0.68 (.00)	0.75 (.00)
Cigarettes/Day	21.29* (.11)	17.43* (.09)	15.48* (.08)	0.26 (.00)
FTCD	2.23 (.01)	5.46* (.03)	0.19 (.00)	0.18 (.00)
		Experiment 3		
Intercept	11.17* (.06)	0.14 (.00)	101.69* (.38)	1.39 (.01)
Concentration	1.18 (.01)	3.68* (.04)	0.50 (.01)	14.85* (.15)
BL Intensity/Elasticity		654.54* (.80)		258.64* (.61)
Sex	0.52 (.00)	0.04 (.00)	1.08 (.01)	0.60 (.00)
Income	3.31 (.02)	0.37 (.00)	5.26* (.03)	0.26 (.00)
Age	2.66 (.02)	0.27 (.00)	1.44 (.01)	0.06 (.00)
Cigarettes/Day	6.66* (.04)	0.00 (.00)	0.96 (.01)	2.12 (.01)
FTCD	0.35 (.00)	1.63 (.01)	6.90* (.04)	0.40 (.00)

Note.
*** p < .05**
a: CPT = Cigarette Purchase Task
b: FTCD = Fagerström Test of Cigarette Dependence

to the 100% frame estimated they would purchase *fewer* cigarettes when cigarettes were free compared to participants in any of the other concentration groups but found no evidence suggesting concentration amount influenced elasticity of demand. The increased intensity observed in the reduced-nicotine groups compared to the 100% group may suggest a perceived need to compensate in order to obtain the feelings associated with participant's usual-brand cigarette, which implicitly contains 100% nicotine.

Because we were unable to detect systematic relations between demand and concentration amount, we conducted a second experiment to investigate

the effects of framing nicotine concentration. Specifically, we kept all aspects from Experiment 1 constant, but isolated the 100% and 2% concentration amounts (as we found no systematic differences in demand parameters across the intermediate concentrations) and reframed concentration as a reduction in the amount of nicotine in the cigarettes (0% reduction, 98% reduction). We also sought to replicate Experiment 1's findings by using 2 of the original concentration percentages (100%, 2%).

EXPERIMENT 2 METHODS

Participants

We recruited participants using mTurk as described in Experiment 1 and workers who participated in Experiment 1 were not able to participate in Experiment 2. Altogether, 214 workers completed the experiment, which required an average of approximately 23 minutes to complete. Participants were paid $3.00 for completing the survey (mean realized hourly wage of $7.76).

Procedures

Tasks were identical to those in Experiment 1 with the following exception. Two groups received a modified framing of the concentration, framed as a reduction in the amount of nicotine, and 2 groups received the same original framing as in Experiment 1. The 4 groups included: 100% (current market control), 2%, 0% reduction, and 98% reduction.

Data Analysis

Data analyses were conducted similarly as in Experiment 1, except we compared demand parameters using 2-way analysis of covariance (ie, multiple regression) for variables of concentration amount (ie, 100%, 2%) and frame (ie, no frame, reduction frame). In this experiment, we excluded 2 participants from all analyses for reporting smoking >100 cigarettes in one day on the Timeline Followback. Additionally, 12 and 7 participants displayed intensity and elasticity values greater than 3.29 SDs from the respective means and were excluded from their respective analyses.

EXPERIMENT 2 RESULTS

Demographics

The third column of Table 1 displays overall participant demographics for the current experiment, which were largely similar to Experiment 1. The only statistically significant difference across the 4 groups was in education (Table S5). Spearman rank-order correlations among the variables are displayed in Table S6.

Effects of Concentration and Framing on Cigarette Demand

Nine participants failed systematic criteria for either version of the CPT, which reflected a relatively small 4.25% of the full sample, and were excluded from subsequent analyses. Equation 1 provided an excellent fit to the data (Mdn R^2 = 0.98, IQR = 0.96, 0.98) resulting in a median elasticity of 0.01 (IQR = 0.0057, 0.0221) and median intensity of 21.07 (IQR = 11.61, 27.24). We observed no statistically significant differences in baseline CPT intensity while controlling for demographic variables as a function of concentration amount or frame (see middle of Table 2). Cigarettes per day was the only statistically significant predictor of baseline CPT intensity. Examination of variable-nicotine CPT revealed amount, but not frame significantly predicted intensity. Exposure to the 2% concentration amount resulted in higher intensity compared to the 100% amount (b = 4.57, SE = 1.66). Additionally, number of cigarettes smoked per day and FTCD positively and significantly predicted variable-nicotine CPT intensity (b = 0.60, SE = 0.14; b = 1.05, SE = 0.45, respectively). These results are consistent with those found in Experiment 1 suggesting increased cigarette purchasing was influenced by the low, stated concentration and was not affected by framing nicotine amount as a reduction.

We observed no statistically significant differences in baseline CPT elasticity as a function of frame, but did with concentration amount when controlling for demographic variables. Cigarettes per day negatively and significantly predicted baseline CPT elasticity (b = -0.053, SE = -0.014); thus, greater cigarettes per day were associated with greater cigarette valuation. Consistent with our findings from Experiment 1, we observed no statistically significant differences in variable-nicotine CPT elasticity as a function of concentration amount or frame when controlling for baseline elasticity and demographic variables. Baseline CPT elasticity significantly predicted variable-nicotine CPT elasticity.

EXPERIMENT 2 DISCUSSION

Results from Experiment 2 suggested that concentration amount, but not framing significantly altered demand intensity; however, neither manipulation influenced elasticity. Specifically, exposure to the 2% concentration amount resulted in higher intensity compared to the 100% amount (approximately 4.6 cigarettes higher; b = 4.57, SE = 1.66). Notably, these results are consistent with the effects observed in Experiment 1.

Therefore, we conducted a final follow-up experiment with 2 aims. First, we attempted to replicate our findings from Experiments 1 and 2 with respect to differential changes in demand intensity based on a specified concentration amount (100% and 2%). Because results from Experiment 2 suggested a simple reduction framing was not effective in altering cigarette elasticity, we leveraged ideas from narrative theory[36] and sought to test whether providing an "undesirable" narrative description associated with the 2% variable-nicotine cigarettes would alter cigarette elasticity. Briefly, narrative theory suggests that stories or anecdotes related to someone else's experiences may be effective in influencing decision-making, especially when compared to information alone. For example, these narratives have been shown to influence real-world decisions related to health outcomes (eg, scheduling vaccinations,[37] driving while under the influence of alcohol[38]). Relevant to the current study, however, is that research has shown narratives are effective for promoting substitution of electronic cigarettes (a harm-reduction method[24]) and reducing cigarette smoking.[39,40] Neff et al[39] found media ads featuring negative consequences of smoking cigarettes resulted in increased quit attempts and quit successes since the inception of the US Centers for Disease Control and Prevention's "Tips from Former Smokers" ad campaign. Thus, evaluating whether a narrative based on actual feedback from smokers who have experienced reduced-nicotine cigarettes will reduce intentions to smoke would help inform marketing and education efforts.

EXPERIMENT 3 METHODS

Participants

Participants were recruited from mTurk consistent with Experiments 1 and 2. Overall, 188 workers participated and task duration took an average of approximately 22 minutes. Participants were paid $3.00 for completing the experiment, which resulted in a mean realized hourly wage of $8.04.

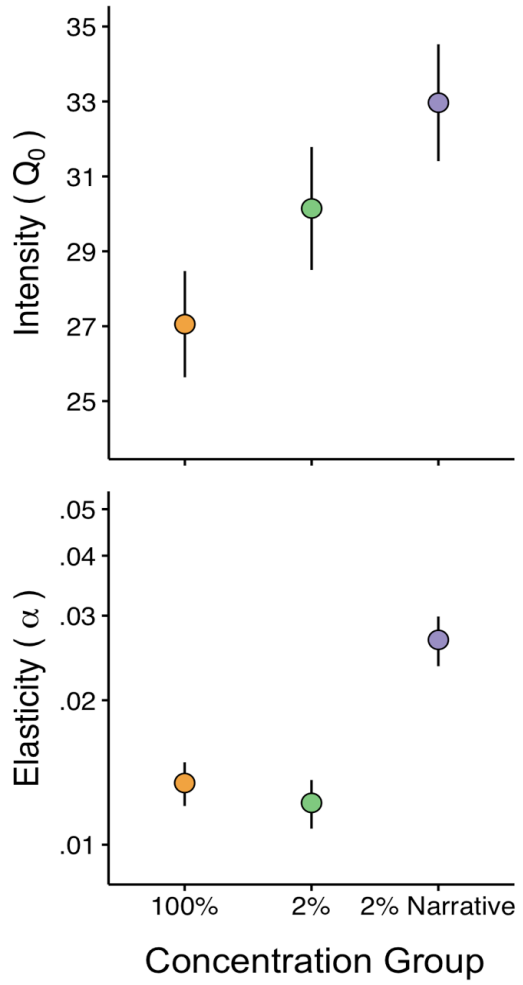
Procedures

All tasks used in Experiments 1 and 2 were used in Experiment 3. We again isolated the 100% (current market control) and 2% concentration amounts (using the same vignette as Experiments 1 and 2) but included one group that received an undesirable narrative about the cigarettes (2% narrative group). Using information from previous research[21] in which participants provided ratings about reduced-nicotine cigarettes, this 2% narrative group received the following vignette instructions describing the new cigarette on the market (additions bolded):

For the following questions, we would like to imagine that there is a new cigarette on the market. These new cigarettes look and smell the same as cigarettes out on the market, including those of your preferred brand. Imagine that your preferred brand of cigarettes now carries these new cigarettes. The difference between these new cigarettes and your usual cigarettes is that these cigarettes have only 2% the amount of nicotine in them, **an amount of nicotine that is too small to have any positive effects. Other people who have used these new cigarettes rate them as less satisfying, less rewarding, and less effective at reducing cravings compared to the cigarettes they usually smoke.**

Furthermore, we included 2 additional tasks we believed might be sensitive to decisions related to cigarette purchasing intentions. The first task, a hypothetical cross-price purchase task, was similar to the CPT, but with both cigarettes concurrently available for purchase. The new, variable-nicotine cigarette was set at a fixed price ($0.25/cigarette), whereas the price of the participant's usual-brand cigarette increased across trials in the same price progression used in the CPT. With both cigarette options presented concurrently, this task allows us to quantify the degree of substitutability of reduced-nicotine cigarettes for conventional cigarettes, which is a measure of interchangeability of purchasing intentions (ie, how much purchasing switches to another product if their preferred product is unavailable or too expensive). Instructions (ie, assumptions) in this task were identical

Figure 1
Derived Intensity (Q_0; top panel) and Elasticity (α; bottom panel) for Variable-Nicotine Cigarettes after Accounting for Baseline Cigarette Purchase Task Intensity and Elasticity, Respectively



Note.
Although intensity increased nominally with concentration group, elasticity was statistically significantly higher after exposure to the Narrative. Symbols and error bars indicate mean and standard error of the mean. Note the logarithmic y-axis (bottom panel).

to those of the CPT, and at each price combination participants were asked: "How many of each of the following would you purchase and consume at the indicated prices?" The only datasets excluded in this analysis were for decreasing or inconsistent responding for the new cigarette alternative. Inconsistent responding occurred anytime purchasing decreased and then subsequently increased on more than one instance.

The second task was a concurrent choice task[17] in which participants indicated their preference for purchasing either the old, usual-brand cigarette at increasing prices ($0.13, 0.25, 0.50, 1.00, 2.00, 4.00, 8.00/cigarette) or the new, variable-nicotine cigarette (100%, 2%) at a fixed price ($0.25/cigarette). Similar to the hypothetical cross-price purchase task, at each price combination, participants were asked: "Which would you prefer to purchase?" However, rather than reporting a quantity measure, participants indicated their relative preference for each of the alternatives at each price, allowing us to model the likelihood of switching cigarettes at each price.

Data Analysis

Data analysis was conducted similarly as the previous experiments. Five participants displayed unsystematic demand trends for either versions of the CPT (2.81% of the full sample). For the concurrent choice task, we used a generalized logistic model with a logit link function and binomial distribution to predict the probability of choosing the new, variable-nicotine cigarette at each price. For the hypothetical cross-price purchase task, we used Equation 1 to examine usual-brand cigarette demand (ie, the fixed-price alternative) and we used an exponentiated version of the exponential cross-price equation[33,41] to fit substitution curves:

Equation 2: $$Q = Q_{Alone} * 10^{I*e^{-\beta C}}$$

Where Q represents purchasing of the new, variable-nicotine cigarette, Q_{Alone} is the estimated number of new, variable-nicotine cigarettes purchased when the price of the variable-price alternative (usual-brand cigarette) approaches infinity, I is the interaction coefficient, β is purchasing sensitivity of the new, variable-nicotine cigarette to price of the variable-price alternative, and C is the price per usual-brand cigarette. An extra sum-of-squares F-test was conducted to compare Q_{Alone} derived from this model. Finally, in this experiment, we excluded 3 participants from all analyses

for reporting smoking >100 cigarettes in a day on the Timeline Followback.

EXPERIMENT 3 RESULTS

Demographics

The final column of Table 1 displays overall participant demographics for Experiment 3, which were similar to those of the previous experiments. There were no statistically significant differences among the 3 groups.

Effects of Concentration on Cigarette Demand

Equation 1 provided an excellent fit to the data (Mdn R^2 = .97, IQR = .95, .98) resulting in a median elasticity of 0.0078 (IQR = 0.0044, 0.0127) and median intensity of 21.02 (IQR = 15.55, 30.74). No participants displayed intensity values exceeding 3.29 SDs. Baseline CPT intensity was not significantly different across the 3 groups (see bottom of Table 2). When predicting variable-nicotine CPT intensity (ie, following group assignment), we found a statistically significant effect of concentration, as well as baseline CPT intensity. *Post hoc* comparisons indicated variable-nicotine CPT intensity was significantly higher under the 2% narrative condition compared to the 100% condition (see top panel of Figure 1; t[164] = 2.78, p = .018). Additionally, although we observed intensity was higher for the 2% group compared to the 100% group and for the 2% narrative compared to the 2% group, these comparisons were not significant (p*s* = .315). Only cigarettes per day significantly predicted baseline CPT intensity, such that more cigarettes smoked per day predicted higher baseline CPT intensity (b = .99, SE = 0.39). These results are largely consistent with the findings from the previous 2 experiments, suggesting concentration amount influenced initial purchasing intentions.

Four participants had elasticity values exceeding 3.29 SDs on either CPT and were excluded from the following analysis. We observed no statistically significant differences in baseline CPT elasticity between groups when controlling for demographic variables. Concentration group and baseline elasticity both significantly predicted variable-nicotine CPT elasticity. *Post hoc* tests indicated exposure to the narrative resulted in statistically significantly *higher* elasticity values (see bottom panel of Figure 1) compared to both the 100% (t[160] = 4.66, p < .001) and 2% groups (t[160] = 4.96, p < .001), but these latter 2 groups were not different from each other (t[160] = 0.65, p = .518). Income (b = -7.6×10^{-6}, SE = -3.0×10^{-6}) and FTCD score (b = -0.10, SE = -0.047) were both negatively and significantly associated with baseline elasticity.

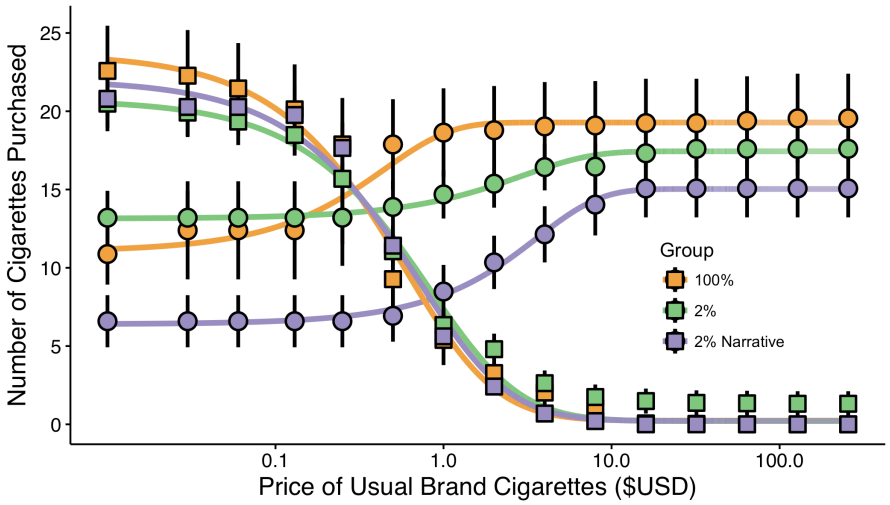
Taken together, these results suggest the potential for compensatory purchasing as evidenced by increasing intensity values. That is, we observed the same directional trend in intensity as we did in Experiments 1 and 2, but with the 2% narrative resulting in the most compensation. In contrast to the previous experiments, in this experiment we observed an increase in elasticity, which is indicative of the narrative *decreasing* the perceived value of the new, variable-nicotine cigarettes. In other words, participants exposed to the narrative demonstrated greater sensitivity to price and cigarette purchasing decreased at a relatively faster rate as compared to the other 2 groups.

Usual-brand Cigarette Demand and Variable-nicotine Cigarette Substitution in the Hypothetical Cross-price Purchase Task

Concentration amount was positively related to the degree to which variable-nicotine cigarettes substituted for usual-brand cigarettes and usual-brand demand intensity (F[2,1464] = 3.11, p = .045, η_p^2 = .004) but did not influence demand elasticity (F[2,1464] = 0.58, p = .563, η_p^2 = .001). As Figure 2 shows, the number of variable-nicotine cigarettes purchased at the lowest usual-brand cigarette price (the y-intercept) differed across groups. Participants in the 2% narrative group purchased fewer variable-nicotine cigarettes (M = 6.59, SEM = 1.67) compared to the 100% (M = 10.88, SEM = 1.95) and 2% (M = 13.20, SEM = 1.72) groups. Consistent with our previous findings, the 2% concentration amount resulted in slightly more cigarettes being purchased at unrestricted cost (ie, free) compared to the 100% concentration amount, and the narrative resulted in fewer cigarettes purchased compared to the 2 other groups.

In addition, fitted Q_{Alone} (ie, the terminal intensity of substitution; far right side of Figure 2) was significantly different across the 3 groups (F[2,1461] = 6.21, p = .002, η_p^2 = .008). *Post hoc* comparisons indicated Q_{Alone} for the 2% narrative was signifi-

Figure 2
Usual-brand Cigarette Demand (square symbols) and Variable-nicotine Cigarette Substitution (circle symbols), Fixed at $0.25 per Cigarette, as a Function of Increasing Price of Usual-brand Cigarettes



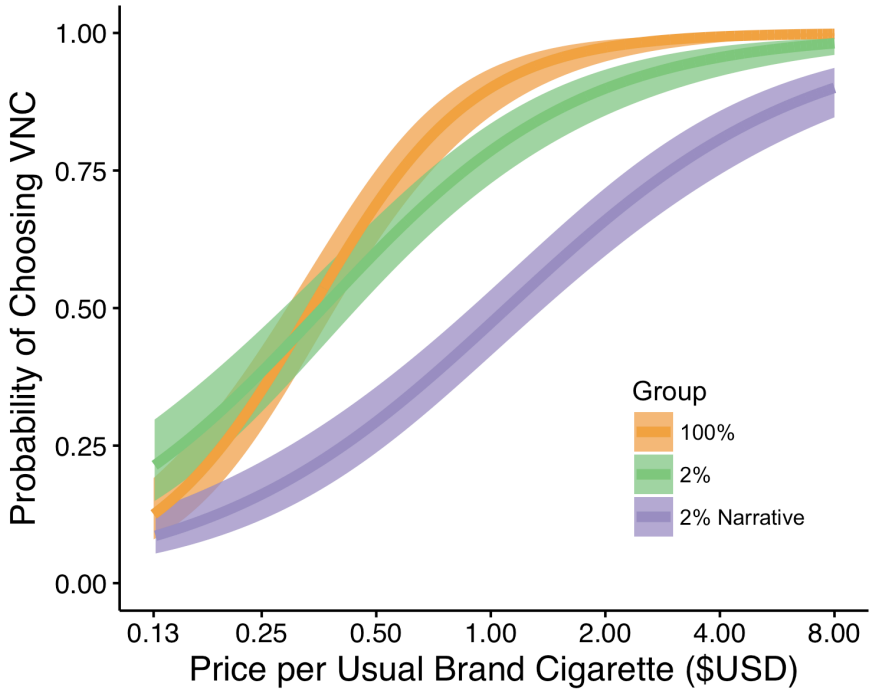
Note.
Variable-nicotine cigarettes in all three groups served as partial substitutes for usual-brand cigarettes with cigarettes under the Narrative condition demonstrating least substitution. Symbols and error bars indicate mean and standard error of the mean. Note the logarithmic x-axis.

Table 3
Generalized Logistic Regression

	Choosing Variable-Nicotine Cigarette			
Regression Term	**Odds Ratio**	**95% Confidence Interval**	**Standard Error**	**p**
Intercept	3.67	2.69, 5.16	0.61	<.001
Price	18.99	10.70, 35.93	5.85	<.001
Group: 100%	2.46	1.41, 4.46	0.72	<.01
Group: 2% Narrative	0.24	0.16, 0.36	0.05	<.001
Price X Group: 100%	5.68	2.00, 17.21	3.11	.001
Price X Group: 2% Narrative	0.68	0.31, 1.46	0.27	.329
Observations	1267			
AIC	1036.89			
Null Deviance	1664.62			
Residual Deviance	1024.89			
$\chi^2_{deviance}$	$p < .001$			
Family (link)	Binomial (Logit)			

Note.
2% coded as reference group

Figure 3
Estimated Probability of Choosing Variable-nicotine Cigarettes (set at a fixed $0.25 per cigarette) Over Usual-brand Cigarettes (increasing in price) Based on Group



Note.
Participants in the 100% group switched to the variable-nicotine cigarette more rapidly as price increased compared to participants in the 2% and 2% Narrative groups. Participants in the 2% group were more likely to purchase variable-nicotine cigarettes regardless of price compared to the 2% Narrative group. Shaded curves represent 95% confidence intervals.

cantly lower compared to Q_{Alone} for both the 100% ($F[1,939] = 10.15$, $p = .002$, $\eta_p^2 = .021$) and 2% groups ($F[1,969] = 6.27$, $p = .013$, $\eta_p^2 = .012$). No differences were found between the 100% and 2% groups ($F[1,1014] = 1.88$, $p = .171$, $\eta_p^2 = .004$). These findings provide further support for the efficacy and domain specificity of the narrative to influence estimated purchasing of variable-nicotine cigarettes, but not usual-brand cigarettes.

Effects of Concentration on Concurrent Choice Task

Results from the concurrent choice task indicated a significant price by group interaction, $\chi^2(2) = 20.48$, $p < .001$ (Table 3 and Figure 3). As the price of the usual-brand cigarette increased, the odds of switching to the variable-nicotine cigarette increased more quickly for participants in the 100% group compared to those in the 2% (OR = 5.68, $p = .001$) and 2% narrative groups (OR = 8.36, $p < .001$). Although the rate at which participants switched to the variable-nicotine cigarettes was not different between those in the 2% group compared to the 2% narrative group (OR = 1.47, $p = .329$), participants in the 2% group were more likely to purchase the variable-nicotine cigarette overall (OR = 4.10, $p < .001$).

EXPERIMENT 3 DISCUSSION

The purpose of this experiment was to determine the effects of concentration amount and an undesirable narrative associated with the 2% concentra-

tion amount on demand indices and substitution. Although we did not observe a concentration amount (100% vs 2%) effect on either demand intensity or elasticity, we found that intensity was nominally higher under the 2% amount compared to the 100% amount, as well as a consistent and pronounced effect of the narrative in altering the value of variable-nicotine cigarettes across a number of tasks. That is, demand elasticity for these cigarettes was higher (greater price sensitivity) in the variable-nicotine CPT, and the price of usual-brand cigarettes had to be sufficiently high for participants to switch to the variable-nicotine cigarettes.

GENERAL DISCUSSION

Emerging evidence suggests a tobacco regulatory policy limiting the amount of nicotine in cigarettes may result in a socially significant reduction in cigarette use and dependence.[6] Whereas much of this research has used experiential contexts, the current set of experiments explored initial intentions of cigarette uptake by measuring how cigarette smokers estimate their cigarette purchasing under different scenarios. We approximated a realistic scenario in which the participant's usual-brand cigarette manufacturer replaced their old cigarettes with a new cigarette containing some variable amount of nicotine (variable-nicotine cigarette) and that the only difference was the amount of nicotine in the cigarette. When the stated concentration was 100% of their usual-brand cigarette, we observed a reduction in the estimated number of these new cigarettes participants would purchase when they were free.

However, relative to the 100% group, our current market control, participants in all other groups tended to show an increase in the estimated number of cigarettes purchased if cigarettes were free. This finding was unexpected and may indicate some minimal amount of compensatory smoking behavior based solely on perceptions of what it means to have a reduction in nicotine content, but not necessarily commensurate with the degree of nicotine reduction. Consistent with previous research,[8,15] the observed increases in purchasing may reflect participants' misconceptions of the role of nicotine such that any reductions in nicotine compared to their usual brand are associated with decreased health risks. If this were the case, however, we would expect that decreases in concentration amount would be systematically associated with increases in purchasing, similar to the results found by Pacek et al.[8] However, this was not the case as participants in the very low concentration groups did not purchase relatively more cigarettes compared to the more intermediate groups. In addition, we note that neither the vignette describing the new type of cigarette nor the narrative included any information about changes in health effects; rather the narrative described differences in the subjective feelings associated with the new cigarette. Whether differences in risk perceptions between the different nicotine concentrations mediated estimated uptake is unknown, but this knowledge could be of value when designing marketing or education campaigns associated with a nicotine reduction policy.

Related to concentration amount, another major finding was the lack of influence the stated percentage had on altering cigarette elasticity, one of the main measures of cigarette valuation. Across all the experiments conducted, we did not observe any changes in demand elasticity for any group as a function of nicotine framing alone. Only when we described the new cigarette scenario associated with an undesirable narrative did cigarette demand elasticity increase, which is reflective of relatively rapid declines in purchasing as price increases. This effect was captured across a variety of tasks, which may speak to the power of the narrative in influencing decision making. Moreover, even though the narrative itself was relatively short (only one sentence) and only the 2% concentration was shown when participants were completing the demand and choice tasks, the narrative maintained its effectiveness. These findings suggest information alone about any changes in nicotine content will not reduce either smoking intentions or cigarette valuation, and may actually lead to smokers purchasing more cigarettes. Rather, an effective policy would consider not only providing narratives about the cigarettes' undesirable subjective effects, but also would include targeted information about the cigarettes' health risks. Such a campaign could dampen both initial smoking intentions as well as alter initial cigarette valuation prior to experiencing the cigarettes. This combinatorial approach would be consistent with the findings of Mercincavage et al[15] where subsequent smoking of reduced-nicotine cigarettes was predicted by a combination of sub-

jective taste ratings and degree of false beliefs.

Finally, we note the potential utility of using tasks grounded in the behavioral economic paradigm, which among others include self-administration, simulated purchase tasks, and discrete choice tasks, for assessing the efficacy of reduced-nicotine cigarettes.[6,42] Indeed, these tasks have been used successfully in recent studies investigating reduced-nicotine cigarettes[17,19,21] and their results hold promise for shedding insight into the cigarettes' abuse liability and public reactions to policy changes.

Limitations and Future Directions

Two aspects of the current experiments differed from previous investigations of reduced-nicotine cigarettes, including the hypothetical nature of the tasks and our description of the new cigarette scenario. Much of the research on reduced-nicotine cigarettes has been conducted using experiential procedures (ie, participants experience the subjective effects of the reduced-nicotine cigarettes) and participants are typically blinded to the cigarette concentration.[5,6,19] Here, we conveyed how these cigarettes differed by indicating the nicotine content as a percentage of their usual-brand cigarette and describing a realistic scenario in which only reduced-nicotine cigarettes are available. We sought to isolate the potential influence of cigarette concentration amount by describing the new, variable-nicotine cigarettes as similar to participants' usual-brand cigarette. It is plausible that tobacco companies would try to market reduced-nicotine cigarettes as being similar in characteristics to conventional-nicotine cigarettes. To our knowledge, we are not aware of any experiential research on reduced-nicotine cigarettes that has assessed estimates of purchasing prior to and following the experience of these cigarettes. In addition, we did not measure either participants' knowledge of reduced-nicotine cigarettes nor participants' perceptions of the health risks (eg, Perceived Health Risks scale[43]) associated with our hypothetical reduced-nicotine cigarette so the relations between individual knowledge, risk perceptions, and estimated purchasing is unknown. Future research may benefit from examining a potential moderating role of knowledge and/or perceived health risks and prospective purchasing intentions on the CPT, as well as subsequent correspondence of uptake.

Taken together, the results of the current study suggest estimated uptake of variable-nicotine cigarettes is largely unaffected by a specified nicotine concentration amount alone, and if anything results in small, but consistent, compensatory purchasing. Importantly, narratives describing variable-nicotine cigarettes as less satisfying, less rewarding, and less effective at reducing cravings significantly reduced the value of cigarettes indicating a potential mechanism for reducing cigarette purchasing. Our results suggest a public policy initiative reducing nicotine content aimed at reducing cigarette smoking might benefit from careful marketing and education, and our results provide content that may be important to include in such endeavors.

IMPLICATIONS FOR TOBACCO REGULATION

Lowering the nicotine content in combustible cigarettes may be a viable strategy for reducing dependence and toxin exposure, however our results suggest information about nicotine content alone is unlikely to reduce the number of cigarettes purchased without accompanying narratives about the effects of this reduced nicotine content. Therefore, policymakers should not market or describe reduced-nicotine cigarettes in terms of the nicotine percentage alone. Rather, policymakers should also market and describe reduced-nicotine cigarettes with respect to their subjective effects (eg, less satisfying, less effective at reducing cravings). Researchers should also consider utilizing tasks from the behavioral economic framework (eg, purchase tasks, substitution tasks) to prospectively assess policy change initiatives.

Human Subjects Statement

The treatment of human participants was in accordance with ethical standards, all study procedures were approved by the Institutional Review Board at Virginia Tech (IRB #17-311), and all participants provided informed consent. Additionally, the current study meets the ethical standard outlines in Helsinki Declaration of 1975 as revised in 2000.

Conflict of Interest Statement

W.K.B. is a principal of HealthSim, LLC and

Notifius, LLC; a scientific advisory board member of Sober Grid, Inc. and DxRx, Inc.; and a consultant for ProPhase, LLC and Teva Branded Pharmaceutical Products R&D, Inc. B.A.K. and W.K.B. are principals of BEAM Diagnostics, Inc.

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