Published in final edited form as:

Tob Regul Sci. 2016 October ; 2(4): 309–316. doi:10.18001/TRS.2.4.3.

Reduced Nicotine Content Expectancies Affect Initial Responses to Smoking

Melissa Mercincavage, PhD [Postdoctoral Researcher],

Tobacco Center of Regulatory Science, University of Pennsylvania Philadelphia, PA

Joshua M. Smyth, PhD [Professor],

Biobehavioral Health, The Pennsylvania State University, University Park, PA

Andrew A. Strasser, PhD [Associate Professor], and

Tobacco Center of Regulatory Science, University of Pennsylvania, Philadelphia, PA

Steven A. Branstetter, PhD [Associate Professor]

Biobehavioral Health, The Pennsylvania State University, University Park, PA

Abstract

Objectives—We sought to determine if negative responses to reduced nicotine content (RNC) cigarettes during open-label trials result from smokers' (negative) expectancies. We examined the effects of nicotine content description – independent of actual nicotine content – on subjective responses (craving reduction, withdrawal suppression, mood changes, and sensory ratings) and smoking behaviors (topography measures and carbon monoxide [CO] boost).

Methods—Thirty-six 12-hour-abstinent daily smokers completed a 3-session crossover trial. During each session, participants smoked their preferred brand cigarette – blinded and described as containing “usual,” “low,” and “very low” nicotine content – through a topography device and completed CO and subjective response assessments.

Results—Although nicotine content was identical, compared to the “usual” content cigarette, participants experienced less craving reduction after smoking the “very low” nicotine cigarette, and rated its smoke as weaker ($p < .05$). Participants took shallower puffs of the “low” nicotine cigarette ($p < .05$), and rated the “low” and “very low” nicotine cigarettes as weaker and too mild ($p < .01$).

Conclusions—Negative responses to RNC cigarettes may be due, in part, to negative expectancies about using cigarettes containing less nicotine. In this context, RNC cigarette marketing and labeling are likely important considerations if a federal nicotine reduction policy is initiated.

Correspondence Dr Mercincavage; melmer@upenn.edu.

Human Subjects Statement

This study was reviewed and approved by the Pennsylvania State University Institutional Review Board (CATS #586).

Conflict of Interest Statement

All authors have no conflict of interests to declare.

Keywords

reduced nicotine; expectancies; low nicotine content; subjective ratings; nicotine descriptions

The United States Food and Drug Administration (FDA) has the authority to regulate nicotine,¹ making a federal nicotine reduction policy a promising strategy for decreasing cigarette use.^{2–5} Clinical evidence supports such a policy; reduced nicotine content (RNC) cigarette use generally reduces toxicant exposure and dependence without increasing smoking behaviors, and may facilitate cessation.^{6–14} Few studies, however, have evaluated consumer responses to RNC cigarettes, which likely influence product experimentation and consequent long-term use.¹⁵ This information is needed to understand how RNC cigarettes may be adopted and used during policy implementation.

Limited research suggests that smokers dislike RNC cigarettes. For example, smokers given cigarettes with progressively decreasing nicotine content over 6-week and 6-month periods rated these cigarettes as less strong, flavorful, and satisfying, and of poorer quality compared to their preferred brand.^{7,9} Studies also report significant attrition⁹ and non-compliance^{10,14} due to participants' unwillingness to use RNC cigarettes exclusively during trials. Thus, although clinical evidence supports a nicotine reduction approach, negative consumer response could signal larger impediments to product acceptance. Greater product acceptance may avoid unintended consequences of a nicotine reduction policy, such as the expansion of a "black market" in which smokers seek out products with nicotine content above the federally-mandated level from illicit sources.^{3,4}

To understand the potential impact of negative consumer responses to RNC cigarettes, it is essential to evaluate the role of expectancies (ie, expectations about consequences of use¹⁶); for example, prior work documents that negative drug treatment expectancies (eg, expecting negative side effects or poor treatment outcomes) significantly (and independently) increase the likelihood of their occurrence.^{17–21} To simulate real-world conditions reflecting a nicotine reduction policy, several studies have employed open-label designs in which smokers knew study-supplied cigarettes contained reduced nicotine. As such, it is unclear if negative responses to these cigarettes resulted from product design features (eg, RNC cigarettes objectively tasted worse) or participants' expectancies (eg, associating nicotine with taste caused smokers to expect and consequently report poorer taste).

Prior studies of nicotine dose expectancies demonstrate that smokers generally respond negatively to cigarettes that they expect have no nicotine, regardless of actual nicotine content.^{22–25} As such, a policy informing smokers that cigarettes contain "reduced" or "low" nicotine content may adversely bias responses to these products, although further research is needed. Studies evaluating "very low" nicotine content expectancies are particularly critical, as the FDA cannot reduce nicotine content to zero. This research would provide evidence that the FDA may use to anticipate reactions to, and guide labeling, marketing, and public education decisions about, RNC cigarettes.

This study examined the influence of reduced nicotine content expectancies – independent of actual nicotine content – on subjective responses and smoking behaviors. We

hypothesized that nicotine content expectancies would demonstrate dose-response effects on these outcomes, with the lowest and highest nicotine content expectancies producing the least and most favorable responses, respectively.

METHODS

Participants

Participants were daily smokers recruited from a large rural university student population and surrounding community. Prospective participants either responded to digital and print advertisements for a study assessing ‘how smokers respond to cigarettes with different levels of nicotine,’ or were contacted by research staff because they participated in previous smoking studies, and were screened for eligibility via telephone. Eligible participants were 18 years old and reported smoking 5 cigarettes/day (CPD) for 6 months. Exclusion criteria were: plans to quit smoking in the next month, pregnancy, medical condition exacerbated by smoking, or initial exhaled carbon monoxide (CO) sample < 9 ppm.

Procedure

Telephone-eligible participants completed an in-person visit to provide written informed consent, verify eligibility, and complete baseline demographic questionnaires. Participants also provided CO samples for future visit comparisons, and visually displayed their preferred brand cigarette; this brand was subsequently purchased by research staff from commercial outlets and used as the blinded cigarette during all sessions.

Participants returned for 3 experimental sessions, prior to which they abstained from smoking and using nicotine-containing products for 12 hours to control for previous nicotine consumption effects. Participants supplied CO samples to verify 12-hour abstinence (8 ppm or > 50% reduction from baseline), and completed subjective response assessments. They were then given 5 minutes to smoke their blinded preferred cigarette *ad lib* through a topography device. At smoking onset, participants viewed a computer slideshow presentation containing a description of the cigarette’s nicotine content. Participants then provided post-cigarette CO and subjective response assessments.

Experimental sessions were identical in format (except for nicotine content description); sessions occurred between 7:00 AM and 1:00 PM within a one-hour window per participant to ensure similar experimental conditions within subjects, with at least one day between to eliminate potential carry-over effects. Study completers received \$100 compensation.

Manipulation of nicotine content expectancies—Participants were randomized after the in-person visit to one of 6 counterbalanced nicotine content description orders, although all cigarettes were participants’ blinded preferred brand. To reduce bias and preserve blinding, descriptions were administered via computer slideshow presentations stating:

The cigarette you are smoking contains:

1. “...the same level of nicotine as your usual brand.
2. “...a low level of nicotine compared to your usual brand.

3. "...a very low level of nicotine compared to your usual brand."

At study conclusion, participants were debriefed about the nicotine content deception.

Measures

To determine if the experimental manipulation of participants' nicotine content expectancies was successful, participants estimated at each session, on a 100-point scale (0="None"; 100="Very Much"), how much nicotine the study-supplied cigarette and their preferred cigarette contained.

Subjective responses included computerized questionnaire assessments (Empirisoft MediaLab,²⁶ New York, NY) of: craving reduction (10-item Brief Questionnaire of Smoking Urges²⁷ total and subscale scores); withdrawal suppression (9-item Minnesota Nicotine Withdrawal Scale²⁸ total score); mood changes (20-item Positive and Negative Affect Scale²⁹ subscales scores); and subjective ratings (14 items from 100 mm visual analog scale of cigarette characteristics^{30–33}).

Smoking behaviors included: CO boost, a biomarker of tobacco exposure^{30,31,33} defined as the difference between pre- and post-cigarette CO values (coVita Micro+ Smokerlyzer, Haddonfield, NJ); and smoking topography measures collected using the portable Clinical Research Support System device (Borgwaldt KC, Richmond, VA) including: puff count; total puff volume; mean puff volume; mean puff duration; and mean interpuff interval.

Analytic Plan

Analyses were conducted using IBM SPSS Statistics v23.³⁴ Unpaired t-tests and chi-square tests examined continuous and dichotomous descriptive outcomes, respectively, by attrition status. Repeated measures analysis of variance models evaluated the experimental manipulation, and examined expectancy effects on primary outcomes. All analyses used nicotine content description as the 3-level ("usual," "low," "very low") within-subjects independent variable. For experimental manipulation analyses, dependent variables were estimated nicotine content of study-supplied and preferred brand cigarettes. Analyses of outcomes assessed pre- and post-smoking used a change score as the dependent variable. Correlated (eg, craving subscales) or conceptually similar outcomes (eg, subjective rating items) were analyzed within the same model using repeated measures multivariate analysis of variance, with significant multivariate tests followed-up with univariate analyses of individual dependent outcomes. Mauchly's test examined sphericity assumptions; Huynh-Feldt and Greenhouse-Geisser corrections were applied for violations with epsilon values >0.75 and <0.75, respectively.³⁵ Bonferroni-corrected pairwise comparisons explored significant univariate effects.

RESULTS

Sample Characteristics

Enrollment occurred from August 2014 through April 2015 (Figure 1). Fifty participants met in-person eligibility criteria and were randomized to a description order. Nine participants did not complete the study; 7 were lost due to attrition, and 2 were removed (one was

discovered to be initially ineligible; the other repeatedly failed to meet abstinence criteria). Forty-one participants completed the study, although analyses excluded data for 5 participants due to incorrect abstinence verification. Data are presented for the 36 abstinent study completers.

On average, participants (58.3% male) were 26.39 years old ($SD = 9.30$; range = 18–53), self-reported smoking 12.81 CPD ($SD = 6.78$; 5–32), had smoked regularly for 7.17 years ($SD = 6.19$; 1–24), and had low-moderate nicotine dependence³⁶ ($M = 3.75$; $SD = 1.70$; 1–7). The majority was single (75.0%), white (69.4%), and had completed some college/technical training (52.8%). Study completers ($N = 36$) and non-completers ($N = 9$) did not differ on baseline variables.

Confirmation of Expectancy Manipulation

Nicotine content description had a significant effect on estimated nicotine content of study-supplied cigarettes [$F(2,70) = 35.96$, $p < .001$, $\eta_p^2 = 0.51$]. Cigarettes described as having “low” and “very low” nicotine content were estimated to have 35.6% and 46.4% less nicotine, respectively, than the “usual” cigarette. Estimated nicotine content for participants’ preferred brand did not differ across sessions, or from the “usual” cigarette ($p = .104$). Table 1 provides full pairwise comparisons of each description.

Effects on Subjective Responses

Nicotine content description had a significant effect on reduction in total craving [$F(2,70) = 3.93$, $p = .024$, $\eta_p^2 = .10$] and the combined craving subscales [Wilks’ $\lambda = .86$, $F(4,138) = 2.69$, $p = .034$, $\eta_p^2 = .07$]. The magnitude of total craving reduction between the “usual” versus “very low” nicotine content cigarettes was marginally different ($p = .054$) after adjusting for multiple comparisons. In univariate analyses of craving subscales, nicotine content description affected craving reduction related to anticipation of negative affect relief [$F(2,70) = 4.77$, $p = .011$, $\eta_p^2 = .12$], but not urge to smoke [$F(2,70) = 2.49$, $p = .09$, $\eta_p^2 = .07$]. The “usual” cigarette provided greater craving reduction for this subscale than the “very low” nicotine cigarette ($p = .031$; Table 1).

Nicotine content description had a significant multivariate effect on subjective ratings [Wilks’ $\lambda = .52$, $F(2,114) = 1.60$, $p = .045$, $\eta_p^2 = .28$]. Univariate effects were significant for strength [$F(2,70) = 6.17$, $p = .003$, $\eta_p^2 = .15$], mildness [$F(2,70) = 5.64$, $p = .005$, $\eta_p^2 = .14$], and strength of smoke [$F(2,70) = 7.15$, $p = .001$, $\eta_p^2 = .17$] items. Participants rated the “low” and “very low” nicotine content cigarettes as weaker in strength ($p = .019$ and $.003$, respectively) and too mild ($p = .016$ and $.046$) compared to the “usual” cigarette (Table 1). The “very low” nicotine content cigarette was rated as having weaker smoke strength than the “usual” cigarette ($p = .004$); the “low” and “usual” cigarettes did not differ ($p = .098$). Description had a marginal effect on harshness [$F(2,70) = 3.14$, $p = .05$, $\eta_p^2 = .08$].

Description had no effect on withdrawal suppression or mood changes ($p > .2$).

Effects on Smoking Behaviors

Equipment failures caused the loss of 9 participants' topography data; results describe the 25 participants with valid data. Nicotine content description had a significant effect only on mean puff volume [$F(2,39.78) = 4.71$, $p = .02$, $\eta_p^2 = .16$]. Participants took deeper puffs of the "usual" cigarette compared to the "low" – but not the "very low" – nicotine cigarettes ($p = .02$ and $.16$, respectively; Table 1). Description had no effect on other topography measures or CO boost ($p > .20$).

Discussion

This study addressed important gaps in the RNC cigarette consumer response literature by examining how RNC expectancies affect initial responses to smoking. Whereas blinded RNC cigarette studies have likely underestimated the effects of negative expectancies on smokers' responses to these products, the current study provides evidence useful for interpreting and extending findings from unblinded trials. Expectancies affected some craving reduction, topography, and subjective rating measures, but did not appear to impact withdrawal suppression, mood changes, CO boost, or other subjective rating and topography measures. We observed the strongest expectancy effects on subjective ratings, suggesting that negative ratings of similar sensory characteristics in extant trials^{7,9} are at least partially due to participants' negative expectancies. Conversely, the absence of expectancy effects on actual smoking behaviors suggests that behavioral responses to RNC cigarettes may result from product design features (ie, low nicotine content) rather than expectancies about use.

This approach demonstrates that tobacco product expectancies can be manipulated in a laboratory setting, providing a useful method of studying psychological influences on initial consumer reactions to such products. Future studies evaluating consumer response to other tobacco products may consider utilizing similar designs in which participants are blinded to using their own preferred product.

Despite the utility these laboratory methods offer for understanding nicotine content expectancy effects on initial product responses, some caveats should be noted. First, findings represent expectancy effects on smoking behaviors and subjective ratings during a single exposure while abstinent; thus, results may differ during longer exposure under non-abstinence conditions. Second, although sufficiently powered for primary analyses, our small sample was underpowered for exploring covariate influences, and additionally, may not generalize to the general smoking population. Third, because this study manipulated only nicotine content description, future studies which cross expectancies with actual content are needed to determine the relative independent and synergistic influences of these factors on smokers' responses. Finally, this was not a double-blind study, and it is possible that unblinded research staff members may have biased results.

Acknowledgments

This study was completed in partial fulfillment of doctoral degree requirements, and was supported by internal awards from the Pennsylvania State University. Training support was provided by P50 DA036107 and P50 CA179546 from the National Institutes of Health and FDA Center for Tobacco Products (CTP). The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH or the Food and Drug Administration (FDA). The authors thank Drs Joshua Muscat, Rob Turrissi, Stephen Wilson, and David

Vandenbergh for their guidance in the design of the study; Drs Cynthia Conklin and Charles Geier for providing study equipment; and Sebastian Tapia, Russell Nye, Sarah Ghattas, Mandy Lacue, Naeem Murray, Joey Sipko, and Andrea Stroup for their valuable assistance with data collection.

References

1. US Congress. [Accessed March 8, 2016] Family Smoking Prevention and Tobacco Control Federal Reform Act. 2009. Available at: <https://www.congress.gov/bill/111th-congress/house-bill/1256>
2. Benowitz NL, Henningfield JE. Establishing a nicotine threshold for addiction: the implications for tobacco regulation. *N Engl J Med*. 1994; 331:123–125. [PubMed: 7818638]
3. Hatsukami DK, Perkins KA, LeSage MG, et al. Nicotine reduction revisited: science and future directions. *Tob Control*. 2010; 19(5):e1–e10.
4. Hatsukami DK, Benowitz NL, Donny EC, et al. Nicotine reduction: strategic research plan. *Nicotine Tob Res*. 2013; 15(6):1003–1013. [PubMed: 23100460]
5. Henningfield JE, Benowitz NL, Slade J, et al. Reducing the addictiveness of cigarettes. *Tob Control*. 1998; 7(3):281–293. [PubMed: 9825424]
6. Benowitz NL, Jacob P, Herrera B. Nicotine intake and dose response when smoking reduced-nicotine content cigarettes. *Clin Pharmacol Ther*. 2006; 80(6):703–714. [PubMed: 17178270]
7. Benowitz NL, Hall SM, Stewart S, et al. Nicotine and carcinogen exposure with smoking of progressively reduced nicotine content cigarette. *Cancer Epidemiol Biomarkers Prev*. 2007; 16(11): 2479–2485. [PubMed: 18006940]
8. Benowitz NL, Dains KM, Hall SM, et al. Progressive commercial cigarette yield reduction: biochemical exposure and behavioral assessment. *Cancer Epidemiol Biomarkers Prev*. 2009; 18(3): 876–883. [PubMed: 19258480]
9. Benowitz NL, Dains KM, Hall SM, et al. Smoking behavior and exposure to tobacco toxicants during 6 months of smoking progressively reduced nicotine content cigarettes. *Cancer Epidemiol Biomarkers Prev*. 2012; 21(5):761–769. [PubMed: 22354905]
10. Hammond D, O'Connor RJ. Reduced nicotine cigarettes: smoking behavior and biomarkers of exposure among smokers not intending to quit. *Cancer Epidemiol Biomarkers Prev*. 2014; 23(10): 2032–2040. [PubMed: 25150282]
11. Hatsukami DK, Kotlyar M, Hertsgaard LA, et al. Reduced nicotine content cigarettes: effects on toxicant exposure, dependence and cessation. *Addiction*. 2010; 105(2):343–355. [PubMed: 20078491]
12. Hatsukami DK, Heishman SJ, Vogel RI, et al. Dose-response effects of Spectrum research cigarettes. *Nicotine Tob Res*. 2012; 15(6):1113–1121. [PubMed: 23178320]
13. Donny EC, Houtsmuller E, Stitzer ML. Smoking in the absence of nicotine: behavioral, subjective and physiological effects over 11 days. *Addiction*. 2007; 102(2):324–334. [PubMed: 1722288]
14. Donny EC, Denlinger RL, Tidey JW, et al. Randomized trial of reduced-nicotine standards for cigarettes. *N Engl J Med*. 2015; 373(14):1340–1349. [PubMed: 26422724]
15. Rees VW, Kreslake JM, Cummings KM, et al. Assessing consumer responses to potential reduced-exposure tobacco products: a review of tobacco industry and independent research methods. *Cancer Epidemiol Biomarkers Prev*. 2009; 18(12):3225–3240. [PubMed: 19959675]
16. Perkins K, Sayette M, Conklin C, Caggiula A. Placebo effects of tobacco smoking and other nicotine intake. *Nicotine Tob Res*. 2003; 5(5):695–709. [PubMed: 14577986]
17. Bingel U, Wanigasekera V, Wiech K, et al. The effect of treatment expectation on drug efficacy: Imaging the analgesic benefit of the opioid remifentanyl. *Sci Transl Med*. 2011; 3(70):70ra14.
18. Cocco G. Erectile dysfunction after therapy with metoprolol: the Hawthorne effect. *Cardiology*. 2009; 112(3):174–177. [PubMed: 18654082]
19. Mondaini N, Gontero P, Giubilei G, et al. Finasteride 5 mg and sexual side effects: how many of these are related to a nocebo phenomenon? *J Sex Med*. 2007; 4(6):1708–1712. [PubMed: 17655657]
20. Myers MG, Cairns JA, Singer J. The consent form as a possible cause of side effects. *Clin Pharmacol Ther*. 1987; 42(3):250–253. [PubMed: 3621780]

21. Varelmann D, Pancaro C, Cappiello EC, Camann WR. Nocebo-induced hyperalgesia during local anesthetic injection. *Anesth Analg*. 2010; 110(3):868–870. [PubMed: 20042440]
22. Perkins KA, Ciccocioppo M, Conklin CA, et al. Mood influences on acute smoking responses are independent of nicotine intake and dose expectancy. *J Abnorm Psychol*. 2008; 117(1):79–93. [PubMed: 18266487]
23. Perkins KA, Grottenthaler A, Ciccocioppo MM, et al. Mood, nicotine, and dose expectancy effects on acute responses to nicotine spray. *Nicotine Tob Res*. 2009; 11(5):540–546. [PubMed: 19351782]
24. Juliano LM, Brandon TH. Effects of nicotine dose, instructional set, and outcome expectancies on the subjective effects of smoking in the presence of a stressor. *J Abnorm Psychol*. 2002; 111(1):88–97. [PubMed: 11866182]
25. Darredeau C, Stewart SH, Barrett SP. The effects of nicotine content information on subjective and behavioural responses to nicotine-containing and denicotinized cigarettes. *Behav Pharmacol*. 2013; 24(4):291–297. [PubMed: 23787293]
26. Jarvis, BG. MediaLab. New York, NY: Empirisoft Corporation; 2008.
27. Cox LS, Tiffany ST, Christen AG. Evaluation of the brief questionnaire of smoking urges (QSU-brief) in laboratory and clinical settings. *Nicotine Tob Res*. 2001; 3(1):7–16. [PubMed: 11260806]
28. Hughes JR, Hatsukami D. Signs and symptoms of tobacco withdrawal. *Arch Gen Psychiatry*. 1986; 43(3):289–294. [PubMed: 3954551]
29. Watson D, Clark LA, Tellegen A. Development and validation of brief measures of positive and negative affect: the PANAS scales. *J Pers Soc Psychol*. 1988; 54(6):1063–1070. [PubMed: 3397865]
30. Strasser AA, Ashare RL, Kaufman M, et al. The effect of menthol on cigarette smoking behaviors, biomarkers and subjective responses. *Cancer Epidemiol Biomarkers Prev*. 2013; 22(3):382–389. [PubMed: 23334588]
31. Strasser AA, Lerman C, Sanborn PM, et al. New lower nicotine cigarettes can produce compensatory smoking and increased carbon monoxide exposure. *Drug Alcohol Depend*. 2007; 86(2):294–300. [PubMed: 16930853]
32. Strasser AA, Pickworth WB, Patterson F, Lerman C. Smoking topography predicts abstinence following treatment with nicotine replacement therapy. *Cancer Epidemiol Biomarkers Prev*. 2004; 13(11):1800–1804. [PubMed: 15533910]
33. Strasser AA, Tang KZ, Sanborn PM, et al. Behavioral filter vent blocking on the first cigarette of the day predicts which smokers of light cigarettes will increase smoke exposure from blocked vents. *Exp Clin Psychopharmacol*. 2009; 17(6):405–412. [PubMed: 19968405]
34. IBM. IBM SPSS Statistics for Windows. Armonk, NY: IBM Corp; 2011.
35. Girden, E. ANOVA: Repeated Measures. Newbury Park, CA: Sage; 1992.
36. Heatherton TF, Kozlowski LT, Frecker RC, Fagerström KO. The Fagerström Test for Nicotine Dependence: a revision of the Fagerström Tolerance Questionnaire. *Br J Addict*. 1991; 86(9):1119–1127. [PubMed: 1932883]

IMPLICATIONS FOR TOBACCO REGULATION

The FDA has the authority to regulate both cigarette nicotine content and marketing.¹ The current study addresses the potential impact of labeling of low nicotine cigarettes by specifically examining how reduced nicotine content expectancies affect smoking behaviors and subjective responses. Cigarettes described as containing “low” and “very low” nicotine content (but which actually had normal content) provided less craving relief after 12-hour abstinence, and received more negative subjective ratings on several sensory items. Findings suggest that smokers held negative expectancies about RNC cigarettes’ sensory effects, but that these expectancies did not substantially affect laboratory measures of smoking behavior. If labeled as “low” or “very low” nicotine cigarettes, public education campaigns may need to provide information about similarities in sensory effects between RNC cigarettes and traditional cigarettes to promote positive product expectancies, and consequently increase product acceptance. Product acceptability is necessary for encouraging appropriate use of RNC cigarettes and avoiding unintended consequences of a nicotine reduction policy.

Figure 1.
Overall Study Recruitment and Retention
Note.

* Asterisk indicates N = 36 for analyses of all outcomes except topography measures; due to equipment failure, topography analyses were conducted using N = 25.

Table 1

Outcome Measures for Each Nicotine Content Description (N = 36; N = 25 for Topography Measures)

	Usual Nicotine Content (UBC) Description	Low Nicotine Content (LNC) Description	Very Low Nicotine Content (VLNC) Description
Estimated nicotine content			
Usual brand	73.97 (2.21)	73.56 (2.77)	73.69 (2.57)
Cigarette smoked during session ^{***a,b}	68.00 (2.87)	43.78 (3.12)	36.47 (3.56)
Subjective responses			
<i>Craving reduction</i>			
Total craving [*]	-36.22 (3.97)	-30.84 (3.75)	-26.28 (3.52)
Urge to smoke subscale	-42.79 (4.80)	-39.69 (4.44)	-33.61 (4.34)
Relief of negative affect subscale ^b	-29.64 (3.67)	-21.98 (3.74)	-18.95 (3.58)
<i>Withdrawal suppression</i>	-20.46 (2.74)	-18.79 (2.56)	-15.67 (2.46)
<i>Mood changes</i>			
Positive affect	1.19 (1.31)	0.08 (0.94)	-0.47 (0.88)
Negative affect	-3.08 (0.73)	-3.33 (0.57)	-3.39 (0.67)
<i>Subjective ratings</i>			
Strength ^{**a,b}	64.97 (2.63)	54.33 (2.80)	53.86 (3.44)
Harshness	45.56 (4.07)	39.89 (3.70)	32.86 (4.28)
Heat	43.86 (3.64)	38.28 (3.66)	39.08 (3.47)
Draw	35.56 (4.70)	30.89 (3.27)	31.89 (4.02)
Taste	58.47 (3.60)	58.08 (3.66)	55.28 (4.15)
Satisfaction from smoking	69.67 (5.04)	71.03 (3.35)	64.78 (4.39)
Burn rate	50.53 (4.54)	43.06 (4.00)	45.89 (4.98)
Taste (mildness)	44.17 (3.78)	39.00 (3.25)	35.17 (3.69)
Too mild ^{**a,b}	72.19 (3.04)	58.64 (4.19)	60.53 (4.70)
Harshness of smoke	58.81 (4.37)	63.69 (3.88)	68.83 (4.86)
After taste	55.92 (4.35)	56.92 (3.55)	53.50 (3.94)
Staleness	64.56 (4.03)	67.83 (3.77)	56.92 (4.61)
Strength of smoke ^{**b}	59.81 (2.91)	50.22 (3.44)	43.11 (3.89)
Smoke smell	53.39 (4.57)	54.92 (3.34)	52.64 (3.41)
Behavioral responses			
<i>Smoking topography</i>			
Puff count	15.20 (1.27)	14.92 (0.87)	15.44 (0.91)
Total puff volume (ml)	897.22 (103.00)	754.16 (71.51)	780.20 (66.75)
Mean puff volume (ml) ^{*a}	59.49 (3.65)	49.62 (2.82)	50.73 (3.28)
Mean puff duration (ms)	1753.17 (131.09)	1733.12 (131.29)	1684.53 (114.43)
Mean Interpuff interval (ms)	16413.78 (1178.63)	15693.90 (939.93)	16511.15 (1078.17)
<i>CO boost</i>	6.00 (0.48)	7.08 (0.64)	6.67 (0.60)

* = p < .05,

**
= p < .01,

= p < .001

Note.

Data presented as mean (standard error)

Asterisks indicate significance for univariate ANOVA

Letters indicate statistically significant pairwise comparisons:

a = significant result for UBC vs LNC

b = UBC vs VLNC

c = LNC vs. VLNC