Original investigation

Smoking Through a Topography Device Diminishes Some of the Acute Rewarding Effects of Smoking

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Abstract

Background: Smoking topography (ST) devices are an important methodological tool for quantifying puffing behavior (eg, puff volume, puff velocity) as well as identifying puffing differences across individuals and situations. Available ST devices are designed such that the smoker's mouth and hands have direct contact with the device rather than the cigarette itself. Given the importance of the sensorimotor aspects of cigarette smoking in smoking reward, it is possible that ST devices may interfere with the acute rewarding effects of smoking. Despite the methodological importance of this issue, few studies have directly compared subjective reactions to smoking through a topography device to naturalistic smoking.

Methods: Smokers ($N = 58$; 38% female) smoked their preferred brand of cigarettes one time through a portable topography device and one time naturalistically, in counterbalanced order across two laboratory sessions. Smoking behavior (eg, number of puffs) and subjective effects (eg, urge reduction, affect, smoking satisfaction) were assessed.

Results: Negative affect reduction was greater in the natural smoking condition relative to the topography condition, but differences were not significant on measures of urge, withdrawal, or positive affect. Self-reported smoking satisfaction, enjoyment of respiratory tract sensations, psychological reward, craving reduction, and other rewarding effects of smoking were also significantly greater in the naturalistic smoking condition.

Conclusions: The effects of using a ST device on the smoking experience should be considered when it is used in research as it may diminish some of the rewarding effects of smoking.

Implications: When considering the inclusion of a smoking topography device in one's research, it is important to know if use of that device will alter the smoker's experience. This study assessed affective and subjective reactions to smoking through a topography device compared to naturalistic smoking. We found that smoking satisfaction, psychological reward, enjoyment of respiratory tract sensations and other rewarding effects were all diminished when smoking through the topography device. The effects of using a smoking topography device on the smoking experience should be considered when it is used in future research.

Introduction

Smoking topography (ST) devices electronically capture and quantify various aspects of smoking behavior including the number of puffs,

time between puffs, puff volume, puff duration, puff velocity, and total time smoked.¹ ST devices are an important tool for assessing smoking behavior and exposure and have been used in hundreds of studies to date.² Current ST devices are portable and permit the observation of

smoking behavior both in and outside of the laboratory. An embedded microchip in the ST device records puffing data and the time and date for each smoking episode, which can be downloaded to a computer immediately or at a later time. The controlled assessment of puffing behavior using electronic ST devices is a valuable method for quantifying nicotine/smoke exposure, and identifying individual differences and situational factors predictive of more intense smoking.

Various ST studies have revealed that the way in which a cigarette is smoked can have large effects on nicotine and smoke exposure during a smoking episode. Individuals smoking cigarettes of the same brand can extract very different levels of smoke and nicotine based on their specific puffing profiles.^{3,4} In fact, ST has been instrumental in understanding the phenomenon of smoking compensation, which is observed when smokers maintain their nicotine levels even when switched to lower nicotine yield cigarettes by taking more intense, larger, and longer puffs.^{5,6}

ST devices have also been utilized to identify individual differences associated with different puffing patterns. For example, studies have identified differences in ST among males and females,⁷ menthol and non-menthol smokers,⁸ blacks and whites,³ as well as among individuals with and without post-traumatic stress disorder,⁹ depression,¹⁰ schizophrenia,¹¹ or specific gene variants associated with nicotine metabolism.^{12,13} ST was also found to vary among individuals with different levels of nicotine dependence.¹⁴ Furthermore, while there were no differences in puffing characteristics between light (cigarettes per day = 5 or less, at least 4d/wk) and heavy smokers, (cigarettes per day = 20), there was greater variability in ST measures among the light smokers.

ST devices have also been used to investigate the impact of situational factors on puffing behavior.¹⁵ The manipulation of stress,¹⁶ smoking/nicotine pre-exposure,¹⁷ smoking cues,¹⁸ alcohol exposure,¹⁹ and the suppression of urges to drink alcohol²⁰ have each been shown to affect puffing characteristics. Furthermore, some studies have shown that differences in the intensity of smoking (as measured by puff volume, puff velocity, or interpuff interval) prior to a smoking quit attempt predicts smoking abstinence success.^{21,22}

While ST devices are sensitive and reliable research tools,^{23,24} researchers must also be aware of potential limitations of smoking through a topography device. Currently available ST devices do not permit a smoker to feel the cigarette with their hands or mouth, as the cigarette is smoked through a plastic mouthpiece while holding a small plastic box, or piece of plastic tubing. Thus, it is possible that the artificial feel of ST devices alters smoking behavior and/or smoking effects. In one study involving the repeated use of ST in the natural environment 35% of participants reported that ST did not feel "natural" and 58% reported that it changed their smoking behavior.⁴

To address these validity concerns, controlled laboratory studies have compared how cigarettes are smoked via ST devices to naturalistic smoking (NS). Lee and colleagues found that smoking with a ST device and NS produced similar puffing characteristics (time to smoke and number of puffs) and exposure (plasma nicotine levels and exhaled carbon monoxide [CO]).²⁵ Blank, Disharoon, and Eissenberg compared two different ST devices (stationary and portable) and NS by having participants ($N = 30$, ≥ 15 cigarettes per day) complete six sessions in which they smoked two times each through the desktop device, portable device, and naturalistically.²⁶ In each session the participant smoked four cigarettes in 30-minute intervals after overnight abstinence. Topography measures did not significantly differ among the three measurement methods (r values $> .68$) and that each method was reliable across multiple smoking bouts (most r values $> .78$).

While most studies have concluded that smoking through an ST device does not significantly alter smoking behavior and nicotine exposure, few studies have investigated the effects of ST on the

rewarding effects of smoking. A large body of research demonstrates that the sensorimotor aspects of cigarette smoking are a central component of its rewarding and reinforcing effects.²⁷⁻³¹ Thus, it is important to understand to what extent ST devices could interfere with the pleasure derived from cigarette smoking, perhaps due to alterations in sensorimotor stimulation and/or difficulty in handling the device. The potential attenuation of smoking reward could pose significant limitations on the sensitivity and generalizability of reward assessed when using a ST device. The study by Blank and colleagues, described above, found that while smoking behavior did not differ between NS and stationary or portable ST devices, smoking through either topography device diminished smoking acceptability as indicated by reports that the devices altered smoking behavior, increased smoking difficulty, reduced smoking enjoyment, made smoking less likely, and affected cigarette taste.²⁶ We are aware of no other studies that have directly compared subjective reactions to NS and ST in cigarette smokers.

The principal aim of the present study was to extend this prior research by comparing NS to smoking with a portable ST device using a within subjects design, while including a more comprehensive assessment of rewarding affective and sensory effects. Our primary hypothesis was that smokers would report greater rewarding effects and improved affect when smoking naturalistically relative to ST. A secondary aim was to support previous research evaluating smoking behavior and urge/withdrawal relief between conditions. Consistent with the literature, we did not anticipate differences in smoking behavior or urge/withdrawal relief between conditions. Our last objectives, which were more exploratory in nature, were first to expand upon sensory and rewarding factors that may differ between conditions, and second to examine individual differences (ie, sex and menthol status) associated with smoking behavior as measured with the ST device.

Methods

Participants

Participants were recruited from the American University campus and the surrounding Washington, DC metropolitan area using flyers and web-based advertisements (eg, Craigslist). Eligible participants were 18 to 65 years old and reported smoking at least five cigarettes daily for at least the past year. We choose this cut-off to ensure we recruited regular smokers who exhibited at least low to moderate nicotine dependence. Exclusion criteria included a desire to quit in the next 30 days, study concurrent marijuana use, exclusive use of roll-you-own cigarettes (as they do not fit in the ST device), and any health condition exacerbated by smoking (ie, chronic obstructive pulmonary disease, emphysema). This study was approved by the Institutional Review Board at American University.

Measures

Alveolar CO Breath Sample

Breath samples were obtained using a Bedfont Micro+ Smokerlyzer (Kent, England). CO readings were used to verify smoking status (> 5 ppm) and as a bogus pipeline to encourage compliance with the 3 hours of abstinence required before the first session. Pre- to post-smoking CO boost was also examined as a measure of smoke exposure during the experimental manipulations.

Demographic and Smoking History Questionnaire

This questionnaire contained demographic information questions, smoking history questions, and the Fagerström Test for Nicotine Dependence.³² The Fagerström Test for Nicotine Dependence is

a six-item validated measure of nicotine dependence (Cronbach's $\alpha = .68$ in the present study). This measure also contained one item that measured the participants' readiness to consider smoking cessation (ie, Contemplation Ladder) on which participants circled one number on a ladder from 0 ("No thought of quitting") to 10 ("Taking action to quit").³³

Diener and Emmons Affect Scale³⁴

This nine-item measure is composed of four positive affect items (eg, happy, joyful, pleased) and five negative affect items (eg, unhappy, worried, depressed/blue). The scale was modified from the original five-point scale. A value from 0 ("Not at all") to 100 ("Extremely much") was obtained depending on where the participant placed the mark on a visual analogue scale. Cronbach's α reliability in the present study was .90 for the positive affect scale, and .85 for the negative affect scale.

Urge Rating Scale³⁵

Participants rated three items indicating their desires, wants, and cravings to smoke a cigarette on a visual analogue scale from 0 ("No urge/wanting/craving at all") to 100 ("Greatest urge/wanting/craving I have ever experienced"). These items have been used in many studies assessing urge to smoke.^{36,37} This scale has good reliability and validity. Cronbach's α reliability in the present study was .95.

Minnesota Nicotine Withdrawal Scale—Revised

Participants rated 10 symptoms of tobacco withdrawal (eg, difficulty concentrating) in terms of how they are feeling "right now" on visual analogue scale from 0 ("None") to 100 ("Severe").³⁸ This scale has been shown to have excellent internal consistency and is sensitive to smoking abstinence.³⁹ Cronbach's α reliability in the present study was .91.

Modified Cigarette Evaluation Scale³¹

This widely used 12-item scale assessed participants' immediate reactions to smoking a cigarette (eg, "Was the cigarette satisfying," "Did smoking calm you down") using an 11-point scale from 0 ("Not at all") to 10 ("Extremely"). This measure yields five subscales: Smoking Satisfaction, Psychological Reward, Aversion, Enjoyment of Respiratory Sensations, and Craving Reduction.⁴⁰ Twelve items were added to this measure to examine additional sensory elements of smoking (eg, "Was the cigarette harsh"), as well as additional elements that may be related to the rewarding properties of the cigarette (eg, "Did smoking make you feel less anxious"). The additional items used the same 11-point scale described above. Cronbach's α reliability for the original Modified Cigarette Evaluation Scale (mCES) items was .85 in the present study, while the coefficient α reliability of the original and 12 added items was .92.

CRSSmicro Computerized Topography Device (Plowshare Technologies, Baltimore, MD)

This device is a portable and battery-operated unit ($6.5 \times 5.5 \times 2.9$ cm). A cigarette is placed into the plastic mouthpiece that connects to a pressure transducer where inhalation based changes in pressure are amplified, digitized, and sampled at a rate of 1000 Hz. CRSS Host software was used to download data from the device after each use. Measures of number of puffs, puff volume, puff duration, average puff flow, peak puff flow, inter-puff-interval, and smoking duration were collected.

Observation of Smoking Behavior

Experimenters weighed the cigarettes before and after smoking. Smoking in both conditions was videotaped through a one-way

mirror and later coded by two independent raters for number of puffs and smoking duration. A puff was defined as a hand to mouth movement accompanied by the glowing tip of the cigarette. However, if the cigarette was kept in the mouth after exhalation, the glowing tip alone would suffice to count as a puff. Smoking duration was timed from when the cigarette was lit to when it was extinguished. Any discrepancies greater than one puff or 20 seconds were settled by a third rater ($N = 16$). Puff characteristics such as flow and volume cannot be measured via video recording and thus were not compared between the two conditions.

Procedure

Phone Screening

Participants who completed a phone screen and were interested and eligible were scheduled for two sessions, at least 24 hours apart. All participants were instructed to abstain from smoking for 3 hours before their appointment time to ensure that they did not arrive to the experiment satiated from recent smoking and to roughly equate recent smoking exposure. Participants who reported smoking within the last 3 hours were rescheduled. Participants were asked to bring a pack of their preferred brand of cigarettes with them to the first session. Measures were administered via computer using Inquisit software (version 3.0.6, Millisecond Software, Seattle, WA).

Experimental Sessions

Upon arrival, participants were greeted by the experimenter and led to a room that contained desks, chairs, a computer, speakers, and an intercom. After written informed consent, a CO breath sample was obtained and the experimenter recorded the time since last cigarette. The experimenter collected two of the participant's preferred cigarettes, one for each day of the study. At their first session, participants completed a demographic and smoking history questionnaire followed by measures of affect, urge, and withdrawal. Participants then smoked one cigarette either through the topography device or naturalistically, with the experimental condition randomly counterbalanced across participants. Participants were told to, "smoke the cigarette as you normally would" and given unlimited time to do so. After smoking, participants completed post-smoking measures (affect, urge, withdrawal, and the cigarette evaluation scale) and another CO sample was collected. In the second session, participants completed an experiment evaluation form, were debriefed about the purpose of the study, and compensated US \$40.

Data Analytic Strategy

To determine the effect of smoking on dependent measures assessed before and after smoking (ie, urge, positive affect, negative affect, and withdrawal, CO, cigarette weight) paired samples t tests were used. To evaluate our primary objective, pre- to post-smoking change scores were created to assess differences between the NS and ST conditions on the affect measure, and the post-smoking rating of the subjective measure, since the mCES was only administered after smoking, using paired samples t tests ($N = 7$). Similarly, for our secondary aims, paired samples t tests using change scores on measures of urge, withdrawal, and smoke exposure, as well as paired samples t tests using post-smoking ratings of the added subjective items were also calculated ($N = 16$). Controlling for smoke exposure, gender, or menthol status (using analysis of covariance) had no meaningful effects on the findings and thus t tests are presented for ease of interpretation.

In further exploratory analyses, Pearson correlation coefficients were used to evaluate ST device validity and the associate between puffing characteristics and smoke exposure. Since the ST condition measured more topography variables than the video recordings of the NS condition, puffing characteristics (ie, puff number, duration, volume, and flow) and smoke exposure from the ST condition were compared among those with high versus low dependence, men versus women, and menthol versus non-menthol smokers using independent samples *t* tests.

Results

Sample Characteristics

For adequate power (0.80) we aimed to recruit 60 smokers since the effect sizes in previous research²⁶ of device acceptability ranged from 0.29 to 0.38. Sixty-one smokers began the study. Three participants had incomplete data resulting in a final sample of 58 (36 males, 22 females). Fifteen participants identified themselves as Caucasian, 38 as black, five as other or mixed race. Six participants identified as Hispanic. Participants smoked a mean of 11.8 (*SD* = 5.6) cigarettes per day for a mean of 17.5 years (*SD* = 10.4). Additional background information is shown in Table 1.

Primary Aims

Positive and Negative Affect

Positive affect did not significantly change after smoking through the ST device, $t(57) = 1.69$, $P = .093$, but was significantly improved when smoking naturalistically, $t(57) = 3.05$, $P = .003$. Negative affect was significantly reduced after smoking in both conditions (P s < .001). As shown in Figure 1, negative affect decreased more in the NS condition than the ST condition, $t(57) = -2.00$, $P = .050$, Cohen's $d = -0.292$. Pre to post changes in positive affect ($P = .210$), were in the expected directions but not significantly different between ST and NS conditions.

Modified Cigarette Evaluation Scale

As shown in Figure 2, there were significant main effects of smoking condition on four of five mCES subscales. Smoking

satisfaction, $t(56) = 5.26$, $P < .001$, Cohen's $d = 0.748$, psychological reward, $t(57) = 3.81$, $P < .001$, Cohen's $d = 0.365$, enjoyment of respiratory tract sensations, $t(57) = 4.86$, $P < .001$, Cohen's $d = 0.638$, and craving reduction, $t(57) = 2.28$, $P = .027$, Cohen's $d = 0.340$, were all greater during NS than ST. There was no effect of smoking condition on the aversion subscale ($P = .090$) of the mCES.

Table 1. Demographic and Smoking History Information

Variable	Percent of participants ^a
Sex	
Male	62%
Female	38%
Age (in years)	40.02 (<i>SD</i> = 13.23)
Race	
Caucasian	26%
Black	64%
Mixed/other	10%
Hispanic	
Yes	10%
No	90%
Employment	
Full-time	14%
Part-time	28%
Unemployed	43%
Retired/disability	15%
Student status	
Full-time	12%
Part-time	5%
Not a student	83%
Cigarettes per day	11.84 (<i>SD</i> = 5.62)
Years smoking	17.50 (<i>SD</i> = 10.40)
Number of quit attempts	3.58 (<i>SD</i> = 7.89)
Menthol preference	45%
FTND	4.00 (<i>SD</i> = 2.34)

FTND = Fagerström Test for Nicotine Dependence.

^aMeans and standard deviations presented for age and smoking history items.

Figure 1. Differences in subjective affect, urge, and withdrawal. Significant main effect for condition on negative affect relief (* denotes $P < .05$ on paired samples *t* test). Change scores were calculated as post- minus pre-smoking values. Error bars represent the standard error of the mean.

Secondary Aims

Urge and Withdrawal

Smoking in both conditions significantly decreased urge to smoke and withdrawal (P s < .001). Changes in urge (P = .432), and withdrawal (P = .103), were not significantly different between ST and NS conditions.

Smoking Behavior

Inter-Rater Reliability and Device Validity

Correlation coefficients (r) were high (r 's > .97, P s < .001) between the two independent raters for the hand-coded smoking characteristics (ie, puff number, and smoking duration) from the video data for each condition. The smoking data collected by the topography device and observed by the raters were also highly correlated (r s > .90, P s < .001).

Puffing Behavior/Smoke Exposure

Smoking in both conditions provided a significant boost in expired CO (avg. 5.5 ppm; P s < .001). Participants took a mean of 15.93 puffs (SD = 6.44) with the ST device compared with a mean of 14.64 puffs (SD = 7.74) when smoking naturalistically, $t(57)$ = 2.67, P = .010, Cohen's d = 0.183. However, there was a

marginally significant effect on CO boost in the opposite direction with a greater increase in the NS condition (M = 6.54, SD = 5.12) than the ST condition (M = 5.69, SD = 4.26), $t(57)$ = 1.78, P = .081, Cohen's d = 0.181. There were no differences between ST and NS on smoking duration or the post smoking cigarette weight (P s > .10). The association between CO boost and number of puffs measured with the ST device did not reach significance, $r(58)$ = 0.221, P = .095, which is consistent with associations between other puffing characteristics (ie, puff volume, and puff flow) and CO boost (P s > .10).

Exploratory Aims

Individual Cigarette Evaluation Items

As shown in Table 2, there were also significant differences between smoking conditions for various other ratings of the cigarette and smoking experience. Ratings of acceptability, relaxation, pleasantness, and that the cigarette was high in tar, high in nicotine, smells good, was acceptable, and produced enjoyable sensations on the lips and tongue were all higher during NS than ST (all P s < .04). Smoking condition had no significant effects on ratings of harshness, strength/intensity, or feeling buzzed (all P s > .20).

Figure 2. Differences in subjective smoking reward. Significant main effect for condition on four out of five subscales of the Modified Cigarette Evaluation Scale (* denotes P < .05 on paired samples t test). Error bars represent the standard error of the mean. ERTS = enjoyment of respiratory tract sensations.

Table 2. Individual Cigarette Rating Items

Measure/item	Topography		Natural		P
	Mean	SD	Mean	SD	
Acceptable	6.48	2.87	8.19	1.86	.001*
Feel more relaxed/ less anxious	5.14	2.76	6.19	2.92	.007*
Pleasant	6.07	2.83	7.64	2.04	.001*
High in tar	5.88	2.97	6.60	2.70	.032*
High in nicotine	6.74	2.65	7.33	2.37	.029*
Smells good	4.12	2.93	5.36	3.13	.001*
Enjoy sensation (lips/tongue)	4.69	3.09	6.40	2.99	.027*
Strong/intense	5.03	2.68	5.34	2.92	.428
Harsh	3.71	3.01	3.40	3.23	.522
Feel buzzed	4.45	3.37	4.98	3.40	.216

*Significant P value (< .05) on paired samples t test. Items "Feel more relaxed," and "Less anxious," as well as items "Strong," and "Intense" were highly correlated and combined in the analysis.

Individual Differences by Nicotine Dependence, Sex, and Menthol Status

No significant associations were found between CReSS collected topography variables (eg, puff volume, average flow, etc.) and Fagerström Test for Nicotine Dependence scores. Although there was a marginally significant positive association between Fagerström Test for Nicotine Dependence and number of puffs, $r(58) = 0.236$, $P = .075$.

Males took larger puffs ($M = 81.14$ ml, $SD = 16.54$) than females ($M = 70.30$ ml, $SD = 15.22$), $t(56) = 2.49$, $P = .016$, Cohen's $d = 0.665$. There were no significant gender differences on any other ST variables, all P s $> .10$.

Menthol smokers had significantly greater average flow than non-menthol smokers ($M = 45.14$ ml/s, $SD = 7.62$ vs. $M = 39.87$ ml/s, $SD = 8.33$), $t(56) = 2.49$, $P = .016$, Cohen's $d = 0.786$. In addition, menthol smokers took shorter puffs ($M = 1.76$ seconds, $SD = 0.45$) than non-menthol smokers ($M = 2.08$ seconds, $SD = 0.47$), $t(56) = -2.63$, $P = .011$, Cohen's $d = -0.703$. There was a marginally significant effect for number of puffs with menthol smokers taking fewer puffs ($M = 17.44$, $SD = 7.44$) than non-menthol smokers ($M = 14.63$, $SD = 4.62$), $t(56) = -0.70$, $P = .096$, Cohen's $d = -0.454$.

Discussion

The present study was designed to determine if smoking through a topography device influences the rewarding effects of cigarette smoking, which could have important methodological implications for the use of ST devices in studies assessing the subjective rewarding effects of smoking. To build upon previous research this study included a measure of positive and negative affect and an expanded version of the mCES, which has been used in many prior studies investigating the rewarding and somatosensory effects of smoking. Certain elements of smoking reward were influenced by smoking condition. NS produced greater ratings of smoking satisfaction, psychological reward, enjoyment of respiratory tract sensations, and craving reduction compared to the ST condition. Furthermore, on individual items, ratings of enjoyment, relaxation, pleasantness, that the cigarette was high in tar, high in nicotine, smells good, was acceptable, and produced enjoyable sensations on the lips and tongue were all higher for NS than during ST. These findings support and expand upon research by Blank and colleagues who found that smoking through a mouthpiece reduced smoking enjoyment, increased smoking difficulty, and affected cigarette taste.¹ Furthermore, the present study is the first to elucidate greater negative affect relief when smoking naturalistically compared with ST. This builds upon research by Perkins and colleagues who have shown that negative affect relief from smoking can be situation dependent.¹⁰ In their 2010 study, participants smoked through a topography device after different negative mood inductions, and while negative affect relief was greater in certain situations, their use of the device may have underestimated the negative affect relief actually experienced.

Smoking in either condition produced expected decreases in urge and withdrawal. However, we observed no evidence in support of a differential relationship between smoking condition and urge reduction or withdrawal relief. This is consistent with the findings of Blank and colleagues who also found no differences on measures of withdrawal and urge.²⁶ However, it is important to note that the groups were not equivalent. As seen in Figure 1 the difference between ST and NS approached trend levels for withdrawal ($P = .103$) and had a small effect size (Cohen's $d = 0.174$), which

could have practical significance in ST studies assessing withdrawal effects. It is worth noting that in addition to withdrawal, craving reduction was also assessed in the mCES. There was evidence indicating a difference in craving reduction between the two conditions, such that craving reduction was greater in the NS condition, indicating that some aspects of withdrawal relief may be hampered when using the ST device.

Participants took 1.3 more puffs during ST than NS. This small effect did not result in an observed difference in smoke exposure, as measured by CO Boost. In fact, there was a trend toward greater CO boost after NS than ST. These inconsistent findings may be due to measurement error as they do not appear to reflect systematic differences in smoking behavior between ST and NS. Participants lit their own cigarette after it was placed into the device by the researcher. Taking an extra puff in this condition may have been due to differences in the drag/pull experience when lighting a cigarette through a ST device. Furthermore, there were no differences in the amount of the cigarette smoked (assessed by weight) or the total time smoked. Although our subjects took more puffs with the ST device, this finding was absent in previous research and did not lead to a significant difference in smoke exposure. Thus, similar to a number of prior studies,^{25,26} we conclude that there are not systematic differences in how cigarettes are smoked with ST devices relative to NS. ST continues to be a reliable measure of smoking behavior/exposure, however future studies may benefit from a practice session with the device (which was not included in the present study) to avoid possible measurement error.

Unlike some prior findings, this study did not provide evidence for a relationship between ST characteristics measured by the CReSSmicro and CO boost. However, it should be noted that the post-smoking CO reading was taken at the end of the experimental session (approximately 5–15 minutes after smoking) rather than immediately following smoking so that participants could complete subjective measures prior to any interruptions by the experimenter. This may have obscured a potential association.

We investigated the relationship between puffing characteristics measured in the ST condition and nicotine dependence, gender, menthol status albeit the sample size was small. We found no evidence in support of a relationship between topography characteristics and nicotine dependence. This is consistent with research that found no differences in smokers who are chippers (and usually less nicotine dependent), versus those who are nicotine dependent.¹⁴ Consistent with prior research by Eissenberg and colleagues, males took larger puff volumes than females.⁷ Differences between menthol and non-menthol smokers were also observed. In the present study, menthol smokers took in quicker, but shorter puffs than non-menthol smokers. Although this contradicts findings by Jarvik et al.,⁴¹ who found that menthol smokers had a lower puff flow rate than non-menthol smokers, the literature investigating the effect of menthol cigarettes on ST is quite mixed. Of the handful of studies that experimentally tested the effects of menthol on ST, three found that menthol smokers had lower puff volume, one found increased puff volume, and three found no effect.⁴² Many of these studies had small sample sizes and restricted samples (eg, all males). Future research should continue to explore the potential effect of menthol cigarette use on ST, especially since menthol status can be highly confounded with race. In our sample 88.4% of the menthol smokers were black. However including sex or menthol status as a covariate did not appreciably impact the results of the current study.

There are limitations of this study that should be noted. Although participants were regular smokers, who smoked at least five cigarettes per day, we did not exclude additional tobacco use (ie, cigars, cigarillos, e-cigarette) which could affect ST. In addition, the 3-hour abstinence requirement was only confirmed by self-report. Participants only smoked one time in each condition so the reliability of each methodology over time could not be assessed. Furthermore, the present study only calculated number of puffs and smoking duration during the NS condition. Since our main interest was not in assessing the validity of the device itself, other topographical variables like puff duration and inter-puff interval were not calculated and compared to measurements taken with the CReSS device as was done by Blank et al.²⁶ Furthermore, this study was conducted in the laboratory, and although participants were allowed to smoke their preferred brand of cigarettes *ad libitum*, this may have reduced the ecological validity. Also participants were informed that they would be videotaped while smoking. Although the camera was placed behind a one-way mirror to decrease reactivity, this may have altered how participants smoked. Previous research indicates that smoking in the laboratory may elicit different smoking patterns than natural smoking behavior.⁴³

Future research should continue to investigate how smoking through a topography device affects subjective measures of smoking motivation, especially aspects of smoking reward. Although this study and others indicate subjective ratings of urge and withdrawal do not significantly differ after smoking through a mouthpiece or after smoking naturally, ratings of device “acceptability,” negative mood reduction, and other rewarding effects did appear to be attenuated when using a ST device.

Development of a ST device that does not require one to smoke through a mouthpiece is already being tested by Tiffany and colleagues.⁴⁴ Their creation of the Personal Automatic Cigarette Tracker uses a respiratory inductance plethysmograph for monitoring breathing and a hand gesture sensor for detecting cigarette to mouth movements. Although it is unable to measure characteristics like puff volume or velocity, it is able to measure smoking holding in the lungs. Further validation of this system is required; however, it poses an interesting alternative to traditional computerized topography devices and eliminates the possible effects of reduced smoking satisfaction seen with mouthpiece-based devices while quantifying smoking behavior.

In conclusion, ST remains a valuable tool for quantifying smoking exposure, and identifying individual differences and situational factors that predict greater smoking intensity. However, smoking through a topography device did attenuate subjective responses on the rewarding aspects of smoking, which could possibly decrease the sensitivity and generalizability of rewarding effects assessed in the context of ST studies. If researchers are interested in outcomes related to smoking reward, they should carefully consider the use of a mouthpiece based device in their research.

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Declaration of Interests

None declared.

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