Effect of nicotine corrective messaging on nicotine-related beliefs in US adults: a randomised controlled trial

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► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/tc-2023-058252).

ABSTRACT

Introduction Widespread misperceptions of the health risks of nicotine could undermine the public health benefits of the Food and Drug Administration's actions, including modified risk tobacco product authorisations and a reduced nicotine product standard for cigarettes.
Methods 794 US adults (aged 18+) in NORC's AmeriSpeak panel participated in a randomised controlled trial in Spring 2021 to test the effect of three exposures to eight nicotine corrective messages (NCM) on beliefs about nicotine, nicotine replacement therapy (NRT), e-cigarettes and reduced nicotine content (RNC) cigarettes at 3-month follow-up. Analyses conducted in 2022 examined the effect of study condition (NCM (n=393) vs no message control (n=401)) on nicotine beliefs, use intentions and use of nicotine and tobacco products.
Results Exposure to three NCM doses reduced nicotine (b=−0.33; 95% CI −0.60, −0.07), NRT (b=−0.49; 95% CI −0.85, −0.14), e-cigarette (b=−0.32; 95% CI −0.59, −0.05) and RNC cigarette false beliefs (b=−0.64; 95% CI −1.26, −0.02) compared with the control, controlling for baseline beliefs. Baseline tobacco use and concern about nicotine addiction attenuated intervention effects on false beliefs about RNC cigarettes. There were few intervention effects on intention or use of nicotine and tobacco products.
Conclusions Repeated exposure to NCM was necessary to reduce false beliefs about nicotine and tobacco products. Future studies will improve understanding of the dose and duration of nicotine education needed to shift intentions and behaviour, as well as tailored content for tobacco product users to achieve similar reductions in false beliefs as non-users.
Trial registration number NCT04805515.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Exposure to brief nicotine education may reduce false beliefs about nicotine. However, existing studies on nicotine education messaging have been limited to single-exposure studies and only two have experimentally tested a series of messages that might be delivered in a mass media health communication campaign.

WHAT THIS STUDY ADDS

⇒ Findings from this randomised controlled trial in US adults show that three exposures to the same series of nicotine corrective messages over 3 months reduced adults' false beliefs about nicotine, nicotine replacement therapy, e-cigarettes and reduced nicotine content (RNC) cigarettes at follow-up. Past 30-day tobacco use and concern about addiction to nicotine at baseline attenuated intervention effects related to RNC false cigarette beliefs at 3-month follow-up.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Results suggest that comprehensive public education on nicotine that follows the Centers for Disease Control and Prevention's recommended duration for a widespread public education effort can reduce false beliefs about nicotine, nicotine replacement therapy, e-cigarettes and RNC cigarettes in a general population sample of adults. These findings are relevant and timely given the Food and Drug Administration's (FDA) authorisation of modified risk tobacco products and impending FDA rulemaking on nicotine content in cigarettes and other combusted products.

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INTRODUCTION

Tobacco-related harms ultimately result from addiction to the nicotine in tobacco products[1] and in June 2022, the US Food and Drug Administration (FDA) announced its intention to propose a rule restricting the maximum nicotine content in cigarettes in 2023.[2] However, widespread misperceptions about the harms of nicotine[3–6] have only increased in the USA over time.[7] As of 2019, 86% of US adults understand that nicotine increases the appeal of tobacco products, but only 22% understand that nicotine does not 'cause most of the cancer caused by smoking'.[7] Communicating about the risks of smoking separately from the risks of nicotine will be essential to maximising the public

health benefit of products authorised as modified risk tobacco products (MRTPs) and planned regulations to reduce the nicotine content in cigarettes.

Previous qualitative work has identified that people who smoke lack knowledge on nicotine separate from smoking,[8] and even when they know the risks of nicotine they are inconsistent in their assessment of the relative harmfulness of tobacco products.[9] Findings from our prior work suggest that exposure to a brief nicotine corrective messaging (NCM) intervention reduced nicotine misperceptions in convenience samples of adult tobacco users and non-users[10] and adults who use

opioids,[11] a group with a high prevalence of cigarette use. The few studies that have tested candidate educational messages about reduced nicotine content (RNC) cigarettes have had mixed effects on harm perceptions.[12–16] Byron and colleagues found that a message that conveyed the percentage reduction in nicotine content—similar to VLN's '95% less nicotine' claim—increased accuracy of beliefs about nicotine content and addictiveness of RNC cigarettes, but decreased accuracy of beliefs about cancer risk compared with a control message.[15] Differding and colleagues found that a message about mortality (eg, 'Cigarettes with 95% less nicotine are AS DEADLY as current cigarettes') increased accuracy of beliefs about RNC cancer harms in people who currently smoke cigarettes compared with a control message, but not among people who do not smoke.[16] These experimental studies, as well as a focus group study examining candidate messages about RNC cigarettes, underscore the difficulty in achieving accurate nicotine *and* RNC beliefs among people who do and do not smoke with the same messages.[12] To date, existing studies on nicotine education messaging have been limited to single-exposure studies[10 11 15 16] and only two have experimentally tested a series of messages that might be delivered in a mass media health communication campaign.[10 11]

Guided by the Theory of Planned Behavior,[17 18] this study examined the effect of multiple exposures to a series of evidence-based nicotine corrective messages (NCM) on nicotine beliefs in a general sample of adults over a 12-week period. We hypothesised that adults in the NCM condition would report fewer false beliefs about nicotine, nicotine replacement therapy (NRT), e-cigarettes and RNC cigarettes at follow-up compared with those in the control condition. We also hypothesised that current smoking would moderate the effect of NCM on false beliefs of nicotine, NRT, e-cigarettes and RNC cigarettes, with the effect of NCM on these outcomes attenuated in adult smokers compared with non-smokers. Our secondary outcomes were intention and use of nicotine and tobacco products at follow-up.

METHODS
Study overview
This study examines the effect of multiple exposures to a brief NCM intervention on nicotine, NRT, e-cigarette and RNC cigarette-related beliefs, and likelihood of subsequent tobacco and nicotine use in a population sample of adults. Sample size calculations were based on the effects observed for nicotine and NRT false belief outcomes in the pilot study.[10] With 715 participants (~357 per group) and assuming 70% retention at 3-month follow-up, the study was powered to detect differences of <1 unit between the intervention and control group means for the nicotine, NRT and e-cigarette false belief scales and a 1.64 difference in the group means for the RNC cigarette false beliefs scale with 80% power and two-tailed alpha=0.05. This trial was registered on ClinicalTrials.gov (NCT04805515).

Participants
Participants were 794 US English-speaking adults aged 18 and older recruited in Spring 2021 from the NORC's *AmeriSpeak* national consumer market research panel. The panel provides sample coverage of approximately 97% of the US household population.

Recruitment and enrolment
AmeriSpeak panel members eligible for the current study were English-speaking adults aged 18+ who were sent a standard email invitation describing a study about 'Feelings on nicotine'.

The email invitation introduced study procedures and directed interested panel members to the eligibility screener. Potential participants were identified by randomly selecting households within the panel with an adult within the study age range, and targeting study invitations based on recent study participation, and other demographic characteristics as needed to ensure a representative sample. If a given panel household had more than one active adult panel member, one adult was randomly selected for eligibility. Interested panel members who met eligibility criteria were directed to the online experiment.

Intervention and retention
Intervention
The nicotine corrective messaging (NCM) intervention condition was based on messages tested in our team's pilot study.[10] It included our six original messages and two new messages addressing nicotine in tobacco and e-cigarette products that were adapted from several evidence-based sources to be more accessible to a lay audience (online supplemental figure S1). The sources consisted of FDA's 2017 comprehensive plan for tobacco and nicotine regulation,[1] FDA's 2013 modifications to labelling of NRT products for over-the-counter human use,[19] the 2014 US Surgeon General's Report on the Health Consequences of Smoking,[20] reports on carcinogens from the International Agency for Research on Cancer[21–23] and the National Academies of Science, Engineering, and Medicine report on the 'Public Health Consequences of E-cigarettes'.[24] Participants in the NCM condition were exposed to all eight messages in the same order at each exposure: (1) 'Nicotine is the addictive substance in tobacco products'; (2) 'Nicotine makes it easier for people to start smoking regularly'; (3) 'Nicotine makes it harder for people to quit smoking'; (4) 'Nicotine does not cause cancer'; (5) 'Chemicals in cigarette smoke, not nicotine, largely cause cancer, heart disease, and other health problems in people who smoke'; (6) 'Nicotine can be used safely in quit smoking products like nicotine patches, gum, or lozenges, even long-term'; (7) 'E-cigarettes may expose users to significantly lower amounts of toxic substances than regular cigarettes. But they contain as much or more nicotine'; and (8) 'Low nicotine cigarettes are as harmful as regular cigarettes. But they may help people quit and prevent new users from becoming addicted to cigarettes'. The Flesch-Kincaid Reading Grade level across all messages was 9.5.

Exposure to the NCM intervention was assessed in two ways: (1) assignment to the NCM study condition or control and (2) number of times exposed to study messages, with control participants coded as 0 and NCM participants coded as 1, 2 or 3, depending on survey waves completed.

Study design
This study consisted of four survey waves that occurred over 3 months between 12 February 2021 and 14 May 2021. We allowed responses over 3 weeks to maximise the collection of wave 1 (weeks 1–3) and wave 4 (weeks 11–13) data and 2 weeks for wave 2 (weeks 5–6) and wave 3 (weeks 8–9).

In wave 1 of the main study, panellists completed baseline survey measures of nicotine beliefs and intentions/use of nicotine and tobacco products. They were then randomised in a 1:1 ratio within the survey system to the NCM intervention condition (n=393) or the delayed message control condition (n=401), with those in the NCM condition then receiving their first exposure to the study messages. NCM participants viewed each of the eight NCM messages for at least 5 s and were assessed for visual attention using a heatmapping task[25 26]

during which they were instructed to point and click at up to three areas of the message that attracted their attention. Panel members who completed the wave 1 survey were eligible to complete the remaining two surveys in waves 2 and 4, with panel members assigned to the NCM condition also invited to the wave 3 message exposure.

In wave 2, all participants completed a survey of nicotine beliefs and intentions/use of nicotine and tobacco products, which provided the first postexposure measures of the key outcomes. Participants in the NCM condition received their second exposure to the study messages and completed a heatmapping task.[25] Only participants in the NCM condition received the wave 3 survey, which comprised the third exposure to study messages and the heatmapping task. At waves 1–3, control participants did not see any study messages. The wave 4 survey included the final assessment of nicotine beliefs and intentions/use of nicotine and tobacco products for the full sample; after collection of wave 4 outcome measures, all participants were exposed to the study messages and heatmapping task which served as delayed exposure for the control group. At the end of this survey, both conditions received a thank you message with a list of tobacco cessation resources. All surveys and research procedures were administered by fully trained and experienced NORC staff under the direction of ACV.

Retention
To encourage participation, NORC sent up to four email reminders per survey wave to panellists who had not yet completed the survey. This study also incorporated an incentive structure where participants received a $3 cash equivalent for completing the wave 1 and 2 surveys, a $2 cash equivalent for completing the wave 3 exposure and a $4 cash equivalent for completing the wave 4 survey. These incentives were administered by NORC through their standard procedures for panel members' survey participation and are consistent with our team's work with similar consumer research panels.

Measures
Outcomes
Our primary outcome variable was nicotine beliefs, using items from the National Cancer Institute's 2017 Health Information National Trend Survey (HINTS) and earlier studies.[3 27 28] These items were adapted and validated for use in this study[5 10 29–34] and related specifically to nicotine's addictive nature, nicotine as a cause of cancer and the role of nicotine in the health harms and cancer caused by smoking. In addition to assessing beliefs about nicotine, we also assessed NRT beliefs (6 items), e-cigarette beliefs (4 items) and RNC cigarette beliefs (11 items). These product-specific constructs (ie, NRT, e-cigarette, RNC cigarette beliefs) included items related to the addictiveness of the product and the perceived health risks of the product compared with regular cigarettes.

Secondary outcomes included intention and use of nicotine and tobacco products. Four items assessed intention to use cigarettes, e-cigarettes, nicotine replacement products or low nicotine content cigarettes in the next 12 months using items adapted from the PhenX Toolkit (710302). Ever use and number of days used in the past 30 days was asked for cigarettes, cigars, little cigars/cigarillos, e-cigarettes/vapes, smokeless tobacco, hookah/shisha/waterpipe, nicotine pouches and nicotine gum, patches or lozenges.

Baseline measures
Sociodemographics (eg, age, gender, race/ethnicity, education, employment, household income, region, metropolitan residence and internet access) were collected as profile variables by NORC. We assessed literacy using a validated, single-item measure,[35] as well as concern about addiction to nicotine, smoking-related beliefs and cancer risk beliefs using measures from the 2017 HINTS.

Analyses
At the conclusion of data collection, NORC provided a deidentified data file of survey results and demographic data as well as full documentation of study procedures, including study invitation processes, recruitment and enrolment, and response rates across the four waves. First, we explored potential differences in effects of the NCM condition by baseline variables using bivariate analyses, then estimated differences between groups on wave 4 outcomes. Using multiple linear regression, we modelled the effects of study condition on change in the four false belief scales (ie, nicotine, NRT, e-cigarette and RNC cigarette), intention to use nicotine or tobacco products in the next 12 months and total days of use of nicotine and tobacco products in the past 30 days at waves 2 and 4. These analyses compared intent-to-treat analysis to per protocol analysis and complete case analysis. Prespecified moderators included past 30-day tobacco use at baseline, age group, sex and literacy; concern about addiction to nicotine was exploratory. We examined potential moderators of the relationship between study condition and wave 4 false belief scales using per protocol analysis and controlling for baseline false beliefs. Finally, we explored the role of exposure dose (number of times exposed to NCM) on wave 4 false belief scales using per protocol analysis.

RESULTS
Of 2384 invited panellists, 794 or 31.6% of sampled members were eligible and completed the wave 1 survey and were randomised to the NCM intervention (n=393) or control group (n=401; figure 1). At wave 4, six hundred and nine of the 792 invited panellists (76.9%; n=290 NCM and n=319 control) completed the survey, with 551 completing all waves (complete cases). Half of participants were female and 62% identified as
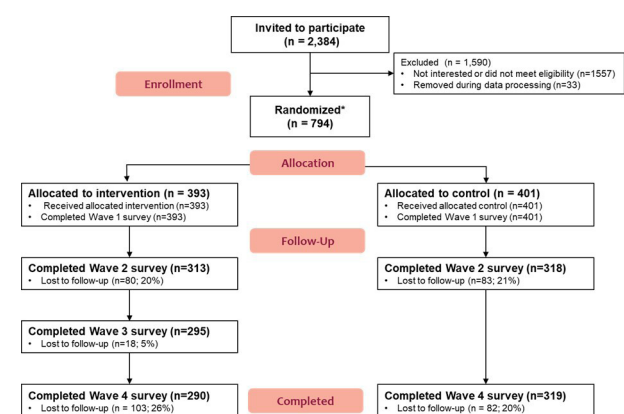
Figure 1 Consolidated Standards of Reporting Trials (CONSORT) diagram. *As part of data processing, NORC removed 23 surveys from wave 2, and 25 from wave 4 when response patterns suggested speeding (survey duration <33.3% of overall median duration), excessive skipping of items (>50% of survey items) or 'straight lining' responses (selecting the same response for 'selected grid items').

white, non-Hispanic; most (78%) reported having completed some college or more education, 82% lived in a metropolitan area and 90% had internet access in their household (table 1 and online supplemental table S1). Approximately 15% of participants reported past 30-day cigarette use. There were no baseline differences in participant demographics, tobacco use characteristics, literacy, nicotine/smoking beliefs or cancer beliefs by study condition; similarly, there were no differences in these variables by study condition in complete cases (data available on request).

There were few differences in individual nicotine, NRT, e-cigarette or RNC cigarette false beliefs between groups at wave 4 (online supplemental table S2). Compared with control participants, NCM intervention participants, however, had lower mean false beliefs about NRT (10.9 vs 11.3) and e-cigarettes (8.9 vs 9.2), but similar mean false beliefs about nicotine (7.5 vs 7.8) and RNC cigarettes (29.8 vs 30.3) at wave 4 (table 2). Multivariable linear regression models controlling for baseline beliefs showed no effect of study condition on wave 2 false beliefs, regardless of analytical approach (ie, intent to treat, per protocol or complete case; online supplemental table S3). Multivariable models with wave 4 false beliefs, however, indicated that the NCM condition reduced false beliefs about nicotine (b=−0.28; 95% CI −0.55, −0.009), NRT (b=−0.39; 95% CI −0.74, −0.04) and e-cigarettes (b=−0.29; 95% CI −0.57, −0.01) in complete case analyses controlling for baseline beliefs.

Further, there were few effects of the NCM intervention on intention to use cigarettes, e-cigarettes, nicotine replacement products or low nicotine content cigarettes at either follow-up (online supplemental table S4). There was a positive association between NCM condition and intention to use cigarettes at wave 2 in all models, which remained in the intent-to-treat analysis at wave 4 (b=0.05; 95% CI 0.0006, 0.10). The NCM intervention also had little impact on the number of days used nicotine or tobacco products, combusted or non-combusted, in the past 30 days at wave 2 or wave 4 (online supplemental table S5). In complete case analyses, exposure to the NCM intervention reduced the number of days used non-combusted tobacco at wave 4, but this is likely to be an unreliable estimate due to the small sample size of baseline non-combusted users (n=33).

Exploratory analyses suggested that baseline tobacco use, age, sex, literacy and concern about addiction to nicotine did not moderate the effect of study condition on wave 4 false beliefs about nicotine, NRT or e-cigarettes (table 3). However, there were main and interaction effects of past 30-day tobacco use and concern about addiction to nicotine on wave 4 RNC cigarette false beliefs. Main effects supported fewer false beliefs about RNC cigarettes among those in the NCM condition (vs control; b=−0.93) and those reporting past 30-day tobacco use (vs no use; b=−1.76); people in the NCM condition who had used tobacco products, however, had higher false beliefs than would have been expected by the joint effect of those two variables (b=−1.01), suggesting attenuation of the intervention effect. Similarly, concern about addiction to nicotine moderated the relationship between NCM and RNC false beliefs, such that those in the NCM condition who were concerned about nicotine at baseline had higher false beliefs about RNC cigarettes than would have been expected by the combination of study condition and concern at baseline (b=−0.78).

Examination of wave 4 outcomes by dose in per protocol analyses suggested that compared with the control condition, exposure to all three NCM doses produced consistent effects on nicotine false beliefs (b=−0.33; 95% CI −0.60, −0.07), NRT false beliefs (b=−0.49; 95% CI −0.85, −0.14), e-cigarette false beliefs (b=−0.32; 95% CI −0.59, −0.05) and RNC cigarette

Table 1 Participant characteristics by study condition

	All (n=794) n (%)	Nicotine corrective messaging intervention (n=393) n (%)	Control (n=401) n (%)	P value
Sex (%)				0.089
Female	400 (50)	186 (47)	214 (53)	
Male	394 (50)	207 (53)	187 (47)	
Age (%)				0.747
18–24	55 (7)	25 (6)	30 (7)	
25–34	162 (20)	78 (20)	84 (21)	
35–44	124 (16)	57 (14)	67 (17)	
45–54	123 (15)	61 (15)	62 (15)	
55–64	145 (18)	74 (19)	71 (18)	
65–74	135 (17)	68 (17)	67 (17)	
75+	50 (6)	30 (8)	20 (5)	
Race/ethnicity (%)				0.525
Hispanic	152 (19)	73 (19)	79 (20)	
White, non-Hispanic	496 (62)	243 (62)	253 (63)	
Black, non-Hispanic	77 (10)	40 (10)	37 (9)	
Asian, non-Hispanic	19 (2)	13 (3)	6 (1)	
More than 1 race, non-Hispanic	34 (4)	18 (5)	16 (4)	
Other, non-Hispanic	16 (2)	6 (1)	10 (2)	
Education (%)				0.903
Less than high school	39 (5)	21 (5)	18 (4)	
High school/General Education Development (GED)	139 (17)	72 (18)	67 (17)	
Some college/associate degree	351 (44)	172 (44)	179 (45)	
Bachelor's degree	141 (18)	66 (17)	75 (19)	
Postgraduate degree	124 (16)	62 (16)	62 (15)	
Income (%)				0.834
Less than $30 000	159 (20)	75 (19)	84 (21)	
$30 000–$59 999	237 (30)	120 (30)	117 (29)	
$60 000–$99 999	227 (29)	116 (29)	111 (28)	
$100 000 or more	171 (21)	82 (21)	89 (22)	
Single-item literacy screener (%)				0.215
Adequate reading ability	683 (86)	332 (84)	351 (87)	
Limited reading ability	111 (14)	61 (16)	50 (13)	
Past 30-day tobacco use (%)				
Any	169 (21)	80 (20)	89 (22)	0.527
Cigarette	119 (15)	61 (16)	58 (15)	0.698
Cigar	23 (3)	11 (3)	12 (3)	0.866
Little cigar or cigarillo	29 (4)	14 (4)	15 (4)	0.899
E-cigarette	47 (6)	25 (6)	22 (6)	0.601

Continued

Table 1 Continued

	All (n=794) n (%)	Nicotine corrective messaging intervention (n=393) n (%)	Control (n=401) n (%)	P value
Nicotine replacement therapy	14 (2)	9 (2)	5 (1)	0.264

Comparisons were tested using Pearson's χ^2 test. Missing data: past 30-day cigarette use (n=4); past 30-day cigar use (n=1); past 30-day little cigar or cigarillo use (n=3); past 30-day e-cigarette use (n=2).

false beliefs (b=−0.64; 95% CI −1.26, −0.02), controlling for baseline beliefs (figure 2).

DISCUSSION

In a study of 794 US adults, three exposures to eight NCMs over 3 months reduced false beliefs about nicotine, NRT, e-cigarettes and RNC cigarettes at follow-up. The emergence of NCM effects on all four products following sufficient dose is promising and underscores the importance of conducting well-controlled studies with high ecological validity to inform public education on nicotine. While these results were consistent with our hypothesis, the magnitude of the effects was smaller than in our pilot study[10] and was only seen for all nicotine products after multiple exposures to intervention messages. Additionally, past 30-day tobacco use at baseline attenuated intervention effects related to RNC false cigarette beliefs at follow-up as hypothesised but, counter to our hypothesis, did not impact nicotine, NRT or e-cigarette false beliefs. A novel finding from our study was that concern about addiction to nicotine also attenuated the relationship between the intervention and RNC false beliefs, producing smaller effects than expected; these results suggest that concern about addiction to nicotine may induce resistance to NCM. There were few effects of the intervention on intention or use of nicotine and tobacco products, which may be due to the short duration of the study.

Studies over the past 20 years have repeatedly shown that smokers in the USA and abroad have little knowledge of NRT and equate the harms of NRT use with the harms of cigarette smoking.[5 27 28 36–40] Nicotine misperceptions have been identified as a barrier to NRT use among smokers[39]; they may also limit uptake of FDA-authorised MRTPs. In line with expert consensus,[41] more than 50% of adult smokers in 2007 who held incorrect beliefs about NRT reported that being exposed to scientific information to correct their misperceptions would make them more likely to use it in a quit attempt.[36] Our intervention reduced false beliefs about NRT and e-cigarettes regardless of dose, highlighting these products as potential targets for brief interventions that could facilitate product switching among adults who smoke cigarettes. However, these findings also suggest resistance to changing beliefs about combusted tobacco products, which are overwhelmingly responsible for the death and disease associated with tobacco use.[20]

Study findings regarding RNC cigarettes are particularly important given the introduction of these products to the commercial market after completion of our trial. In December 2021, FDA authorised the RNC cigarettes VLN King and VLN Menthol King as MRTPs,[42] representing one-third of the products designated with this status.[43] MRTP authorisation of these products and impending FDA rulemaking on nicotine content in cigarettes and certain other combusted products are likely to rapidly increase the number of RNC cigarettes and cigars in the tobacco market. The fact that the NCM intervention impacted false beliefs about RNC cigarettes only among those who received all message exposures aligns with findings of previous studies[10 11 15 16] demonstrating the difficulty in communicating nuance about risks of nicotine and combusted tobacco use to encourage proper understanding of RNC cigarette risks. Our study underscores the need for repeated exposures to nuanced messages on nicotine that address nicotine more comprehensively and in NRT, e-cigarettes and RNC cigarettes.

Strengths of our study include the general population sample of US adults, randomised controlled design, use of a message series rather than individual messages, multiple follow-ups and assessment of message impacts on intentions and use of tobacco products. Further, we did not assess message response following intervention exposures as in our pilot study,[10] providing a more valid estimate of message effects as delivered in a real-world setting. Limitations of our study include the lack of qualitative data from participants to better understand the impact of the intervention on study outcomes, limited visuals in the messages and the lack of cognitive testing of individual study messages to improve the effectiveness of future NCMs.

CONCLUSION

Our trial in a large population sample of US adults moves beyond trials of a single exposure to a single message or a single product to understand how a more comprehensive nicotine public education campaign could reduce false beliefs about nicotine, NRT, e-cigarettes and RNC cigarettes. Findings suggest that multiple exposures to NCM over 3 months, the Centers for Disease Control and Prevention's recommended duration for a widespread public education effort like a mass media campaign,[44] would reduce false beliefs about nicotine, NRT, e-cigarettes and RNC cigarettes. Weakened effects of NCM in adults concerned about nicotine addiction suggest that the effectiveness of adult education campaigns could be hampered by nicotine and tobacco prevention messaging that increases fear of nicotine addiction.[45] Future studies will improve our understanding of the dose and duration of nicotine education needed to shift intentions and behaviour related to nicotine and tobacco product use, as well as a tailored approach for tobacco product users to achieve similar reductions in false beliefs as non-users.

Table 2 Unadjusted wave 4 outcomes by study condition

	Nicotine corrective messaging intervention (n=290) Mean (SD)	Control (n=319) Mean (SD)	P value
Nicotine false beliefs scale	7.5 (2.3)	7.8 (2.1)	0.084
NRT false beliefs scale	10.9 (2.8)	11.3 (2.8)	**0.048**
E-cigarette false beliefs scale	8.9 (2.2)	9.2 (2.1)	**0.032**
RNC cigarette false beliefs scale	29.8 (4.7)	30.3 (4.1)	0.174

Comparisons of continuous variables were conducted using t-test.
Bold values indicate p<0.05.
NRT, nicotine replacement therapy; RNC, reduced nicotine content.

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Table 3 Adjusted linear regression models examining potential moderators of the relationship between study condition and false beliefs at wave 4 (n=609; per protocol analysis)†

	Nicotine false beliefs		Nicotine replacement therapy false beliefs		E-cigarette false beliefs		Reduced nicotine content cigarette false beliefs	
	b	(95% CI)	b	(95% CI)	b	(95% CI)	b	(95% CI)
Past 30-day tobacco use at baseline (yes vs no)								
Intervention	−0.41**	(−0.70 to −0.12)	−0.34	(−0.72 to 0.043)	−0.20	(−0.49 to 0.094)	−0.93**	(−1.59 to −0.26)
Tobacco use	−0.40	(−0.83 to 0.031)	−0.21	(−0.79 to 0.36)	0.19	(−0.25 to 0.63)	−1.76**	(−2.75 to −0.77)
Tobacco use * intervention	0.58	(−0.063 to 1.22)	0.022	(−0.83 to 0.87)	−0.30	(−0.95 to 0.36)	1.67*	(0.20 to 3.15)
Age (18–34 vs 35+)								
Intervention	−0.29	(−0.59 to 0.00095)	−0.26	(−0.65 to 0.13)	−0.23	(−0.53 to 0.071)	−0.62	(−1.30 to 0.062)
Age	−0.17	(−0.58 to 0.25)	0.19	(−0.35 to 0.74)	0.17	(−0.25 to 0.58)	0.30	(−0.65 to 1.26)
Age * intervention	−0.029	(−0.65 to 0.59)	−0.32	(−1.14 to 0.51)	−0.13	(−0.76 to 0.50)	0.33	(−1.12 to 1.77)
Gender (female vs male)								
Intervention	0.18	(−0.63 to 0.99)	−0.46	(−1.54 to 0.61)	−0.51	(−1.33 to 0.31)	0.16	(−1.71 to 2.03)
Female	0.26	(−0.098 to 0.62)	0.13	(−0.34 to 0.60)	0.11	(−0.25 to 0.47)	0.84*	(0.019 to 1.67)
Female * intervention	−0.31	(−0.83 to 0.21)	0.093	(−0.59 to 0.78)	0.17	(−0.35 to 0.70)	−0.47	(−1.67 to 0.72)
Literacy (low vs adequate)								
Intervention	−0.30*	(−0.58 to −0.021)	−0.23	(−0.60 to 0.13)	−0.20	(−0.48 to 0.083)	−0.88**	(−1.52 to −0.24)
Literacy	0.039	(−0.49 to 0.57)	0.57	(−0.14 to 1.27)	0.31	(−0.23 to 0.85)	−0.50	(−1.72 to 0.73)
Literacy * intervention	0.055	(−0.71 to 0.81)	−0.76	(−1.77 to 0.25)	−0.48	(−1.25 to 0.29)	2.33**	(0.58 to 4.09)
Concern about addiction to nicotine (true vs false/don't know)								
Intervention	−0.44*	(−0.78 to −0.098)	−0.021	(−0.47 to 0.43)	−0.25	(−0.59 to 0.098)	−1.13**	(−1.92 to −0.35)
Concern about addiction	−0.17	(−0.54 to 0.20)	0.15	(−0.34 to 0.63)	−0.22	(−0.59 to 0.15)	−1.08*	(−1.92 to −0.23)
Concern about addiction * intervention	0.35	(−0.17 to 0.88)	−0.69	(−1.38 to 0.0027)	0.015	(−0.52 to 0.55)	1.43*	(0.22 to 2.64)

**P<0.01, *p<0.05.
†All models control for baseline false beliefs (eg, nicotine false belief models for wave 4 control for nicotine false beliefs at baseline).

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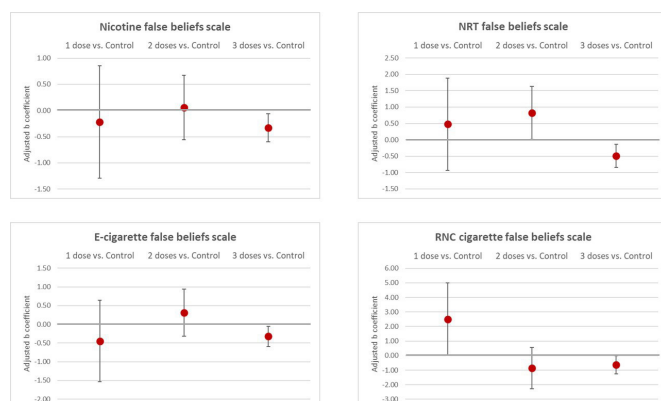
Figure 2 Adjusted estimates and 95% CIs of nicotine, nicotine replacement therapy (NRT), e-cigarette and reduced nicotine content (RNC) cigarette false beliefs at wave 4, by dose of exposure to nicotine corrective messaging (NCM). Note: All models control for baseline false beliefs.

firewalls, (3) destruction of data after data analysis and (4) proper citation in publications or other written materials. A record of transfer of data and a copy of the dataset that was distributed will be kept by Rutgers University.

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Effect of Nicotine Corrective Messaging on Nicotine-Related Beliefs in U.S. Adults: A Randomized Controlled Trial
Supplemental Appendix

Figure S1. Nicotine corrective messaging (NCM) stimuli and their Flesch-Kincaid reading grade levels
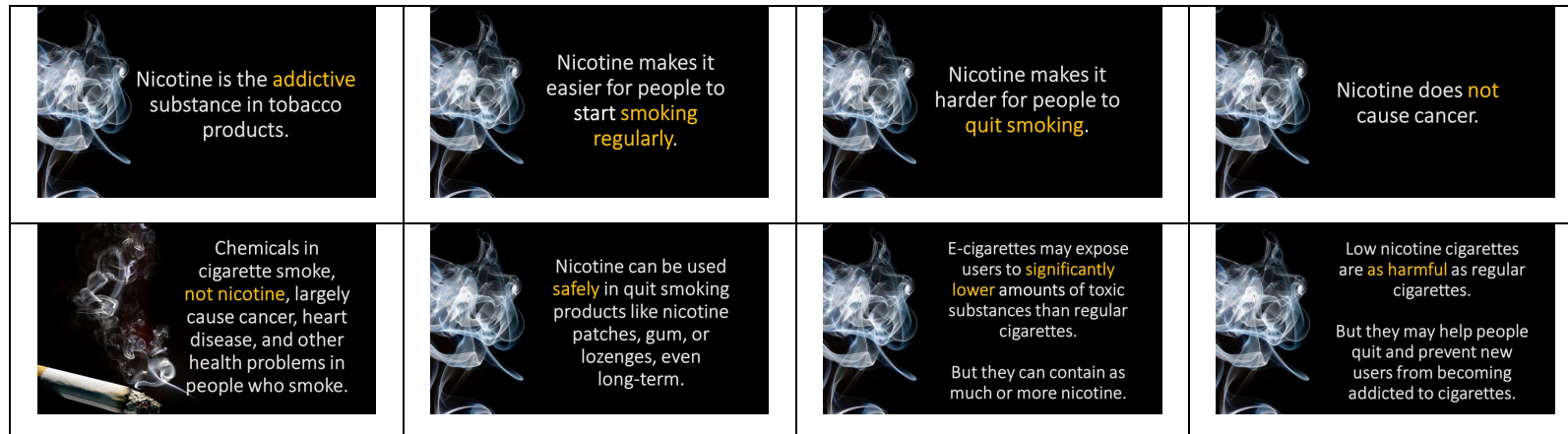
Note: Flesch-Kincaid Reading Grade level across all messages: 9.5

[a] Nicotine is the addictive substance in tobacco products (Flesch-Kincaid Reading Grade level: 11.1)
[b] Nicotine makes it easier for people to start smoking regularly (Flesch-Kincaid Reading Grade level: 9.5)
[c] Nicotine makes it harder for people to quit smoking (Flesch-Kincaid Reading Grade level: 6.2)
[d] Nicotine does not cause cancer (Flesch-Kincaid Reading Grade level: 5.2)
[e] Chemicals in cigarette smoke, not nicotine, largely cause cancer, heart disease, and other health problems in people who smoke (Flesch-Kincaid Reading Grade level: 11.0)
[f] Nicotine can be used safely in quit smoking products like nicotine patches, gum, or lozenges, even long-term (Flesch-Kincaid Reading Grade level: 11.1)
[g] E-cigarettes may expose users to significantly lower amounts of toxic substances than regular cigarettes. But they can contain as much or more nicotine (Flesch-Kincaid Reading Grade level: 10.9)
[h] Low nicotine cigarettes are as harmful as regular cigarettes. But they may help people quit and prevent new users from becoming addicted to cigarettes. (Flesch-Kincaid Reading Grade level: 9.7)

Table S1. Participant characteristics by study condition

	All (*n* = 794)	Nicotine Corrective Messaging Intervention (*n* = 393)	Control (*n* = 401)	*p*
Sex				0.089
Female	400 (50%)	186 (47%)	214 (53%)	
Male	394 (50%)	207 (53%)	187 (47%)	
Age				0.747
18-24	55 (7%)	25 (6%)	30 (7%)	
25-34	162 (20%)	78 (20%)	84 (21%)	
35-44	124 (16%)	57 (14%)	67 (17%)	
45-54	123 (15%)	61 (15%)	62 (15%)	
55-64	145 (18%)	74 (19%)	71 (18%)	
65-74	135 (17%)	68 (17%)	67 (17%)	
75+	50 (6%)	30 (8%)	20 (5%)	
Race/Ethnicity				0.525
Hispanic	152 (19%)	73 (19%)	79 (20%)	
White, non-Hispanic	496 (62%)	243 (62%)	253 (63%)	
Black, non-Hispanic	77 (10%)	40 (10%)	37 (9%)	
Asian, non-Hispanic	19 (2%)	13 (3%)	6 (1%)	
More than 1 race, non-Hispanic	34 (4%)	18 (5%)	16 (4%)	
Other, non-Hispanic	16 (2%)	6 (1%)	10 (2%)	
Education				0.903
Less than high school	39 (5%)	21 (5%)	18 (4%)	
High school/GED	139 (17%)	72 (18%)	67 (17%)	
Some college/ Associate's degree	351 (44%)	172 (44%)	179 (45%)	
Bachelor's degree	141 (18%)	66 (17%)	75 (19%)	
Post-grad degree	124 (16%)	62 (16%)	62 (15%)	
Income				0.834
Less than $30K	159 (20%)	75 (19%)	84 (21%)	
$30K to $59,999	237 (30%)	120 (30%)	117 (29%)	
$60K to $99,999	227 (29%)	116 (29%)	111 (28%)	
$100K or more	171 (21%)	82 (21%)	89 (22%)	
Region				0.256
Northeast	114 (14%)	55 (14%)	59 (15%)	
Midwest	201 (25%)	103 (26%)	98 (24%)	
South	282 (35%)	128 (33%)	154 (38%)	
West	197 (25%)	107 (27%)	90 (22%)	
Metropolitan				0.543
Non-metro area	142 (18%)	67 (17%)	75 (19%)	
Metro area	652 (82%)	326 (83%)	326 (81%)	

	All (*n* = 794)	Nicotine Corrective Messaging Intervention (*n* = 393)	Control (*n* = 401)	*p*
Internet access				0.359
Non-internet household	81 (10%)	44 (11%)	37 (9%)	
Internet household	713 (90%)	349 (89%)	364 (91%)	
Single Item Literacy Screener				0.215
Adequate reading ability	683 (86%)	332 (84%)	351 (87%)	
Limited reading ability	111 (14%)	61 (16%)	50 (13%)	
Past 30-day tobacco use				
Any	169 (21%)	80 (20%)	89 (22%)	0.527
Cigarette	119 (15%)	61 (16%)	58 (15%)	0.698
Cigar	23 (3%)	11 (3%)	12 (3%)	0.866
Little cigar or cigarillo	29 (4%)	14 (4%)	15 (4%)	0.899
E-cigarette	47 (6%)	25 (6%)	22 (6%)	0.601
Nicotine replacement therapy	14 (2%)	9 (2%)	5 (1%)	0.264
Nicotine/smoking beliefs				
Addiction to nicotine is something I am concerned about				0.062
Not true	392 (49%)	177 (45%)	215 (54%)	
Unsure	75 (10%)	41 (11%)	34 (9%)	
True	325 (41%)	173 (44%)	152 (38%)	
Nicotine is the main substance in tobacco that makes people want to smoke	3.52 (0.66)	3.52 (0.67)	3.52 (0.64)	0.985
Smoking behavior is something basic about a person that they can't change very much	1.91 (0.90)	1.89 (0.91)	1.94 (0.90)	0.414
Cancer beliefs				
Cancer is most often caused by a person's behavior or lifestyle	2.44 (0.80)	2.43 (0.81)	2.45 (0.80)	0.774
It seems like everything causes cancer	2.61 (0.84)	2.62 (0.87)	2.61 (0.81)	0.889

Note. Comparisons were tested using Pearson's chi-square test.

Missing data: Past 30-day cigarette use (n=4); past 30-day cigar use (n=1) past 30-day little cigar or cigarillo use (n=3); past 30-day e-cigarette use (n=2); Addiction to nicotine is something I care about (n=2); Nicotine is the main substance in tobacco that makes people want to smoke (n=1); Smoking behavior is something basic about a person that they can't change very much (n=3); Cancer is most often caused by a person's behavior or lifestyle (n=4); It seems like everything causes cancer (n=11).

Table S2. Unadjusted Wave 4 Outcomes by Study Condition

	Nicotine Corrective Messaging Intervention (*n* = 290)	Control (*n* = 319)	*p*
	n (%)	n (%)	
Thinking about the harm that individual substances within a cigarette may cause, how much harm comes from			
Substances produced when raw tobacco burns?	3.3 (1.3)	3.3 (1.2)	0.934
The nicotine in a cigarette?	3.4 (1.4)	3.5 (1.3)	0.396
Naturally occurring substances in tobacco?	2.9 (1.3)	3.0 (1.2)	0.435
Things that are added to cigarettes during the manufacturing process?	3.6 (1.2)	3.6 (1.2)	0.995
Nicotine is the addictive substance in tobacco products.			**0.050**
False	24 (8%)	12 (4%)	
Unsure	23 (8%)	22 (7%)	
True	243 (84%)	285 (89%)	
Nicotine false beliefs			
Nicotine is a cause of cancer			0.059
False	86 (30%)	69 (22%)	
Unsure	79 (27%)	105 (33%)	
True	125 (43%)	145 (45%)	
In your opinion, how large a part of the health risks of cigarette smoking comes from the nicotine itself?			0.579
None or a very small part	21 (7%)	15 (5%)	
A relatively small part	80 (28%)	88 (28%)	
A relatively large part	137 (47%)	154 (48%)	
A very large part or all of the health risks	51 (18%)	62 (19%)	
In your opinion, how large a part of the cancer caused by cigarette smoking comes from the nicotine itself?			**0.019**
None or a very small part	44 (15%)	23 (7%)	
A relatively small part	85 (29%)	105 (33%)	
A relatively large part	111 (38%)	134 (42%)	
A very large part or all of the health risks	50 (17%)	57 (18%)	
Nicotine false beliefs scale (Mean, SD)	7.5 (2.3)	7.8 (2.1)	0.084
NRT false beliefs			
It is easy to get addicted to nicotine gum			0.565
False	33 (11%)	28 (9%)	
Unsure	117 (40%)	132 (41%)	
True	140 (48%)	159 (50%)	

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Tob Control

	Nicotine Corrective Messaging Intervention (*n* = 290)	Control (*n* = 319)	*p*
Long term use of nicotine from patches or gums is almost as harmful to health as cigarette smoking.			0.087
False	81 (28%)	71 (22%)	
Unsure	120 (42%)	126 (40%)	
True	87 (30%)	121 (38%)	
Are nicotine gum, patches, and lozenges more likely, about the same, or less likely to cause someone to become addicted as regular cigarettes?			**0.016**
Less likely	152 (53%)	145 (46%)	
About the same	115 (40%)	159 (50%)	
More likely	22 (8%)	13 (4%)	
Are nicotine gum, patches, and lozenges more likely, about the same, or less likely to cause someone to have a heart attack as cigarettes?			0.335
Less likely	155 (54%)	152 (48%)	
About the same	117 (41%)	144 (46%)	
More likely	14 (5%)	19 (6%)	
Are nicotine gum, patches, and lozenges more likely, about the same, or less likely to cause cancer as cigarettes?			0.241
Less likely	189 (66%)	190 (60%)	
About the same	88 (31%)	116 (37%)	
More likely	11 (4%)	9 (3%)	
Relative harm of nicotine products (like gum, patches, lozenges) compared with cigarettes			0.317
A lot less harmful	72 (25%)	63 (20%)	
A little less harmful	139 (48%)	150 (47%)	
About the same	61 (21%)	89 (28%)	
A little more harmful	10 (4%)	11 (3%)	
A lot more harmful	6 (2%)	6 (2%)	
NRT false beliefs scale (Mean, SD	10.9 (2.8)	11.3 (2.8)	**0.048**
E-cigarette false beliefs			
Long term use of e-cigarettes/vapes is almost as harmful to health as cigarette smoking.			0.341
False	26 (9%)	24 (8%)	
Don't know	72 (25%)	66 (21%)	
True	191 (66%)	227 (72%)	

	Nicotine Corrective Messaging Intervention (*n* = 290)	Control (*n* = 319)	*p*
Are e-cigarettes/vapes more likely, about the same, or less likely to cause someone to have a heart attack as cigarettes?			0.291
Less likely	76 (26%)	69 (22%)	
About the same	182 (63%)	207 (65%)	
More likely	30 (10%)	42 (13%)	
Are e-cigarettes/vapes more likely, about the same, or less likely to cause cancer as cigarettes?			**0.009**
Less likely	106 (37%)	81 (25%)	
About the same	154 (54%)	203 (64%)	
More likely	25 (9%)	33 (10%)	
Relative harm of e-cigarettes compared with cigarettes			0.172
A lot less harmful	12 (4%)	14 (4%)	
A little less harmful	93 (32%)	78 (24%)	
About the same	142 (49%)	184 (58%)	
A little more harmful	22 (8%)	18 (6%)	
A lot more harmful	19 (7%)	24 (8%)	
E-cigarettes false beliefs scale (Mean, SD	8.9 (2.2)	9.2 (2.1)	**0.032**
RNC cigarette false beliefs			
Cigarettes that are lower in nicotine are less likely to cause cancer than regular cigarettes.	2.3 (0.9)	2.4 (0.8)	0.438
Cigarettes that are lower in nicotine are safer than regular cigarettes.	2.3 (1.0)	2.3 (0.9)	0.912
Cigarettes that are lower in nicotine are healthier than regular cigarettes.	2.1 (1.0)	2.2 (0.8)	0.422
Cigarettes that are lower in nicotine have fewer chemicals than regular cigarettes.	2.4 (1.0)	2.3 (0.9)	0.777
Cigarettes that are lower in nicotine are less addictive than regular cigarettes.[a]	3.4 (1.0)	3.6 (0.9)	0.050
Smoking cigarettes that are lower in nicotine make it easier to quit smoking completely compared to regular cigarettes.[a]	3.3 (1.0)	3.4 (0.9)	0.119
Cigarettes that are lower in nicotine also have less tar than regular cigarettes.	2.7 (0.8)	2.6 (0.8)	0.134

	Nicotine Corrective Messaging Intervention (*n* = 290)	Control (*n* = 319)	*p*
High nicotine content cigarettes are worse for your health than low nicotine cigarettes, even if you smoke the same number of each.	3.0 (1.1)	3.0 (1.0)	0.695
A low nicotine cigarette is safer to smoke than a high nicotine cigarette, even if you don't quit.	2.4 (1.0)	2.4 (0.9)	0.832
Low nicotine cigarettes are healthier for you than high nicotine cigarettes even before you quit.	2.3 (0.9)	2.4 (0.8)	0.281
A cigarette brand that says it is low in nicotine means that it is less addictive.[a]	3.6 (1.0)	3.7 (0.9)	0.143
RNC cigarette false beliefs scale (Mean, SD	29.8 (4.7)	30.3 (4.1)	0.174

Note. Comparisons of categorical variables were conducted using Pearson's chi-square test. Comparisons of continuous variables were conducted using t-test.

[a] These items were reverse coded in scale scores.

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Tob Control

Table S3. Effect of study condition on nicotine, NRT, e-cigarette and reduced nicotine content false beliefs at Wave 2 and Wave 4[a]

	Wave 2			Wave 4		
	n	**b**	**95% CI**	**n**	**b**	**95% CI**
Nicotine false beliefs						
Intent-to-treat[b]	794	-0.10	(-0.30 - 0.10)	794	-0.17	(-0.38 - 0.04)
Per protocol	631	-0.13	(-0.38 - 0.13)	609	-0.29*	(-0.55 - -0.03)
Complete case	551	-0.21	(-0.48 - 0.06)	551	-0.28*	(-0.55 - -0.009)
NRT false beliefs						
Intent-to-treat[b]	794	-0.26	(-0.55 - 0.02)	794	-0.36*	(-0.64 - -0.07)
Per protocol	631	-0.26	(-0.61 - 0.08)	609	-0.33	(-0.67 - 0.01)
Complete case	551	-0.24	(-0.61 - 0.13)	551	-0.39*	(-0.74 - -0.04)
E-cigarette false beliefs						
Intent-to-treat[b]	794	-0.013	(-0.23 - 0.20)	794	-0.19	(-0.41 - 0.03)
Per protocol	631	0.001	(-0.26 - 0.26)	609	-0.26	(-0.52 - 0.001)
Complete case	551	-0.031	(-0.31 - 0.24)	551	-0.29*	(-0.57 - -0.01)
Reduced nicotine content cigarette false beliefs						
Intent-to-treat[b]	794	-0.24	(-0.70 - 0.21)	794	-0.43	(-0.93 - 0.06)
Per protocol	631	-0.33	(-0.88 - 0.23)	609	-0.56	(-1.16 - 0.03)
Complete case	551	-0.38	(-0.98 - 0.21)	551	-0.48	(-1.10 - 0.15)

** $p<0.01$, * $p<0.05$

[a] All models control for baseline false beliefs (e.g., nicotine false beliefs models for Wave 2 and Wave 4 control for nicotine false beliefs at baseline)

[b] Intent to treat analyses use last observation carried forward; assumes no change in outcomes if lost to follow-up

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Tob Control

Table S4. Effect of study condition on intention to use cigarettes, e-cigarettes, NRT, and RNC cigarettes in the next 12 months among baseline respondents who had not used tobacco in the past 30 days at Wave 2 and Wave 4[a]

	Wave 2			Wave 4		
	n	b	95% CI	n	b	95% CI
Intention to use cigarettes						
Intent-to-treat[b]	622	0.054*	(0.0088 - 0.098)	621	0.050*	(0.00060 - 0.100)
Per protocol	499	0.066*	(0.010 - 0.12)	482	0.061	(-0.00077 - 0.12)
Complete case	439	0.068*	(0.0063 - 0.13)	438	0.044	(-0.017 - 0.11)
Intention to use e-cigarettes						
Intent-to-treat[b]	620	0.023	(-0.020 - 0.065)	619	0.020	(-0.028 - 0.068)
Per protocol	497	0.034	(-0.019 - 0.086)	480	0.012	(-0.047 - 0.071)
Complete case	437	0.019	(-0.037 - 0.076)	436	-0.0050	(-0.060 - 0.049)
Intention to use nicotine replacement products						
Intent-to-treat[b]	620	0.010	(-0.023 - 0.044)	619	0.026	(-0.017 - 0.070)
Per protocol	499	0.017	(-0.024 - 0.058)	481	0.032	(-0.020 - 0.083)
Complete case	438	0.0093	(-0.033 - 0.051)	437	0.014	(-0.034 - 0.062)
Intention to use low nicotine content cigarette						
Intent-to-treat[b]	622	0.014	(-0.025 - 0.053)	622	0.016	(-0.031 - 0.063)
Per protocol	501	0.021	(-0.027 - 0.069)	482	0.014	(-0.042 - 0.069)
Complete case	439	0.0070	(-0.040 - 0.054)	439	0.0030	(-0.053 - 0.059)

** p<0.01, * p<0.05

[a] All models control for baseline intention or use

[b] Intent to treat analyses use last observation carried forward; assumes no change in outcomes if lost to follow-up

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Tob Control

Table S5. Effect of study condition on total number of days used nicotine or tobacco products in the past 30 days among baseline respondents who had used tobacco in the past 30 days at Wave 2 and Wave 4[a]

	Wave 2			Wave 4		
	n	b	95% CI	n	b	95% CI
Total number of days used nicotine or tobacco products						
Intent-to-treat[b]	169	1.79	(-1.85 - 5.43)	169	1.71	(-1.95 - 5.36)
Per protocol	125	1.88	(-2.86 - 6.62)	121	0.93	(-3.81 - 5.67)
Complete case	108	1.62	(-3.65 - 6.90)	108	0.57	(-4.60 - 5.75)
Total number of days used combusted tobacco products						
Intent-to-treat[b]	141	2.06	(-1.31 - 5.43)	141	2.01	(-1.48 - 5.49)
Per protocol	99	3.01	(-1.79 - 7.81)	102	2.58	(-1.46 - 6.62)
Complete case	88	2.17	(-3.04 - 7.38)	91	1.95	(-2.40 - 6.30)
Total number of days used non-combusted nicotine or tobacco products						
Intent-to-treat[b]	61	0.41	(-2.96 - 3.77)	61	-3.32	(-7.56 - 0.93)
Per protocol	39	0.22	(-5.15 - 5.59)	37	-5.65	(-12.0 - 0.69)
Complete case	31	1.97	(-4.26 - 8.21)	32	-7.57*	(-14.6 - -0.52)

** $p < 0.01$, * $p < 0.05$

[a] All models control for baseline number of days of use

[b] Intent to treat analyses use last observation carried forward; assumes no change in outcomes if lost to follow-up