

Beliefs and Characteristics Associated With Believing Nicotine Causes Cancer: A Descriptive Analysis to Inform Corrective Message Content and Priority Audiences

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Abstract

Introduction: Many cigarette smokers want to quit but have not. Switching to noncombustible products can reduce disease risk, but misperceptions that nicotine causes cancer might impact relative harm perceptions about noncombustible products and considering switching. Identifying which smokers are most likely to hold this misperception and associated beliefs can inform the content of and priority audiences for corrective messaging.

Methods: Bivariable log binomial models were run on a sample of 9,013 adult established smokers from Wave 3 of the Population Assessment of Tobacco and Health. Post hoc testing identified groups and beliefs associated with significantly higher-than-average prevalence of the misperception.

Results: About 61.2% of smokers believe nicotine causes cancer or don't know. Non-Hispanic Black (PR: 2.09) and Hispanic (PR: 1.73) smokers, as well as those making under \$10,000 a year (PR: 1.36) had significantly higher-than-average prevalence of the misperception. Smokers who had recently used ENDS or smokeless tobacco had significantly lower-than-average prevalence of the misperception (PR: 0.70 and 0.63, respectively). Prevalence of nicotine misperceptions was significantly higher-than-average among those who recognized all ten smoking-caused diseases (PR: 1.34), believed additive-free cigarettes were more harmful than regular cigarettes (PR: 1.71), or did not report subjective norms supporting noncombustible use (PR: 1.05).

Conclusion: High perceived threat of tobacco may be overgeneralized to nicotine. High prevalence of the misperception among Non-Hispanic Black and low-income smokers is concerning, considering existing health disparities. Messaging should attempt to correct the misperception that nicotine causes cancer. Inferential reasoning after message exposure should assess accuracy of relative harm perceptions.

Implications: The current study supports the need for corrective messaging to address the misperception that nicotine causes cancer. Identifying that nicotine misperceptions are associated with higher harm perceptions about tobacco suggests that there may be unintended consequences of high perceived harm of tobacco that need to be addressed. As nicotine misperceptions are significantly more prevalent among those already at higher risk of tobacco caused diseases, care should be taken to ensure equity in message dissemination.

Introduction

Despite declining cigarette smoking prevalence in the United States, the annual percentage of smokers who successfully quit remains under 10%.¹ Cigarette smokers who have not quit can reduce their exposure to harmful constituents^{2,3} and reduce their risk of respiratory and cardiovascular diseases^{3,4} by switching completely to a noncombustible nicotine product (NNP).

While all tobacco and nicotine products pose risks to health, NNPs like oral tobacco (e.g. chewing tobacco, moist snuff, and snus) electronic nicotine delivery systems (ENDS), and Nicotine Replacement Therapy (NRT) fall much lower on the harm continuum compared to combustible products.³ A substantial portion of the US public may not understand

the harm continuum, as evidenced by inaccurate perceptions about the relative risk of different tobacco products.^{5,6} One survey found that only 3.5% of respondents reported scientifically accurate relative harm perceptions that no cigarette is less harmful than any other cigarette, and that e-cigarettes and smokeless tobacco are less harmful than combustible cigarettes.⁷

The heart of this issue may be the misunderstanding of how tobacco causes morbidity and mortality. Survey's approximate that only 18%–25% of adults who smoke correctly identify that most of the disease-causing chemicals in cigarette smoke are created during pyrolysis.^{8,9} Nicotine is more commonly identified as a major cause of disease from smoking, with about 50%–60% of smokers reporting that nicotine causes

much of the cancer caused by smoking and 20%–30% reporting being unsure if nicotine causes cancer.^{10–13} Although nicotine is not harmless and indirectly increases risk of disease due to its pairing with carcinogens and other toxicants, it is not a major direct cause of disease in adults.¹⁴

Because people tend to incorrectly attribute the cause of tobacco-related diseases like cancer to nicotine,^{10–13} rather than to constituents generated during combustion,^{8,9} they have an incomplete and inaccurate understanding of how tobacco causes harm. This may create barriers to switching to NNPs, some of which are being authorized as Modified Risk Tobacco Products by the FDA. Additionally, this misunderstanding may be associated with the prevalent but inaccurate belief among those who smoke that very low nicotine cigarettes (VLNC) are less likely to cause disease than regular cigarettes when they are smoked the same way.^{13,15}

Messages targeting smokers are needed to address the misperception that nicotine is carcinogenic. Content for these corrective messages can be informed by exploring the relationship between other harm perceptions about tobacco and the belief that nicotine causes cancer.¹⁶ Identifying related harm perceptions can inform additional target beliefs that need to be addressed to determine message scope.¹⁶ Media exposures, including exposure to anti- and protobacco messaging, can provide important information about the context of where smokers might be exposed to nicotine misperceptions.¹⁷ Additionally, understanding the prevalence of the misperception by different social norms involving tobacco use can provide guidance on corrective message framing, as normative appeals are often powerful components of communication campaigns.^{16,18}

It is also important to determine what groups have higher-than-average prevalence of believing nicotine causes cancer to ensure messaging reaches smokers who are at disproportionate risk for smoking-caused disease.^{19,20} This is crucial to avoid contributing to widening health disparities from smoking.²¹ Although several papers have identified that racial minorities,^{12,22,23} women,^{10,22,23} those with lower educational attainment,^{10,22,23} and older age^{22,23} are more likely to have the misperceptions about nicotine's health impacts, these findings reflect differences in the general population, rather than among smokers. Knowing the prevalence of the misperception among smokers who use other tobacco products can additionally inform identification of what tobacco use behavior may be most affected by the misperception. Only one study has specifically assessed smokers and found that correctly believing that nicotine is not a cause of cancer was associated with past year use of smokeless tobacco and stop smoking medication, but these results were aggregated across four countries, and it is unclear if these results are true of US smokers.²⁴

To fill these gaps and inform both the content of and priority audiences for messages to correct the misperception that nicotine causes cancer, this study aims to describe the proportion of established adult smokers with nicotine misperceptions by sociodemographic measures, product use, related harm perceptions, media exposures and normative influences.

METHODS

Sample

The Population Assessment on Tobacco and Health (PATH) survey provides a large nationally representative sample

of the noninstitutionalized adult population of the United States.²⁵ PATH uses a stratified, address-based, area-probability sampling design. Responses are self-reported using audio computer-assisted self-interviews. The current analysis uses a subset of the 28,148 adult participants interviewed from the Wave 3 Public Use File (data collected between 10/2015–10/2016). The weighted response rate for Wave 3 was 78.4%.²⁸ Details regarding study design and methods are available.²⁶ The subpopulation used for analysis includes 9,013 established smokers (those who have smoked at least 100 cigarettes in their lifetime and report smoking some or all days in the past 30 days). Recommended sampling weights were applied to adjust for differential probability of survey selection, nonresponse, and sampling frame bias; and subpopulation commands were used to ensure weights were applied appropriately so that population estimates could be made.²⁵

Measures

Outcome

The outcome of interest, believing that nicotine is a major source of tobacco-caused cancer, was measured using the question, “Do you believe nicotine is the chemical that causes most of the cancer caused by smoking cigarettes?” The response “definitely no” was considered correct because the FDA and the International Agency for Research on Cancer do not consider nicotine carcinogenic.^{14,27} Based on some amount of scientific uncertainty that nicotine may facilitate cancer development and progression in animal models and in vitro studies, the response “probably no” was also considered accurate.^{28,29} Response options “definitely yes,” “probably yes” and “don't know” were considered incorrect.

Variables Relevant to Message Priority Audiences

Race/ethnicity, sex, age, educational attainment, income, and sexual orientation were included as sociodemographic characteristics.

Product use behaviors were assessed via past 12-month NRT use, and past 30-day use of: combustible tobacco products other than cigarettes (cigarillos, hookah, pipe tobacco, filtered cigars, traditional cigars), menthol cigarettes, ENDS, and snus or other smokeless tobacco products. Interest in switching from cigarettes to a noncombustible product was also included.

To inform message content, several variables were included: Perceived harm related to tobacco was assessed using: recognition of smoking caused diseases; perceived absolute harm of cigarettes; perceived susceptibility to developing a smoking-caused disease; perceived relative harm of combustible tobacco products (cigarillos, hookah, pipe tobacco, filtered cigars, traditional cigars), additive-free cigarettes, and noncombustible tobacco products (ENDS, snus, other smokeless tobacco). Exposure to pro-tobacco messages (for tobacco products other than ENDS and for ENDS) and to anti-tobacco messages (from the Tips from Former Smokers campaign), and normative influences (injunctive norms against smoking, injunctive norms against ENDS use, and descriptive norms supporting noncombustible tobacco use) were also assessed.

[Supplementary Table S1](#) details the wording of each measure and how variable categories were collapsed or combined.

Statistical Analysis

All analyses were conducted in STATA version 15.³⁰ Descriptive statistics are presented as unweighted sample proportions and weighted population estimates among established smokers.

Bivariable log binomial models were run for each independent variable to evaluate the prevalence of having the misperception relative to a reference category. Log binomial models were selected over logistic models due to the high prevalence of the outcome, which can inflate odds ratios.³¹ Post hoc testing was used to calculate and assess the significance of the prevalence ratio where the reference category is the average prevalence of having the misperception using a one degree of freedom test (i.e. STATA's "contrast" command). These results are compared to the prevalence ratios when a variable category is the reference group. All tests use complete case analysis. Due to the large number of tests and the inflation of family-wise error, a Bonferroni correction was used. The combination of testing all variable categories against the mean resulted in 77 tests. The alpha level has therefore been adjusted to .0006.³² The large size of the subpopulation under investigation allows for this significance threshold.³³

RESULTS

Table 1 shows the sociodemographic characteristics of established smokers ($N = 9,013$) by misperception as well as for all established smokers. Descriptive statistics for all other variables can be found in [Supplementary Table S2](#).

Sample Characteristics

The majority of established smokers in the PATH sample are non-Hispanic White (63.3%), male (50.2%), and the largest percentage was 25–34 years of age (24.1%). Over half (71.2%) had no college education. About 6.2% of smokers in the sample made over \$100,000 in annual household income. Only 14.0% of smokers in the sample considered switching to a noncombustible product.

An estimated 61.2% of established smokers incorrectly believe that nicotine definitely or probably causes cancer or did not know if nicotine causes cancer. One hundred and fifty-three smokers in the sample responded "don't know" (included in incorrect responses) and 27 refused to answer the question and were treated as missing.

Variables Relevant to Message Priority Audiences

Table 2 includes both the prevalence ratio compared to a reference category as well as the prevalence ratio compared to the mean for sociodemographic and tobacco use characteristics.

Sociodemographic Characteristics

Compared to the average prevalence of smokers who believe nicotine causes cancer, a significantly higher prevalence of non-Hispanic Black (PR: 2.09) and Hispanic smokers (PR: 1.73) believed this misperception, whereas a significantly lower prevalence of non-Hispanic white smokers reported the misperception (PR: 0.78). Women (PR: 1.12), 45–54-year-olds (PR: 1.27), 55–64-year-olds (PR: 1.55) those with a high school diploma/GED (PR: 1.21) or less (PR: 1.56), and those making less \$10,000 in annual income (PR: 1.36) had significantly higher-than-average prevalence of the misperception. Those with \$50,000–\$99,999 (PR: 0.81) or more than \$100,000 (PR: 0.58) in annual household income, as well as

18–24-year-olds (PR: 0.61) and 25–34-year-olds (PR: 0.72) had a lower-than-average misperception prevalence. There were no significant differences from the average by sexual orientation.

Tobacco Use and Characteristics

There was no significant difference from the average proportion of smokers believing nicotine causes cancer by past 12-month use of NRT (PR: 1.13), past 30-day use of another combustible product (PR: 0.91), or past 30-day use of menthol cigarettes (PR: 1.03). Smokers who had used ENDS (PR: 0.70), or smokeless tobacco/snus (PR: 0.63) in the past 30 days had lower-than-average prevalence of the misperception.

Variables Relevant to Message Content

Table 3 includes both the prevalence ratio compared to a reference category and the prevalence ratio compared to the mean for variables relevant to informing message content.

Related Harm Beliefs

While recognizing that all 10 presented diseases were caused by smoking was associated with above-average prevalence of the misperception (PR: 1.34), recognizing that only 1 or none of the listed diseases were caused by smoking was associated with lower-than-average prevalence of the misperception (PR: 0.47, PR: 0.40, respectively). Believing cigarettes were slightly (PR: 0.68) or somewhat (PR: 0.78) harmful, not worrying about susceptibility to smoking-caused diseases (PR: 0.75), believing at least one combustible was less harmful than cigarettes (PR: 0.57), believing that additive-free cigarettes are less harmful than regular cigarettes (PR: 0.51), and believing that all listed noncombustible products are less harmful than cigarettes (PR: 0.37) were all associated with below-average prevalence of believing nicotine causes cancer. Those who thought cigarettes were very harmful (PR: 1.14) thought additive-free cigarettes were more harmful than regular cigarettes (PR: 1.71), and those with the misperception that at least one noncombustible was more harmful than cigarettes (PR: 1.03) had significantly higher-than-average prevalence of the misperception.

Media Exposures

The proportion of smokers believing nicotine causes cancer did not differ significantly from the average by past 30-day exposure to tobacco or ENDS advertising or past 12-month exposure to Tips.

Normative Influence

Smokers who reported injunctive norms against smoking (e.g. that the disapproval of close friends and family led them to think about quitting very much) had significantly higher-than-average prevalence of the misperception (PR: 1.33), while those who did not report this approval had significantly lower prevalence of the misperception (PR: 0.80). There is a significantly higher prevalence of the misperception among those who reported injunctive norms against ENDS use (PR: 1.54). Smokers who reported subjective norms supporting noncombustible use had a significantly lower prevalence of the misperception (PR: 0.64).

In many cases using an existing variable category as the reference for the prevalence ratio also yielded the same inferences as comparison to the mean. There are, however, several exceptions as seen in [Tables 2](#) and [3](#). Significance by variable

Table 1. Sociodemographic Characteristics of the Subpopulation of Established Smokers from Wave 3 of the Population Assessment on Tobacco and Health Study by Belief in the Misperception that Nicotine Causes Cancer

Variable name	All established smokers (N = 9013)		Smokers with the misperception 61.2% (60.1%, 62.4%)	Smokers with correct perception 38.5% (37.3%, 39.7%)
	Weighted % (95% CI)	Unweighted % (Count)	Weighted % (95% CI)	Weighted % (95% CI)
Race/ethnicity				
Non-Hispanic White	67.1% (65.7%, 68.4%)	63.3% (5702)	37.2% (36.1%, 38.4%)	29.7% (28.4%, 31.0%)
Non-Hispanic Black	13.5% (12.7%, 14.4%)	14.6% (1314)	10.4% (9.6%, 11.2%)	3.1% (2.7%, 3.5%)
Hispanic	11.8% (11.0%, 12.7%)	13.3% (1199)	8.7% (7.9%, 9.4%)	3.1% (2.7%, 3.6%)
Non-Hispanic Other	5.6% (5.1%, 6.2%)	7.0% (632)	3.6% (3.2%, 4.0%)	2.0% (1.7%, 2.4%)
Missing	2.0% (1.7%, 4.2%)	1.8% (166)	1.4% (1.2%, 1.8%)	0.6% (0.4%, 0.8%)
Sex				
Male	53.7% (52.6%, 54.8%)	50.2% (4527)	31.7% (30.8%, 32.6%)	21.9% (21.0%, 22.8%)
Female	46.3% (45.2%, 47.3%)	49.8% (4484)	29.5% (28.4%, 30.6%)	16.6% (15.6%, 17.6%)
Missing	0.03% (0.01%, 0.16%)	0.02% (2)	0.03% (0.01%, 0.16%)	0.0% (0.0%, 0.0%)
Age (in years)				
18–24	11.2% (10.6%, 11.8%)	17.7% (1595)	5.5% (5.1%, 6.0%)	5.6% (5.2%, 6.1%)
25–34	23.2% (22.0%, 24.3%)	24.1% (2169)	12.4% (11.6%, 13.3%)	10.7% (9.9%, 11.5%)
35–44	19.6% (18.5%, 20.7%)	17.8% (1604)	11.3% (10.5%, 12.1%)	8.2% (7.5%, 8.9%)
45–54	19.4% (18.5%, 20.4%)	17.9% (1614)	13.0% (12.3%, 13.9%)	6.4% (5.8%, 7.0%)
55–64	17.6% (16.6%, 18.5%)	15.3% (1380)	12.5% (11.8%, 13.4%)	5.0% (4.4%, 5.7%)
65–74	7.0% (6.3%, 7.8%)	5.7% (518)	4.9% (4.3%, 5.7%)	2.0% (1.6%, 2.5%)
75+	2.1% (1.7%, 2.6%)	1.5% (133)	1.4% (1.1%, 1.8%)	0.6% (0.4%, 1.0%)
Missing	0.0% (0.0%, 0.0%)	0.0% (0)	0.0% (0.0%, 0.0%)	0.0% (0.0%, 0.0%)
Educational attainment				
Less than HS/GED	17.1% (16.1%, 18.1%)	18.1% (1631)	12.2% (11.5%, 12.9%)	4.8% (4.2%, 5.5%)
HS grad/GED	38.2% (37.0%, 39.5%)	37.3% (3361)	25.1% (23.9%, 26.4%)	12.9% (12.1%, 13.8%)
Some College	32.9% (31.7%, 34.1%)	33.9% (3053)	17.9% (16.9%, 18.8%)	15.1% (14.2%, 16.0%)
Bachelor's degree	8.9% (8.0%, 9.8%)	7.7% (698)	4.7% (4.2%, 5.3%)	4.1% (3.5%, 4.8%)
Advanced degree	2.3% (2.0%, 2.7%)	2.4% (217)	1.0% (0.8%, 1.3%)	1.3% (1.1%, 1.6%)
Missing	0.6% (0.5%, 0.8%)	0.6% (53)	0.3% (0.1%, 0.5%)	0.2% (0.1%, 0.3%)
Income				
Less than \$10,000	19.8% (18.7%, 21.0%)	22.6% (2041)	13.5% (12.3%, 14.2%)	6.3% (5.7%, 6.9%)
\$10,000–\$24,999	25.5% (24.3%, 26.7%)	26.3% (2371)	16.4% (15.5%, 17.2%)	9.1% (8.4%, 9.9%)
\$25,000–\$49,999	23.2% (22.2%, 24.3%)	22.6% (2033)	13.9% (13.0%, 14.8%)	9.3% (8.6%, 10.1%)
\$50,000–\$99,999	18.5% (17.4%, 19.7%)	16.6% (1493)	10.4% (9.5%, 11.3%)	8.1% (7.4%, 8.9%)
\$100,000 or above	7.2% (6.4%, 8.2%)	6.2% (556)	3.5% (2.9%, 4.2%)	3.8% (3.3%, 4.4%)
Missing	5.7% (5.1%, 6.4%)	5.8% (519)	3.7% (3.2%, 4.2%)	1.9% (1.6%, 2.3%)
Sexual orientation				
LGB	7.2% (6.7%, 7.7%)	8.7% (782)	3.9% (3.5%, 4.4%)	3.2% (2.9%, 3.6%)
Straight	91.5% (90.9%, 92.1%)	90.0% (8112)	56.6% (55.4%, 57.8%)	34.7% (33.6%, 35.9%)
Missing	1.4% (1.1%, 1.7%)	1.3% (119)	0.7% (0.5%, 0.9%)	0.5% (0.4%, 0.8%)

level differed for: knowledge of diseases caused by smoking, worrying about the health harms of smoking, and perceptions regarding the absolute harm of cigarettes because the prevalence of the misperception in the reference category was very different than the mean prevalence.

DISCUSSION

In line with estimates from the general population, an estimated 61.2% of established smokers in the United States thought nicotine definitely or probably caused cancer or did not know if nicotine caused cancer,^{10–13,23} indicating a clear need for corrective messaging.

Priority Concepts for Message Content

Prevalence of believing that nicotine causes cancer was higher among those who had higher overall risk perceptions about tobacco. This included those who: believed that additive-free cigarettes were more harmful than regular cigarettes, recognized all 10 smoking-caused diseases, perceived all combustible products were as or more harmful than cigarettes, and had high absolute harm beliefs about cigarettes. These findings suggest that higher harm perceptions about tobacco might be generalized to apply specifically to nicotine. This could be the result of heuristic processing. Heuristics are “cognitive shortcuts” used to make decisions under conditions of uncertainty, or when motivation to process or processing

Table 2. Prevalence Ratios Comparing the Prevalence of Having the Misperception Compared to a Reference Group and the Mean by Priority Audience Variables

Variables to inform priority audience	PR (95% CI), <i>p</i>	PR (reference: mean), <i>p</i>
Race/ethnicity		
Non-Hispanic White	ref	0.78 (0.75, 0.81), <i>p</i> < .0001
Non-Hispanic Black	2.69 (2.27, 3.17), <i>p</i> < .0001	2.09 (1.81, 2.41), <i>p</i> < .0001
Hispanic	2.23 (1.84, 2.70), <i>p</i> < .0001	1.73 (1.47, 2.04), <i>p</i> < .0001
Non-Hispanic Other	1.40 (1.13, 1.74), <i>p</i> = 0.002	1.09 (0.89, 1.34), <i>p</i> = .39
Sex		
Male	0.81 (0.73, 0.90), <i>p</i> = 0.0001	0.91 (0.87, 0.95), <i>p</i> = .0001
Female	ref	1.12 (1.06, 1.18), <i>p</i> = .0001
Age		
18 to 24 years old	ref	0.61 (0.55, 0.68), <i>p</i> < .0001
25 to 34 years old	1.18 (1.00, 1.38), <i>p</i> = 0.044	0.72 (0.65, 0.80), <i>p</i> < .0001
35 to 44 years old	1.40 (1.24, 1.59), <i>p</i> < .0001	0.86 (0.77, 0.95), <i>p</i> = .0043
45 to 54 years old	2.08 (1.79, 2.41), <i>p</i> < .0001	1.27 (1.15, 1.40), <i>p</i> < .0001
55 to 64 years old	2.54 (2.04, 3.18), <i>p</i> < .0001	1.55 (1.35, 1.78), <i>p</i> < .0001
65 to 74 years old	2.53 (1.86, 3.44), <i>p</i> < .0001	1.54 (1.18, 2.02), <i>p</i> = .0019
75 years old or older	2.31 (1.25, 4.25), <i>p</i> = 0.008	1.41 (0.79, 2.53), <i>p</i> = .25
Educational attainment		
Less than HS/GED	ref	1.56 (1.36, 1.79), <i>p</i> < .0001
High school grad/GED	0.77 (0.64, 0.93), <i>p</i> = .008	1.21 (1.12, 1.30), <i>p</i> < .0001
Some College	0.47 (0.39, 0.57), <i>p</i> < .0001	0.74 (0.68, 0.79), <i>p</i> < .0001
Bachelor's degree	0.45 (0.36, 0.57), <i>p</i> < .0001	0.71 (0.60, 0.84), <i>p</i> < .0001
Advanced degree	0.31 (0.23, 0.43), <i>p</i> < .0001	0.48 (0.36, 0.66), <i>p</i> < .0001
Income		
Less than \$10,000	ref	1.36 (1.22, 1.51), <i>p</i> < .0001
\$10,000–\$24,999	0.84 (0.71, 0.98), <i>p</i> = .032	1.14 (1.04, 1.24), <i>p</i> = .0037
\$25,000–\$49,999	0.69 (0.60, 0.80), <i>p</i> < .0001	0.94 (0.86, 1.03), <i>p</i> = 0.18
\$50,000–\$99,999	0.59 (0.50, 0.70), <i>p</i> < .0001	0.81 (0.72, 0.90), <i>p</i> = .0003
\$100,000 or above	0.43 (0.33, 0.55), <i>p</i> < .0001	0.58 (0.47, 0.71), <i>p</i> < .0001
Sexual orientation		
LGB	0.76 (0.64, 0.90), <i>p</i> = .0019	0.77 (0.66, 0.91), <i>p</i> = .0019
Straight	ref	1.02 (1.01, 1.03), <i>p</i> = .0019
Past 12-month NRT use		
Yes	1.15 (0.90, 1.46), <i>p</i> = .26	1.13 (0.91, 1.42), <i>p</i> = .26
No	ref	0.99 (0.97, 1.01), <i>p</i> = .26
Past 30-day other combustible tobacco product use		
Yes	0.89 (0.80, 0.99), <i>p</i> = .037	0.91 (0.84, 0.99), <i>p</i> = .037
No	ref	1.02 (1.00, 1.05), <i>p</i> = .037
Past 30-day menthol use		
Yes	1.05 (0.95, 1.17), <i>p</i> = .32	1.03 (0.97, 1.09), <i>p</i> = .32
No	ref	0.98 (0.94, 1.02), <i>p</i> = .32
Past 30-day ENDS use		
Yes	0.65 (0.56, 0.76), <i>p</i> < .0001	0.70 (0.62, 0.80), <i>p</i> < .0001
No	ref	1.08 (1.05, 1.11), <i>p</i> < .0001
Past 30-day smokeless/snus use		
Yes	0.61 (0.51, 0.73), <i>p</i> < .0001	0.63 (0.53, 0.74), <i>p</i> < .0001
No	ref	1.03 (1.02, 1.04), <i>p</i> < .0001
Considered switching to a noncombustible product		
Yes	0.61 (0.53, 0.70), <i>p</i> < .0001	0.66 (0.58, 0.744), <i>p</i> < .0001
No	ref	1.07 (1.05, 1.09), <i>p</i> < .0001

Table 3. Prevalence Ratios Comparing the Prevalence of Having the Misperception Compared to a Reference Group and the Mean by Message Content Variables

Variables to inform message content	PR, <i>p</i>	PR (reference: mean), <i>p</i>
Recognition of 10 smoking-caused diseases		
0	ref	0.40 (0.33, 0.49), <i>p</i> < .0001
1	1.17 (0.78, 1.75), <i>p</i> = .45	0.47 (0.33, 0.67), <i>p</i> < .0001
2	1.72 (1.18, 2.49), <i>p</i> = .005	0.69 (0.50, 0.95), <i>p</i> = .023
3	2.01 (1.38, 2.92), <i>p</i> = .0004	0.81 (0.61, 1.07), <i>p</i> = .14
4	2.17 (1.62, 2.91), <i>p</i> < .0001	0.87 (0.68, 1.12), <i>p</i> = .28
5	2.45 (1.91, 3.16), <i>p</i> < .0001	0.99 (0.85, 1.15), <i>p</i> = .88
6	2.19 (1.73, 2.77), <i>p</i> < .0001	0.88 (0.77, 1.01), <i>p</i> = .06
7	2.44 (1.88, 3.19), <i>p</i> < .0001	0.98 (0.83, 1.16), <i>p</i> = .86
8	2.44 (1.91, 3.11), <i>p</i> < .0001	0.98 (0.84, 1.15), <i>p</i> = .84
9	2.62 (2.05, 3.34), <i>p</i> < .0001	1.05 (0.91, 1.22), <i>p</i> = .49
10	3.33 (2.63, 4.21), <i>p</i> < .0001	1.34 (1.23, 1.46), <i>p</i> < .0001
Absolute harm of cigarettes		
Not at all harmful	ref	0.60 (0.41, 0.88), <i>p</i> = .0097
Slightly harmful	1.13 (0.72, 1.78), <i>p</i> = .58	0.68 (0.56, 0.83), <i>p</i> = .0002
Somewhat harmful	1.30 (0.87, 1.95), <i>p</i> = .19	0.78 (0.72, 0.85), <i>p</i> < .0001
Very harmful	1.90 (1.28, 2.82), <i>p</i> = .002	1.14 (1.06, 1.21), <i>p</i> = .0001
Extremely harmful	1.86 (1.25, 2.75), <i>p</i> = .002	1.11 (1.04, 1.19), <i>p</i> = .003
Worried about susceptibility to smoking-caused diseases		
Not at all worried	ref	0.75 (0.66, 0.86), <i>p</i> < .0001
A little worried	1.36 (1.14, 1.62), <i>p</i> = .0007	1.02 (0.95, 1.09), <i>p</i> = .55
Moderately worried	1.36 (1.15, 1.61), <i>p</i> = .0004	1.02 (0.95, 1.10), <i>p</i> = .57
Very worried	1.52 (1.27, 1.81), <i>p</i> < .0001	1.14 (1.04, 1.26), <i>p</i> = .007
Relative harm perceptions of other combustibles (compared to cigarettes)		
No product is less harmful	ref	1.16 (1.13, 1.18), <i>p</i> < .0001
At least one product is less harmful	0.49 (0.44, 0.56), <i>p</i> < .0001	0.57 (0.52, 0.63), <i>p</i> < .0001
Relative harm perception of additive-free cigarettes (compared to regular cigarettes)		
Less harmful	0.46 (0.40, 0.53), <i>p</i> < .0001	0.51 (0.45, 0.57), <i>p</i> < .0001
About the same	ref	1.10 (1.07, 1.14), <i>p</i> < .0001
More harmful	1.55 (1.28, 1.88), <i>p</i> < .0001	1.71 (1.44, 2.04), <i>p</i> < .0001
Relative harm perceptions of noncombustible products (compared to cigarettes)		
No misperceptions	ref	0.37 (0.26, 0.53), <i>p</i> < .0001
At least one misperception	2.78 (1.91, 4.04), <i>p</i> < .0001	1.03 (1.02, 1.04), <i>p</i> < .0001
Past 30-day exposure to tobacco advertising (excluding ENDS advertising)		
Yes	0.89 (0.79, 0.99), <i>p</i> = .04	0.95 (0.90, 1.00), <i>p</i> = .04
No	ref	1.07 (1.00, 1.14), <i>p</i> = .04
Past 30-day exposure to ENDS advertising		
Yes	0.85 (0.76, 0.95), <i>p</i> = .003	0.93 (0.88, 0.97), <i>p</i> = .003
No	ref	1.09 (1.03, 1.16), <i>p</i> = .003
Past 12-month exposure to Tips from Former Smokers		
Yes	0.87 (0.78, 0.96), <i>p</i> = .005	0.92 (0.87, 0.97), <i>p</i> = .005
No/don't know	ref	1.06 (1.02, 1.11), <i>p</i> = .005
Injunctive norm against smoking (disapproval of close friends and family lead the smoker to think about quitting)		
Not at all	ref	0.80 (0.75, 0.85), <i>p</i> < .0001
Somewhat	1.39 (1.23, 1.56), <i>p</i> < .0001	1.11 (1.04, 1.18), <i>p</i> = .001
Very much	1.66 (1.42, 1.94), <i>p</i> < .0001	1.33 (1.19, 1.48), <i>p</i> < .0001
Injunctive norm against ENDS (people disapprove of using e-cigarettes)		
Yes	1.67 (1.39, 2.00), <i>p</i> < .0001	1.54 (1.32, 1.79), <i>p</i> < .0001
No	ref	0.92 (0.90, 0.95), <i>p</i> < .0001
Subjective norms supporting noncombustible use (people important to them used non-combustibles)		
Yes	0.61 (0.51, 0.73), <i>p</i> < .0001	0.64 (0.55, 0.75), <i>p</i> < .0001
No	ref	1.05 (1.03, 1.06), <i>p</i> < .0001

ability are limited.³⁴ Specifically, the “horn effect”—the opposite of the “halo effect”—might be at play. The horn effect is an erroneous negative inference when something is incorrectly perceived as worse than it is because it is associated with something that is known to be bad.³⁵ In this case, tobacco use is almost universally recognized as very harmful to health, and this harm perception could be generalized to the most well-known constituent in tobacco, nicotine.³⁶

Further support for the horn effect presented as lower-than-average belief in the misperception that nicotine causes cancer among those with lower perceived harm beliefs. Those who did not recognize any or many of the presented diseases were caused by smoking, those who thought at least one combustible was less harmful than cigarettes, and those who correctly believed all noncombustibles were less harmful than cigarettes had lower-than-average prevalence of the misperception.

Collectively, these findings suggest that high perceived harm of tobacco more generally may be related to the specific misperception that nicotine causes cancer. As hypothesized by others, this could be the result of non-nuanced health communication in the United States that emphasizes that no tobacco use is safe without detailing the indirect role of nicotine in diseases like cancer.^{5,37} Future messaging should clarify that while nicotine is addictive, it is not a major cause of cancer or other disease. The findings that the misperception that nicotine causes cancer cooccurs with misperceptions about relative harm of noncombustible nicotine products (NNPs) as well as accurate perceptions about the number of diseases caused by smoking and absolute harm beliefs indicate that both accurate and inaccurate perceptions can exist within the same mental conceptualization of tobacco. It is unclear from this study if misperceptions about the relative risk of NNPs are the result of the belief that nicotine causes cancer, or if other misperceptions might also influence relative risk beliefs. Only correcting the misperception that nicotine is carcinogenic, therefore, might not be sufficient to ensure accurate inferences about the relative harm of NNPs. Further study is needed to fully map mental models regarding how smokers think tobacco causes disease, as misunderstanding the role of combustion in disease risk may additionally influence inaccurate harm perceptions.

No differences were seen in prevalence of the misperception by exposure to pro-tobacco advertising. The FDA must authorize products if they are to be marketed as less harmful, and at the time of data collection, no product had been deemed a Modified Risk Tobacco Product (MRTP) and thus no products were legally allowed to market themselves as lower harm. Now that the FDA has started authorizing some products as MRTPs, research should explore if exposure to MRTP marketing results in more accurate beliefs about nicotine.

The difference in the prevalence of the misperception that nicotine causes cancer by normative influences was significant and substantial in magnitude. Persuasive communication has used descriptive and injunctive norms to motivate behavior change to great effect.¹⁸ Future studies should test whether including normative appeals in corrective messages about nicotine improves their efficacy to correct misperceptions. The combination of injunctive and descriptive norms has been successfully used to increase cessation message effectiveness,³⁸ and corrective messaging about nicotine could discuss public disapproval of smoking and the rising use and social acceptability of NNPs.

Priority Groups for Corrective Message Audience

Similar to other work in this area, we found higher-than-average prevalence of nicotine misperceptions among racial and ethnic minority smokers,^{12,22,23} women,^{10,22,23} those with lower SES,^{10,22,23} and older age.^{22,23} Also in line with other findings, past 30-day ENDS and smokeless users have lower-than-average prevalence of believing nicotine causes cancer.^{22,24} Previous experience with NNPs could potentially be related to lower prevalence of the misperception if people have accurate understanding of the indirect relationship between nicotine and cancer and make accurate inferences about relative harm of NNPs that inform use decisions.³⁹ Alternatively, people’s sensory experience with NNPs as less harsh than smoking could lead to assumptions that they are less harmful.⁴⁰ Although overall prevalence of the misperception is high, future corrective efforts should prioritize racial and ethnic minority, older, and lower SES smokers, as these groups suffer from a disproportionate burden of tobacco-caused morbidity and mortality.^{19,20} It is essential that corrective messaging reach them so that educational efforts do not exacerbate existing disparities and instead work to increase health equity.²¹

Prevalence of believing nicotine causes cancer was significantly lower among smokers who considered switching to a NNP. This finding may indicate that correctly believing nicotine does not cause cancer can support switching. The fact that half of smokers who had considered switching believed the misperception might explain why they had considered switching, but had not switched completely. The high prevalence of the misperception and the low prevalence of considering switching is further evidence for the need to develop more nuanced communication campaigns to educate smokers about nicotine. Additionally, future efforts should explore the characteristics and beliefs of those who are considering switching, as this population is likely in the contemplation or preparation stages of change and will more readily advance to the action phase of change.⁴¹

The FDA recently confirmed that a nicotine product standard that would reduce nicotine in cigarettes to minimally or nonaddictive levels is still under consideration.⁴² It is crucial that smokers understand that very low nicotine cigarettes (VLNC) would be less addictive, but, when smoked like regular cigarettes, would be no less likely to cause disease. The misperception that nicotine causes cancer could underlie the misperception that VLNC are less harmful,^{13,15,23} highlighting the need for corrective messaging and supporting the explicit discussion of VLNC in those messages.

As it stands, the tobacco control community continues to produce communication that aims to increase the perceived harm of tobacco and has not produced national campaigns that correct commonly held misperceptions about nicotine. While FDA’s webpage on nicotine clearly states that nicotine is addictive, but not primarily responsible for disease risk from tobacco,¹⁴ this information would have to be intentionally sought out and is unlikely to reach the majority of smokers. The tobacco industry, however, has already pushed into this area. Transnational tobacco company corporate twitter accounts, for example, publicly discuss their “next-generation nicotine products.”⁴³ Without a concerted effort from the tobacco control community to fill the gap in understanding about nicotine, the industry could take over this space, where they have the potential to promote lower absolute harm perceptions about all NNPs without the accompanying nuance

that some NNPs are less harmful than others than that all products pose risks. There is also an urgent need to further investigate mental models about how smokers think tobacco causes disease to further inform corrective messages about nicotine.⁴⁴ Future work should also assess the impact of nicotine corrective messages on adolescents and test targeted messages that prioritize smokers. While it is possible that corrective messaging could reduce risk perceptions of nicotine, pairing these messages with existing campaigns that highlight harmful constituents in popular NNPs (e.g. heavy metals in e-cigarettes) could help avoid unintended consequences.

Strengths and Limitations

The large size and nationally representative nature of the sample allowed us to describe estimated population prevalence of the misperception that nicotine causes cancer across many variable categories while still controlling for type I error.

This analysis also had a number of limitations. Cross-sectional analysis prevents us from making any claims regarding temporality. As this was a secondary data analysis, some of the variables included are not as nuanced as they could have been had the study been designed to focus on beliefs. For instance, although we were interested in beliefs about nicotine as a major cause of all tobacco-caused diseases, not just cancer, this question was the best available proxy. Additionally, the wording for this question could have led to imprecision. The question wording does not account for people understanding that nicotine contributes to prolonged exposure to carcinogenic constituents that cause cancer. Participants who understand this indirect route and responded “probably yes” or “definitely yes” would be misclassified. Reassuringly, many studies have used different wording of this question and have reported similarly high prevalence of the misperception,^{10–13,23} supporting the validity of the results reported here.

It is unclear why prevalence of smokers who selected “don’t know” in the PATH sample is so much lower than prevalence of that response cited in other studies.^{10–13} This could potentially be explained by the longitudinal nature of PATH, which may discourage “don’t know” responses.

While not statistically significant, the higher-than-average prevalence of believing nicotine causes cancer among those who used NRT in the past 12 months is contrary to previous findings.²⁴ Overall population prevalence of NRT use among smokers was low (5.6%) and campaigns seeking to correct nicotine misperceptions should be clear that NRT is the only product approved by the FDA as a safe way to help smokers quit.

Some variables, such as exposure to the Tips campaign, lacked granularity, which could be responsible for null results. Similarly, collapsing variables, including the outcome, may have resulted in lost detail.

Further research could assess patterns in beliefs across all beliefs of interest. A latent class analysis would be well suited for this purpose, and the latent class analysis by Villanti et al., on young adults, could serve as a model.¹⁰

Data for this analysis were collected between 2015 and 2016, before the widespread use of JUUL e-cigarettes, the EVALI crisis, and the FDA’s 2017 Comprehensive Plan for Tobacco and Nicotine Regulation that increased discussion of both nicotine and very low nicotine cigarettes, which may have led to changes in nicotine perceptions that were not

captured in this analysis. Use of Wave 4 data (the most recent wave of publicly available data collected in 2016–2017) was considered, but this wave of data did not include exposure to the Tips campaign. As this was considered an important variable to assess, we chose to analyze the older data from Wave 3.

Conclusions

The misperception that nicotine is carcinogenic is prevalent in more than half of the US smoking population. The above findings support the need for more nuanced communication efforts to better inform smokers that nicotine does not cause cancer. Messaging could provide the accurate causal alternative that the major cause of disease from tobacco products is from constituents generated during combustion. Designing effective corrective communication to address this misperception should be a tobacco control priority, especially in an era where new tobacco products are flooding the market, the tobacco industry is moving into the communication space surrounding these new products, and the mechanisms that cause morbidity and mortality need to be understood for smokers to make informed decisions about what products could potentially lower their disease risk.

Funding

CW’s effort is supported by the **National Cancer Institute** (T32 CA009314; PI: Platz). The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

Declaration of Interests

MBM has served as a paid expert witness in litigation sponsored by the Public Health Advocacy Institute against RJ Reynolds. This arrangement has been reviewed and approved by the Johns Hopkins University in accordance with its conflict of interest policies.

Data Availability

Data may be made available upon request to the study contact author.

Supplementary Material

A Contributorship Form detailing each author’s specific involvement with this content, as well as any supplementary data, are available online at <https://academic.oup.com/ntr>.

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