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Effective Formats for Communicating Risks from Cigarette Smoke Chemicals

M. Justin Byron, PhD,
Research Scientist, Lineberger Comprehensive Cancer Center, University of North Carolina, Chapel Hill, NC

Allison J. Lazard, PhD,
Assistant Professor, School of Media and Journalism, University of North Carolina, Chapel Hill, NC

Ellen Peters, PhD,
Distinguished Professor of Psychology, Department of Psychology, The Ohio State University, Columbus, OH

Huyen Vu, MSPH,
Project Manager, Lineberger Comprehensive Cancer Center, University of North Carolina, Chapel Hill, NC

Annie Schmidt, MPH, and
Research Assistant, Department of Health Behavior, Gillings School of Global Public Health, University of North Carolina, Chapel Hill, NC

Noel T. Brewer, PhD
Professor, Department of Health Behavior, Gillings School of Global Public Health, University of North Carolina, Chapel Hill, NC

Abstract

Objective—The US government requires the public display of information about toxic chemicals in cigarettes and smoke by brand in a way that is understandable and not misleading. We sought to identify risk communication formats that meet these goals.

Methods—We conducted 3 online experiments with US adult convenience samples (total N = 1866). Participants viewed a webpage displaying information about chemicals in the smoke of a cigarette brand. Experiment 1 varied the chemicals listed and format for their health effects. Experiments 2 and 3 varied the format of chemical quantities and presence/absence of a visual risk indicator. Outcomes were understandable (increasing knowledge) and not misleading (not reinforcing misperceptions).

Correspondence Dr Brewer; ntb@unc.edu.

Human Subjects Statement
The University of North Carolina's Institutional Review Board exempted this study from review.

Conflict of Interest Statement
Dr Brewer has served as a paid expert consultant in litigation against tobacco companies. The other authors of this article declare they have no conflicts of interest.

Results—Information about chemicals and health effects increased knowledge of these topics by ~30% ($p < .001$) compared to no information. Quantity format and use of a risk indicator generally did not affect knowledge. The proportion of participants misled ranged from 0% to 92%, depending on measure. Findings indicated 52% would use a website to search for safer cigarettes. Risk communication formats did little to reduce being misled.

Conclusions—Some risk communication formats successfully increased knowledge of chemicals and health effects. However, the formats did little to reduce the proportion of people misled.

Keywords

tobacco regulation; tobacco use; smoking; tobacco constituents; tobacco additives; tobacco ingredients

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Although tobacco smoke contains thousands of chemicals,[1] including at least 72 carcinogens, [2] the public knows little about most of these chemicals.[3] When asked what chemicals are in cigarettes, most people can name only nicotine, carbon monoxide, and "tar."[4–9] The public has an interest in knowing more about the chemicals in cigarette smoke, [10–12] and some studies suggest that learning about the chemicals may increase quit intentions. [3] Some experts argue the public has a fundamental right to know what they are consuming when they smoke, just as they currently know what ingredients are in food.[13–15]

Per the 2009 Tobacco Control Act, the US government requires the "public display" of a list harmful and potentially harmful constituents (HPHCs) in cigarette smoke.[16] This list must show the quantities of the HPHCs by brand and sub-brand, and be published in a format that is "understandable and not misleading to a lay person."[16] The US Food and Drug Administration (FDA) created lists of HPHCs[17,18] and conducted formative testing. [19] However, it has not yet met the requirement to publicly display HPHC information, as it has expressed a concern that the public "may be misled by quantitative information insofar as mistakenly believing lower risk to harm from a product that contains lower amounts of specific constituents or fewer overall constituents."[20]

Our research team investigated how to design a website that would be effective at meeting the "understandable" and "not misleading" requirements. First, a team of legal scholars and behavioral scientists met and translated these terms from the law into behavioral science concepts.[21] We then created survey measures that hewed closely to the legal interpretation. The legal scholars defined "understandable" as "communicated so that a lay person can comprehend and appreciate the meaning of the disclosed HPHC information for her or his health." The legal team suggested consideration of viewers' ability to learn the HPHC information and the health impacts of the HPHCs. We operationalized understandable as increasing knowledge of HPHCs and their health effects. The legal scholars defined "not misleading" as "does not present facts in ways that result in viewers having inaccurate impressions, making inaccurate conclusions, or taking inappropriate or harmful actions." They suggested that communications should not reinforce common myths about smoking and not lead people to believe that brands vary in risk if they are similarly dangerous. Current science indicates one cigarette is no safer than any other.[22] Therefore, we operationalized not misleading as: (1) not facilitating beliefs that HPHC quantity substantially affects risk; (2) not facilitating the perception that brands vary in risk; and (3) not decreasing perceptions of individual harm from smoking.

The FDA's assignment to disseminate HPHC information in a way that is understandable and not misleading is essentially a risk communication task.[23] A review of relevant health communication literature suggests that the website should use plain language, include only the information that is necessary, convey the relevance of the information on one's health, and use visuals to help communicate quantitative information.[12,23–35] Based on this literature and the FDA's prior formative research,[19] which investigated different lists of chemicals and icons for health effects, we determined that the 3 most important issues to study were which chemicals to include in the webpage, how to present health effects, and how to communicate chemical quantities. Regarding the goal of increasing knowledge of chemicals, we sought to determine whether to focus only on familiar chemicals, which people are more likely to remember, or also to include unfamiliar chemicals, which people may be more likely to be concerned about.[24,26] For increasing knowledge of health effects, we sought to determine whether visual depictions (icons) are helpful in reinforcing text labels of health effects.[32] For conveying chemical quantities, which are potentially hard to interpret,[12] we sought to determine whether webpages with quantity as a single number or a range performed differently on misleadingness than those without a quantity. Finally, visual keys can give contextual meaning to numeric information,[23] so we sought to determine the effect on misleadingness of including a visual risk indicator, a colored dot that showed the level of harm of the given quantity of the chemical.

Our approach was to conduct a series of 3 experiments, moving from the more straightforward components to the more complex. In Experiment 1, we varied the way we presented the 2 main elements of the webpage—chemicals and health effects —and sought to examine interactions between them. We predicted that webpages that present information about chemicals and health effects would increase knowledge of these chemicals and health effects, because people learn this information from the webpage, as previous research has indicated that webpages can increase health knowledge.[36] In Experiment 2, we focused on the more difficult question of how to present quantities. We predicted that webpages that depict quantities or that include a risk indicator would be more misleading than webpages without this information, based on the FDA's formative work that found the public to be misled by quantifiable information.[12,20] In Experiment 3 we replicated the most promising conditions of Experiment 2 with the same predictions.

EXPERIMENT 1: CHEMICALS AND THEIR HEALTH EFFECTS

The first experiment varied information about chemicals and health effects to learn how this affects knowledge. In the *chemicals* manipulation, we investigated whether a webpage should display only chemicals that are familiar to the public (eg, lead) or both familiar and unfamiliar chemicals (eg, acrylonitrile).[37] More familiar chemicals may be more meaningful because they are readily recognized by the public as poisons. Alternatively, providing new information is generally more effective in communications campaigns,[25] and in some cases unfamiliar, difficult-to-pronounce hazards, are perceived as riskier.[24,26] The 6 familiar and

14 unfamiliar chemicals we used were from the FDA's HPHC lists.[17,18] The *health effects* manipulation refers to the inclusion of information about the health effects caused by the chemicals, displayed as text or as icons alongside text.[38] Including information about health effects may make the overall risk more vivid and concrete, increasing understanding.[32] Our predictions were that webpages that present information about chemicals and health effects would increase knowledge of these chemicals and health effects.

METHODS

Participants—Participants were a convenience sample of US smokers and nonsmokers recruited using Amazon Mechanical Turk (MTurk, www.mturk.com).[39] Our recruitment materials stated we were seeking both smokers and nonsmokers. We included both smokers and nonsmokers because the FDA's task is to communicate with the general public. All experiments used a similar recruiting approach and were conducted in 2016. We used an MTurk tool to allow participants to be in only one of the experiments. The analytic sample for Experiment 1 had 607 participants after removing 19 participants who did not complete at least half of the survey.

Procedures—Experiment 1 employed a between-subjects design. The 3 (*chemicals*: none, familiar, or both familiar and unfamiliar) × 3 (*health effects*: no health effects, health effects as text, or health effects as text with icons) experiment also had a no-intervention *control*. In the no chemicals / no health effects condition, participants saw the webpage with only a header and footer. We randomly assigned participants to one of the 10 conditions, yielding ~50 people per condition. To facilitate planned analyses, we doubled the number of people in the control condition and the most complex experimental condition (familiar and unfamiliar chemicals and text with icons).

The experiments used a no-intervention control to measure existing knowledge and beliefs among the public. In the no-intervention control condition, participants answered questions without seeing any mocked-up webpage. In the other conditions, participants viewed a mocked-up webpage about the chemicals in the smoke of Brentfield Gold cigarettes (a fictitious brand) with the instruction to "look carefully" at the webpage before responding to the questions. Participants saw the survey questions only once.

We pretested 3 webpage layouts (Appendix A) and found that the layouts were equivalent in credibility, believability, and perceived ease of use.[40] Because we found no differences among the layouts, each of our experiments used a different one. In each of the experiments, participants received a payment of $3.00 for completing the study.

Measures—The survey assessed knowledge of specific familiar chemicals, unfamiliar chemicals, and health effects. We categorized chemicals as familiar or unfamiliar based on previous research, defining "familiar" as >75% of US adults have heard of the chemical.[37] Items for chemical knowledge read: "Does cigarette smoke contain [chemical name]?" The survey had 2 questions for familiar chemicals (ammonia and lead) and 3 for unfamiliar chemicals (1-aminonaphthalene, acrylonitrile, and isoprene). Items for health effects read: "Does smoking cause [health effect]?" The 5 health effects were addiction, blood clots, cancer of the pancreas, erectile dysfunction, and lung damage. We scored responses for each variable as correct (1) or incorrect (0). We marked the one missing response as incorrect. We created 3 indices for knowledge of familiar chemicals, unfamiliar chemicals, and health effects by summing the number of correct answers in each area.

The survey assessed misleadingness with 15 items in 4 categories: (1) beliefs that chemical quantity substantially affects risk; (2) beliefs that brands vary in risk; (3) evidence of making comparisons with incomplete data; and (4) perceptions that smoking is less dangerous (Table 1). Most of the misleadingness items were agreement/disagreement statements, using a 5-point response scale: "strongly disagree" (coded as 1), "somewhat disagree" (2), "neither agree nor disagree" (3), "somewhat agree" (4), "strongly agree" (5). Control participants were not asked items about the webpage. We scored misleadingness variables as misled (1) or not misled (0). For example, for the item: "My brand of cigarettes has fewer chemicals than Brentfield Gold," agreement (4 or 5) was coded as misled. A tobacco toxicologist reviewed our statements and confirmed our coding of what is correctly categorized as "misled" based on the current HPHC literature. The survey also assessed participant demographics.

Data Analysis—To check whether random assignment created equivalent experimental conditions, we used chi-square tests and linear regression, with *chemicals* or *health effects* as the predictor variable and demographic variable or smoking status as the outcome. Participant demographics and smoking status did not vary by experimental condition in 14 of 16 comparisons. The smoking rate was higher among participants in the no health effects condition as compared to the other health effects conditions, and more people lived below the poverty line in the health effects text condition as compared to the other health effects conditions (both ps $< .05$). Because adjusting for smoking and poverty-level status yielded the same pattern of findings, we report unadjusted analyses.

For the knowledge outcomes, analyses used planned contrasts in ANOVA models. When outcomes were not normally distributed, we also used nonparametric tests and note one analysis that yielded somewhat different results. The 3 (*chemicals*) × 3 (*health effects*) plus 1 (*control*) design required an analysis plan with several steps. We first examined the impact of each experimentally manipulated variable separately and included the no-webpage control. Thus, a one-way ANOVA modeled *chemicals* as a 4-level variable: no webpage; webpage with no chemicals; webpage with familiar chemicals; and webpage with both familiar and unfamiliar chemicals. For the outcome of knowledge of familiar chemicals, the 3 planned contrasts compared the familiar chemicals condition with each of the 3 other conditions. Similarly, for the outcome of knowledge of unfamiliar chemicals, we conducted an ANOVA with 3 planned contrasts comparing the familiar and unfamiliar chemicals condition to each of the 3 other conditions. We then conducted an additional one-way ANOVA that modeled *health effects* as a 4-level predictor variable: no webpage; webpage with no health effects; webpage with health effects as text; and webpage with health effects as text with icons. The outcome was the knowledge of health effects and the 3 planned contrasts compared the text condition to each of the 3 other conditions.

For the misleadingness outcomes, we used chi-square tests for the analysis. We conducted separate analyses for *chemicals* and for *health effects,* treating each as a 4-level variable.

Finally, we checked for interactions among the manipulated variables (3 × 3) using general linear models (GLM) for the knowledge indices, and logistic regressions for the misleadingness variables. We report the few statistically significant interactions. All analyses in this paper used 2-tailed tests with a critical alpha of .05 and were conducted using SAS.[41]

RESULTS

Sample Characteristics—The mean age of participants was 34.8 years (SD = 10.7). About 83% were white, 7% black, 8% Asian, and 9% Hispanic (Table 2). Current smokers made up 48% of the sample. Participant characteristics were similar across the 3 experiments.

Knowledge of Chemicals—Webpages with *familiar* chemicals elicited higher knowledge of those chemicals than webpages without familiar chemicals (Figure 1). Presenting only familiar chemicals elicited somewhat higher knowledge of familiar chemicals (81%) than presenting familiar and unfamiliar chemicals (75%, $p < .05$ in nonparametric test, $p = .07$ in ANOVA) and higher knowledge than presenting no chemical information on the webpage (47%, $p < .001$) or not showing a webpage at all (34%, $p < .001$).

Findings for knowledge of *unfamiliar* chemicals were like those for familiar chemicals (Figure 1). Presenting both familiar and unfamiliar chemicals elicited higher knowledge of unfamiliar chemicals (42%) than presenting familiar chemicals only (10%, $p < .001$), presenting no chemical information on the webpage (12%, $p < .001$), or not showing a webpage at all (7%, $p < .001$).

Knowledge of Health Effects—Webpages with health effects elicited more knowledge of those health effects than webpages without them (Figure 2). Presenting health effects information as text only (83%) elicited higher knowledge of health effects than presenting information as text with icons (76%, $p < .01$), presenting no health effects information on the webpage (66%, $p < .001$), or not showing a webpage at all (59%, $p < .001$).

Misleadingness—The percentage of participants classified as misled varied greatly depending on the measure used (Table 1). The highest percentage of participants was misled according to items in the first category of measures: beliefs that chemical quantity substantially affects risk. Among smokers, 92% said that if they learned their cigarette brand had a lot more of a dangerous chemical than other cigarettes they might or definitely would switch brands. Among smokers and nonsmokers, 54% agreed that if a person cannot quit they should switch to a brand with fewer chemicals. Many participants were also misled according to items in the second category: beliefs that brands vary in risk. We found that 52% of participants (65% of smokers) said they would use a website like this to see which cigarettes are safer than others. Fewer participants were misled according to items in the third category: evidence of making comparisons with incomplete data. Only 9% of smokers said their cigarettes are safer than the brand on the webpage. Few participants were misled according to the items in the fourth category: perceptions that smoking is less dangerous after viewing the webpage. Less than 1% of smokers said that reading the webpage made them less likely to quit smoking.

The chemical familiarity and health effects format manipulations did not affect the 15 measures of misleadingness.

Interactions—In analyses using 17 parameterizations for interactions between *chemicals* and *health effects*, no interactions were statistically significant (9 interactions were $p > .05$; 8 interactions did not converge due to empty cells).

DISCUSSION

Showing chemical names, either familiar or unfamiliar, led to greater knowledge that those specific chemicals are in cigarette smoke. Similarly, presenting health effects led to greater knowledge of these specific health effects. Showing health effects as text led to greater knowledge than when icons were shown alongside the text. However, based on our related research that found icons increase perceived clarity, perceived usability, and cognitive elaboration[40] and other research about the benefits of images for attention and comprehension,[42] we suggest including icons. Our findings about knowledge are in line with prior literature and the FDA's formative work which found that being exposed (vs not exposed) to a list of HPHCs resulted in higher knowledge of those HPHCs.[43]

We found a wide range of misleadingness depending on the measure. The type of misleadingness that the FDA is concerned about[20] – that smokers might see quantities as indicating substantial differences in health risk – was evident. Most smokers would consider switching brands if they found out their brand had higher levels of a dangerous chemical than other cigarettes, and many said they would use a website like this to compare the safety of brands. On the other hand, there was little misleadingness regarding the website making smoking seem less harmful than previously believed.

EXPERIMENT 2: QUANTITY AND RISK INFORMATION

In Experiment 2, we examined the effects of varying quantity format and the presence/absence of a visual risk indicator on knowledge and misleading. By *quantity format*, we refer to whether or not quantity information was provided, and if so, whether a midpoint (eg, 49 μg) or a range (eg, 10–88 μg) was shown. Studies have found mixed results as to whether the inclusion of numeric information aids or hinders comprehension.[12,28–31] The range condition is the more accurate scientifically but midpoints may be easier for the public to interpret. The visual *risk indicator* was a colored dot next to each chemical indicating the level of harm caused by the amount of chemical present: a green dot for "Safe: does not cause health problems;" a light red dot for "Risky: puts you at risk to develop health problems;" or a dark red dot for "Dangerous: can cause immediate damage to your body." These indicators give the "gist" of information, as recommended by fuzzy trace theory,[34] and give meaning to the amount of the chemical.[33] We predicted that webpages that depict quantities or that include a risk indicator would be more misleading than webpages without this information.

METHODS

Methods were the same as for Experiment 1 except as noted.

Participants—The analytic sample had 650 participants after removing 12 participants who did not complete at least half of the survey.

Procedures—The between-subjects experiment used a 3 (*quantity format*: no quantities, quantities as midpoints, quantities as ranges) × 2 (*risk indicator*: present, absent) design plus a no-webpage control. We randomly assigned ~80 participants per condition, except for the control condition, which had ~160. A tobacco toxicologist reviewed the experimental stimuli for accuracy. All webpages in Experiment 2 included all 20 chemicals and health effects displayed as text with icons.

Measures—Due to space constraints, we dropped one of the misleading items previously used in Experiment 1 (Table 1). We also combined the indices for knowledge of familiar and unfamiliar chemicals into one chemical knowledge index.

Data Analysis—Demographics and smoking status did not vary across experimental condition in 15 of 16 tests. For quantity format, smoking was more common in the no-website and no-quantity condition than the other conditions ($p < .05$); because controlling for smoking yielded the same pattern of findings, we report only unadjusted findings.

For the knowledge of chemicals and health effects outcomes, we conducted a one-way ANOVA, modeling *quantity format* as a 4-level predictor variable: no webpage; webpage with no quantities; webpage with quantities as midpoints; and webpages with quantities as ranges. In 3 planned contrasts, we compared the range condition to each of the other 3 conditions. Similarly, *risk indicator* was a 3-level predictor variable: no webpage; webpage with no risk indicator; and webpage with risk indicator, and the 2 planned contrasts were the webpage with risk indicator condition compared to each of the other 2 conditions. The misleadingness outcomes were analyzed in the same way as Experiment 1. To examine the 3 × 2 interaction of *quantity format* and *risk indicator*, we used GLM for knowledge outcomes and logistic regression for misleadingness outcomes and report the few statistically significant interactions between conditions.

RESULTS

Knowledge of Chemicals—Webpages that included chemical quantities given as ranges elicited higher knowledge of chemicals (60%) than no webpage (24%, $p < .001$). The range webpage did not differ from the no-quantities webpage (59%, $p = .64$) or the midpoint webpage (59%, $p = .66$).

Webpages that included risk indicators elicited higher knowledge of chemicals (56%) than no webpage (24%, $p < .001$; Figure 3). The risk indicator webpage elicited somewhat lower knowledge than the webpage without one (63%, $p < .05$).

Knowledge of Health Effects—Webpages that included chemical quantities given as ranges elicited higher knowledge of health effects (79%) than no webpage (67%, $p < .001$).

The range webpage did not differ from the no-quantities webpage (82%, p = .25) or the midpoint webpage (80%, p = .77).

Webpages that included a risk indicator elicited higher knowledge of health effects (79%) than no webpage (67%, p < .001). The risk indicator webpage did not differ from the webpage without the risk indicator (81%, p = .34).

Misleadingness—The percent of participants who were misled again varied widely depending on the measure, varying from 1% for some measures to 92% for others (Table 1). The 14 misleading items did not differ across the 4 quantity format conditions or the 3 risk indicator conditions. In contrast to our prediction, we did not see a difference in misleadingness between conditions that includes quantities (or risk indicators) versus those with no quantifiable information.

Interactions—In analyses using 16 parameterizations for interactions between *quantity format* and *risk indicator*, 2 interactions were statistically significant (p < .05; 11 interactions were p > .05, 3 interactions did not converge due to empty cells). For the misleadingness item: "My brand of cigarettes is probably safer than Brentfield Gold," quantity format had no effect in the absence of the risk indicator. However, with the risk indicator, not having quantities led to substantial misleadingness (35%) that was lower when including quantity as ranges (9%, p < .05). For the item: "If a website had information like this for all cigarette brands, I would use it to see which cigarettes are safer than others," misleadingness was higher for the midpoint condition (64%) than the no quantities condition (49%) (p < .05) in the absence of the risk indicator. With risk indicator, the quantity-format manipulation had no effect.

DISCUSSION

In Experiment 2, results were consistent with Experiment 1 in indicating that webpages with chemicals and health effects increased knowledge of these topics. The manipulations of quantity format and the use of a risk indicator generally did not affect knowledge, although the risk indicator appeared to lead to somewhat lower knowledge of chemicals. It is possible that the risk indicator competed with the chemical names for visual attention. In other work, we found that the risk indicator had substantial benefits in conveying whether the quantity shown is harmful.[40] Misleadingness did not generally vary across the quantity-format or risk-indicator conditions.

EXPERIMENT 3: REPLICATION

In Experiment 3, we sought to replicate the main findings of Experiment 2 regarding the risk indicator versus range conditions.

METHODS

Experiment 3 used the same methods as Experiment 2 except as noted. The analytic sample had 609 participants, after removing 22 participants who did not complete at least half of the survey. The experiment used 4 of the conditions from Experiment 2 to replicate those findings: no-webpage control; chemicals names only (no quantity or risk indicator); range;

and risk indicator. We randomly assigned ~160 participants per condition. All webpages in Experiment 3 included all 20 chemicals and health effects displayed as text with icons. To measure misleading, we used all but 3 of the items from Experiment 2 (Table 1).

Demographics and smoking status did not vary across experimental condition in 7 of 8 tests. Participants in the range and risk indicator conditions were younger than those in the other 2 conditions ($p < .05$). Because controlling for age yielded the same pattern of findings, we report only unadjusted findings. We analyzed the experiment as a 4-level variable: no webpage; webpage with chemical names only; webpage with quantities as ranges; and webpage with risk indicators. We conducted 3 planned contrasts in ANOVA models comparing the risk indicator condition with each of the other 3 conditions.

RESULTS

The webpage that included chemical names and the risk indicator elicited higher knowledge of chemicals (63%) than the no-webpage condition (26%, $p < .001$), but similar knowledge to the name-only webpage (65%, $p = .59$) and the range webpage (64%, $p = .83$). The webpage that included the risk indicator elicited higher knowledge of health effects (79%) than the no webpage condition (65%, $p < .001$), but similar knowledge as compared to the name only webpage (82%, $p = .24$) and the range webpage (79%, $p = .92$). None of the 11 misleading outcomes differed across experimental conditions (all $p > .0045$, Bonferroni adjustment used).

DISCUSSION

The results of Experiment 3 replicated many of the results of Experiments 1 and 2. One notable exception is that, whereas Experiment 2 found that adding a risk indicator reduced knowledge of chemicals, Experiment 3 found no difference. Because some of the conditions in this comparison in Experiment 2 also included quantity information, the additional complexity may have made the format harder to understand, thereby reducing the knowledge of chemicals.

Conclusion—We conducted 3 experiments to test risk communication formats for an HPHC webpage to determine the extent to which the formats were understandable and not misleading. We found mixed results.

Websites containing chemical information can be understandable. The websites increased knowledge of HPHCs in cigarette smoke and the health effects they cause as compared to not being presented with this information. The webpages increased knowledge of each chemical and health effect shown by ~30%. These results concur with FDA research[43] and other research about the use of webpages for communication.[36]

However, some chemical website designs are likely to be misleading. Most viewers incorrectly believed that if webpages showed different levels of chemicals between cigarette brands, then a meaningful difference existed in the harmfulness of these brands. This is in line with established psychology research concerning Gricean maxims, which suggests that people expect provided information to be useful.[44,45] The public may interpret a website that allows for seeing differences between brands as suggesting that these differences are meaningful to their health. Across the 3 studies, results were remarkably consistent – 89%–92% of smokers said they would be interested in switching brands if they found out their brand had more harmful chemicals, and 52% of all respondents said they would use a webpage like this to find safer cigarette brands. Such interpretations are incorrect because current science does not show that one brand is safer than another.[22] These results add weight to FDA's concerns about misleading the public.[20] We also found that misleadingness can vary widely depending on the measure, indicating the importance of an agreed-upon definition. Importantly, our manipulations of chemicals, health effects, quantity format, or use of a risk indicator were not able to notably reduce misleadingness. In Experiment 2, we found possible benefit in displaying quantities as ranges if a risk indicator was used, and of not providing quantities if a risk indicator was not used, an intriguing finding if replicated.

Our studies used national online convenience samples; although this makes the generalizability of point estimates unknown, experimental findings in MTurk tend to be consistent with replications in nationally representative samples. The rank order of measures does tend to replicate, suggesting that the wide range among the misleadingness measures may be important. Although we manipulated what we believed were important risk formats for the webpages and used best practices in website graphic design, other variations could have greater effects. Whereas our use of different webpage layouts for the experiments could have affected the results, our pre-testing suggests this is unlikely. Use of a no-intervention control allowed for an estimate of the prevalence of understanding and misleading outcomes, but using a different type of control (such as an unrelated webpage) may have yielded different experimental findings. Finally, people using interactive websites in a naturalistic setting for self-initiated searches may have different experiences.

In future research, new webpage designs could add additional messaging to reduce the misperception that different quantities of HPHCs indicate differences in harm. However, we caution that once quantity or other differential information about cigarette brands is presented to the public, it may be copied, reanalyzed, and presented out of context on social media, blogs, and other websites.

The findings indicate the need for caution when providing information about levels of harmful HPHCs in cigarette smoke by brand and sub-brand. Although we did not study the effects of presenting differences between brands of cigarettes, doing so may lead smokers who might otherwise make quit attempts to switch brands instead, under the false perception that they have made a partial step in improving their health. The essential message for the public is that all cigarettes are highly toxic; providing details about HPHCs and quantities may be a misleading distraction.

IMPLICATIONS FOR TOBACCO REGULATION

Historically, disclosures about quantities of tar and nicotine in cigarettes have misled the public, contributing to a belief that cigarettes with lower quantities of these constituents were safer.[22] The US Food and Drug Administration must now collect and publicly display the quantities of dozens of specific HPHCs in each cigarette brand, and do so in a way that is understandable and not misleading. [16] Across 3 studies of possible website designs for this purpose, we found that chemical websites can be understandable but are likely to be misleading in important ways.

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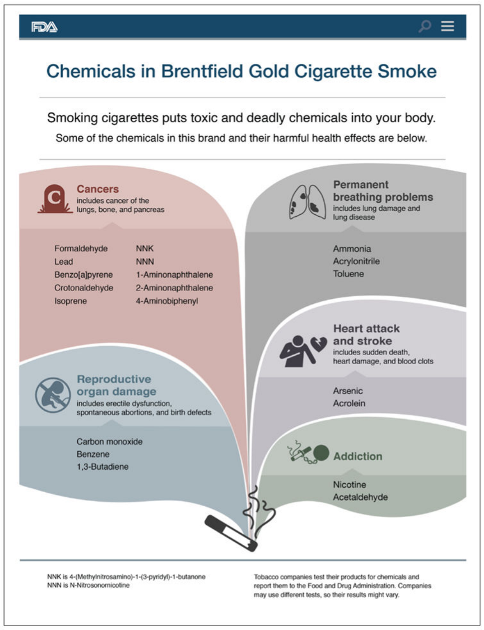
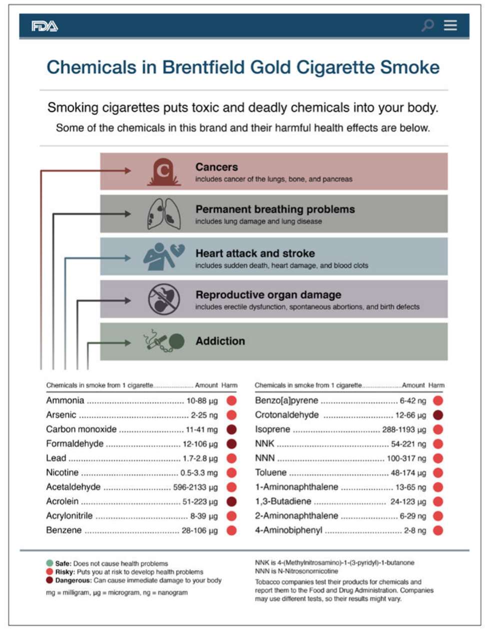
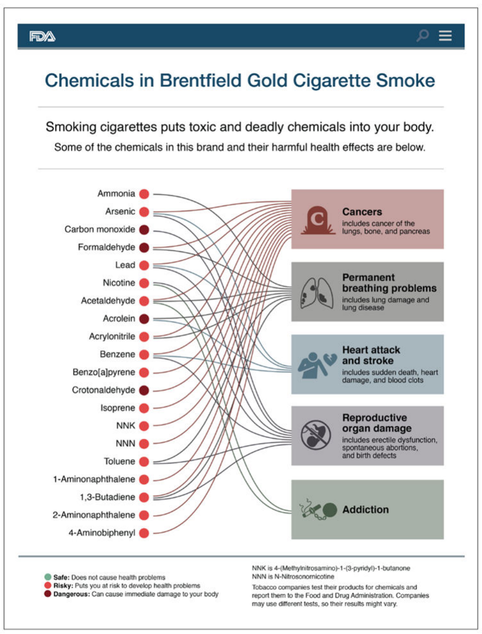
Appendix A. Webpage Layouts







Note.

The most complex version of each webpage is shown. Experiment 1 used the first layout, Experiment 2 used the second layout, and Experiment 3 used the third layout. Webpage footers had minor variations based on the experimental condition (eg, if the webpage did not list NNN, the footer did not explain that NNN is N-Nitrosonornicotine).

Appendix B. Knowledge Survey Items

Knowledge Index	Item
Familiar Chemicals	Does cigarette smoke contain ammonia?
	Does cigarette smoke contain lead?
Unfamiliar Chemicals	Does cigarette smoke contain 1-aminonaphthalene?
	Does cigarette smoke contain acrylonitrile?
	Does cigarette smoke contain isoprene?
Health Effects	Does smoking cause addiction?
	Does smoking cause blood clots?
	Does smoking cause cancer of the pancreas?
	Does smoking cause erectile dysfunction?
	Does smoking cause lung damage?

Note.

Experiments 2 and 3 used a chemical knowledge index that was the sum of the familiar and unfamiliar chemicals indices.

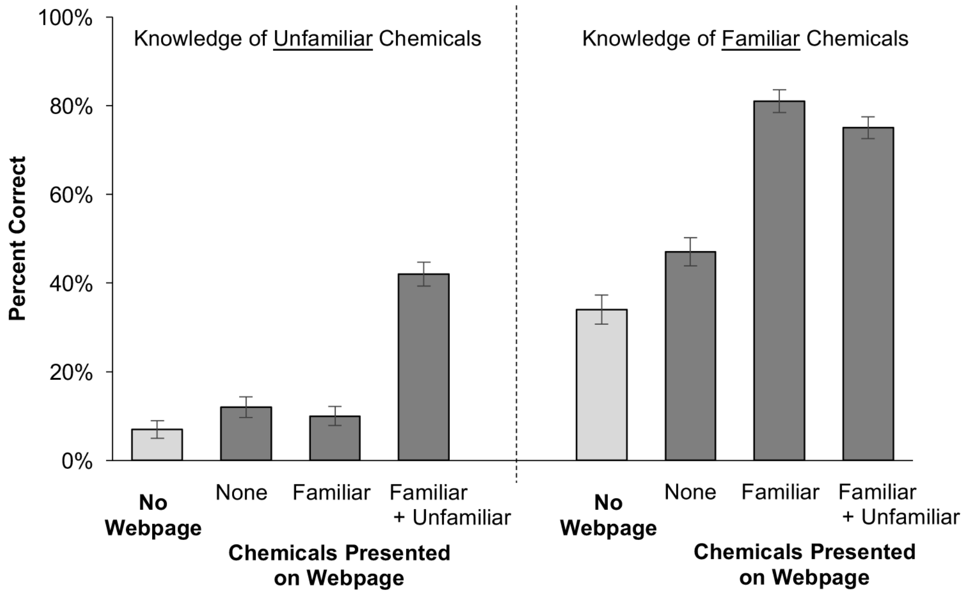


Figure 1.

Knowledge that Chemicals are in Cigarette Smoke, Experiment 1

Error bars indicate standard errors.

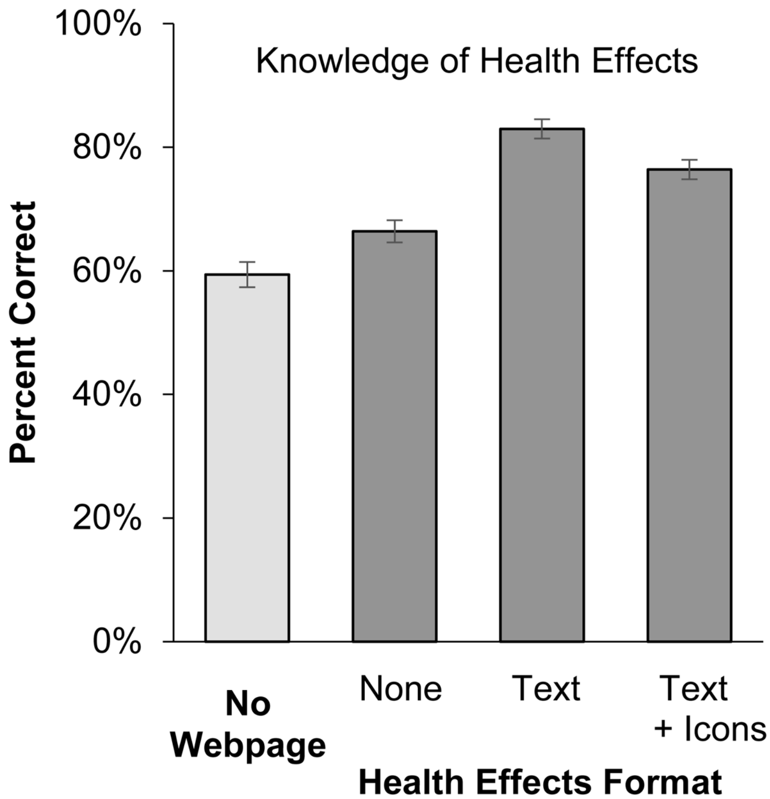


Figure 2.
Knowledge of the Health Effects Caused by Smoking, Experiment 1
Error bars indicate standard errors.

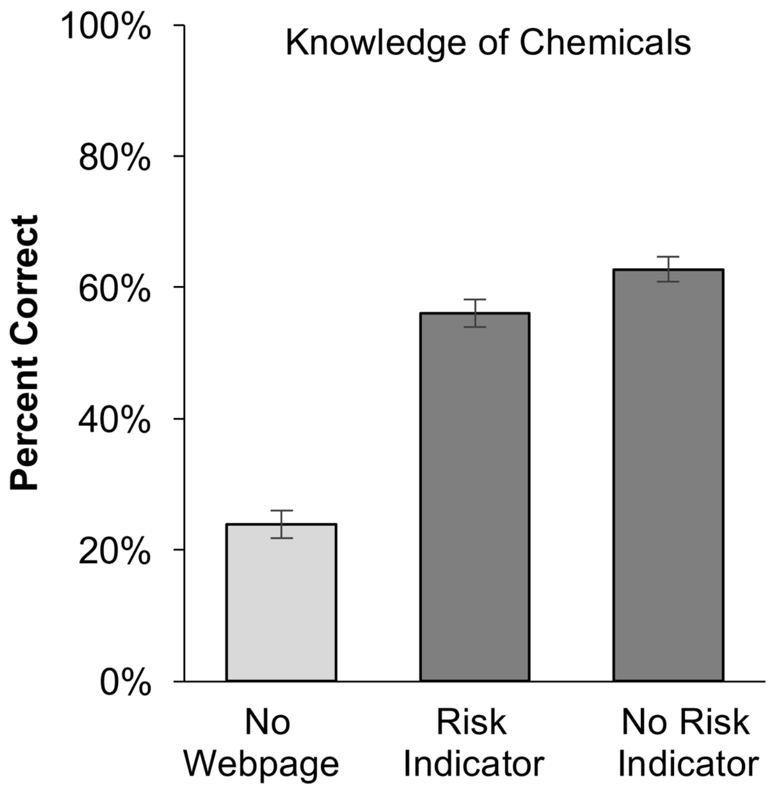


Figure 3.

Knowledge of the Chemicals in Cigarette Smoke, Experiment 2

Error bars indicate standard errors.

Table 1

Percent of Participants Misled in Each Experiment

Misleadingness Items by Category	Exp. 1	Exp. 2	Exp. 3
Beliefs That Chemical Quantity Substantially Affects Risk			
If you learned that your cigarettes have a lot more of a dangerous chemical than other cigarettes, how likely, if at all, would you be to switch brands? [I might, I would definitely][a,b]	92%	92%	89%
If you can't quit, you should switch to a brand with fewer chemicals.[b]	54%	54%	56%
It's much safer to smoke cigarettes with fewer chemicals.	38%	41%	42%
A cigarette is much safer to smoke if it has less arsenic than other cigarettes.	29%	29%	34%
A cigarette is much safer to smoke if it has less crotonaldehyde than other cigarettes.	18%	20%	-
A cigarette is much safer to smoke if it has less 4-aminobiphenyl than other cigarettes.	18%	-	-
Beliefs That Brands Vary in Risk			
Some cigarette brands are much more harmful to smoke than others.[b]	46%	53%	58%
If a website had information like this for all cigarette brands, I would use it to see which cigarettes are safer than others.	52%	52%	-
Evidence of Making Comparisons with Incomplete Data			
My brand of cigarettes is probably safer than Brentfield Gold.[a]	9%	19%	20%
My brand of cigarettes has fewer chemicals than Brentfield Gold.[a]	10%	18%	23%
Perceptions That Smoking Is Less Dangerous			
Reading this webpage makes me...[less likely to quit smoking].[a]	0%	1%	1%
After viewing this webpage, I now feel that smoking is... [less dangerous].	0%	1%	-
How harmful are Brentfield Gold cigarettes (the cigarettes described in the webpage)? [not at all harmful, a little harmful]	0%	1%	1%
It's safer to smoke Brentfield Gold cigarettes than most other cigarettes.	2%	4%	7%
Brentfield Gold cigarettes have fewer chemicals than other cigarettes.	2%	6%	7%

Note.

For most items, the response scale was a 5-point scale from "strongly disagree" to "strongly agree," and agreement was coded as being misled. Because there were no differences in percent of participants misled by condition in any of the 3 experiments, percentages given are across all conditions in each experiment. Hyphens indicate items that were not asked in the survey for that experiment.

[a]Item only asked of smokers.

[b]"brand/styles" in Experiments 2 and 3.

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Table 2

Participant Demographics

	Exp. 1	Exp. 2	Exp. 3
Smoker	48%	48%	45%
Gender			
Male	53%	50%	49%
Female	46%	49%	50%
Transgender or other	0%	1%	1%
Race			
White	83%	83%	84%
Black	7%	8%	5%
Asian	8%	5%	7%
Other	2%	3%	4%
Hispanic	9%	9%	10%
Age (mean)	34.8	34.2	34.9
Gay, lesbian or bisexual	10%	10%	11%
High school education or less	14%	14%	13%
Below 100% of federal poverty level	12%	13%	11%