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BRIEF REPORT

Is a cigarette brand with fewer chemicals safer? Public perceptions in two national US experiments

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Abstract By law, the US government must publicly display the quantities of harmful chemicals in cigarettes by brand, but doing so could mislead people to incorrectly think that some cigarettes are safer than others. We evaluated formats for presenting chemical quantities side-by-side to see if any were misleading. We recruited US convenience ($n = 604$) and probability ($n = 1440$) samples. We randomized participants to 1 of 5 formats: checklist, point estimates, ranges, a visual risk indicator, or no-quantity control. Participants were far more likely to incorrectly endorse one cigarette brand as riskier than the other in the checklist (65% made error), point estimate (67–70%), range (64–67%), or risk indicator (68–75%) conditions as compared to the no-quantity control (1%, all $p < .001$). Among smokers, erroneous risk perceptions mediated the impact of quantity format on interest in switching brands. People viewing chemical quantities for cigarette brands side-by-side misperceived differences in risk, suggesting limited public health value of this information.

Keywords Smoking · Tobacco · Communication · Behavior · Chemicals · Ingredients

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Introduction

Cigarette smoke contains thousands of chemicals, including 93 harmful or potentially harmful constituents (Rodgman & Perfetti, 2013; U.S. Food and Drug Administration, 2012). By law, the US Food and Drug Administration must publicly display quantities of the harmful or potentially harmful chemicals in cigarette smoke by brand and subbrand in a way that is “understandable” and “not misleading to a lay person” (Tobacco Control Act, 2009). The law does not stipulate the location or format for this public display. In the context of this law, the word “misleading” has been interpreted by a legal analysis to mean presenting facts “in ways that result in viewers having inaccurate impressions, making inaccurate conclusions, or taking inappropriate or harmful actions” (Berman et al., 2017). Internationally, the 182 parties to the WHO Framework Convention on Tobacco Control have committed to publicly disclose information about the toxic constituents and emissions of tobacco products, although there is limited guidance in how to do so (WHO Framework Convention on Tobacco Control Conference of Parties, 2012; World Health Organization, 2003).

Informing the public of what they are consuming is an intuitively appealing policy. However, people generally have difficulty making sense of chemical quantities (Hammond & White, 2012). Additionally, in the case of the complex toxicology of cigarettes, there is no evidence that differences in quantities of harmful chemicals between brands make a substantive difference in health risk (U.S. Deptartment of Health & Human Services, 2014). Yet a large study of US adults found that more than half agree with the general statement that "If you can't quit, you should switch to a brand with fewer chemicals" (Byron et al., 2018).This presents a concern that smokers could use quantitative information about the chemicals in cigarettes to erroneously seek out "safer" brands (Byron et al., 2018; U.S. Food and Drug Administration, 2014) rather than focusing on making quit attempts (Kozlowski et al., 1998). Youth and young adults who are beginning to experiment with cigarettes may also be misled by the information into thinking some brands may be less harmful to try (Czoli & Hammond, 2014). It is important to determine how to present the quantities of chemicals in cigarettes to the public in a way that does not mislead smokers and nonsmokers to believe that some cigarettes are safer than others. People may naturally be inclined to examine the chemical listings side-by-side to look at differences and make decisions (Zhang et al., 2017). This desire to compare brands is logical since people typically expect that information is provided to them for a useful reason (Grice, 1975). However, no study we are aware of has examined how disclosures of chemical quantities for cigarette brands affect perceived risk when participants are able to compare them side-by-side.

The present experiment evaluated how several common formats for presenting chemical quantities in cigarette smoke affect perceived risk and interest in switching brands when viewed side-by-side. We first hypothesized that participants viewing formats showing different harm information between brands interpret a brand with a higher quantity of harmful chemicals as more harmful than the other brand (Hypothesis 1). Second, we hypothesized that smokers are more interested in switching to a brand if it has lower quantities of chemicals (Hypothesis 2). Finally, we hypothesized that belief about the harm of the brand mediates interest in switching to the brand (Hypothesis 3). These hypotheses were based on the expectation among people that information is provided to them for a reason (Grice, 1975) and the logical (albeit incorrect in this case) belief that fewer harmful chemicals translates to less actual harm (Byron et al., 2018; Morgan et al., 2017).

Methods

Participants

The project conducted experiments with two samples. The first experiment was with a national convenience sample of US adults (ages 18+) recruited through Amazon Mechanical Turk (www.mturk.com) in 2016. The analytic sample had 604 participants after removing 5 who did not complete the outcome measure. The second experiment was with a national probability sample of US adolescents (ages 13–17) and adults in 2016–2017. This second analytic sample had 1440 participants after removing 2 respondents who did not complete the outcome variable questions. Details of the sampling are available elsewhere (Byron et al., 2018; Lazard et al., 2019).

Procedures

In experiments embedded within online surveys, participants viewed information on harmful chemicals in a pair of mock cigarette brands (Fig. 1; Supplementary Fig. 1). The information included both familiar chemicals (e.g., ammonia) and unfamiliar chemicals (e.g., 1-aminonapthalene) (Hall et al., 2014) in realistic quantities per cigarette (Rodgman & Perfetti, 2013).

We randomly assigned participants to one of several quantity formats or to a control format (between subjects). In the experiment with the convenience sample, we evaluated 3 formats for depicting chemical quantity: quantities as *point estimates* (e.g., "17 µg"), quantities as *ranges* (e.g., "15–18 µg"), and a *visual risk indicator* that showed 3 levels of quantity with a colored circle and an accompanying legend ("safe," "risky," or "dangerous"). We presented quantities as point estimates because this is a common way to convey quantitative information and is

Brand A

Chemicals in smoke from 1 cigarette	Amount
Ammonia	62 µg
Arsenic	5 ng
Carbon monoxide	28 mg
Crotonaldehyde	17 µg
Isoprene	936 µg
1-Aminonaphthalene	32 ng

Brand B

Chemicals in smoke from 1 cigarette	Amount
Ammonia	35 µg
Arsenic	3 ng
Carbon monoxide	24 mg
Crotonaldehyde	20 µg
Isoprene	541 µg
1-Aminonaphthalene	23 ng

mg = milligram, µg = microgram, ng = nanogram

Fig. 1 Example of a quantity format used (point estimate condition). Full set of quantity formats in shown in Supplementary Fig. 1

what the US public is accustomed to with food and other commercial products (U.S. Food and Drug Administration, 2013). We presented the range because it reflects the scientific reality of variation among product batches, and it is an approach that the FDA initially explored (Tessman, 2013). We chose a visual risk indicator following research that showed that visually giving meaning to information can aid comprehension (Peters et al., 2009). Another condition was a *no-quantity control* condition that did not show quantities. For the experiment with the probability sample, we included an additional quantity format, *checklist,* which showed the presence or absence of chemicals in that brand, as potentially the simplest way to convey quantity under the law (Berman et al., 2017). For each pair of brands (Brand A and Brand B) shown in the intervention formats, one brand showed generally higher quantities than the other brand. For half of participants, Brand A showed generally higher quantities of chemicals than Brand B. For the other half, Brand A had generally lower quantities of chemicals. A toxicologist confirmed that our quantities were realistic and did not indicate a meaningful difference in health risk. The institutional review board at the University of North Carolina at Chapel Hill approved the study.

Measures

The survey assessed perceived risk with the item, "Would you be more likely to experience health problems if you regularly smoked…" with 3 response options: "Brand A cigarettes," "Brand B cigarettes," or "No difference between the two brands of cigarettes." When Brand A generally had more chemicals, we coded selection of Brand A as selecting the brand with more chemicals, and selecting Brand B as selecting the brand with fewer chemicals. When Brand B had more chemicals, the coding was opposite. We dichotomized perceived risk as selecting the brand shown as having more chemicals as "perceived higher risk from more chemicals" (coded as 1, an erroneous belief) vs. selecting another response (0).

The survey for the probability sample included an additional outcome item measuring smokers' interest in switching cigarette brands. The item read, "If you found out your cigarettes were Brand A, would you switch to Brand B to reduce your chance of harm from smoking?" with 4 response options: "Definitely not," "Probably not," "Probably yes," and "Definitely yes" (4). We dichotomized interest in switching brands as follows: "Probably yes" and "Definitely yes" were coded as "would switch" (coded as 1) and "Definitely not" and "Probably not" were coded as "would not switch" (0).

Analyses

We used SAS 9.4 for analyses. Randomization checks using chi square tests found no differences among experimental condition with respect to current smoking status (categorized as current cigarette smoker or not), age group (13–17, 18–34, 35–54, > 55), race (white, Black, Asian, other), and educational attainment group (less than high school, high school, some college, bachelor's or higher) between conditions. Preliminary analyses did not find differences by presentation order (whether Brand A or Brand B had more chemicals) so we do not discuss it further.

The main analysis used multivariable logistic regression with smoking status and quantity format as the categorical predictors and perceived risk as the outcome. Next, among smokers only, we conducted a logistic regression with quantity format as the categorical predictor and interest in switching brands as the outcome.

We also examined whether perceived risk mediated the impact of quantity format (dichotomized as conditions with quantities vs. control) on smokers' interest in switching to a brand with fewer chemicals in the second experiment, using the MacKinnon approach (MacKinnon et al., 2007). In M*plus* 8.4, we used bootstrapped 95% confidence intervals with 1000 repetitions and full information maximum likelihood estimation. The model was just-identified and therefore did not produce fit statistics (Bollen, 1989). We report standardized regression coefficients (βs). All analyses used unweighted data.

Results

Sample description

In the convenience sample experiment, participants' mean age was 35 years and 49% were male. About 84% of participants were White, 5% Black, and 7% Asian; 10% were Hispanic (Table 1). Current smokers made up 45% of the sample. In the probability sample, participants' mean age was 32 years; 45% were male; 76% were White, 15% Black, and 3% Asian; and 7% were Hispanic. The current smoking rate in the probability sample was 18%.

Perceived risk

In the first experiment with the convenience sample, participants were more likely to incorrectly endorse one cigarette brand as riskier when the information showed quantity differences (vs. the no-quantity control) (all $p < 0.001$, Table 2). Most participants in the first experiment thought a brand

Table 1 Participant demographics

	Convenience sample ($n=604$) %	Probability sample ($n=1440$) %
Smoker	45	18
Age (mean)	35	32
Gender		
Male	49	45
Female	50	54
Other	1	1
Gay, lesbian, or bisexual	11	7
Race		
White	84	76
Black	5	15
Asian	7	3
Other	4	6
Hispanic	10	7
Education		
Less than high school	1	32
High school	12	18
Some college	39	26
Bachelor's or higher	48	25
Poverty (< 100% of federal poverty level)	11	15

Table 2 Perceived risk of health problems

	Participant response (%) Health problems more likely from brand with…		
	Fewer chemicals	No difference	More chemicals
Quantity format (convenience sample, $n=604$)			
Control (no quantity shown)	1	98	1
Point estimate	8	22	70*
Range	11	25	64*
Visual risk indicator	11	21	68*
Quantity format (probability sample, $n=1440$)			
Control (no quantity shown)	1	98	1
Checklist	6	30	65*
Point estimate	9	23	67*
Range	7	26	67*
Visual risk indicator	8	17	75*

*$p < .001$ comparing the response of "more chemicals" in experimental and control conditions

would lead to more health problems if shown with higher *point estimates* (70%), higher *ranges* (64%), or more chemicals indicated as "dangerous" with a *visual risk indicator* (68%). In the control condition, only 1% said the brand they were asked about was riskier than the other brand. Smoking status was not associated with saying the brand with more chemicals was riskier ($p > 0.05$).

Findings were similar in the second experiment with the probability sample. In the quantity conditions, participants were more likely to believe one brand was riskier than the other (all $p < 0.001$). Participants indicated a brand was risker if there were more chemicals marked as present on a *checklist* (65%), higher *point estimates* (67%), higher *ranges* (67%), or more chemicals indicated as "dangerous" with a *visual risk indicator* (75%). In the control condition, only 1% said the brand they were asked about was riskier than the other brand. Smokers were less likely than nonsmokers to say that the brand with more chemicals was riskier ($p < 0.01$, OR = 0.66 (95% CI 0.48, 0.90)).

Smokers' interest in switching brands

Of the 262 smokers in the second experiment, those in the quantity conditions (vs. control) were much more likely to indicate an interest in switching brands in the second experiment (all $p < 0.05$, Table 3). For the half of smokers asked if they would switch to Brand B when it showed fewer chemicals, interest in switching to it was high: *checklist* (70% interested in switching), *point estimate* (59%), *range* (79%), *visual risk indicator* (76%) compared to *control* (13%). For smokers asked if they would switch to Brand B when it showed more chemicals, interest was muted: *checklist* (29%), *point estimate* (23%), *range* (10%), *visual risk indicator* (26%), versus control (4%).

Mediation

Perceived risk mediated the impact of quantity format (experimental formats vs. control) on smokers' interest in switching to a brand with fewer chemicals in the second experiment. Viewing chemical information that showed quantity differences increased belief that the brand with more chemicals was riskier ($\beta = 0.53$, $p < 0.001$), which was associated with being more likely to say they would switch brands ($\beta = 0.33$, $p < 0.05$). The mediated effect was 0.17, $p < 0.05$ (Fig. 2).

Discussion

In 2 national samples, most participants believed that brands with more chemicals were more likely to harm their health, an error created by every quantity format we evaluated. We tried both numeric formats (point estimate, range) and more visual formats (visual risk indicator, checklist). We also found that most smokers were interested in switching to the brand with fewer chemicals. The analysis showing that

Table 3 Smokers' interest in switching from own to another cigarette brand

	Offered opportunity to switch to cigarette brand with fewer chemicals ($n=131$) Would switch (%)	Offered opportunity to switch to cigarette brand with more chemicals ($n=131$) Would switch (%)
Quantity format (probability sample)		
Control (no quantity shown)	13	4
Checklist	70*	29*
Point estimate	59*	23
Range	79*	10
Visual risk indicator	76*	26*

*$p < .05$ compared to control

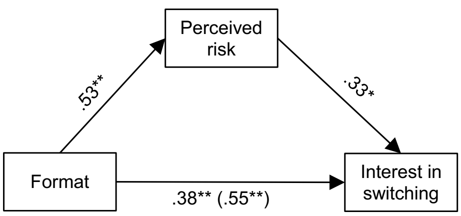

Fig. 2 Mediation for smokers offered the option to switch to a brand with fewer chemicals ($n=131$). *$p<.05$, **$p<.001$

perceived risk mediated interest in switching indicates that the motivation to switch is likely due to a belief that these cigarettes are meaningfully less toxic. Previous research, in which participants only had information about one brand, found little impact of quantity format on misunderstandings about risk (Byron et al., 2018). It is likely that the greater error came from greater "evaluability" or meaning generated by seeing two brands side-by-side (Hsee & Zhang, 2010). While an FDA public display, such as on a website, is unlikely to directly offer such information side-by-side, a viewer could easily do so by opening two internet browser windows, or a third party could scrape the information from the website and post it to a different website or on social media.

With respect to limitations, we acknowledge that our experiment examined a limited number of formats and asked about harm to health but not specific health outcomes. Additionally, it is possible—although previous research suggests unlikely (Baig et al., 2018)—that accompanying disclaimers (e.g., "Do not use this information to compare cigarette brands. No brand is safer than any other brand.") might partially correct misperceptions. However, relying on disclaimers would also require assuming that anyone sharing the quantity information with others (e.g., on social media) would also include the disclaimers.

Policy implications

Most of the public is likely to draw incorrect conclusions about threat to health if provided with information that shows different quantities of chemicals between two cigarette brands. This is likely due to the expectation that information presented to them is meant to be useful (Grice, 1975) and the commonsense belief that having less of a harmful chemical is safer. Until a difference between brands is shown to be substantially meaningful in terms of actual health outcomes, quantity information will likely mislead the public.

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Data and code availability We will consider requests from researchers for de-identified data and our statistical code.

Declarations

Conflict of interest The authors declare no competing interests.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee (University of North Carolina Institutional Review Board 15-2762) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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