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Identifying principles for effective messages about chemicals in cigarette smoke☆

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ABSTRACT

US law requires the Food and Drug Administration (FDA) to disclose information on harmful and potentially harmful chemicals in cigarette smoke (i.e., constituents) to the public. To inform this effort, we sought to identify principles for creating constituent messages that effectively discourage smoking. Participants were an online convenience sample of 1148 US smokers ages 18 +. We developed a library of 76 messages about constituents only and constituents plus contextualizing information (i.e., toxic products that also contain the chemical, health effects, or both). We randomized smokers to receive 1 message from each of 7 message panels in a mixed between-/within-subjects experiment. Participants rated each message on perceived message effectiveness. Results indicated that smokers perceived messages about arsenic, formaldehyde, lead, uranium, and ammonia as more effective than messages about nitrosamines. Messages that contained information on toxic products, health effects, or both received higher effectiveness ratings than constituent-only messages. Among constituent-only messages, those that referenced multiple constituents received higher effectiveness ratings than those with fewer constituents. We conclude that chemical messages may have more impact if they pair known constituents with toxic product or health effect information. These message principles can be used to inform studies examining the impact of constituent messages on smoking beliefs and behavior.

1. Introduction

Tobacco use is responsible for nearly six million deaths each year (World Health Organization, 2013), making it the leading cause of preventable death in the world. Approximately 20% of all deaths in the US are directly attributable to tobacco use (Mokdad et al., 2004). These deaths are the consequence of the myriad negative health effects of smoking such as cardiovascular disease, cancer, respiratory disease, and reproductive complications. Smoking also exacerbates communicable diseases, including tuberculosis and respiratory tract infections (World Health Organization, 2012; U.S. Department of Health and Human Services, 2014a). The direct (i.e., healthcare expenses) and indirect (i.e., productivity losses) costs of smoking are substantial, with estimates as high as $193 billion per year in the US (US National Cancer Institute and World Health Organization, 2016).

Cigarette smoke contains more than 7000 constituents, many of which are toxic to human health and at least 69 of which are carcinogenic (Rodgman & Perfetti, 2008; Talhout et al., 2011; U.S. Food and Drug Administration, 2012a). Some constituents occur naturally in tobacco (e.g., nicotine), some are added during the manufacturing process (e.g., ammonia), and most are generated through burning the tobacco and paper (e.g., acrolein) (Hecht, 2012; International Agency for Research on Cancer, 2004; U.S. Department of Health and Human Services, 2014b). Carcinogenic constituents present in cigarettes include benzene, 1,3-butadiene, and formaldehyde, as well as tobacco-specific nitrosamines (nicotine-derived nitrosamine ketone or NNK, and *N*-Nitrosonornicotine or NNN) (Hecht, 2012; International Agency for Research on Cancer, 2004; Fowles & Dybing, 2003; Biener et al., 2013). Different constituents have been linked to specific negative health consequences. For example, acrolein and acetaldehyde are two of the most harmful constituents to respiratory health, and arsenic and hydrogen cyanide pose great risk to cardiovascular health (Fowles & Dybing, 2003). In addition to direct health effects, some constituents (e.g., nicotine, ammonia) may cause indirect harm to

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consumers by increasing cigarette addictiveness, leading to higher intensity or frequency of tobacco use as well as hindering tobacco cessation success (U.S. Food and Drug Administration, 2011).

The 2009 Family Smoking Prevention and Tobacco Control Act granted the US Food and Drug Administration (FDA) broad authority to regulate tobacco products, including educating the public about the harms of tobacco constituents (Public Law 111-31, H.R. 1256, n.d.). To that end, in 2012, FDA published draft guidance on 93 harmful and potentially harmful constituents in tobacco products and tobacco smoke (Food & Administration, 2012b) and later released an abbreviated list of 18 cigarette smoke constituents prioritized for industry reporting. Cigarette manufacturers are required to submit information on the quantities of those 18 constituents to the FDA by cigarette brand and sub-brand (U.S. Food and Drug Administration, 2012a; Public Law 111-31, H.R. 1256, n.d.). The FDA is required to eventually release this information to the public in a way that is both “understandable” and “not misleading” (U.S. Food and Drug Administration, 2011). In addition to enforcing industry reporting of constituents, FDA has the authority to communicate with the public about tobacco constituents in various ways (e.g., requiring constituent disclosure labels on packs) if the information benefits public health (Public Law 111-31, H.R. 1256, n.d.).

Several studies have examined knowledge, risk perceptions, and attitudes about tobacco constituents, both qualitatively (Environics Research Group, 2003; Swayampakala et al., 2014; Moracco et al., 2016) and quantitatively (Environics Research Group, 2003; Brewer et al., 2016; Cummings et al., 2004; Hammond et al., 2006). These studies have indicated that the public has little knowledge about tobacco constituents beyond nicotine and tar, and that the public generally assumes that most harmful chemicals are added during the manufacturing process. As a consequence, many people erroneously perceive cigarettes without additives to be less harmful than those with additives (Pearson et al., 2016). Studies have found that people want more readily accessible information about constituents and that well-designed constituent information increases knowledge and has potential to change behavior (Swayampakala et al., 2014; Morgan et al., 2017).

Research has demonstrated that consumers are likely to better understand non-numerical, descriptive information about tobacco constituents compared to numerical information about constituent levels (Environics Research Group, 2003; Hammond & White, 2012). Some evidence suggests that providing numerical information about quantities or amounts of constituents may mislead consumers by creating the impression that cigarettes with lower quantities of constituents cause less harm than those with higher quantities (Hammond & White, 2012). This pattern of findings holds some parallels to the now disallowed marketing of some cigarette types as “light,” which consumers interpreted as presenting a lower health risk (due to low tar) compared to other cigarettes (Gilpin et al., 2002). To date, few studies have experimentally tested descriptive, non-numerical cigarette pack constituent disclosures to understand which descriptive disclosure messages have the greatest potential for increasing knowledge of constituent content and their associated harms. One set of “proof of concept” experiments found that adding health effect or toxic product information to a cigarette smoke constituent disclosure discouraged smoking more than disclosing just the constituent (Baig et al., 2016). Although informative, this experiment examined a limited range of constituents, toxic products, and health effects.

In order to develop evidence-based constituent disclosures appropriate for national dissemination via cigarette packs and other media, systematic research is needed to develop scientifically-supported messages and to identify principles of effective constituent disclosures. The current study builds upon a series of studies by our research team that began with a systematic review (Morgan et al., 2017) and focus groups examining smokers' and non-smokers' thoughts about cigarette smoke constituents (Moracco et al., 2016). Then, we conducted nationally representative surveys assessing the public's awareness and perceptions of constituents (Brewer et al., 2017). Finally, we conducted a study to examine effective elements to use in disclosure messages (Kelley et al., 2017). In the current message-testing study, we sought to examine: 1) whether perceived message effectiveness varied by constituent; 2) whether the presence of more than one constituent in a disclosure increased perceived message effectiveness; and 3) whether the presence of contextualizing information in disclosures – toxic products that also contain tobacco constituents and constituent-associated health effects – increased perceived message effectiveness.

2. Methods

2.1. Participants and procedures

In April 2015, we recruited 1148 US cigarette smokers ages 18 or older to participate in an online experiment of messages about chemicals in cigarette smoke. Recruitment took place through Amazon Mechanical Turk (MTurk), a web-based platform commonly used for social science and experimental research (Berinsky et al., 2012; Buhrmester et al., 2011; Paolacci et al., 2010; Rand, 2012). Although MTurk uses nonprobability-based methods, MTurk samples are typically more representative of the US population than other convenience samples commonly used for social science and health research (Berinsky et al., 2012; Paolacci et al., 2010). Moreover, MTurk research replicates findings from a variety of studies and settings (Berinsky et al., 2012; Buhrmester et al., 2011; Goodman et al., 2012). To recruit smokers from MTurk, we used 3 methods. First, we launched a 5-question screener with items about health behaviors, including smoking, and invited all participants (~300) who indicated they smoked cigarettes some days or every day to take part in our study. We also invited ~2000 cigarette smokers from previous MTurk studies conducted by the team in the prior 18 months. These methods together yielded about 900 smokers. Finally, we opened up the survey to all MTurk workers, and used recruitment language indicating that we preferred cigarette smokers, but that non-smokers were welcome to participate as well. This method yielded ~250 additional smokers. The analytic dataset excluded any non-smokers who took the survey. After providing informed consent, participants completed an online questionnaire. Participants received $1.81 USD after completing the survey. The University of North Carolina at Chapel Hill Institutional Review Board approved this study.

2.2. Experimental manipulations

Participants received one message randomly selected from each of seven message panels for a total of seven messages in this mixed within/between experimental study. We presented the messages in a random order. Six of the panels each featured one constituent previously demonstrated to discourage smoking (arsenic, formaldehyde, uranium, lead, and ammonia) (Brewer et al., 2017; Hall et al., 2014) or an especially toxic carcinogen (nitrosamines) (Hecht et al., 2016). Five of the panels included 11 message structure variations about each constituent (Table 1): constituent only (one message), constituent plus one toxic product that the constituent is also found in (two messages), constituent plus two toxic products (one message), constituent plus one health effect (two messages), constituent plus two health effects (one message), and constituent plus one toxic product and one health effect (four messages). Choice of toxic products and health effects was informed by the scientific literature (Abadin et al., 2007; Roney et al., 2004; Wilbur et al., 1999; Chou et al., 2007; Keith et al., 2013), consultations with toxicologists, and an earlier study that identified toxic products and health effects that especially discourage smoking (Kelley et al., 2017). The sixth panel (nitrosamines) was the same but had only 10 message variations because the sole toxic product associated with nitrosamines was tobacco. Finally, the seventh panel consisted of 11

Table 1
Message panel example of 11 message variations tested for formaldehyde.

		Toxic products			
		None	1 product (embalming fluid)	1 product (car exhaust)	2 products (embalming fluid and car exhaust)
Health effects	None	*Cigarette smoke contains formaldehyde.*	*Cigarette smoke contains formaldehyde. This is found in embalming fluid.*	*Cigarette smoke contains formaldehyde. This is found in car exhaust.*	*Cigarette smoke contains formaldehyde. This is found in embalming fluid and car exhaust.*
	1 health effect (chronic bronchitis)	*Cigarette smoke contains formaldehyde. This causes chronic bronchitis.*	*Cigarette smoke contains formaldehyde. This is found in embalming fluid and causes chronic bronchitis.*	*Cigarette smoke contains formaldehyde. This is found in car exhaust and causes chronic bronchitis.*	–
	1 health effect (throat cancer)	*Cigarette smoke contains formaldehyde. This causes throat cancer.*	*Cigarette smoke contains formaldehyde. This is found in embalming fluid and causes throat cancer.*	*Cigarette smoke contains formaldehyde. This is found in car exhaust and causes throat cancer.*	–
	2 health effects (chronic bronchitis and throat cancer)	*Cigarette smoke contains formaldehyde. This causes chronic bronchitis and throat cancer.*	–	–	–

Note. Underlining added to table to show similarities and differences in messages. Participants saw messages without underlining.

messages: nine constituent-only messages featuring two, three, and four constituents (e.g., Cigarette smoke contains arsenic, formaldehyde, lead, and nitrosamines), as well as two additional messages (Ammonia is added to cigarettes, which makes them more addictive; Cigarette smoke has over 70 chemicals that cause cancer and death). Altogether, we developed and tested 76 unique messages (see online Appendix for message library of 76 messages).

2.3. Measures

Participants rated each of the seven constituent messages on perceived message effectiveness, believability, and reactance. The random selection of a message from each panel resulted in an unequal number of ratings by message—the average number of ratings for a message was 106 (SD = 11). After participants rated their assigned messages, we assessed demographics and tobacco use.

2.3.1. Perceived message effectiveness

The survey assessed our primary outcome of perceived message effectiveness using three items: "This message makes smoking seem less appealing to me;" "How much does this message make you concerned about the health effects of smoking?" and "How much does this message discourage you from wanting to smoke?" The 5-point response scales ranged from "strongly disagree" (coded as 1) to "strongly agree" (5) for the first item and "not at all" (1) to "very much" (5) for the other two. We created a perceived message effectiveness composite score by averaging these three items together (Cronbach's alpha = 0.93).

2.3.2. Believability and reactance

The survey assessed message believability using two items, "How believable is this message?" and "I already knew about the information in this message." The 5-point response scale ranged from "not at all" to "extremely." To disentangle the person-level and message-level effects of believability on perceived message effectiveness we used a centering approach (Curran & Bauer, 2011) to create two variables for each construct. First, for each message rating we averaged the two believability scores to create a composite measure ($r = 0.51$). We next computed each person's average believability score across their seven constituent messages (i.e., person-level believability). Finally, we subtracted each person's average believability score from their believability score for each of their seven messages, resulting in a variable indicating whether a person's believability score for a particular message was higher or lower than their average believability score (i.e., message-level believability). This created both a person-level and message-level variable for planned multilevel analyses. The survey assessed message reactance using two items: (Hall et al., 2016) "This message is trying to manipulate me;" and "This message irritates me." The 5-point response scale ranged from "strongly disagree" (coded as 1) to "strongly agree" (5). We averaged two items to create a reactance score ($r = 0.39$) and followed the same variable centering procedure as for believability.

2.3.3. Demographics and tobacco use

The survey assessed sex (female [coded as 0], male [1]), sexual orientation (straight or heterosexual [0], gay, lesbian, or bisexual [1]), age, education (greater than high school diploma or GED [0], high school education or less [1]), numeracy using four validated mathematical word problems (Schwartz et al., 1997; Lipkus et al., 2001) (3–4 numeracy items correct [0], < 3 numeracy items correct [1]), health literacy using four items from the S-TOFHLA (Baker et al., 1999), income, race (non-white [0], white [1]), ethnicity, smoking frequency (does not smoke every day [0], smokes every day [1]), and other tobacco product use.

2.3.4. Data analysis

To identify message-level and person-level predictors of perceived message effectiveness, we built a multilevel model (MLM). As perceived message effectiveness was normally distributed, we conducted the analyses using the PROC MIXED procedure in SAS 9.3 using maximum likelihood estimation and a Satterthwaite approximation for degrees of freedom. The analysis strategy employed a bottom-up model building approach. We first examined an intercept-only model and computed the intraclass correlation (ICC) to quantify message characteristic variability (Level 1). Next, we individually examined each message characteristic (Level 1) and person-characteristic (Level 2) as predictors in univariate models, treating the intercept as a random effect. Finally, we examined an adjusted model that included any variables with p-values < 0.10 in the unadjusted models as predictors. The ICC for the perceived effectiveness multilevel model was 0.67, indicating that two-thirds of the variability for the outcome variable was at the person level and the remaining one-third was at the message level. We report findings from the models as unstandardized regression coefficients (b). Critical alpha was 0.05 and statistical tests were two-tailed.

3. Results

Smokers' average age was 35.7 ($SD = 11.2$; range 18–73 years). The majority were white (85%), had at least some college education (83%) and made less than $50,000 per year (60%). Participants reported

Table 2
Participant characteristics, $n = 1148$ smokers (April 2015).

	% (*n*) or *M* ± SD
Male	52.1% (598)
Gay, lesbian or bisexual	11.9% (137)
Age, years	35.7 ± 11.2
Age category, years	
18–25	18.1% (208)
26–34	37.4% (429)
35–44	23.1% (265)
45–54	12.9% (148)
55–64	6.9% (79)
65 +	1.3% (15)
Education	
High school diploma or less	17.4% (200)
Some college	33.6% (386)
Associate's degree	12.6% (145)
Bachelor's degree	30.1% (346)
Master's degree	4.6% (53)
Professional or doctoral degree	1.5% (17)
Low numeracy, < 4 items correct	29.8% (342)
Low health literacy, < perfect score	31.8% (365)
Income	
< $25,000 per year	24.0% (275)
$25,000–$49,999 per year	36.1% (414)
$50,000–$74,999 per year	22.6% (259)
$75,000–$100,000 per year	9.4% (108)
> $100,000 per year	7.9% (91)
Race	
White	84.8% (973)
Black or African American	6.4% (73)
Asian	5.0% (57)
Native American	0.9% (10)
Native Hawaiian/Pacific islander	0.3% (4)
Other	2.7% (31)
Hispanic	6.4% (73)
Cigarettes smoked per day	14.6 ± 8.5
Other tobacco product use in past 30 days	
E-cigarettes or other vaping devices	43.0% (494)
Traditional cigars	10.9% (125)
Cigarillos, filtered cigars, or little cigars	12.5% (143)
Pipe filled with tobacco	3.4% (39)
Hookah	7.1% (82)
Smokeless tobacco	6.4% (73)
None of the above	43.6% (501)

smoking an average of 14.6 cigarettes per day ($SD = 8.5$). Fifty-six percent of smokers reported having used a tobacco product other than cigarettes at least once within the last 30 days (Table 2).

3.1. Type and number of constituents

Perceived effectiveness ranged from a low of $M = 2.86$ for messages with nitrosamines to a high of $M = 3.34$ for messages with arsenic (Table 3 and Fig. 1). Compared to messages with nitrosamines, smokers perceived messages with the other five constituents as more effective: arsenic ($b = 0.37$, $p < 0.001$), formaldehyde ($b = 0.26$, $p < 0.001$), lead ($b = 0.23$, $p < 0.001$), uranium ($b = 0.37$, $p < 0.001$), and ammonia ($b = 0.12$, $p < 0.001$) in the adjusted multilevel analysis (Table 4).

Perceived effectiveness of the constituent-only messages varied by number of constituents, with a gradual increase in perceived effectiveness ratings for messages with one ($M = 2.83$), two ($M = 2.99$), three ($M = 3.11$), four ($M = 3.19$), and 70 (non-specified) carcinogenic constituents ($M = 3.93$) (Fig. 1). Messages with two ($b = 0.22$, $p < 0.001$), three ($b = 0.37$, $p < 0.001$), or four ($b = 0.41$, $p < 0.001$) constituents elicited higher perceived effectiveness than messages containing one constituent, in unadjusted analyses (Table 4 and Fig. 1).

3.2. Contextualizing information

Perceived effectiveness was higher for messages with constituents plus contextualizing information ($M = 3.50$) compared to messages without contextualizing information ($M = 2.85$; $p < 0.001$). Messages containing either type of information – toxic products or health effects – received higher perceived effectiveness ratings than the constituent-only messages in the adjusted multilevel analysis ($p < 0.001$), as did messages with two toxic products or health effects ($p < 0.001$) or messages containing both a single toxic product and a single health effect ($p < 0.001$) (Table 4).

3.3. Covariates

Messages rated as more believable had higher perceived effectiveness ratings ($b = 0.19$, $p < 0.05$), while messages eliciting greater reactance had lower perceived effectiveness ratings ($b = -0.14$, $p < 0.001$). Several person-level variables were associated with perceived message effectiveness. Being gay, lesbian or bisexual ($b = -0.27$, $p < 0.001$); smoking every day ($b = -0.26$, $p < 0.001$); and generally experiencing more reactance to the constituent messages ($b = -0.23$, $p < 0.001$) were all associated with lower perceived effectiveness. People with low numeracy ($b = 0.24$, $p < 0.001$) and those who generally found constituent messages more believable ($b = 0.09$, $p < 0.05$) reported higher perceived message effectiveness.

4. Discussion

Our study identified several principles that explain why some constituent messages may outperform others (Table 5), and these findings corroborate and extend our previous work (Baig et al., 2016; Brewer et al., 2017; Hall et al., 2014). The first principle is that messages with constituents that are familiar and have negative associations elicit higher perceived effectiveness. In a nationally representative survey, only 11% of adult smokers were aware that nitrosamines are in cigarette smoke, compared to 50% for arsenic, 49% for formaldehyde, and 39% for ammonia, and higher awareness was associated with greater discouragement from wanting to smoke (Brewer et al., 2017). In

Table 3
Mean (SD) perceived effectiveness of messages, by constituent, $n = 1148$ smokers (April 2015).

	Condition	Arsenic $i = 1692$	Formaldehyde $i = 1666$	Lead $i = 1453$	Uranium $i = 1677$	Ammonia $i = 1540$	Nitrosamines $i = 1582$
1	Constituent(s) only, $i = 1593$	3.17 (1.05)	2.96 (1.18)	3.00 (1.10)	2.68 (1.21)	3.02 (1.18)	2.27 (1.00)
2	One toxic product, $i = 1284$	3.30 (1.16)	3.08 (1.07)	2.95 (1.21)	3.14 (1.21)	2.95 (1.15)	2.06 (1.03)
3	Two toxic products, $i = 484$	3.25 (1.23)	3.34 (1.05)	3.25 (1.21)	3.18 (1.33)	2.98 (1.19)	.
4	One health effect, $i = 1228$	3.34 (1.02)	3.32 (1.08)	3.16 (1.18)	3.17 (1.22)	3.04 (1.10)	3.33 (1.10)
5	Two health effects, $i = 650$	3.27 (1.03)	3.37 (1.16)	3.39 (1.10)	3.42 (1.24)	3.22 (1.10)	3.28 (1.18)
6	One product & health effect, $i = 2588$	3.43 (1.13)	3.33 (1.13)	3.15 (1.15)	3.10 (1.23)	3.19 (1.09)	3.14 (1.14)
	OVERALL	3.34 (1.11)	3.26 (1.11)	3.13 (1.17)	3.12 (1.24)	3.09 (1.12)	2.86 (1.21)

i = number of message ratings for that message type.

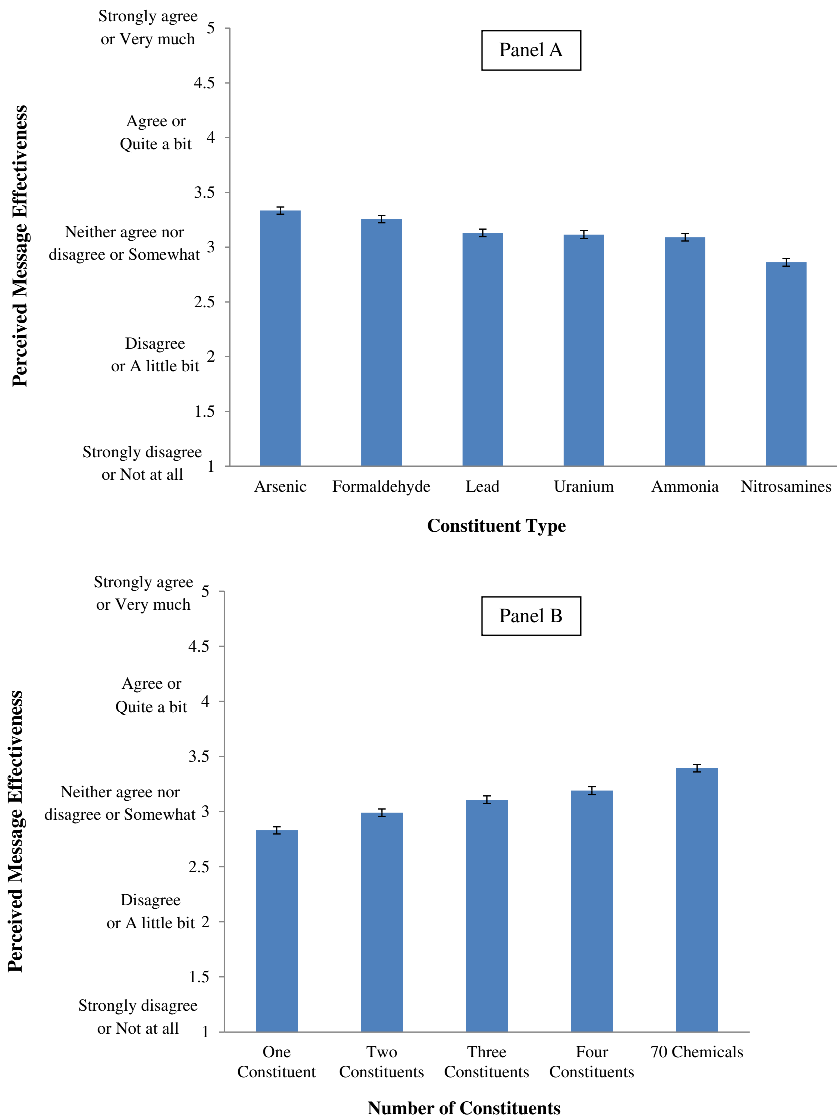

Fig. 1. Perceived message effectiveness by constituent type (Panel A) and number of constituents (Panel B). Error bars show standard errors.

qualitative work, participants have reported that familiar constituents with which they have negative associations are most likely to discourage them from smoking (Moracco et al., 2016). The present findings are consistent with this work, with nitrosamine messages being perceived as least effective as compared to the five better-known constituents tested. From a public health perspective, nitrosamines are one of the most dangerous carcinogens in cigarette smoke (Hecht et al., 2016). However, without the benefit of prior knowledge or negative associations, brief messages about unfamiliar constituents may have little impact. While messages about familiar constituents are likely to have more impact in the short term, in the longer term campaigns could be used to educate the public about lesser known constituents such as nitrosamines, thereby gradually increasing the impact of messages about those constituents (Brewer et al., 2017).

The second principle is that messages that pair constituents with information about associated toxic products, health effects, or both leads to higher ratings of effectiveness than messages about constituents alone. This finding – that pairing constituents with contextualizing information facilitates perceived message effectiveness – is consistent with a recent experiment that reported similar results in nationally representative surveys of adolescents and adults (Baig et al., 2016). Such contextualizing information likely helps people better understand the potential harms of cigarette constituents (Moracco et al., 2016). In the case of a toxic product (e.g., Cigarette smoke contains arsenic. This is found in termite poison.), this information may help the public better understand the toxicity of a particular constituent. In the case of health effects (e.g., Cigarette smoke contains arsenic. This causes heart damage), this information explains to smokers how a particular harmful constituent affects the body. In qualitative work, participants have reported wanting to know more about the many constituents in cigarette smoke, including constituents' impact on the body (Moracco et al., 2016). Also, while toxic product and health effect information presented in a single message effectively communicates smoking harms, our study – as well as previous work (Baig et al., 2016) – suggests that messages referring to *either* a toxic product or a health effect are similarly effective. Our findings indicate there does not appear to be a large additional benefit of including both types of contextualizing information in a constituent message (Baig et al., 2016), especially on a cigarette pack where space is typically quite limited. Also, if new constituent disclosures were to replace old messages and rotate on a regular basis (Noar et al., 2016), smokers would ultimately be exposed to a variety of different constituent messages even if each message only disclosed a single toxic product or health effect. Many countries have used such a rotation approach to great effect with cigarette pack warnings (Noar et al., 2016; Noar et al., 2017; Hammond, 2011).

Table 4
Multilevel model predicting perceived message effectiveness, $n = 1148$ smokers (April 2015).

	Unadjusted model		Adjusted model	
	b	*SE*	*b*	*SE*
Intercept	3.13**	0.03	3.02**	0.18
Message characteristics (level 1)				
Constituent				
Arsenic	0.47**	0.03	0.37**	0.03
Formaldehyde	0.39**	0.03	0.26**	0.03
Lead	0.27**	0.03	0.23**	0.03
Uranium	0.25**	0.03	0.37**	0.03
Ammonia	0.23**	0.03	0.12**	0.03
Nitrosamines (ref)	.	.	.	.
Constituent message content				
One constituent (ref)	.	.	.	.
Two constituents	0.22**	0.05	.	.
Three constituents	0.37**	0.05	.	.
Four constituents	0.41**	0.05	.	.
70 chemicals	0.66**	0.07	.	.
Ammonia added to make cigarettes more addictive	0.09	0.07	.	.
One constituent with one toxic product	0.12**	0.03	0.13**	0.03
One constituent with two toxic products	0.44**	0.04	0.35**	0.04
One constituent with one health effect	0.46**	0.03	0.42**	0.03
One constituent with two health effects	0.57**	0.04	0.50**	0.04
One constituent with one product & one health effect	0.47**	0.03	0.45**	0.03
Reactance, deviation from person's *M* score	− 0.21**	0.01	− 0.14**	0.02
Believability, deviation from person's *M* score	0.23**	0.009	0.19**	0.01
Person characteristics (level 2)				
Male	− 0.12*	0.06	0.00	0.05
Gay, lesbian or bisexual	− 0.31**	0.09	− 0.27**	0.08
Age in decades, grand mean centered	− 0.03	0.03	.	.
White (vs. all other racial groups)	− 0.10	0.08	.	.
Low education, high school or less	0.14†	0.08	0.03	0.07
Low numeracy	0.36**	0.06	0.24**	0.06
Smoked every day (vs. some days)	− 0.24**	0.06	− 0.26**	0.03
Reactance, person's *M* score	− 0.41**	0.03	− 0.23**	0.03
Believability, person's *M* score	0.37**	0.04	0.09*	0.04

Note. Outcome was 3-item perceived message effectiveness scale (range 1–5). Intraclass correlation (ICC) = 0.67. b = unstandardized regression coefficient. SE = standard error of the estimate. M = mean. SD = standard deviation. The 1, 2, 3, and 4 constituent messages and the 70 carcinogenic chemicals messages could not be included in the adjusted model because each participant was randomized to receive only 1 of those messages. Therefore, for the adjusted model, the reference group for constituent message content was all constituent-only messages that a participant received.
† $p \le 0.08$.
* $p < 0.05$.
** $p < 0.001$.

A final principle is that, in cases where communications can only be about constituents themselves (due to length, legal, or other issues), communicating about a single constituent may be somewhat less effective (e.g., Cigarette smoke contains arsenic) as compared to messages with multiple constituents. This finding is especially important given that the only constituent-based message that, to date, has ever been used on packs in the US, ("Cigarette smoke contains carbon monoxide"), references a single constituent. Our results suggest that if a constituent message can only list constituent names with no contextualizing information, then increasing the number of listed constituents may lead to greater message impact. However, if possible, single constituents should be paired with toxic products or health effects because constituent only messages provide smokers with little information regarding the meaning of constituents (Moracco et al., 2016), and may have less impact (Baig et al., 2016).

4.1. Limitations and future directions

One study limitation is our use of a convenience sample, although the findings are consistent with a recent nationally representative survey study (Baig et al., 2016), suggesting that these message principles are likely to be robust. Second, our evaluation of multiple constituent-only messages was limited to one message panel with minimal variations, and we did not test some variations of messages because we thought they would be difficult to understand and impractical to implement on cigarette packs (e.g., multiple constituents with toxic products and health effects). Finally, our primary outcome was perceived (not actual) message effectiveness. While evidence suggests that messages with higher perceived effectiveness ratings have greater impact on smoking-related behaviors (Brennan et al., 2014; Davis et al., 2017), such measures do not directly assess actual message impact (i.e., change in beliefs, behaviors).

Future work is needed to establish the impact of cigarette pack constituent disclosures on smoking knowledge, beliefs and behavior, and the message principles identified here can contribute to such work, as can our library of constituent messages (see online appendix). Follow-up experimental studies are needed to examine the impact of adding evidence-based constituent disclosures to cigarette packs on cessation-related outcomes. The ultimate value in disclosures relies on evidence that they have an actual (and not just perceived) impact on smoking knowledge, beliefs, intentions, and perhaps behavior. Additional research should also consider other aspects of the messages beyond message content, such as the impact of size, font, color, and placement.

5. Conclusion

Since 2009, the FDA has had broad authority to regulate tobacco products, including educating the public about the harms of tobacco constituents. Evidence-based constituent messages – on cigarette packs and potentially in public education campaigns – could be an effective

Table 5
Principles for communicating about harmful constituents.

Principle	Example message	Evidence
Communicate about familiar constituents that have negative associations, such as arsenic, formaldehyde, and lead	*Cigarette smoke contains arsenic.*	Hall et al.[34] Moracco et al.[19] Brewer et al.[28] Current study
Pair constituents with a toxic product….	*Cigarette smoke contains arsenic. This is found in termite poison.*	Baig et al.[45] Current study
Or health effect…	*Cigarette smoke contains arsenic. This causes heart damage.*	
Or both.	*Cigarette smoke contains arsenic. This is found in termite poison and causes heart damage.*	
If messages can use only the constituent name, use multiple constituents	*Cigarette smoke contains arsenic, formaldehyde, uranium, and lead.*	Current study

way to communicate this information to the public and have an impact. Our findings suggest that to be most effective, constituent messages should follow the principles identified in this study. That is, they should prioritize familiar constituents and pair those constituents with information about an associated toxic product or health effect. Effective communication with the public regarding harmful constituents shows great promise for discouraging smoking and encouraging quitting behavior, thus improving public health.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ypmed.2017.09.005.

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