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Running Head: RELATIVE HARMS OF SMOKING AND VAPING

Smoking versus vaping: How (not) to communicate their relative harms.

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Abstract

Here we consider how the relative harms of two nicotine products were communicated in a public health campaign. Following a peer-reviewed evaluation that rated the relative harm of a range of nicotine products relative to the harm of smoking, and which rated the relative harm of vaping as about 5% that of smoking (D. J. Nutt et al., 2014 *European Addiction Research*, *20*(5), 218–225), the UK government launched a campaign which transposed these relative harms into relative safety, promoting the message that "vaping is 95% safer than smoking". We discuss the communication issues arising from transposing a measure of relative harms into relative safety and report the results of an experiment which shows that significantly more people correctly appreciated the ratio of the relative harms from smoking and vaping after reading the statement "vaping is 5% as harmful as smoking" than after reading the statement "vaping is 95% safer than smoking". We discuss the policy implications of our findings.

Smoking versus vaping: How (not) to communicate their relative harms

Rarely in life are we able to refer to precise quantitative and authoritative evaluations of the relative degrees of harm associated with hazardous options that we may wish, or, feel compelled, to pursue. However recent work by Nutt et al. (2014) using multi-criteria decision analysis (MCDA) (Keeney & Raiffa, 1976) has produced estimates of the relative harms associated with the use of twelve different nicotine-containing products (e.g. cigarettes, cigars, nicotine patches, electronic cigarettes). The harms associated with different products vary in terms of the distinctive effects they have on both users and others. The use of MCDA enabled a panel of experts with expertise in the field of nicotine and tobacco research - but drawn from different disciplines (animal and behavioural pharmacology, toxicology, medicine, psychiatry, policy and law) – to produce an integrated evaluation of the overall harm associated with each product. This was done using fourteen diverse harm criteria that they determined after reviewing the 16 criteria that had first been agreed by the UK Advisory Council on the Misuse of Drugs (*Advisory Council on the Misuse of Drugs*, 2010) and also used by the Independent Scientific Committee on Drugs in their 2010 decision conference on 20 psychoactive drugs (Nutt, King, & Phillips, 2010).

The expert panel convened by the Independent Scientific Committee on Drugs selected the criteria the products were to be compared on; scored each product on each of the criteria; weighted the criteria[1] and then calculated weighted scores to give an overall index of the harm of each product on a 0-100 point scale, with 100 assigned to the most harmful product on a given criterion and zero representing 'no harm'. In scaling the products, care

[1] The different criteria vary in importance and although the magnitude of harm of each product on each criterion can be informed by data, Nutt et al., (2014) noted that determining the weight of each criterion - how much it matters - entails a judgment. Moreover, given that moral and political *values* will underlie judgments of criterion importance, different people might legitimately weight the harm criteria differently. The MCDA approach enables values and evidence to be considered separately and then appropriately combined in the evaluations of harm. The idea that risk management can benefit from deliberative analysis that combines values from stakeholders with analysis from experts in a cooperative discourse has prominent advocates (Renn, 1999).

was taken to ensure that each successive point on the scale represented equal increments of harm. Accordingly, a product scored at 50, should be understood to be half as harmful as a product scored 100.

Information about relative harms is very useful both for policy makers, who will need to understand the quantified relative harms of nicotine delivery systems in order to design policies that reduce harm, as well as for nicotine users considering their options – particularly given the fact that the harms of different products vary so widely. While cigarettes were evaluated as the most harmful product, and therefore scored at 100% of the maximum relative harm (MRH), pipes were rated at 22%, water pipes at 14% and electronic nicotine delivery system products (e.g. e-cigarettes) were rated at 4% MRH. Nutt et al. (2014) concluded from their analysis that attempts to use other forms of nicotine such as electronic nicotine delivery system products (e.g. e-cigarettes), as well as nicotine replacement products (e.g. nicotine "patches"), to reduce cigarette smoking should be encouraged as the harms of these products are much lower.

Subsequently Public Health England - the UK government's health protection agency - published an expert independent evidence review (McNeil et al., 2015) that drew on the findings of Nutt et al.'s (2014) study to recommend that, because e-cigarettes are "95% safer" than normal cigarettes, smokers who cannot, or do not want to, stop smoking should be encouraged to switch to e-cigarettes to help reduce smoking related disease, death and health inequalities. The report identified: "…a need to publicise the current best estimate that using e-cigarettes is around 95% safer than smoking."

The transposing of the relative harms reported by Nutt et al. (2014) into a description of relative safety in the Public Health England review is evidently entirely intentional. Although in the foreword of the McNeil et al. (2015) review the Chief Executive of Public Health England wrote that "…the best estimates show e-cigarettes are 95% less harmful to

your health than normal cigarettes…" (p. 5) that is the only time the relationship is expressed in terms of relative harms; repeatedly throughout the rest of the review, including in the executive summary and in a one page list of eight key points preceding the executive summary, it is claimed that using e-cigarettes is "around 95% safer" than smoking. Following this, in late 2018, Public Health England launched a widely publicised campaign in an attempt to convince the UK's smokers that vaping (using e-cigarettes) is not as harmful as smoking. The campaign gave prominent press coverage to the statement that "vaping is 95% safer than smoking" (Boseley, 2018a; Embury-Dennis, 2018; Kmietowicz, 2018).

Given that Nutt et al. (2014) did not indicate the relative *safety* of the nicotine products but their relative *harm*, the expression "vaping is 95% safer than smoking" can be viewed as somewhat questionable. The "95% safer" expression - which did not appear in Nutt et al.'s (2014) paper – and arising because 100-5 = 95 - assumes that relative safety is simply the inverse of relative harm. While in a narrow sense this might be defended, one could object that use of this transposition lends a spurious semantic sanctity to the contemplation of what are harmful products. Is it reasonable to describe the less harmful of two harmful things as *safer*? It is apparent on reflection that not all antonym pairs are straightforwardly exchangeable in this way: for example to describe a business that lost £5 million as more profitable than one that lost £100 million would, we suspect, be seen by many as deceptive; describing it as 95% more profitable - without clarifying that it made a loss – would further compound the deception.

In terms of its expressive potential the transformation of relative harms to relative safety bears some instructive comparison to *litotes*, a figure of speech in which an affirmative is expressed by the negative of the contrary (e.g. "not bad"; ``no mean feat"; "not entirely wrong"). Note that as someone who is not unhappy may not be happy either, or that an occurrence may not be infrequent without being frequent, so the negation of a logical

contrary yields an ‘unexcluded middle’ (Horn, 2017). As a consequence while litotes can serve as a vehicle for irony or understatement (Neuhaus, 2016) this rhetorical form has nuanced expressive power beyond the merely stylistic (Horn, 2017). However converting 5% as harmful to 95% safer offers no analogous expository benefit.

We can only speculate as to why this transposition from relative harms to relative safety was performed; nevertheless the Pollyanna Hypothesis asserts that there is a universal human tendency to use evaluatively positive words more frequently than evaluatively negative words in communicating (Boucher & Osgood, 1969; Hildebrandt & Snyder, 1981). Perhaps, in advocating vaping as a substitute for smoking, Public Health England wished to emphasise a positive message because of an intuition that this might be more likely to encourage smokers who cannot, or do not want to, stop smoking to switch to e-cigarettes. If so this would not unreasonably acknowledge that people’s evaluations and decisions are susceptible to subtle influences. Indeed there is clear evidence from a plethora of research into human judgment and decision making that human preferences are labile and that evaluations of a wide range of target items depend on the contexts, norms, and standards relative to which the items are judged (e.g. Mussweiler, 2003).

Where not detrimental to either the integrity of the message or its understanding, no objection to any change in the wording of messages could reasonably be made. However in regard to the transposition of relative harm into relative safety we note that psycholinguistic analyses of the characteristics of antonym pairs indicate that they are not semantically symmetrical: one is usually “marked” and the other “unmarked” (Clark, 1969b; Ingram, Hand, & Maciejewski, 2016). Semantic markedness is a variable characteristic of antonymous pairs of adjectives in which unmarked terms (e.g., “long”) are considered to be the default or neutral term in most contexts, whilst the marked member (e.g., “short”) cannot be used generically. Markedness influences adjective usage in a number of ways. Hence, we

wouldn't usually ask "How short is the flight?"; instead we ask "How long is the flight?" - unless some prior context had established expectations that the flight will indeed be short. Furthermore because "long" is the default expression, asking "How long…?" does not pre-suppose the flight to be long, whereas asking how short something is *does* presuppose it is short. Finally, a scale of "length" implies the full range of the scale from the shortest to the longest, while a scale of "shortness" would highlight one - negative - end of the scale.

Aside from having conventions of usage the markedness characteristic has psychological implications for the ease of understanding of - and reasoning with – sentences where items are compared on a dimension. Clark, (1969a; 1969b) reported evidence that unmarked adjectives are cognitively simpler and easier to represent: people take longer and make more errors in reasoning with three-term series problems with marked adjectives compared to unmarked adjectives. Thus, the problem, "If John is better than Pete, and John is worse than Bill, then who is best?" encourages far more errors in problem solvers than the problem, "If John is better than Pete, and Bill is better than John, then who is best?", even though both problems superficially present the same information. This same pattern is reported by several other authors (DeSoto, London, & Handel, 1965; Handel, DeSoto, & London, 1968; Hunter, 1957; Huttenlocher, 1968) with problems using a wide range of adjective pairs (better-worse, more-less, faster-slower, farther-nearer, happier-sadder, warmer-colder, taller-shorter, and deeper-shallower). Problems containing an unmarked comparative are solved more quickly, or with fewer errors in a fixed interval of time, than the problems containing its marked counterpart.

Quantitative comparisons using unmarked adjectives may also be more intuitive than quantitative comparisons using their marked counterparts. For example, while the expressions "twice as thick" and "half as thick" are readily apprehended as indicating quite different quantities, and not often or easily confused, the expressions "twice as thin" and

"half as thin" are not so intuitive – indeed, in ordinary parlance the expressions "twice as thin" and "half as thin" would both commonly be understood to mean the same as "half as thick". Despite the logic that, treating thin as the opposite of thick, the expression "half as thin" should mean the same as "twice as thick", the use of a marked adjective (thin) may compromise understanding of logical meanings by drawing attention to just one end of the continuum it describes. As a result the identified meaning of phrases such as "half as thin" appears to fluctuate with context in a similar way as do some ambiguous sentence such as "Wines such as these cannot be kept too long", or "You can't come too early". In short people may, rather than parse verbal expressions for their normative meaning, guess at the intended meaning using context and prior assumptions.

In a striking example of how people can be led to reason fallaciously by the way logically impeccable sentences are worded Wason & Reich (1979) found that most people, including psychologists and linguists, when presented with the sentence "No head injury is too trivial to be ignored" took it to mean that all head injuries should be attended to – the exact opposite of its actual meaning[2]. Wason & Reich reported that: "When the correct interpretation was explained it was often adamantly rejected" (p. 597) and that "Rational attempts to correct this error frequently seemed to generate some affect on the part of the respondents" (p. 592). They concluded that our prior opinions and beliefs about the world can strongly predominate when sentences are more difficult to interpret - which we can see could lead to errors in the understanding of relative risk information which strongly conflicted with people's prior assumptions.

It is not clear exactly how the transposition from relative harms to relative safety might affect perception and understanding of the relative standing of smoking and vaping,

[2] Readers experiencing the same difficulties as Wason & Reich's (1979) participants might usefully consider the sentence: *No gate is too squeaky to be oiled*. Most people correctly suppose that this means that all gates should be oiled however squeaky. By parity of argument, it follows that "No head injury is too trivial to be ignored" means that all head injuries should be ignored however trivial.

which is why we conducted the empirical study we report later, but, nevertheless, we can see clear evidence from this very brief glimpse of the psychology of comprehension to challenge the assumption that it could not have any effect. Although the default unmarked term of the safe/harmful antonym pair is safe - it is more natural to enquire how *safe* an activity or substance is rather than how *harmful* it is -– this would not apply to the consideration of activities or substances already identified as harmful. Just as it makes sense to ask how light (rather than how heavy) an object touted as lightweight is, or how near (rather than how far) a place advertised as very near is, so it makes sense to describe how harmful (rather than how safe) harmful activities or substances are. While the default for asking about safety generally would be to ask about the relative safety of different possibilities, the default for asking about harmful events would be to enquire how harmful they are.

A further potential complication that arises from Public Health England's transposition of relative harm to relative safety in the present case pertains to the often difficult, and sometimes counterintuitive, nature of percentage comparisons - well documented as a source of considerable confusion and misconception in consumers (Chen & Rao, 2007; Kruger & Vargas, 2008). Parker & Leinhardt (1995) argue that though use of percent is a way to quantify multiplicative relationships, some multiplicative uses of percent such as "*percent more than"* and "*percent less than"* nevertheless evoke additive cognitive schema leading to confusion. For example, when comparing the numbers 8 and 10 additively, we can either say 10 is 2 greater than 8 or say 8 is 2 fewer than 10. Multiplicatively however, this symmetry is lost: 8 is 4/5 (80%) of 10, 10 is 5/4 (125%) of 8; 8 is also 1/5 (20%) less than 10, 10 is 1/4 (25%) more than 8. While in additive comparisons, the difference of 2 remains constant; in multiplicative comparisons, the separate comparisons use different numerals.

The invoking of additive schema for essentially multiplicative, and hence asymmetric percentage comparisons, can explain why people find it difficult to appreciate that sequential percentage changes should not be assessed with simple additive logic: for example a 60% decrease followed by a 70% increase results not in a net gain of 10% as many assume (Chen & Rao, 2007) but a net decrease of 32%. This difficulty leaves people vulnerable to exploitation: one report (The Economist, 1998) describes how, in the late 1970s, the Mexico city government increased the capacity of the Viaducto, a four-lane motorway, by re-painting lines to make it six lanes wide—in effect, a 50% increase in capacity. Unfortunately, this also resulted in an increase in fatal accidents. After a year the Viaducto was changed back to a four-lane road—a 33% capacity reduction. The government, casting around for facts to support its claims of social progress, subtracted that 33% reduction from the 50% increase to claim a net increase in capacity of 17%.

The relative harm metric used by Nutt et al. (2014) makes it clear that because smoking has an MRH of 100 it is twenty times more harmful than vaping[3] which has an MRH of 5. However the Public Health England statement that vaping is 95% safer than smoking implies that the ratio of their relative safety is less than two to one (note that if A is 100% longer than B it is only twice as long). In order to communicate the ratio of the relative safety of smoking and vaping so that the transposition from relative harm to relative safety was true to the original ratio metric – twenty to one - we would have to say that vaping is 1900% safer than (or 2000% as safe as) smoking (note that if we say that A is 1900% longer than B it is only twenty times as long) though we suspect that this claim might have stretched the notion of referring to harmful things in terms of their relative safety a little too far for comfort.

[3] In response to comments on their 2014 paper Nutt et al. (2016) emphasised that, rather than use the percentage formulation used by Public Health England, they preferred to describe smoking as twenty times more harmful to users than vaping e-cigarettes.

By similar reasoning – and further exemplifying the nonintuitive and asymmetric nature of percentage comparisons - it would also have been possible to claim that smoking is 5% as safe as vaping. However evidence that the perceived difference between two quantities compared on a percent scale varies as a function of the target of the comparison suggests that this might not be as effective. Kruger & Vargas (2008) found that consumers perceived a greater subjective price difference when one item was described as costing 50% more than another than when the latter was described as costing 33% less than the former; whether an analogous effect would occur with relative harms is unclear but should be evaluated.

In considering the potential effects of different, but logically arbitrary, ways of communicating a relationship between two quantities in comparative percentage terms, we note that it would also be justifiable to claim that smoking is 1900% more harmful than - or 2,000% as harmful as – vaping and that such messages might more effectively convey the relative harms of smoking and vaping. However such statements – as well as the message that smoking is 5% as safe as vaping - would make smoking and not vaping the "focal" element of the comparison which, research suggests, could undermine any attempted instigation of a preference for vaping (Dhar & Simonson, 1992).

Finally, for this examination of percentage comparisons, we note that although the claim that "vaping is 95% safer than smoking" does not unambiguously preserve the twenty to one ratio of their relative impacts, the claim that "vaping is 95% less harmful than smoking" does. Accordingly one can see that, at least in the context of claims referring to percentages, "safer" is not synonymous with "less harmful". Consequently we envisage that messages that presume the equivalence of these wordings risk creating misapprehensions. Indeed, following a letter from one of us (Ayton, 2019) to a newspaper reporting Public Health England's campaign, complaining that the campaign's reference to the relative

percentage *safety* of vaping risked confusing the public, the newspaper changed the headline in its online edition from "Vaping is 95% safer than smoking…" (Boseley, 2018a) to "…vaping is 95% less harmful than smoking" (Boseley, 2018b) – reportedly "to more accurately reflect Public Health England's advice on the safety of vaping." This was despite the fact that Ayton (2019) had suggested that reporting that "vaping is 5% (or 1/20th) as harmful as smoking" would be less ambiguous.

Mindful of the concerns about the transposition of harms to safety prompted by the considerations discussed above we designed and conducted a simple experiment in order to empirically investigate how effective different ways of communicating the relative harm – and safety – of smoking and vaping are. Our objective was to study three differently worded versions of the same message specifically to compare how well people understood these different ways of expressing this relationship.

Experiment

The experiment was conducted as an online survey – we recruited participants who read one of three different versions of a description of the relative harms (or relative safety) of smoking and vaping. One group read a message which included the statement that "vaping is 95% safer than smoking" - the wording used by Public Health England; a second group read the same message except it included the statement that "vaping is 95% less harmful than smoking" - the altered wording used by Boseley (2018b) "to more accurately reflect Public Health England's advice on the safety of vaping"; and a third group read a message including the statement that "vaping is 5% as harmful as smoking" - the wording recommended by Ayton (2019). Once they had read the message we asked a number of questions designed to probe their understanding.

Method

Participants

We recruited a total of 303 respondents on-line using Prolific Academic (Age: M=32.4 years, SD=10.0; Female: N = 192). Participation was restricted to UK residents. Respondents were paid £1 for their time. The survey was a between-subjects design. Each participant was randomly allocated to one of the three different versions of the statement about smoking and vaping: 95% safer (N=97), 95% less-harmful (N=94) and 5% as-harmful (N=112).

Procedure

Participants were presented with a short vignette about smoking, which read: "An international expert panel convened by the Independent Scientific Committee on Drugs studied the relative harms related to the use of different types of nicotine-containing products. The harms considered included both harm to users and to those around them, across health, economic, social, psychological, and environmental damage." Below this short text, they were presented with one of the three versions of a statement about smoking and vaping according to which of the three experimental conditions they were randomly assigned. The statement began "After extensive research, they concluded that …" and ended with one of three phrases: in the "*95% Safer*" condition participants read that "vaping is 95% safer than smoking"; in the "*95% Less harmful*" condition participants read that "vaping is 95% less harmful than smoking" and in the "*5% as harmful*" condition participants read that "vaping is 5% as harmful as smoking".

The statement was followed by four sets of questions.

Questions 1.1–1.4. The first set of questions asked participants to signal their interpretation of the relative harms of smoking and vaping. Question 1.1 "Smoking is _ times as harmful as vaping" probed understanding of the *ratio* of relative harms of smoking and vaping, was shown to all participants. Question 1.1 had five potential answers (5, 10, 20, 50, 95) from which participants could choose one.

Two further questions in this set tested how well participants could express their understanding of the *percentage* relationship between the harms of vaping and smoking by completing a phrase that expressed that percentage relationship in a different manner to the way it had originally been communicated to them. Hence participants who had originally read that "*vaping is 95% safer than smoking*" were asked to complete both Q1.2 "Vaping is _% less harmful than smoking and Q1.4 "Vaping is _% as harmful as smoking" while participants who had originally read that "*vaping is 95% less harmful than smoking*" were asked to complete both Q1.3 "Vaping is _% safer than smoking" and Q1.4 "Vaping is _% as harmful as smoking". Finally participants who had originally read that "*vaping is 5% as harmful as smoking*" answered both Q1.2 and Q1.3. Questions 1.2-1.4 elicited responses via a free text box in which participants could input any positive numerical percentage.

Questions 2.1–2.2. The second set of questions asked participants how much they agreed with two statements, using a Likert scale (1-7), from strongly disagree (1) to strongly agree (7). Q2.1: "You are 95% more likely to suffer harm from smoking compared with vaping" explored the extent to which, across the three message conditions, people endorsed a statement about relative harm as a statement about the likelihood of experiencing harm. Q2.2 "Vaping is 95% as harmful as smoking" tested whether participants endorsed an erroneous statement about the relative harms that included a number that, nonetheless, corresponded to the message.

Question 3. The third question asked participants to *graphically* express the relative harms of vaping and smoking – so no numerical reasoning or response was required. A bar chart plot was displayed on screen (See Figure 1), with harm on the vertical axis and two discrete items (bars) on the horizontal axis, labelled smoking and vaping. Smoking was already designated with a set harm value and participants were asked to click on the plot

depicted in the left panel of figure 1 to adjust the vaping bar height to indicate the amount of harm caused by vaping relative to smoking (e.g. right panel of figure 1).

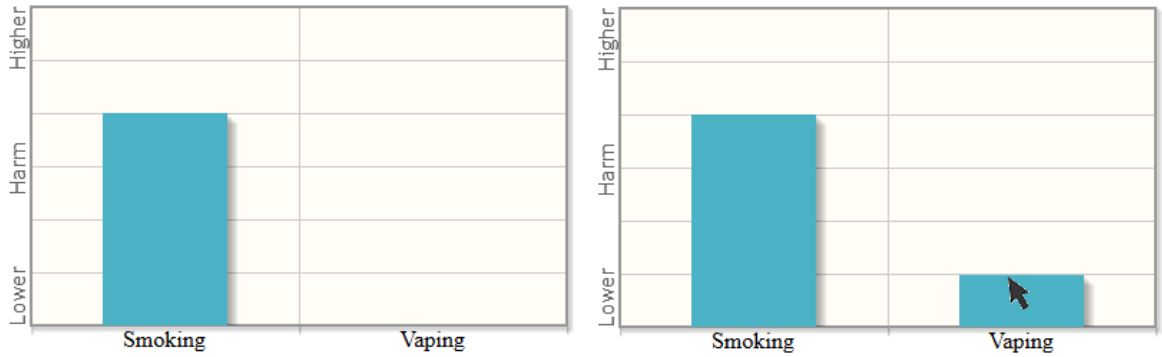

Figure 1: Plot shown to participants to set the relative harm level for vaping. Initially the left hand panel was shown with only the harm of smoking plotted. Participants could click on the figure to indicate the harm of vaping (relative to smoking). The right hand panel shows a participant response indicating vaping is 25% of the harm of smoking.

Question 4. The fourth and final question asked participants how likely they would be to recommend vaping to a close friend or relative who currently smokes, but who finds it impossible to quit. This was done using a Likert scale (1-7), from very unlikely to very likely.

Analyses and Findings

Question 1.1. The task of expressing the information conveyed as a percentage into a ratio of the relative harms of smoking and vaping was clearly challenging for our participants who performed poorly on this question: only 33.7% of respondents chose the correct answer that smoking is 20 times more harmful than vaping (See Table 1).

Confirming that the three different wordings were understood differently there was a significant difference by condition ($\chi^2(8)=20.37$, $p=0.009$), with significantly – and substantially - more respondents correctly answering this question in the "5% as-harmful" condition (44.6%) than in the other two conditions ($\chi^2(1)=9.59$, $p=0.002$).

The majority of respondents (53.8%) gave responses that vastly overstated the harm of smoking relative to vaping with large proportions of respondents in the 95% safer and 95% less-harmful conditions expressing the (false) notion that smoking is 95 times more harmful

than vaping (53.6% and 61.7% respectively). It appears that participants in these two message conditions might have been anchored by the presence of the 95% figure in their statements as, in each of these two message conditions, the majority of participants chose the 95 times as harmful response – unlike the respondents in the "5% as-harmful" condition where the modal response was the correct 20 times as harmful. A similar anchoring effect was not observed for participants in the "5% as-harmful" condition who were not significantly more likely than respondents in the other two conditions to choose the 5 times more often answer - even though 5% appeared in their message statement. Nonetheless, and despite the "5% as-harmful" condition producing the largest proportion of correct answers, a non-negligible 37.5% of participants in this condition seem to have confused 5% as harmful with being equivalent to 95 times as harmful.

	Q1.1 Smoking is _ times as harmful as vaping				
	5	10	20	50	95
Condition					
"95% Safer"	12.4%	3.1%	28.9%	2.1%	53.6%
"95% Less-harmful"	9.6%	1.1%	25.5%	2.1%	61.7%
"5% As-harmful"	11.6%	0%	44.6%	6.3%	37.5%
TOTAL	11.2%	1.3%	33.7%	3.6%	50.2%

Table 1: Percentages of participants in each condition selecting each response to Q1.1

Questions 1.2-1.4. Table 2 shows that participants performed fairly well with these questions - the vast majority of responses being the exact correct response for each question in each message condition. However despite the high level of performance in each message condition, when we collated the responses so as to compare the proportion of respondents in each message condition that were able to give the correct answer to *both* of the two questions they answered, we found statistically significant variance in performance across the three

conditions (χ^2 (2)= 14.39, p<0.001). Moreover, after collapsing the two message conditions that referred to 95% ("95% safer" and "95% less harmful" into one category, we found that the proportion correct in these two conditions collectively differed from the "5% as-harmful" condition (χ^2 (1)= 13.43, p<0.001). This pattern across the message conditions is consistent with the notion that participants in the "5% as-harmful" condition who, having read about a 5% relationship, needed to transpose this into the 95% safer/less harmful relationship, found this harder than those participants in the "95% safer" and "95% less harmful" conditions where obtaining one correct answer required them to merely repeat the 95% figure they had read in the original message.

		Message condition			
	Question	"95% safer"	"95% less harmful"	"5% as harmful"	Correct answer
Q1.3	Vaping is _% safer than smoking	-	92.6%	76.8%	95
Q1.2	Vaping is _% less harmful than smoking	95.9%	-	80.4%	95
Q1.4	Vaping is _% as harmful as smoking	92.8%	88.3%	-	5
	Both questions correct	89.7%	84.0%	69.6%	

Table 2: Percentage of participants giving correct responses to Q1.2-1.4 in each condition

Questions 2.1-2.2. Table 3 shows that participants mostly agreed with statement Q2.1 proposing that the messages about percentage relative harm, or safety, are indicative of the percentage likelihood of suffering harm; though despite the clear majority agreeing with the likelihood statement only a minority in each message condition *strongly* agreed with it suggesting some degree of reticence about the numerical equivalence of these claims.

Most respondents in each message condition strongly disagreed with statement Q2.2, which expressed the incorrect notion that "vaping is 95% as harmful as smoking" which

indicates a degree of understanding of the relative harms, with no significant differences according to message condition (Kruskal-Wallis rank sum tests, both *p*s>.89).

		MESSAGE CONDITION		
STATEMENT	RESPONSE	95% safer	95% less harmful	5% as harmful
Q2.1 You are 95% more likely to suffer harm from smoking compared with vaping	Strongly agree	45.4%	44.7%	47.3%
	Agree (to any extent)	82.5%	88.3%	88.4%
	Disagree (to any extent)	16.5%	9.6%	8.9%
	Strongly disagree	9.3%	5.3%	6.3%
Q2.2 Vaping is 95% as harmful as smoking	Strongly agree	7.2%	2.1%	7.1%
	Agree (to any extent)	11.3%	7.4%	17.9%
	Disagree (to any extent)	84.5%	91.5%	80.4%
	Strongly disagree	63.9%	62.8%	66.1%

Table 3: Percentage of participants agreeing with statements Q2.1 & Q2.2 in each condition

Question 3. Table 4 shows that, using a graphical representation, participants tended to overestimate the harms of vaping relative to smoking, with a mean answer of 18.9% and median of 10.1% (the correct answer was 5%). However, it should be acknowledged that participants might have some difficulty judging the precise 5% position and that, given the plot had a lower limit of 0%, were more likely to err upwards than downwards. There was no difference according to experimental condition ($F(2, 261)=0.25$, $p=.78$). The distributions of responses shown in figure 2 show that the highest density of responses is closely grouped around 5%, but also a non-negligible number of responses scattered away from the correct response in all three conditions.

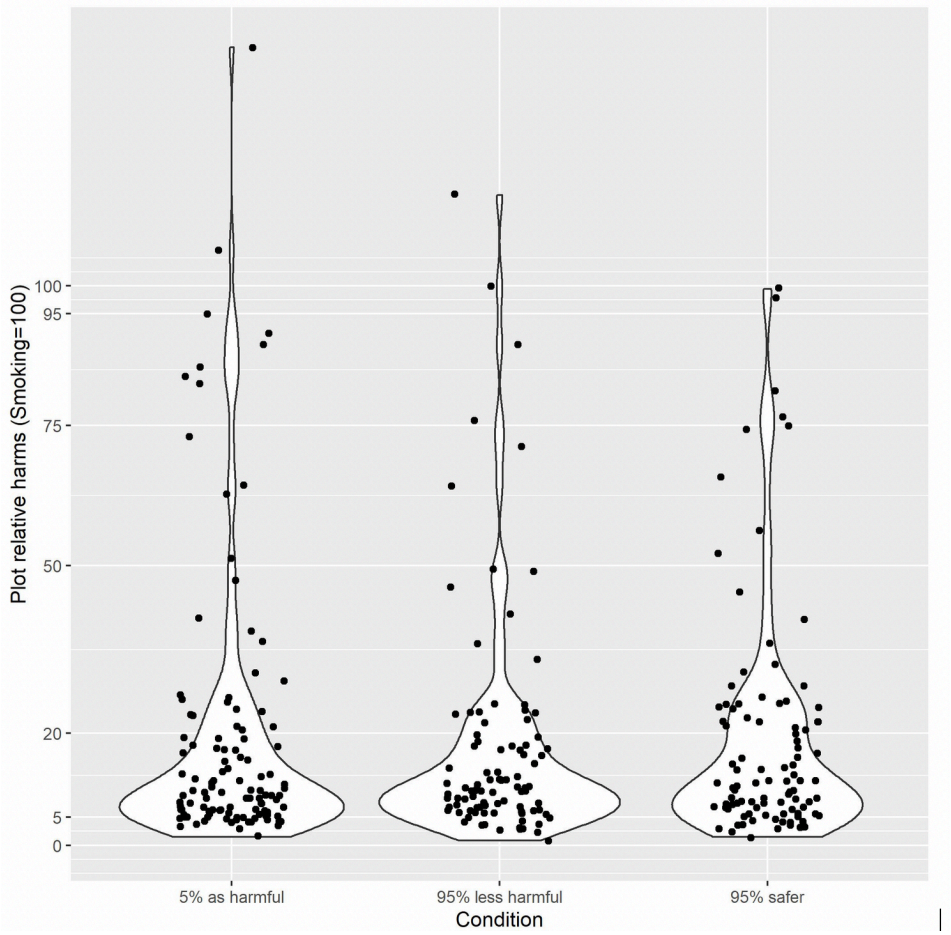

Figure 2: Contour plots of the distribution of graphical responses by message condition

Message Condition	Mean estimated harm (95% CI)	Median estimated harm
"95% Safer"	19.0% (14.4-23.5)	11.1%
"95% Less-harmful"	17.6% (13.0-22.2)	10.1%
"5% As-harmful"	19.9% (15.7-24.1)	9.6%

Table 4: Graphically assessed relative harm of vaping for each message condition

Question 4. The modal answer to the questions asking how likely the respondent was to recommend vaping to a close friend or relative who currently smokes, but who finds it

impossible to quit was, across all conditions, very likely. The majority - more than three quarters - of participants in each condition would be likely to recommend vaping and there was no statistically significant variance across message conditions (Kruskal-Wallis rank sum test, p=.59).

		MESSAGE CONDITION		
STATEMENT	RESPONSE	95% safer	95% less harmful	5% as harmful
Assuming that the statement above is correct, how likely would you be to recommend vaping to a close friend or relative who currently smokes, but who finds it impossible to quit?	Very likely (7)	44.3%	47.9%	37.5%
	likely (5-7)	80.4%	77.7%	80.4%
	Unlikely (1-3)	13.4%	9.6%	10.7%
	Very unlikely (1)	9.3%	5.3%	5.4%

Table 5: Proportion of participants likelihood of recommending vaping on scale from 1-7.

Discussion

Our study shows that the efficacy of messages designed to communicate the relative harms of smoking and vaping expressed as percentages is very limited. When asked to translate the percentage comparison about the relative harm of vaping compared to smoking in the messages they had read, into an expression that directly conveyed the ratio of the relative harm of smoking and vaping, our experimental participants performed poorly. Of particular note is the finding that with the two versions of the statements used by Public Health England ("vaping is 95% safer than smoking" and "vaping is 95% less harmful than smoking") fewer than a third of the experimental participants gave the correct answer – that Smoking is 20 times as harmful as vaping. A clear majority of the experimental participants in each of these two message conditions responded that smoking is 95 times as harmful as vaping – expressing a large quantitative error.

Performance in the message condition where participants read that "vaping is 5% as harmful as smoking" was significantly better. In this condition the correct response "smoking

is 20 times as harmful as vaping" was the modal response with just under half of participants in this condition expressing it. Nonetheless, despite their clearly superior performance, a non-negligible 37.5% of the participants in this condition also responded that smoking is 95 times as harmful as vaping. On the basis of these findings it would be difficult to endorse the use of messages using a percentage format. We can see reason to be in accord with Nutt et al. (2016) who, rather than use the percentage formulation used by Public Health England, preferred to describe smoking as twenty times more harmful to users than vaping e-cigarettes. Communicating the relative harms of smoking and vaping with direct reference to the ratio of their harms avoids the confusion that evidently arise from people's difficulty with percentage comparisons.

Our experiment also shows evidence that, while messages expressing the relative harms of smoking and vaping in percentage terms could not effectively convey the numerical ratio of their relative harms, most people were nonetheless able to convert one percentage expression of the relationship into another; thus people who had read that vaping was 95% safer than smoking were mostly able to express that vaping was both 95% less harmful and that it was 5% as harmful. Yet there were limits to how easily people transposed messages expressing harms in percentages: the message that vaping was 5% as harmful as smoking was not so easily recognised as equivalent to the vaping was 95% safer and 95% less harmful than smoking statements.

Despite the large error in the expressed ratio of harms of vaping and smoking, to some degree of approximation the messages using percentages did transmit a picture of the relative harms. Most respondents disagreed with the false statement that vaping is 95% as harmful as smoking and when availed of the opportunity to express their understanding of the relative harms graphically – thereby bypassing any difficulties with numerical reasoning - the participants gave a median value of the relative harm of vaping as about 10% that of

smoking. The results overall point to a weak understanding of the relative harms, but a good understanding in terms of which was safer or more harmful. We also observed that while the different percentage messages might have produced different perceptions of the relative harm of smoking and vaping, they did not differentially vary the strong likelihood of recommending vaping to a close friend or relative who currently smokes, but who finds it impossible to quit – one of the key messages Public Health England sought to promote (McNeil et al., 2015).

Arguably information only has utility to the extent that it influences decisions. Accordingly, in addition to the consideration of the design of messages for public understanding, we also need to consider the influence of message design on decision making. Acknowledging decision research showing that seemingly quite arbitrarily and subtly different ways of presenting a product relative to other products can affect consumer choices Kaufman, Suls, & Klein (2016) have argued that the tobacco control community should consider the potential unintended consequences of comparisons in communications about the harms of tobacco and alternative products, and how judgment and decision-making science can be leveraged to maximize public health. In this regard, in addition to the large number of phenomena discussed by Kaufman et al. (2016), we would note that the leading descriptive theory of choice, Prospect theory (Kahneman & Tversky, 1979), predicts that people are more risk seeking for losses than gains – suggesting that people's choices between options described in terms of their relative harms would differ from their choices between the same options described in terms of their relative safety[4]. Although much research in health promotion has explored – and, indeed, found - differences in the influence of gain-framed

[4] Other pertinent judgment phenomena include Shafir's (1993) demonstration that, for options with both pros and cons, positive attributes loom larger when one is choosing and negative options loom larger when one is rejecting, resulting in different selections when people are choosing, rather than rejecting, options. Audley & Wallis (1964) found people are quicker at judging the brighter, rather than the dimmer, of two relatively bright stimuli but quicker at judging the dimmer of two relatively dim stimuli. Confirming the generality of this effect Wallis & Audley, (1964) found the same for judgments of auditory pitch of tones.

versus loss-framed messages, the effects vary widely resulting in little reliable guidance. Reviews have concluded that the framing effect may exist under specific but yet undetermined conditions (Akl et al., 2011), that numerous other variables may moderate framing effects (Gong et al., 2013) and that framing inconsistencies could be resolved once the level of audience involvement and interest in a health issue is established (Wansink & Pope, 2015).

Reviewing evidence from judgment and decision research showing that changing the referent of comparisons can change perceived differences between alternatives, Kaufman et al. (2016) query the current practice of using cigarettes as the default referent for comparison of relative harms: what if we were to change to the least harmful referent—no tobacco products? Then, instead of any nicotine produce being described as "safer" than the standard for comparison, they would all be described in terms of how harmful they are. This, Kaufman et al. argue, should lead to judgments of greater harm being associated with use of any tobacco product and, they claim, should also be less misleading because all products will be perceived as "harmful".

Kaufman et al. (2016) argue that, with cigarettes as the referent, the public may believe that the health consequences of tobacco use can be managed through switching (or substitution) behaviour - rather than by quitting altogether. That of course is compatible with UK public health policy; the notion that smokers, who have tried other methods of quitting without success, should be encouraged to try e-cigarettes was a key message of Public Health England's campaign (McNeil et al., 2015) which clearly sought to promote the lesser of two evils. However this recommendation is not made in the USA where public policy on vaping is markedly different from the UK (Bauld & Gage, 2019; Nutt, 2016) and where the harms of alternatives to smoking are strongly emphasised in government public health statements. In contrast with Public Health England's advice that switching from cigarettes to vaping will be

a major benefit to public health, current advice from the US Federal government Office on Smoking and Health is that "E-cigarettes are not safe for youth, young adults, pregnant women, or adults who do not currently use tobacco products." (Office on Smoking and Health, 2018). In a report that warns that the nicotine delivered by e-cigarettes nicotine is highly addictive and "can also harm brain development in ways that may affect the health and mental health of our kids" the US Surgeon General proposed that: "To prevent and reduce the use of e-cigarettes by youth and young adults, we must work together as a society" (U.S. Department of Human Health and Human Services, 2016).

In a series of publications Kozlowski and colleagues (e.g. Kozlowski, 2002; 2018; 2019; Kozlowski & Abrams, 2016; Kozlowski & Edwards, 2005; Kozlowski & Sweanor, 2016, 2018) have been critical of the policy operated in the United States on ethical, rational utilitarian and human rights grounds. They advocate that, in order to promote informed choice, public health agencies should disseminate the message that there are less-harmful nicotine products, instead of – as currently – acting to prevent or reduce use of alternatives to cigarettes and warning that alternatives to cigarettes are "not harmless". Studies of public understanding of risk messages (Popova & Ling, 2014; Wackowski, Hammond, O'Connor, Strasser, & Delnevo, 2016) show that perceptions of the perceived harm of e-cigarettes are amplified by the message "This product is not a safe alternative to cigarettes", prompting the erroneous belief that e-cigarettes are *not* a safer alternative to cigarettes.

Memorably Kozlowski & Sweanor (2016) noted that it is as if needle-exchange programs had to prove no negative public health effects before being implemented—while heroin given via dirty syringes was sold over-the-counter. Curiously a similar reticence to embrace harm reduction can be seen in the USA in relation to needle and syringe exchange programs for drug users which, despite being shown to reduce the spread of certain viral infections such as H.I.V., hepatitis B and hepatitis C by removing contaminated syringes

from circulation (Fernandes et al., 2017; Platt et al., 2017), are limited or prohibited in most states (Frakt, 2016).

In rejecting the lesser of two evils - vaping as an alternative to smoking - because it involves some harm, there is a danger in the US approach of what Voltaire (1772) described as making the perfect the enemy of the good[5]. Demsetz (1969) cautioned against what he described as the 'Nirvana approach' to public policy which he argued was susceptible to logical fallacy: "The view that now pervades much public policy economics implicitly presents the relevant choice as between an ideal norm and an existing "imperfect" institutional arrangement. This *nirvana* approach differs considerably from a *comparative institution* approach in which the relevant choice is between alternative real institutional arrangements. In practice, those who adopt the nirvana viewpoint seek to discover discrepancies between the ideal and the real and if discrepancies are found, they deduce that the real is inefficient. Users of the comparative institution approach attempt to assess which alternative real institutional arrangement seems best able to cope with the economic problem" (p. 1). What some (Stearns, 1994) now call the nirvana *fallacy* - the fallacy of comparing actual things with unrealistic, idealized alternatives – may be facilitated by the selection of a congruent comparative metric.

It is noteworthy that recent surveys of the perceived relative harms of smoking and vaping have shown differences between public perceptions in the UK and USA in line with the different health policies of the two countries. Thus Wilson, Partos, McNeill, & Brose, (2019) find that most (57.3%) UK smokers and recent ex-smokers perceive e-cigarettes as less harmful than smoking while in the USA, Huang et al. (2019) find only 33.5% of smokers and 32.55 of former smokers perceived e-cigarettes as less harmful than smoking (both

[5] In *La Bégueule*, Voltaire (1772) wrote "Le mieux est l'ennemi du bien" - literally "The best is the enemy of the good" - often translated as "The perfect is the enemy of the good" which he credited to an unnamed Italian sage.

surveys conducted in 2017)[6]. That these quite different perceptions co-exist is perhaps more remarkable when one considers that, in the USA, E-cigarette products are marketed in a wide variety of channels that have broad reach, including television, point-of-sale, magazines, promotional activities, radio, and the Internet (U.S. Department of Human Health and Human Services., 2016) while in the UK, almost all forms of e-cigarette marketing have been banned since 2016. Presumably the more permissive marketing regulations in the USA explain why, in spite of the higher perceived relative harm of vaping in the USA compared to the UK, e-cigarettes are currently more popular among young people in the USA than in the UK. Among a sample of about 14,500 USA teenagers around age 18, 37% reported having tried an e-cigarette in the past year in 2018 while a 2018 survey of 484 British 18-year-olds found only 23% had tried vaping (Bauld & Gage, 2019).

The potential health consequences of behaviour change are substantial but clearly critically depend on the extents to which smokers switch to vaping and non-smokers start vaping. While very high use of e-cigarettes could result in net harms, especially to the extent that e-cigarettes attracted those who would not have otherwise smoked, use by non-smokers of e-cigarettes is rare; almost all current e-cigarette users are either current or former cigarette smokers (Jackson et al., 2019; McNeil et al., 2015; Vardavas, Filippidis, & Agaku, 2015). One study modelling the impact of e-cigarettes in the USA concludes that, under most plausible scenarios, this would have a positive public health impact (Levy et al., 2017). Based on current use patterns in the USA Levy et al., (2017) project a reduction of 21% in smoking

[6] A recent review of 54 studies of risk perceptions of nicotine products conducted in various countries (31 in the USA) found that respondents in most studies correctly perceived e-cigarettes as less harmful than tobacco cigarettes. (Czoli, Fong, Mays, & Hammond, 2017). However the studies in this review analysed data before 2015 when the two multiyear nationally representative surveys analysed by Huang et al. (2019) also showed a large proportion of US adults perceived e-cigarettes as less harmful; one of those surveys shows that, since 2015, the proportion of US adults perceiving e-cigarettes as less harmful than cigarettes has significantly declined while the proportions perceiving e-cigarettes as more harmful or ‘about the same’ have increased.

attributable deaths and of 20% in life years lost as a result of e-cigarettes compared to a scenario without e-cigarettes.

A key driver of this behavioural change is public understanding – itself dependent on how well health information is communicated. Despite studies suggesting that anti-tobacco campaigns limited to textual messages signalling the harms of smoking have very limited or no measurable influence on stated willingness to buy tobacco products (Bogliacino et al., 2015), perceptions of the *relative* harms of smoking and vaping have been shown to be significantly influenced by messaging (Popova & Ling, 2014), while a longitudinal study tracking the behavioural consequences of differing perceptions of the relative harms of smoking and vaping shows that smokers' relative harm perceptions are predictive of their likelihood of switching to vaping (Persoskie, O'Brien, & Poonai, 2019).

Unfortunately the challenge of communicating health information has sometimes been made more difficult by industry marketing messages. Gardner & Brandt (2006) have documented how, historically, medical endorsements of tobacco provided a pernicious context for public understanding of smoking risks. As people are active information processers, marketing messages that make no prohibited claims can nevertheless, if skilfully designed, prompt consumers to infer these for themselves on apprehending the text - indeed advertisements and packaging material are frequently designed to elicit consumer inferences. For example, a study by Green (1996) demonstrated that consumers who read an approved marketing message on a pack of breakfast cereal were more likely to draw a legally proscribed inference - that eating the product would reduce the risk of heart disease.

While the MRH measure produced by Nutt et al. (2014) can be commended for clearly communicating the estimated relative harms of nicotine products it does have one clear limitation – whether expressed as a ratio or as a percentage. Use of a relative measure of harms implies that the perceived benefits of vaping compared to smoking - even for those

correctly comprehending the message - will vary with respect to the perceived absolute harms of smoking. Thus, for those perceiving that smoking is relatively low in harm, the perceived absolute benefits of, say, a 95% reduction in harms will be smaller than for those seeing smoking as more harmful.

This matters because while nicotine product users' choices involving two or more options scaled in this way will be well informed by the relative harm ratings, choices comparing the relative harm ratings to zero harm (i.e. total abstinence from nicotine products) would not be well informed: evaluation of the merits of using a nicotine product versus abstaining altogether is not usefully assisted by the relative harm ratings – because any amount of harm is relatively – but not *scalably* - more harmful than none (dividing any number by zero gives infinity). Nevertheless the absolute harms are of course important and so should be communicated. We should certainly be careful not to use message formats that weaken public understanding of absolute harms; for example, for all we currently know, it is possible that advertising that vaping is 95% safer than smoking (rather than 5% as harmful) reduces perception of the absolute harms of smoking.

As we don't currently know about this possibility, as well as many other possible unintended impacts of different message formats, we would argue that it is important that messages designed to communicate important information to the public about harms be pre-tested for their efficacy prior to publication. This is hardly a novel suggestion. More than a quarter of a century ago Fischhoff, Bostrom, & Quadrel (1993) advised that: "*By causing undue alarm or complacency, poor communications can have greater public health impact than the risks that they attempt to describe. It may be no more acceptable to release untested communication than an untested drug. Because communicators' intuitions about recipients' risk perceptions cannot be trusted, there is no substitute for empirical validation*" (pp. 198-199). While we would by no means wish to create the impression that our study provides the

basis for selecting the optimal risk communication on this issue, we would submit that it does provide a basis for questioning the current messaging and provides an impetus for investigating better designs.

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