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Universal or targeted approaches? an experiment about heat risk messaging

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Abstract
Extreme heat causes more deaths than tornadoes and floods combined in the United States. While vulnerable populations are at higher risk of heat-health impacts, anyone can be at risk from extreme heat without appropriate actions. Therefore, heat risk communication efforts, especially those on a wide scale, should engage not only the vulnerable subgroups but also the entire population with the goal of encouraging everyone to take appropriate protective actions during extreme heat events. As one step to achieve this goal, this study examined how to effectively depict people's susceptibility in heat risk messages. Using a survey experiment ($N = 1386$), this study compared the effectiveness of four statements that varied how they depicted which types of people were susceptible to heat-health impacts. Relative to traditional messaging that lists specific vulnerable subgroups, a statement that "anyone can be at risk" and a statement without susceptibility information were respectively more effective in making messages personally relevant. Mentioning the "anyone can be at risk" statement and the "certain subgroups are at more risk" statement together reduced belief in the hazard happening compared to mentioning the latter statement individually. Implications for risk communication in broader domains are discussed.

Keywords Depicted susceptibility · Extreme heat · Risk communication · Message relevance · Vulnerable populations

1 Introduction

Many hazards, ranging from natural hazards to pandemic diseases, pose higher risk to some subgroups who are disadvantaged by physical or socioeconomic status. When communicating information about who is at higher risk with policy makers, such information helps emergency managers prioritize resource allocation and meet the special needs of the vulnerable populations (Phillips and Morrow 2007). However, when communicating similar information with the general public (both vulnerable populations and other populations), mentions of vulnerable populations may produce undesired effects on how the general public respond to hazards. Using a survey experiment, this study examined how

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to effectively depict who is at risk in the context of heat hazards especially for large-scale communication efforts whose intended audience is the general public.

1.1 Severe heat-health impacts and one contributor

Extreme heat has been associated with excess mortality worldwide and is projected to increase in frequency and intensity in the twenty-first century (Smoyer-Tomic et al. 2003; IPCC 2012; Mora et al. 2017b). In the United States, extreme heat caused an average of 430 deaths every year from 2009 to 2018, more than twice the number of deaths from tornadoes, hurricanes, floods, and earthquakes combined (CDC 2020). In addition to heat-related deaths, heat-related illnesses such as heat exhaustion and heat stroke lead to an average of 67,512 emergency department visits per year in the U.S. (CDC n.d.). With respect to affected populations, negative health impacts from extreme heat are not restricted to the elderly, people in the South, or the poor, but widespread across age groups, geographic areas, and income levels (Hess et al. 2014). Taking affected age groups as an example, all age groups are subject to mortality risk from extreme heat, although elderly people are at greater mortality risk than younger adults (Anderson and Bell 2009; CDC 2020). When it comes to heat-related emergency department visits, adolescents and young adults (15–44 years of age) even have a higher incidence rate than adults 65 years or older (Lippmann et al. 2013; Hess et al. 2014; Harduar Morano et al. 2016). The widespread impacts highlight the need for large-scale communication efforts to engage not only the vulnerable subgroups but also the entire population with the goal of encouraging everyone to take appropriate protective actions during extreme heat events.

In contrast to the serious and widespread heat-health impacts, heat-related mortality and morbidity are commonly viewed as largely preventable, given accurate weather forecasts and the availability of effective protective measures (U.S. EPA 2006). Assuming that health risks from extreme heat are preventable yet mortality and morbidity rates remain high, what factors might cause this paradox? This circumstance has been attributed, at least partly, to the fact that people tend to underestimate personal risks posed by extreme heat, and are thus less likely to take protective actions (Kalkstein and Sheridan 2007; Mayrhuber et al. 2018). For example, many elderly people do not think of themselves as being vulnerable to extreme heat (Sheridan 2007; Sampson et al. 2013). Even when some elderly respondents recognized that "the elderly" is a population vulnerable to heat, they defined "the elderly" or "older adults" as those older than themselves and in a worse health or social situation and thus did not associate heat-health risks directly with themselves (Wolf et al. 2010; Sampson et al. 2013).

1.2 Research gaps about heat risk messaging

Informed by the epidemiological evidence and findings about heat-risk perceptions, researchers have reconsidered traditional messaging that lists vulnerable subgroups such as older adults as being at greater risk from extreme heat (i.e., the subgroup statement) (Wolf et al. 2010; Sampson et al. 2013), since the targeted approach may fail to engage both vulnerable subgroups and other populations. For instance, the elderly, as mentioned earlier, disassociate themselves from being part of a vulnerable population (Wolf et al. 2010; Sampson et al. 2013). Following the logic of this finding, researchers proposed that the elderly may perceive messages singling out the elderly as a vulnerable group to be irrelevant to themselves and subsequently deny the heat-health risks warned about in such

messages (Wolf et al. 2010). For younger people, statements depicting the elderly and some other subgroups as being vulnerable to extreme heat may build a false sense of security for younger people, especially if they also do not belong to other vulnerable subgroups such as outdoor workers (Mora et al. 2017a). Although the reconsideration is reasonable, it has not been empirically tested.

Relative to the traditional subgroup statement, a couple of alternative statements can be identified that are either proposed by researchers or actually used by communication practitioners. The first alternative statement is the "anyone" statement, that anyone can be at risk from extreme heat. Researchers proposed the "anyone" statement and argued that the universal approach may make heat risk messages more relevant to people of all ages (Sampson et al. 2013; Mora et al. 2017a). The anyone statement, as with the subgroup statement, is true according to medical evidence in the context of extreme heat (Mora et al. 2017a). Despite lacking empirical testing, the anyone statement has appeared in official heat risk messages in the U.S. (Li et al. 2018). The second alternative statement is the "anyone + subgroup" statement that combines an "anyone can be at risk" message and a "certain subgroups are at more risk from extreme heat" message. The anyone + subgroup statement has been recommended for use in practice by the health department of Canada (Health Canada 2011). The U.S. National Weather Service (NWS) has also used the anyone + subgroup statement in its experimental HeatRisk product to communicate heat-health risks (National Weather Service 2020). The use of these alternative statements in official messages precedes empirical testing, which may result in unintended adverse effects on public response.

To inform communication practitioners with evidence-based messaging strategies, this study compares the relative effectiveness of the subgroup, anyone, and anyone + subgroup statements in heat warning messages when the intended audience is the general public. In the field of risk communication, extreme heat is an under-examined natural hazard in spite of its relatively severe and widespread impacts on public health. Past experiments about heat risk messages have been limited to investigating whether the availability of heat risk messages (versus no heat risk messages) influences responses among vulnerable populations (Takahashi et al. 2015; Nitschke et al. 2017; Mehiriz et al. 2018). The heat risk messages under test in these experiments did not appear to mention the subgroup, anyone, or anyone + subgroup statements. To our knowledge, only one experiment has moved beyond simple message availability and compared the effectiveness of certain types of statements in heat risk messages (Bruine de Bruin et al. 2016); it found that reminding residents in United Kingdom of the most unpleasant highest temperature promotes behavioral intention to take protective actions compared with no statements about temperature recall (Bruine de Bruin et al. 2016). The current study is the second experiment that moves beyond simple message availability and examines specific messaging strategies in the context of heat hazards.

1.3 Research gaps about natural hazard communication

To broaden the practical and theoretical implication of the current study, we situate the specific heat-related psychological barrier and messaging strategies in a broader scholarly context. Underestimation of personal risks, as mentioned earlier, is the psychological barrier to taking protective actions in the specific context of heat hazards. This barrier can be called a lack of "personalization" or more precisely low "perceived susceptibility". Personalization and perceived susceptibility both describe people's belief in the likelihood of

experiencing negative impacts from a threat (Mileti and Sorensen 1990; Witte 1992). The differences between these two concepts are (1) personalization considers the implication of the risk not only for oneself but also for one's family and community but perceived susceptibility only considers the implication for oneself, and (2) personalization is a term commonly used in the field of natural hazard communication but perceived susceptibility is a term commonly used in the field of health communication (Mileti and Sorensen 1990; Witte 1992; So et al. 2016; Sutton et al. 2018).

The traditional and alternative statements about who is at risk from extreme heat (the subgroup, anyone, and anyone + subgroup statements) fit into a commonly investigated message component in health communication literature: depicted susceptibility. Depicted susceptibility refers to descriptions about how likely the message audience will experience negative outcomes of a threat (Witte 1993). Past studies about depicted susceptibility usually compare the effectiveness of different *levels* of depicted susceptibility. High levels of depicted susceptibility emphasize the intended audience's susceptibility via intense and emotional language, vivid presentation, or mentioning reference groups less susceptible than the audience, while low levels of depicted susceptibility describe the intended audience as relatively less susceptible via impartial language, bland presentation, a vague reference group, or mentioning reference groups more susceptible than the audience (Witte 1993; Tannenbaum et al. 2015). For example, when communicating the threat of meningitis infection with college students, the message high in depicted susceptibility stated that college students are more at risk of contracting meningitis than the general public, and the message low in depicted susceptibility stated that children less than five years old is the most vulnerable subgroup for meningitis infection (So et al. 2016). Levels of depicted susceptibility were differentiated in these messages since one mentioned a reference group (i.e., the general public) being less susceptible than the intended audience (i.e., college students) and the other mentioned a reference group (i.e., children) being more susceptible than the intended audience (i.e., college students). According to fear appeal theories and meta-analyses of related empirical studies, high levels of depicted susceptibility are also more likely to produce better behavioral intention and actual behavior than low levels of depicted susceptibility (Tannenbaum et al. 2015). The traditional and alternative statements in the current study demonstrate different types of depicted susceptibility—by mentioning different reference groups—rather than levels of depicted susceptibility. Since the treatment design in this study is problem-driven, statements compared in this study are not intended to correspond with different levels of depicted susceptibility, but rather different types of depicted susceptibility based on existing messages. Therefore this study advances what has been known about depicted susceptibility by comparing under-examined pairs of statements. Moreover, as specified in the next paragraph, this study expands depicted susceptibility research to the new context of natural hazard communication.

Although depicted susceptibility has been widely acknowledged as a persuasive messaging strategy in health communication literature, depicted susceptibility has drawn little research attention in the field of natural hazard communication. When informing the public about an imminent or current natural hazard event, a generic topic of "hazard" that describes the characteristics of the hazard has been recognized as a required component of warning messages of natural hazards (Mileti and Sorensen 1990). Within this, however, depicted susceptibility is not a must-have subcomponent and has drawn much less attention from researchers and practitioners than other subcomponents such as descriptions of hazard uncertainty (e.g., the hurricane cone of uncertainty) and the physical intensity of a hazard itself (e.g., wind speeds and temperatures) (Li et al. 2018; Morss et al. 2018; Potter et al. 2018). Although depicted hazard uncertainty and depicted susceptibility both

communicate the likelihood of being negatively affected, depicted possibility of the hazard happening emphasizes physical vulnerability to the hazard itself but depicted susceptibility emphasizes social vulnerability to hazard impacts which involves social factors such as age, economic status, and preparedness. Past experiments about natural hazard communication have widely investigated how to effectively depict hazard uncertainty (Keller et al. 2006; Doyle 2006; Doyle et al. 2011; Cox et al. 2013), but little research attention has been paid to how to effectively depict people's susceptibility to natural hazards. A few recent experiments about hurricanes and drought found that combined descriptions about the susceptibility and severity of hazard impacts (e.g., "Your farm is susceptible and you will lose a lot if drought occurs") produce higher intentions to take recommended actions than a lack of the combined descriptions (Lebel et al. 2018; Morss et al. 2018). However, to our knowledge, no study in the context of natural hazards has investigated the respective effects of depicted susceptibility on behavioral intention, personalization (or perceived susceptibility) or belief in hazard happening. A lack of investigation on how to effectively depict people's susceptibility to natural hazards leaves the potential for under-informed risk messaging and suboptimal rates of warning compliance.

1.4 The current study

To bridge these research gaps, this study compared the effectiveness of different types of depicted susceptibility in the context of natural hazards and more specifically heat hazards using an online survey-based experiment. The four treatments were the subgroup statement, the anyone statement, the anyone + subgroup statement, and a "no depicted susceptibility" statement. The no depicted susceptibility statement was a neutral statement without any descriptions about who is at risk from extreme heat. We included this statement because heat risk messages without any depicted susceptibility are frequently issued by local weather forecast offices on social media in the U.S. (Li et al. 2018). Online Resource 1 shows examples of official heat warning messages without depicted susceptibility. In the current experiment, heat risk messages specifically refer to heat warning messages that warn the whole population in affected areas about specific upcoming and/or current extreme heat. The intended audience is the general public and thus our participants were not limited to those particularly vulnerable to extreme heat. Four outcome variables used to compare the effectiveness among all pairs of treatments were (1) perceived personal relevance of a message, (2) belief in whether a predicted extreme heat event will happen, (3) perceived susceptibility to heat-health problems (perceived likelihood that the predicted extreme heat event can adversely impact personal health), and (4) behavioral intention to protect oneself from heat-health impacts.

In the prior subsection, we reviewed the current knowledge of how depicted susceptibility influences perceived susceptibility and behavioral intention in the field health communication. We also highlighted the current lack of knowledge about how depicted susceptibility influences belief in a hazard happening, perceived susceptibility, and behavioral intention in the field of natural hazard communication. Perceived message relevance is not a typical outcome variable used to measure the effectiveness of depicted susceptibility. However, we selected perceived message relevance as one of our outcome variables for two reasons. First, perceived message relevance has been used to explain why messages tailored to individual demographics and beliefs produce better behavioral intention or behaviors than non-tailored messages in the context of fruit and vegetable consumption and breast cancer screening (Ko et al. 2011; Jensen et al. 2012). Compared to depicted

susceptibility, tailoring is a different but related messaging strategy since some tailored messages—especially those using personalized language—may respond to higher levels of depicted susceptibility. Second, as mentioned earlier, making messages personally relevant is one of expected benefits of using anyone statements in heat risk messages (Wolf et al. 2010). The current study is the first study to empirically compare the relative effectiveness of statements that vary in depicted susceptibility to heat-health impacts. Our findings could therefore have implications for messaging strategies for heat hazards and other natural hazards.

2 Method

An online survey experiment was conducted using a post-test-only, between-subjects design. Participants ($N = 1386$) were recruited from the SurveyMonkey Audience panel and took our survey using the SurveyMonkey platform. This panel has millions of panelists who are part of the U.S. population aged 18 or older and volunteer to join the panel. The panelists take online surveys in order to donate to charity, get gift cards, and/or gain chances to win sweepstakes. This study ran during autumn (from November 5 to November 13, 2018).

2.1 Procedure and materials

After reading a letter of consent, participants who agreed to take the survey were presented with an introduction about a hypothetical situation that, one day during the past summer, participants saw a heat warning message from their local office of the NWS. Each participant was randomly assigned to a graphic heat warning message that contained one of the four treatments: the subgroup, anyone, anyone + subgroup, or no depicted susceptibility statement. The random assignment of treatment groups was enabled by the A/B test feature of the SurveyMonkey platform, which has been used by other experimental studies to assign participants randomly (Talley and Temple 2015; Saunders et al. 2016). Table 1 shows treatment text, and Online Resource 2 shows the description of the hypothetical situation and full graphic messages in the four treatment groups. Although messages assigned to treatment groups varied in depicted susceptibility, messages used the same textual and visual information describing other aspects of the upcoming extreme heat event such as the affected area that is participants' local area and response instructions. Messages were closely adapted from existing official heat warning messages especially those in the U.S. The no depicted susceptibility statement acted as a proxy for not mentioning either "anyone can be at risk" or "certain subgroups are at more risk". The neutral statement was also like a placebo which made the full graphic message similar to those in other treatment groups in terms of message length, specificity, and layout.

After reading the message, a screening attention check question was placed to catch and remove participants who did not read the graphic message. The screener asked whether the number of words in ***bold italic*** in the above message is greater than, equal to, or less than forty. This unobtrusive screener had an objective right answer, because the words in bold italic were treatment text which varied from 14 to 23 words. Participants had access to the graphic message when they answered this screener. Regardless of participants' response to the screener, they were then asked to answer survey questions measuring outcome

Table 1 Descriptions of experimental conditions

Condition	Treatment text	No. of respondents
Subgroup statement	Older adults, children, people with chronic diseases, and outdoor workers are more at risk. Heat-related illness can set in sooner for these groups	357
Anyone statement	Everyone can be at risk. Heat-related illness can happen to anyone without protective actions	331
Anyone + subgroup statement	Everyone can be at risk without protective actions. Older adults, children, people with chronic diseases, and outdoor workers are at greater risk	354
No depicted susceptibility	People get heat-related illness when the body's temperature control system is overloaded, and sweating just isn't enough	344

Treatment text is a part of the full messages presented to the participants. See Online Resource 2 for the full graphic messages in the four treatment groups

variables and demographic information. Participants who failed the screener were later removed from the analysis.

2.2 Participants

A total of 1722 participants completed the survey. The screener failure rate was 19.4% ($N = 334$), within the range of rates observed in other online samples (2% ~ 63%) (Thomas and Clifford 2017). Compared to those who passed the screening test, those who failed were less educated, less wealthy, less likely to be non-Hispanic White people, more likely to answer the survey using Phone or Tablet (versus Desktop or Laptop), and spent less time to complete the survey. To improve data quality, we excluded participants who failed the screener and another two participants whose answers were "Don't know" for all survey items measuring outcomes. After the exclusion, there were 1386 participants in our sample for the subsequent analyses. Table 2 shows that the distribution of our sample was similar to that of the U.S. adults in sex, age, race/ethnicity, household income, and region, but our sample was more educated than the U.S. adult population. We also performed chi-square tests to check the random assignment of treatment groups. We found that all pre-treatment variables listed in Table 2 are well balanced across treatment groups (see Table A1 in Online Resource 2 for details).

2.3 Outcome measures and data analysis

Table 3 shows the measures and summary statistics of the four outcome variables: (1) perceived message relevance, (2) belief, (3) perceived susceptibility, and (4) behavioral intention. Belief and behavioral intention are traditionally important outcomes in natural hazard communication (Mileti and Sorensen 1990). The measures of perceived message relevance and perceived susceptibility were adapted from health communication studies (Gallagher et al. 2011; Jensen et al. 2012). Behavioral intention to protect oneself originally had a four-item scale. One survey item about wearing dark-colored clothes was negatively worded and was removed from the overall scale since its reverse coded item had a low correlation with the overall scale (the corrected item-total correlation was 0.21).

The effect of statement type on each outcome variable was examined using one-way ANOVA. Post-hoc pairwise comparisons were performed using the Tukey's Honest Significant Difference (HSD) test. We also performed unadjusted pairwise t tests (pooled standard deviation and two-sided tests) to compare the differences in mean outcomes between all pairs of treatments. The use of one-way ANOVA and Tukey's HSD tests is to control the type I error rate, and the use of unadjusted pairwise t tests is to reduce the chances of committing type II errors and generate more hypotheses for future testing (Jaeger and Halliday 1998). The magnitudes of pairwise differences were assessed using Hedges' g, a correction for Cohen's d in estimating population variance. Hedges' g is a preferable measure of effect size even though Hedges' g and Cohen's d are almost equivalent in sample sizes larger than 20 (Lakens 2013).

Table 2 Characteristics of sample compared to U.S. adult population

	Sample[a] N (%)	Population[b] %
Sex		
Male	640 (46.2%)	48.7%
Female	745 (53.8%)	51.3%
Missing data	1	
Age (years)		
18–29	365 (26.4%)	21.3%
30–44	313 (22.6%)	25.0%
45–60	416 (30.0%)	26.7%
Over 60	291 (21.0%)	27.0%
Missing data	1	
Race/ethnicity		
White, non-Hispanic	1015 (76.0%)	63.3%
Black, non-Hispanic	77 (5.8%)	12.1%
Hispanic	103 (7.7%)	16.2%
Other or 2 + races, non-Hispanic	140 (10.5%)	8.3%
Missing data	51	
Education		
High school or less	188 (13.7%)	39.3%
Some college	355 (25.8%)	22.5%
College graduate	556 (40.5%)	27.1%
Graduate degree	275 (20.0%)	11.2%
Missing data	12	
Household income		
Less than $25,000	237 (18.9%)	19.6%
$25,000-$49,999	287 (22.9%)	21.3%
$50,000-$74,999	258 (20.6%)	17.4%
$75,000-$99,999	176 (14.1%)	12.6%
$100,000 or more	294 (23.5%)	29.2%
Missing data	134	
Region		
Northeast	247 (18.0%)	17.5%
Midwest	305 (22.3%)	20.8%
South	477 (34.8%)	37.9%
West	341 (24.9%)	23.7%
Missing data	16	
Device used to take the survey		
Desktop or Laptop	494 (35.7%)	n/a
Phone or Tablet	876 (63.2%)	n/a
Other devices	15 (1.1%)	n/a
Missing data	1	
Total observations	1386	

[a]Each participant's race/ethnicity and education data were collected using survey questions. Each participant's sex, age group, and other information in this table was provided by the SurveyMonkey Audience panel

[b]2018 U.S. population data from (U.S. Census Bureau 2019)

Table 3 Measures and summary statistics of outcome variables

Outcome variable	Survey item[a,b]	Summary statistics			
		N	Min ~ Max	Mean (SD)	Median
Perceived message relevance	1. How much do you agree or disagree with the following statement? "If I received this message, I would think that this message was meant for me."	1374	1 ~ 5	3.81 (1.13)	4
Belief	1. If you received this message, how likely would you think that there would be extreme heat conditions tomorrow in your local area?	1374	1 ~ 4	3.53 (0.76)	4
Perceived susceptibility[c] (Cronbach's alpha = 0.8)	1. How much do you agree or disagree with the following statement? "If I received this message, I would think that my health was likely to be harmed tomorrow."	1384	1 ~ 5	2.96 (1.18)	3
	2. How much do you agree or disagree with the following statement? "If I received this message, I would think that I might experience heat-related illness tomorrow (such as dehydration, heat exhaustion, or heat stroke)."				
Behavioral intention[d] (Cronbach's alpha = 0.69)	1. If you received this message, how likely would you be to spend time in air-conditioned buildings (either at home or elsewhere) tomorrow?	1383	1 ~ 4	3.52 (0.60)	3.67
	2. If you received this message, how likely would you be to drink plenty of fluids to stay hydrated tomorrow?				
	3. If you received this message, how likely would you be to avoid strenuous outdoor activities during the hottest parts of the day tomorrow?				

[a]Response options of perceived message relevance and perceived susceptibility: 1 (Strongly disagree); 2 (Somewhat disagree); 3 (Neither agree nor disagree); 4 (Somewhat agree); 5 (Strongly agree); NA (Don't know)

[b]Response options of belief and behavioral intention: 1 (Very unlikely); 2 (Somewhat unlikely); 3 (Somewhat likely); 4 (Very likely); NA (Don't know)

[c,d]Scale construction for perceived susceptibility and behavioral intention: the intraindividual mean of non-missing survey items

3 Results

Means and standard deviations for each treatment group are shown in Table 4 for each outcome. The results of ANOVA indicated that perception of message relevance was statistically significantly different among participants viewing the subgroup, anyone, anyone + subgroup, and no depicted susceptibility statements, $F(3, 1370) = 3.52$, $p = 0.015$. Post-hoc comparisons using the Tukey's HSD test indicated that participants who read messages mentioning the anyone statement ($M = 3.95$, SD = 1.11) perceived the message as more personally relevant than participants who read messages mentioning the subgroup statement ($M = 3.68$, SD = 1.14, $p = 0.011$). The Hedges' g of the difference was 0.24, indicating a small effect size. The Tukey's HSD test did not find other pairs of statement types that resulted in statistically significantly different perception of message relevance. Unadjusted pairwise t tests suggested another two pairs of treatment types that tended to produce differences in perceived message relevance. Participants who viewed messages with the subgroup statement ($M = 3.68$, SD = 1.14) reported lower perceived message relevance than participants who viewed messages with the no depicted susceptibility statement ($M = 3.86$, SD = 1.06, $p = 0.034$, Hedges' $g = 0.17$). The differences in perceived message relevance between the anyone statement condition ($M = 3.95$, SD = 1.11) and the anyone + subgroup statement condition (M = 3.78, SD = 1.18, $p = 0.050$, Hedges' $g = 0.15$) approached statistical significance.

For other outcome variables, the results of ANOVA indicated that participants viewing different statement types did not have statistically significantly different belief in the hazard happening, $F(3, 1370) = 1.50$, $p = 0.213$, perceived susceptibility to heat-health impacts, $F(3, 1380) = 0.72$, $p = 0.538$, and behavioral intention to protect themselves from heat-health problems, $F(3, 1379) = 0.25$, $p = 0.860$. Unadjusted pairwise t tests found that, compared to the subgroup statement ($M = 3.58$, SD = 0.67), the anyone + subgroup statement ($M = 3.46$, SD = 0.85, $p = 0.041$, Hedges' $g = 0.15$) resulted in a lower degree of belief that the extreme heat event warned about in the message will actually occur. Unadjusted pairwise t tests found no other differences that were statistically significant or approached statistical significance.

Table 4 Means of outcome variables by experimental conditions

Outcome variable	Subgroup statement		Anyone statement		Anyone + subgroup statement		No depicted susceptibility	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Perceived message relevance	**3.68**[a]	1.14	**3.95**[b]	1.11	3.78[ab]	1.18	3.86[b]	1.06
Belief	3.58[a]	0.67	3.55[ab]	0.74	3.46[b]	0.85	3.52[ab]	0.78
Perceived susceptibility	2.95[a]	1.16	3.04[a]	1.19	2.91[a]	1.17	2.96[a]	1.19
Behavioral intention	3.53[a]	0.60	3.53[a]	0.58	3.50[a]	0.60	3.51[a]	0.62

Means in bold are statistically significantly different which are determined by Tukey's HSD tests ($p < 0.05$). The only pair of means in bold had a small magnitude of difference (Hedges' $g = 0.24$)

Statistically significant differences determined by unadjusted p-values are also reported using superscripts

[a,b]In the same row, means not sharing a common superscript letter are statistically significantly different from each other (pairwise t tests with pooled SD, $p < 0.05$). The difference in perceived message relevance between the anyone statement and the anyone + subgroup statement approached statistical significance (unadjusted $p = 0.050$)

4 Discussion

Findings in this exploratory experiment provide two insights into how to effectively communicate heat risk susceptibility with the general public. The first insight is that mentions of vulnerable subgroups appear to be not only a less effective strategy but also a detrimental strategy when it comes to making heat warning messages personally relevant to the public. We found that messages mentioning the subgroup statement were perceived as less personally relevant than messages mentioning the anyone statement. Furthermore, message relevance ratings of the subgroup statement were even lower than those of the placebo treatment (the no depicted susceptibility statement) suggesting a detrimental effect of mentioning vulnerable subgroups on perceived message relevance. Perceived message relevance is an important metric of message success. In an era of information explosion, receiving heat risk messages does not necessarily mean paying attention to the content of the messages especially during a prolonged period of extreme heat. A perception of "the message is meant for me" makes people more likely to attend to the message and process the information thoughtfully (Petty et al. 1981; Bargh 1982).

The second insight is that mentioning the combined statement (i.e., the anyone + subgroup statement) does not increase effectiveness more than mentioning the anyone statement and the subgroup statement separately. Moreover, the combined statement was inferior to its parts in some ways. On the one hand, compared with the anyone statement, the anyone + subgroup statement produced lower ratings of message relevance, albeit with only marginal statistical significance (unadjusted $p = 0.050$). This difference suggested that the negative effect of mentioning vulnerable subgroups on people's evaluation of message relevance still holds true when messages mention an "anyone can be at risk" statement simultaneously. On the other hand, compared with the subgroup statement, the anyone + subgroup statement produced lower ratings of belief that the extreme heat event warned about in the message will actually occur. There are two possible explanations of this difference. The anyone + subgroup statement depicted two aspects of susceptibility together which may have made the message seem overblown, or the two aspects of the anyone + subgroup statement may seem contradictory to each other. In either case, a negative spillover effect is possible on whether recipients believe the warning is real or not. Beyond the four differences mentioned in these two paragraphs, we found no other differences between each pair of treatments in our four outcome variables.

Different types of depicted susceptibility produced similar perceived susceptibility and behavioral intention to protect oneself. Based on a post hoc analysis about treatment effects in each age group (see Online Resource 3 for details), we suspected that heterogeneous treatment effects by age group may exist for these two outcome variables and may partly explain why we found no average treatment effect on perceived susceptibility and on behavioral intention with the whole dataset. For example, although the anyone and anyone + subgroup statements produced similar behavioral intention in the main analysis, the relative effects of this pair of treatments varied by age group in the post hoc analysis. Specifically, we found that young people aged 18 to 29 were more responsive to the anyone statement, but people aged 30 to 44 were more responsive to the anyone + subgroup statement. The two differences in behavioral intention were statistically significant (unadjusted $p < 0.05$, Hedges' $g > 0.3$) but in an opposite direction. For people aged 45 to 60 and people over 60, this pair of treatments resulted in similar behavioral intention. Although treatment effect heterogeneity was outside the scope of this study, such preliminary analysis helps us interpret our results.

The magnitudes of the differences in this study were not large but still theoretically and practically meaningful. The difference between the subgroup statement and the anyone statement in perceived message relevance was the only statistically significant difference determined by the Turkey HSD test and its effect size was Hedges' $g = 0.24$. The other three differences were determined by unadjusted pairwise t tests and their effect sizes ranged from $g = 0.15$ to $g = 0.17$. These effect sizes are comparable to those in previous experimental studies about health communication. For example, compared with messages mentioning the loss of not taking a behavior (loss-framed messages), messages mentioning the benefits of taking a behavior (gain-framed messages) are more effective in promoting illness prevention behavior with a mean effect size of Cohen's $d = 0.17$ (Gallagher and Updegraff 2011). According to another meta-analysis, computer-delivered interventions improve attitude and intention of taking healthy behavior with an effect size of $d = 0.23$ and $d = 0.18$ respectively (Portnoy et al. 2008). In our study, the effect sizes were measured by Hedges' g instead of Cohen's d. However, as long as sample sizes are larger than 20, these two measures produce approximately the same values (Lakens 2013). This statement was confirmed after we checked respective Cohen's d values in this study. According to the commonly used threshold for small effect sizes, $d = 0.2$ (Cohen 1988), only one difference in this study had a small effect size and others had effect sizes less than small. However, these effect sizes can be practically meaningful since the messaging variations tested in this study are cost-effective and easy to implement on a large scale (Litschge et al. 2010).

4.1 Contributions to theory and practice

This study contributes to risk communication literature in two ways. First, this study shows how risk messaging about natural hazards can be informed by established persuasive messaging strategies in other communication contexts. Traditionally, "good" risk messages about natural hazards are mainly informative messages which faithfully describe the risk with specificity, accuracy, and clarity (Mileti and Sorensen 1990; Reynolds and Seeger 2005; Demeritt and Nobert 2014). Research in this tradition often implicitly assumes that technical information about the risk, by itself, is sufficient to change the attitudes and behaviors of message recipients (Demeritt and Nobert 2014). In contrast, "good" risk messages in the field of health communication are mainly persuasive messages which strategically describe the risk with a closer attention to the interaction between technical risk information and social psychological factors of message recipients (Reynolds and Seeger 2005; Demeritt and Nobert 2014). These differences may explain why depicted susceptibility has been widely acknowledged as a persuasive messaging strategy in health communication literature but has drawn little research attention in the field of natural hazard communication. Our prior work adapted depicted susceptibility as a persuasive device to the context of natural hazards (Li et al. 2021), and the current study empirically compared the effectiveness of statements that vary in depicted susceptibility to heat-health impacts. This study highlights the potential of depicted susceptibility to inform weather risk messaging by showing that different ways to depict people's susceptibility to heat-health impacts result in differences in people's perception of message relevance or belief in hazard happening.

Second, this study advances understanding about how to effectively depict people's susceptibility by comparing under-examined pairs of statements. Although there have been prior studies comparing statements that vary in depicted susceptibility, pairs of statements compared in this study have drawn little research attention even in the context of health communication. There are two possible reasons. On the one hand, past experiments in health communication

literature usually use subpopulations, instead of the general public, as the target audience. On the other hand, for most past experiments, the purpose of designing statements that vary in depicted susceptibility is to manipulate perceived susceptibility and then test how different levels of perceived susceptibility influence people's responses to messages (Witte 1993; So et al. 2016). This may explain why pairs of statements in past experiments usually demonstrate clear variations in levels of depicted susceptibility, which means it is easy to tell which statement depicts the target audience as more susceptible than the other statement (see introduction section for detailed explanation about levels of depicted susceptibility). However, since the treatment design in the current study was problem-driven instead of theory-driven, this study compared statements with competing levels of depicted susceptibility and used the general public as the intended audience. For instance, the relative levels of the subgroup statement and the anyone statement are also not clear, since their relative levels depend on the share of vulnerable subgroups in the general public and how people who belong to vulnerable subgroups perceive the pair of statements. Our findings about these under-examined pairs of statements advance understanding of how to effectively depict people's susceptibility when the intended audience is the general public.

Our findings also provide practical implications for risk messaging when risk messages aim to reach the general public. Our findings support the reconsideration of mentioning vulnerable populations in heat risk messages (Sampson et al. 2013) since the presence of such subgroup statements reduced people's perception of message relevance. The "anyone can be at risk" statement appears to be a good substitution as expected (Sampson et al. 2013) because this alternative statement made messages more relevant and performed similarly in other outcome aspects evaluated in this study. In addition, the "more is worse" insight implies that practitioners should reconsider the adoption of the anyone + subgroup statement in official heat risk communication. The combined statement performed worse than the subgroup statement in influencing whether people believe the warning is real and worse than the anyone statement in influencing whether people think the warning is personally relevant. Although the full messages in our experiments were graphic messages, the hypothetical situation did not specify a communication channel and our treatments were textual information. Thus, the practical implications of our findings do not restrict to a certain communication channel and may be applicable across channels such as television and social media. Our findings could also have implications for risk messaging in other contexts such as infectious disease epidemics when the intended audience of risk messages is not only certain vulnerable subgroups but also the general public.

4.2 Limitations and future research

Our exploratory experiment had several limitations. Firstly, this experiment was conducted in the early November, which was in autumn for our participants. Similar to most previous experiments about message testing in the context of natural hazards (Morss et al. 2018; Potter et al. 2018; Sutton et al. 2018), a hypothetical hazardous event was presented to participants in this study (see Online Resource 2 for the description). The hypothetical extreme heat event may have seemed artificial for our participants because they were outside the summer season. The lack of realism might reduce external validity of this experiment because how our participants responded in this hypothetical situation may not be generalizable to real-world extreme heat events. To enhance external validity of our findings, future studies should investigate the effects of depicted susceptibility to heat-health impacts during ongoing extreme heat events and in field settings (e.g., a real-world environment where people may be vulnerable to heat).

Secondly, our experiment used an online convenience sample. Although our sample was similar to the general population in terms of sex, age, race/ethnicity, and income, our participants were more educated than the general public. In addition, it is unknown if our participants were representative of people with chronic diseases and outdoor workers since we did not ask these specific demographic questions in our study. Although average treatment effects estimated using nationally representative samples were very similar to those estimated using online convenience samples in many social science survey experiments (Coppock et al. 2018), future studies should replicate the current experiment using representative samples to know if our results are also generalizable to the general public. Although the first and second limitations affected external validity of our study, they had little impact on internal validity.

Thirdly, our experiment did not examine actual behavior as an outcome. Although our outcome variables (perceived message relevance, belief in the hazard happening, perceived susceptibility and behavioral intention) could have theoretical and practical implications, actual behavior is a critical outcome to determine practical benefits of messaging strategies. The lack of effects on perceived susceptibility and behavioral intention in our study does not necessarily mean a lack of effects on actual behavior, since these two outcomes may not always well predict behavior. For example, a meta-analysis about gain- and loss-framed messages found that message framing promoted illness prevention behavior but had no effect on attitude and behavioral intention (Gallagher and Updegraff 2011). To better realize practical benefits, future studies should investigate the effects of different types of depicted susceptibility on people's self-reported or objective behavior to protect oneself. In addition, future studies should also examine actual behavior of checking on others and self-reported heat-health symptoms as outcomes in order to get a more comprehensive understanding about how to effectively depict people's susceptibility in heat risk messages.

Given the exploratory nature of this experiment, our findings should be tested and replicated in future rigorous studies in order to provide strong evidence for theory and practice. Future studies should prioritize testing the difference between the subgroup and anyone statements in perceived message relevance, since this finding had lower statistical uncertainty and larger effect size. In addition, future studies should investigate how and why the relative effectiveness of susceptibility statements varies by age group. Such studies will benefit heat risk messaging especially when its intended audience is not the general public but people in a certain age group.

5 Conclusion

Extreme heat is an under-examined hazard in natural hazard risk communication despite its relatively severe and widespread impacts on public health. This study contributes to the risk communication literature by empirically comparing the effectiveness of different statements about people's susceptibility to extreme heat and showing how to make heat risk messages personally relevant to the general public. Our findings support the reconsideration of listing vulnerable subgroups in heat risk messages since the targeted approach has negative effects on people's perception of message relevance. Rather than listing specific vulnerable subgroups, a universal message that anyone can be at risk can be a good substitution, as expected. Practitioners should also be cautious about combining the subgroup and anyone statements in one message because the combined statement appears to be worse than its parts in influencing people's perceived message

relevance or belief in the hazard happening. Given the exploratory nature of this experiment, future research with lower methodological uncertainties is needed to test our findings about heat risk messaging. Our findings provide insights into how to effectively communicate people's susceptibility about extreme heat and from which new discoveries might be inspired in the broader domains of natural hazard risk communication and public health communication.

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Declarations

Conflict of interest No potential conflict of interest was reported by the authors. This research was approved by the Utah State University Institutional Review Board (The Protocol Number is 9708).

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