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Message Design Matters: An Experiment on Portrayal of Protective Action Guidance in Warning Messages for Three Hazards

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Abstract

Risk communicators play a crucial role in informing individuals about approaching hazards and guiding them on how to respond effectively during different phases of disaster communication. Protective action guidance has been defined as the information people need to inform them of what to do to protect themselves in the face of a hazardous situation. However, many social media messages disseminated by the National Weather Service do not include protective action guidance. Scholars have called for more research on the portrayal of protective action guidance in a message to prove which design best imparts protective action knowledge. To answer this call, a researcher-developed conceptual framework was used to explore how four portrayals of protective action guidance influence knowledge of protective actions (i.e., protective action literacy). We first describe individuals' perceptions of the appropriate protective actions to take when either a dust storm, snow squall, or tornado is approaching. Then, we report on changes in protective action literacy after exposure to a series of hazard warning messages with varying portrayals of protective action guidance. The study's results reveal important insights regarding the influence of protective action guidance portrayal in warning messages on participants' protective action literacy. Participants' understanding of appropriate protective actions varied across hazards and was influenced by message type. This research highlights the importance of evidence-based message design, the need for comprehensive guidance for all hazards, and the role of agricultural communication in disaster preparedness. The study's findings can inform more effective disaster communication strategies and guide future research.

Keywords

Hazard communication, message design, protective action guidance, weather alerts, snow squall, tornado, dust storm

Cover Page Footnote/Acknowledgements

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Introduction and Literature Review

As part of a changing climate, severe weather events have increased in frequency, increasing 11% from 2018 to 2022 alone (NOAA, 2023). Severe weather events can cause loss of property and life as well as bodily harm. According to the National Safety Council and National Oceanic Atmospheric Administration, in 2022 alone, heat-related weather caused 180 deaths, winter weather caused 159 deaths, and flooding caused 93 deaths (NSC, 2023; NOAA, 2023). In 2021, unprecedented winter cold killed 262 people, with 210 just in the state of Texas. When considering injuries rather than deaths, the numbers are even higher. As severe weather events approach, disaster, hazard, and other risk communicators (e.g., Extension, the National Weather Service, and FEMA) work to inform individuals of the approaching hazard and how to properly respond to minimize loss of life and prevent bodily harm. According to the Federal Emergency Management Agency (FEMA), there are four stages of disaster communication: mitigation, preparedness, response, and recovery (FEMA, n.d.-a), each of which corresponds with specific communication objectives and practices.

Within agricultural and natural resources communications, scholars have investigated disaster, hazard, and severe weather communications in various phases of the disaster timeline. For example, Mike et al. (2020) examined Florida Extension's communication during the preparation, response, and recovery phases of the 2017 hurricane season and called for more research on disaster communication strategies. Ali et al. (2020) specifically examined Florida Extension directors' communication after Hurricane Irma in 2017 and called for increased relationships between Extension and disaster agencies during the recovery phase. Additionally, Ruth et al. (2020) explored public agency communication practices on Twitter during the recovery phase following Hurricane Michael.

These studies highlight recommendations to expand the scope of communication research to include more research on disaster communication and to focus on the under-investigated phase of preparedness. Fischer et al. (2022) also indicated there is a disciplinary need within agricultural communication for organizations like Extension with local expertise to help prepare at-risk individuals by alerting them to the approaching hazard and providing directions on how to take the appropriate actions (i.e., the end of the preparedness and beginning of response phases). FEMA (n.d.-b) refers to these directions as protective actions, which are "research-validated advice that anyone can take to prepare for, keep safe during, and recover from a disaster" (para. 1). Currently, FEMA provides this evidence-based protective action guidance for fifteen hazards, such as winter storms, tornadoes, earthquakes, hurricanes, and wildfires. However, they do not include recommendations for what to do during a dust storm. Notably, in May of 2023, six people were killed in Illinois in a 72-car pileup caused by a dust storm (Foster et al., 2023).

Current Communication by the NWS

To warn people of an approaching hazard, organizations such as FEMA, the National Weather Service, and Extension deliver protective action guidance to those in the geographic area at risk. These are communicated via television, radio, websites, and social media. As an example, the National Weather Service delivers warnings throughout the country using local Weather Forecast Office Twitter (X) accounts (NWS, n.d.-c).

Mileti and Sorensen (1990) determined warning messages should include information about the hazard, protective action guidance (i.e., what people should do to protect themselves), the location of the threat, time of arrival, and message source in order to have the largest intended effect. However, many of the social media messages disseminated by the National Weather Service do not include protective action guidance, despite its understood importance. For instance, Sutton and Fischer (2021) found that individuals exposed to a tweet containing a tornado warning message said in think-aloud interviews that they desired protective action guidance to tell them not only what the hazard is but what they should do to protect themselves. Building upon this research, Fischer et al. (2022) described how participants accurately recalled the type of hazard and its impact, but they also indicated they would tell others about the appropriate protective actions to take, despite those directions not being included in the message. Fischer et al. (2022) posited that this response, not cued by the message, may be related to their prior experience of the threat and related communication, making a cognitive connection between their preexisting knowledge of what to do to protect themselves and others and the approaching threat.

The study at hand advances this line of inquiry about the inclusion of protective action understanding and inclusion of guidance in a warning message. Here, we investigate what individuals believe to be the appropriate protective action before receiving an emergency message (i.e., preexisting knowledge) and how exposure to a series of messages with varying portrayals of protective action guidance influence protective action literacy post-exposure.

Conceptual Framework: Evidence-Based Message Design

Inherently, messages have limited “real estate,” and message designers must make inclusion decisions related to the most effective use of message space. Tweets, like the ones delivered by the NWS’s local Weather Forecast Office accounts (NWS, n.d.-c), have limited space for a photo or graphic as well as text limitations in which to deliver potentially lifesaving information. Message design is indeed a top priority for all strategic communicators working toward a behavior change, based on the understanding that certain message aspects (e.g., content, graphics, and layout) influence message processing and recall (O’Keefe, 2016). For organizations such as Extension, NWS, FEMA, and others determined to prevent harm, it is important that their messages are designed in a way so the public can understand and perform the correct protective action.

Evidence-based messages are those that have been scrutinized in an experimental setting to measure the level of relative influence message exposure has on a dependent variable, thus providing evidence to their effects rather than being based on intuition (O’Keefe, 2016). In fact, practitioners are increasingly urged to use evidence-based messages to increase the likelihood of desired effects (Harrington, 2015). Within agricultural communications, experiments are often conducted to understand message effects to inform future strategic messaging. For example, Ruth and Rumble (2019) experimented with eight messages portraying various viewpoints toward genetically modified foods to inform related education and communication. Holt et al. (2015) varied the channel of a message about local food to understand which channel was most preferred by Florida consumers.

In order to provide evidence-based messaging recommendations for warnings around three hazards, we assembled a conceptual framework to operationalize key constructs of interest in our experimental investigation. The framework provided a review of the literature to understand an individual’s protective action literacy, a major goal of the NWS, and how effective messaging can impact protective action literacy. To examine messaging, we applied the concept of message features, which has been utilized to examine how components of messages are designed to elicit the desired effects (Shen & Bigsby, 2013).

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Protective Action Guidance and Literacy

Prior research (Fischer et al., 2022; Sutton & Fischer, 2021) has shown that protective action guidance should be included in warnings to instruct individuals how to take the appropriate hazard-related actions. Therefore, experimental message testing research should examine multiple potential versions of protective action guidance portrayal to determine relative effects on individuals' protective action literacy (i.e., their understanding of the correct protective actions to take). These findings can reveal which portrayal has the stronger desired effect and inform impactful messaging. We employed Mileti and Sorensen's (1990) definition of protective action guidance both when manipulating the message and when describing participants' protective action knowledge prior to message exposure. We operationalized participants' responses as their protective action literacy, or how their perceived knowledge of hazard-appropriate protective actions aligns with FEMA's recommendations (FEMA, n.d.-b).

Just as practitioners want to use evidence-based methods, the protective action guidance itself should be based on research to ensure that the action has a significant positive impact on safety. FEMA provides a rating of their own protective action guidance statements to assess their validity based on scientific research. These ratings are "robust/sufficient, not robust/conditional, and insufficient" (FEMA, n.d.-b). For two of the three hazards in the study at hand (snow and tornado), FEMA provides protective action guidance that is rated as robust/sufficient by their own standards. However, for the dust hazard, FEMA does not provide protective action guidance. Instead, the dust hazard protective action statements were informed by the NWS (n.d.-b) safety tips for dust storms. To date, there are no evidence-based recommendations provided by FEMA for appropriate protective actions during a dust storm.

Message Features

To operationalize the message variations and understand which portrayal of protective action guidance had the largest impact on protective action literacy, we utilized Shen and Bigsby's (2013) conceptual framework on message features, including *content*, *structure*, and *style*. *Content* is defined as what the message says, or the information represented in the message (Shen & Bigsby, 2013). The content for the messages under examination are the protective action guidance statements, which did not vary between messages. The *structure* of the message refers to the layout, format, and presentation of the message, which was the variable of interest in this experiment (Shen & Bigsby, 2013). The *style* feature represents the linguistic style used to present information, including message framing, tone, and the use of metaphors and other linguistic choices (Shen & Bigsby, 2013). Broadly, this approach has been used to operationalize message features across health communication and persuasion research (Capella & Li, 2023; Harrington, 2016). Previous agricultural communications scholars have also utilized this framework to dissect a message's design (Fischer et al., 2021) and to test messages during the onset of a disaster (Fischer et al., 2022; Sutton & Fischer, 2021).

Our experiment included four versions of Twitter warning messages, where the *structure* (i.e., layout) is manipulated, portraying protective action guidance either nowhere (*control*), in the *text*, *graphic*, or *both* text and graphic. O'Keefe (2014) also urged scholarship to vary message features and experiment with the portrayal of information on relative effects. It is important for message developers to include and portray protective action guidance in a way that the public can understand, recall, and use. Pragmatic research endeavors such as this should also consider real-world use, so this study utilized four manipulations of an actual message distributed by NWS via social media accounts, like Twitter.

Purpose

The current study evaluated how protective action literacy is affected by Twitter warning messages for three unique hazards, that varied the inclusion of protective action guidance. Our overarching aim for this study was to examine the participants' protective action literacy before and after receiving a Twitter warning message and to determine to what extent the presentation of protective action guidance influenced their protective action literacy. To do so, we addressed the following research objectives:

> **RO1**: Describe which protective actions participants knew prior to receiving a Twitter warning message and describe which protective actions participants knew after receiving a Twitter warning.
>
> **RO2:** Examine if the type of message the participants were exposed to (*control*, *graphic*, *text*, and *both*) affected their post-test protective action literacy.

Methods

Research Design

To address the research objectives, this study employed a pre-, post-test 3 (hazard type) x 4 (message structure) between-subjects experiment. The aim of the pre and post-test was to understand the participants' protective action literacy before and after receiving a message and served as a repeated measures variable. Protective action literacy was measured using open-ended questions, which were coded using a deductive approach.

The participants were randomly assigned to view one of 12 messages. We used a 3 (hazard type) x 4 (message structure) between-subjects factorial to determine message randomization. *Hazard type* refers to the type of hazard presented in the message: dust storm, snow squall, or tornado. *Message structure* refers to how protective action guidance was included in the message: protective action guidance only in the text (i.e., only in the Tweet's caption), protective action guidance only in the graphic (i.e., the image uploaded with the Tweet), or in protective action guidance included in both places. Our four message types were as follows: 1) the *control*, or 'standard practice,' message that did not include protective action guidance anywhere in the message, 2) the enhanced *graphic* message, which included protective action guidance next to an icon in the graphic portion of the message, 3) the enhanced *text* message, which included protective action only in the text caption of the message, and 4) the *both* message, which included protective action in the text caption and graphic portion of the message. Following the repeated measure post-test question, the participants answered questions related to their demographic information. The data reported in this manuscript are part of a larger study and were analyzed independently from the additional data.

Participants

We utilized a Qualtrics Market Research Panel to collect data from 1,050 adult participants to obtain a non-probability, opt-in sample of residents from Atlanta, Georgia; Buffalo, New York; and Phoenix, Arizona. These three cities were chosen because they had all previously received an NWS hazard warning message (tornado in Atlanta, snow squall in Buffalo, and dust storm in Phoenix). Qualtrics verified unique responses through digital fingerprints and IP checks. The sample consisted of an approximately equal distribution of respondents from each hazard for a final sample size of N = 1,044 (i.e., n = 362, 35% in Atlanta;

n = 323, 31% in Buffalo, and *n* = 359, 34% in Phoenix), which was verified by ZIP code identifiers. In addition to sourcing participants from specific geographic regions who had experienced the hazard previously, we developed quotas for the sample to represent census demographic information for age (age 18-34: 30%; 35-54: 32%; and 55+: 38%) and gender (identified as a man: approximately 50% and identified as a woman: approximately 50%). Respondents who did not match these quotas were disqualified and removed from the study. Table 1 describes the demographic characteristics of our sample.

Table 1
Demographic Characteristics of the Respondents

Demographic Variable	*f*	%
Age		
18-34	350	33%
35-54	350	34%
55+	350	33%
Ethnicity		
White	662	63%
Black or African American	246	23%
Asian/Asian-American	21	2%
Native American/Pacific Islander	11	1%
Other	26	3%
Hispanic/Latino/Spanish	82	8%
Gender		
Man	500	48%
Woman	529	50%
Non-binary / Prefer not to say	21	2%
Income		
Less than $25,000	241	23%
$25,000 - $49,999	314	30%
$50,000 - $74,999	206	19%
$75,000 - $99,999	113	11%
$100,000 - $124,999	66	6%
$125,000 or more	82	8%
Don’t know/Prefer not to answer	28	3%

Pre and Post-Test Protective Action Literacy

Before exposure to the message, participants were asked, *“Thinking about what you know about [hazard], what actions should a person take to protect themselves or others when exposed to a [hazard]?”* with an open-ended text box provided. After message exposure, participants were asked the same question again. An open-ended response format was chosen to better capture participants' working understanding (i.e., literacy) of relevant protective actions before and after exposure, rather than providing a pre-set list that could inadvertently prompt or remind them. Although quantitative measures may be more reliable, using predefined quantitative measures in this study posed a potential threat to external or ecological validity, as real-world weather alert processing occurs without protective action prompts. In such situations, individuals must retrieve appropriate responses from their own working memory, mirroring actual decision-making conditions more accurately. Additionally, a recall- or memory-based scenario was not desirable for these objectives, which sought to ascertain if those exposed knew the correct action to take before and after exposure (e.g., literacy; what to *do*) rather than if they could simply recall a feature of the message. The qualitative approach also captures thought processes, decision-making, and gaps in understanding, which revealed multiple actions *not* included in the message, both before and after exposure, which have proved to be more limited in a quantitative recall scenario (Höhne, 2022). Cued or assisted recall (i.e., giving participants a list of items or suggestions) does not capture the depth of conceptual understanding, and this study strived to go beyond memory retention and into actionability—can those who receive this message take the correct action?

Pre and Post-Test Protective Action Literacy Data Analysis

The researchers first performed a quantitative content analysis on the pre and post open-ended responses. To do so, we created a codebook based on protective actions for each hazard type, following recommendations from Krippendorf (2004). The codebook categories were informed by FEMA recommendations for protective action, except for the dust categories which were informed by NWS current messaging practices. An initial codebook was used to code a 10% sample of the responses for each hazard, during which the coders identified emerging themes that were unique to each hazard (i.e., protective actions common in the sample but not included in FEMA's recommendations). These new categories were added before attempting to reach intercoder reliability. To establish reliability of the codebook, two coders used the proposed codebook to independently score a 10% sample of responses from each hazard (Krippendorf, 2004).

Using an online reliability calculator called ReCal2 (Freelon, n.d.), Krippendorf's alpha of 0.80 was reached for each variable (Krippendorf, 2004), after which the lead author coded the remaining sample. The Excel codebook included a variable for each action, and participants were given a "1" for each one mentioned to calculate frequencies.

Experimental Design Component

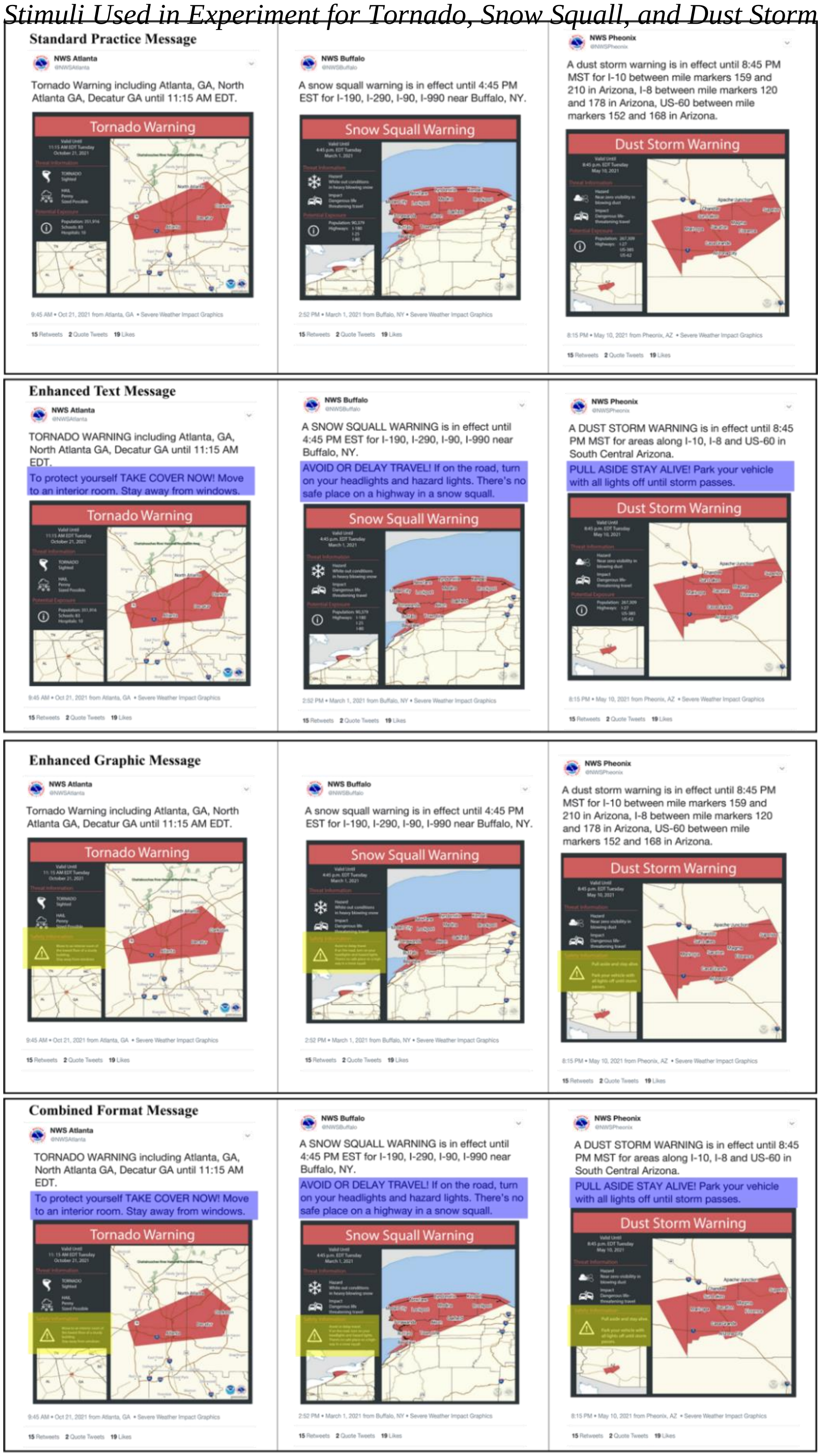
To conduct the experimental design component of this study, the participants were exposed to a message that varied by hazard and message type.

Hazard Type. Hazard type refers to the type of hazard included in the message: dust storm, snow squall, or tornado. These three hazards were selected because they were part of NWS's hazard warning alerts and lacked protective action guidance.

Message Structure. Message structure refers to how protective action guidance was included in the message. The *control* for the experimental design component of this study were messages that were 'standard practice' and distributed in each of the locations by the National Weather Service. The *control* messages did not include protective action guidance. As seen in Figure 1, the *e*nhanced *text* refers to the inclusion of protective action guidance within the text component of the message (blue shading), the enhanced *graphic* refers to the inclusion of protective action guidance within the graphic component of the message (yellow shading), and the *both*, or enhanced graphic and text message, refers to the message with the protective action guidance within the text and graphic of the message. The protective action guidance statements came from recommendations from FEMA and the NWS.

Figure 1

Stimuli Used in Experiment for Tornado, Snow Squall, and Dust Storm



Data Analysis

Using SPSS version 29, we first examined the frequencies and percentages of the pre- and post-test protective action literacy. After, we conducted a series of Analyses of Variance (ANOVAs) on the frequency totals to understand the differences in post exposure protective action literacy by message type followed by Bonferonni post hoc comparisons to reveal specific significant differences. Effect sizes were interpreted by the classifications of Cohen (1988).

Results

RO1: Describe which protective actions participants knew prior to receiving a Twitter warning message and describe which protective actions participants knew after receiving a Twitter warning.

In response to the first research objective, we present the coded responses for the protective actions participants knew prior to viewing their assigned message and after viewing their assigned message. Table 2 contains these frequencies and the percentage based on the number of participants in each hazard group.

Table 2

Frequencies and percentages of responses from open ended pre and post protective action questions for each of the three hazards (N =1044)

Hazard	Protective action response	Pre		Post	
		f	%	*f*	%
Dust (*n* = 359)	Stay indoors; hide; take shelter	225	62.67	203	56.55
	Cover nose and mouth; don't breathe in dust; wear mask or goggles	76	21.17	41	11.42
	Close/ avoid windows, doors, and vents	68	18.94	33	9.19
	I don't know	40	11.14	18	7.8
	Pull aside[a]	**38**	**10.58**	**110**	**30.64**
	Have and enact emergency/safety plan	17	4.74	10	5.01
	Prepare outside of home	17	4.74	9	2.79
	Turn off headlights[b]	**10**	**2.79**	**47**	**13.09**
	Stay off roads	10	2.79	22	6.13
	Make sure brake lights are not illuminated[b]	**9**	**2.51**	**11**	**3.06**
	Set emergency brake[b]	**3**	**0.84**	**2**	**0.56**
	Check news/expert guidance	1	0.28	28	2.51
Snow (*n* = 323)	Stay indoors; limit time outside	144	44.58	149	46.13
	Be prepared (e.g., food, water, power alternatives)	95	29.41	43	13.31
	I don't know.	47	14.55	18	5.57
	Avoid travel[a]	**42**	**13**	**98**	**30.34**
	Cover exposed parts of body; wear warm/layered clothing	37	11.46	27	8.36
	Have and enact emergency/safety plan	14	4.33	6	1.86

	Pull over and stay in vehicle if driving	12	3.72	23	7.12
	Turn on headlights/hazards[a]	**10**	**3.1**	**33**	**10.22**
	Slow down if driving	6	1.86	13	4.02
	Check news/expert guidance	6	1.86	33	10.22
	Avoid carbon monoxide poisoning by not using generators, camp stoves, etc. indoors	1	0.31	1	0.31
Tornado (*n* = 362)	**Take cover** (e.g. closet/bathroom/bottom floor, basement, small room, tornado shelter, etc.)[a]	**277**	**76.52**	**271**	**74.86**
	Avoid windows[a]	**59**	**16.3**	**107**	**29.56**
	Have and enact emergency/safety plan	40	11.05	21	5.8
	I don’t know	15	4.14	10	2.76
	Cover yourself with coat, blanket, mattress, etc.	14	3.87	18	4.97
	Check news/expert guidance	12	3.31	28	7.73
	If in mobile home, go to public shelter or a sturdy building	2	0.55	1	0.28

[a]These responses represent the statements directly included in the messages containing protective action guidance and were used in the subsequent analyses.
[b]These categories were kept separate in this table due to their distinct differences but were combined for subsequent analysis as “lights off,” as each are a separate action taken to make the vehicle totally dark.

Prior to viewing the dust messages, participants (*n* = 359) were most likely to respond that the appropriate protective action was to “take shelter,” (*f* = 225, 62.67%). This response decreased after exposure. “Cover nose and mouth” and “close windows, doors, and vents” also decreased after message exposure. In contrast, following exposure to the dust message statements such as “pull aside” and “turn off headlights” increased by 20.06% and 10.3% respectively. The responses annotated with a [b] in Table 2 were kept separate in this category due to their distinct differences but were combined for subsequent analysis as “lights off.”

Prior to receiving a snow squall message, respondents (*n* = 323) most frequently stated “stay indoors” was an important protective action (*n* = 144), which increased to 149. Following message exposure, two protective actions included in the message, “avoid travel” and “turn on headlights/hazards,” increased by 17.3% and 7.1% respectively. The response of “check news and expert guidance” also increased after exposure.

Prior to exposure to the tornado message, participants (*n* = 362) included the protective action “take cover” most frequently (76.5%). This was followed by “avoid windows” (16.3%). Both of these actions were also included in the tornado text, graphic, and both message, and protective action literacy levels changed little between pre and post message exposure.

RO2: Examine if the type of message the participants were exposed to (control, graphic, text, and both) affected their post-test protective action literacy.

Research objective two sought to understand differences in participants’ post-test protective action scores after exposure to either the control, graphic, text, or both messages for one of the three hazards through an ANOVA of post-test protective action frequency totals. The results of the ANOVA, means, and standard deviations by condition are presented in Table 3.

Table 3
ANOVAs for message condition (N = 1044)

Hazard & Protective Action	Control		Graphic		Text		Both		*MS*	*F*	*p*	η^2
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*				
Dust (*n* = 359)												
Pull aside	.16	.37	.31	.47	.36	.48	.39	.49	.83	3.98	.008*	.033
All lights off	.08	.41	.17	.43	.15	.46	.28	.53	.53	2.55	.056	.021
Snow (*n* = 323)												
Avoid travel	.22	.42	.29	.46	.43	.52	.28	.45	.60	2.80	.040*	.026
Turn on headlight s/hazards	.01	.11	.09	.29	.16	.37	.15	.36	.35	3.83	.010*	.035
Tornado (*n* = 362)												
Take cover	.78	.42	.74	.44	.68	.47	.80	.40	.26	1.39	.246	.011
Avoid windows	.15	.36	.23	.42	.43	.50	.50	.50	2.4	11.88	<.001	.091

Note. *Significant at the p<0.05 level

For the dust hazard's protective action statement of "pull aside," we found a main effect of message type on the protective action guidance, F(3,359) = 3.98, p = .008, η^2 = .03, a medium effect. Bonferroni post hoc comparisons revealed differences between the *control* (*M* = .16, *SD* = .37) and the *text* message (*M* = .36, *SD* = .48; *p* = 0.03), and the *control* and the *both* message (*M* = .39, SD = .49; *p* = .014). For the dust hazard's protective action statement of "all lights off," there was not a significant main effect based on message type, F(3,359) = 2.55, *p* = .056, η^2 = .021, a medium effect.

For the snow hazard's "avoid travel" post-test frequency, there was a significant main effect of message type on protective action guidance, F(3,323) = 2.80, p = .40, η^2 = .026, a medium effect. Bonfereroni post hoc comparisons revealed differences between the *control* (*M* = .22, *SD* = .42) and *text* (*M* = .43, *SD* = .52; *p* = 0.34). For "turn on headlights or hazard lights" there was a significant main effect of message type on the protective action guidance, F(3,323) = 3.83, *p* = .010, η^2 = .035, a medium effect. Bonferonni post hoc comparisons revealed differences between *control* (*M* = .01, *SD* = .11) and *text* (*M* = .16, *SD* = .37; *p* = 0.22) and *control* and *both* message (*M* = .15, *SD* = .36; *p* = .021)

For the tornado hazard, there was not a significant main effect of message type on "take cover" post-test frequencies, F(3,362) = 1.39, p = 2.46, η^2 = .011, a medium effect. However, there was a significant main effect of message type on the post-test "avoid windows" response, F(3,362) = 11.88, p < .001, η^2 = .091, a medium effect. Bonferonni post hoc comparisons revealed significant differences between *control* (*M* = .15, *SD* = .36) and *text* (*M* = .43, *SD* = .50; *p* < .001) and *control* and *both* (*M* = .50, *SD* = .50; *p* < .001).

Discussion, Conclusions, and Implications

The results describe what residents in three cities, Phoenix, Buffalo, and Atlanta, perceive to be the appropriate protective actions to take when a dust storm, snow squall, or tornado approaches, respectively. They also describe how these perceptions change after exposure to a warning message on Twitter with the protective action guidance portrayal varied.

Limitations

First, we explore the limitations of the study, which the reader should maintain while interpreting the discussion, conclusions, and recommendations. Fundamentally, it should be considered that the protective actions included in two of the messages used in the study were designed for those currently driving (see Figure 1), which may have influenced post-exposure responses. Additionally, the study did not control for possible covariates, such as participants' prior experience with social media or the hazards or their general graphic literacy, which could affect their understanding of the presented materials. Future work should consider controlling for these and other relevant covariates. As discussed in the methods, the qualitative approach does introduce limitations related to reliability, and we hope others build upon the qualitative foundation this study offers to measure these actions in a quantitative way. Finally, this study did not use a theoretical framework, and we further discuss potential theories that can be used in future work below alongside the other recommendations.

Dust

Before exposure to any of the dust messages, participants were most likely to respond that the appropriate protective action was to “take shelter,” which decreased in frequency post message exposure, likely because it was not in the message but was a common response identified among the sample. Frequencies also decreased post exposure for other higher frequency pre-exposure protective actions such as “cover nose and mouth” and “close windows, doors, and vents,” likely because they were also not included in the message. The protective actions included in the dust message were to “pull aside” and “turn all lights off” which both experienced increases.

Compared to the other two hazards, the dust storm is the only one where participants stated the NWS recommended protective action guidance (i.e., turn all lights off) among the least stated actions. Although it did increase after message exposure, this initial low frequency indicates the participants were generally unfamiliar with this practice. This may be related to the lack of specifications FEMA has about what to do in a dust storm. In fact, the protective action guidance to pull aside, stay alive, and turn off all lights has only been recommended as a “safety tip” by the National Weather Service (NWS, n.d.-b) rather than the evidence-based recommendations from FEMA, which they provide for the other hazards in the study (i.e., tornado and snow squall). NWS justifies the action by saying, “in the past, motorists driving in dust storms have pulled off the roadway, leaving lights on. Vehicles approaching from the rear and using the advance car's lights as a guide have inadvertently left the roadway and in some instances collided with the parked vehicle” (n.d.-b, para. 7). It seems participants could have been confused by advice such as “turn off lights” which could be rather unintuitive without the provided rationale.

Our results showed for both included protective action statements in the dust message (“pull aside” and “turn all lights off”), the *both* message portrayed protective action guidance in both the text and graphic areas of the message resulted in the highest post-exposure literacy.

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Therefore, when considering delivering emergency messages in advance of or during a dust storm, practitioners should consider including protective action guidance in the text and graphic areas of the message. Additionally, due to the recent road deaths caused by a dust storm (Foster et al., 2023) and the potential for dust storms to increase alongside other severe weather events, more research and ongoing public education should be done on the appropriate protective actions. A major call from this study is for FEMA to work toward research-based protective action guidance for dust storms, especially since participants did not initially identify “turn off lights” as the correct action, and the frequency of this response only increased for a small number of participants. Additionally, more research is needed on how to more effectively communicate and impart the recommended protective action of “turn off lights” in the constraints of message space.

Snow

Before exposure to any of the snow squall messages, participants identified many seemingly “common sense” actions to take when a snow squall is approaching, including staying indoors and being prepared. However, likely because the messages only included protective action guidance to “avoid travel” and “turn on headlights/hazards,” these were the statements that increased in frequency post exposure, suggesting the participants remembered the message content. Notably, the “I don’t know” response was highest for this hazard but did decrease after message exposure, suggesting the possibility that prior to snow squall message exposure participants had much more limited experience with this hazard. When looking at protective action literacy by message type, in contrast with the dust and tornado messages, the snow squall *text* message resulted in higher post-test scores than the other messages. These results indicate that participants were better able to remember the protective action literacy displayed only in the text, suggesting practitioners communicating during snow squalls should include protective action guidance in the text of the message. Because the *both* messages, which were most effective for the other two hazards, did contain protective action guidance in the text and graphic area, we recommend protective action guidance always be included in text.

Tornado

The results related to the tornado hazard show participants identified the correct protective action before message exposure more than the other hazards. In fact, the “take cover” response was the highest frequency for tornado and had the highest frequency of all the protective actions, showing most (77%) respondents already knew to take cover. “Avoid windows” was the second most stated action both before and after message exposure, similarly suggesting participants may have already been familiar with this protocol. “Avoid windows” did increase after exposure, again probably due to its inclusion in the stimuli. Similar to the dust message, the *both* message that included protective action guidance in the graphic and text resulted in the highest post-exposure scores of protective action literacy for the tornado group.

Overarching Conclusions & Recommendations

Interestingly, across all hazards and even though not included in the message, the response of “check news and expert guidance” increased after exposure, which was an unexpected but positive finding of the study. As Mileti and Sorensen (1990) posited, the source of the warning message should be included and was included in these messages as the NWS. Perhaps the message cued participants to want to stay informed by turning to agencies like the

NWS, an unintended but positive effect. Individuals could have felt the need to seek out more information beyond the tweet to stay informed through the duration of the hazard. Similarly, the response of "I don't know" went down across all hazards after exposure, which suggests the messages did fill some knowledge gaps.

Fischer et al. (2023) found the *both* message (i.e., that included protective action guidance in both text and graphic) inspired the highest level of recall for each hazard. While our results mirror this finding for the dust and tornado hazard, we found the *text* message (i.e., the message including protective action guidance only in the text) had the highest impact on protective action literacy for the snow squall. These findings suggest content that needs to be remembered, such as protective action guidance, should be portrayed in both the graphic and text areas of a tweet for maximum understanding. This could be due to the high contrast of the text compared to the graphic portrayal which may be harder to discern in a state of emergency. Additionally, the inclusion of the information in multiple areas may have had a priming effect, in which the guidance was more salient due to being viewed first at the top of the message and again further below (Tulving & Schacter, 1990). More research should investigate if inclusion of other types of content in the text and graphic areas of tweets produce desirable results. Additionally, future research should be done on protective action guidance inclusion in other formats (e.g., other social media platforms, television warnings, radio ads, etc.) to corroborate our findings and provide evidence-based messaging recommendations for these communication channels.

The study at hand utilized a conceptual framework to accomplish its pragmatic mission to describe current and post-exposure protective action literacy for three hazards. This study was designed to assess the influence of message design on protective action literacy (i.e., knowledge). Our conceptual framework was derived from understanding how persuasion scholars design or construct messages and how it impacts literacy levels. Based on the results of these findings, we have multiple ideas for future research. For example, future efforts should design these studies to quantitatively and theoretically measure recall. Specifically, future research should consider utilizing a message processing theory to understand the cognitive processes elicited from message exposure, as similar work by Ruth & Rumble (2019) and Holt et al. (2017) did, using the social judgement theory and media richness theory, respectively. In a similar setting to the study at hand, Fischer at al. (2022) used the Limited Capacity Model of Motivated Mediated Message Processing (LC4MP; Lang, 2017) to understand message recall. The LC4MP could be utilized to parcel out how protective action guidance was encoded, stored, and retrieved in working memory to further understand if the message variations had lasting positive impact on protective action literacy. Additionally, in an alternative setting, the Elaboration Likelihood Model (ELM) could be used to examine the extent to which individuals engaged in central or peripheral processing of the protective action guidance messages, providing insight into how deeply the messages were cognitively processed and whether they led to lasting attitude or behavior change (Petty & Cacioppo, 1986).

For Extension and other practitioner outreach in the preparedness phase, we ultimately recommend that salient information be emphasized in multiple areas of the message, particularly in text and toward the top of the message. Additionally, the introduction of an icon or other visual highlight alongside the second mention may increase desired effects by capturing viewers' attention and implying importance. More broadly, within agricultural and natural resources communications, we echo Ali et al.'s (2020) call to foster increased relationships between Extension and disaster agencies, which have overlapping missions to provide decision-making information to the public in times of disaster. We also bolster Fischer et al.'s (2022) call for increased attention to the details of message design when communicating with at-risk populations during all phases of disaster and further call for experimental analysis to provide evidence-based messaging guidance. Perhaps these goals can be accomplished through increased partnerships between Extension, disaster agencies, and research endeavors such as this determined to provide evidence-based message design recommendations for practitioners.

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