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You Have to Send the Right Message: Examining the Influence of Protective Action Guidance on Message Perception Outcomes across Prior Hazard Warning Experience to Three Hazards

Laura Fischer
Texas Tech University

David Huntsman
University at Albany, State University of New York, dhuntsman@albany.edu

Ginger Orton
Texas Tech University

Jeannette Sutton
University at Albany, State University of New York, jsutton@albany.edu

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Authors:

Laura Fischer, Ph.D.
Corresponding Author
Assistant Professor
Department of Agricultural Education and Communications
Texas Tech University
Laura.fischer@ttu.edu

David Huntsman, Ph.D.
Postdoctoral Associate
College of Emergency Preparedness, Homeland Security and Cybersecurity
University at Albany
dhuntsman@albany.edu

Ginger Orton, M.S.
Doctoral Student
Department of Agricultural Education and Communications
Texas Tech University
gorton@ttu.edu

Jeannette Sutton, Ph.D.
Associate Professor
College of Emergency Preparedness, Homeland Security and Cybersecurity
University at Albany
jsutton@albany.edu

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Abstract

A long-term goal for warning message designers is to determine the most effective type of message that can instruct individuals to act quickly and prevent loss of life and/or injury when faced with an imminent threat. One likely way to increase an individual's behavioral intent to act when they are faced with risk information is to provide protective action information or guidance. This study investigated participant perceptions (understanding, believing, personalizing, deciding, milling, self-efficacy, and response-efficacy) in response to the National Weather Service's experimental product Twitter messages for three hazard types (tornado, snow squall, dust storm), with each message varying by inclusion and presentation of protective action information placed in the tweet text and the visual graphic. We also examine the role of prior hazard warning experience on message perception outcomes. To examine the effects, the experiment used a between-subjects design where participants were randomly assigned to one hazard type and received one of four warning messages. Participants then took a post-test measuring message perceptions, efficacy levels, prior hazard warning experience, and demographics. The results showed that for each hazard and prior hazard experience level, messages with protective action guidance in both the text and graphic increase their understanding, belief, ability to decide, self-, and response-efficacy. These results reinforce the idea that well-designed messages, that include protective action guidance, work well regardless of hazard type or hazard warning experience.

Significance Statement

Preventing injury and/or loss of life during a hazardous event is a prime concern for disaster communicators. The study provides insights to practitioners on how to effectively communicate protective actions to audiences with varying familiarity with the hazard through Twitter posts. We experimented with tweet message design and content for three hazards: tornado, snow squall, and dust storm, to find that posts that include protective action guidance in both the text and image increase participant perceptions that they could perform the suggested protective actions, regardless of hazard type or hazard warning experience. Based on our findings, practitioners should consider including protective action guidance in message text and graphic in order to warn members of the public with varied prior warning experience.

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1. Introduction

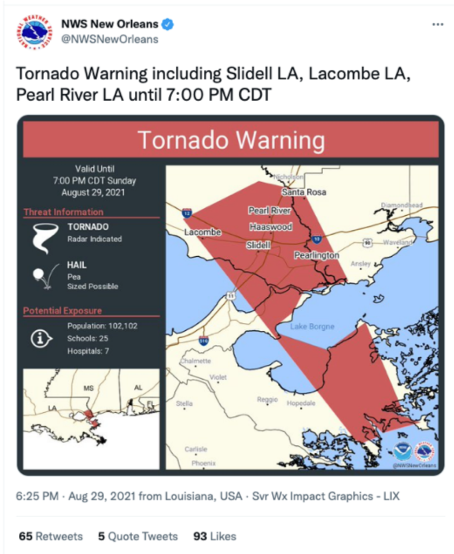
A long-term goal for warning message designers is to determine the most effective type of warning message that can instruct individuals to take an action to quickly prevent loss of life and/or injury when faced with an imminent threat. The content included in warning messages must inform the public about an approaching or potential hazard and should also provide protective action guidance to inform individuals of the actions necessary to protect themselves (Mileti and Peek 2000).

Prior research has indicated that the inclusion of protective action guidance, or instructions, is likely to increase an individual's behavioral intent to act when they are at risk (Frisby et al. 2014; Milne et al. 2000). Further, the guidance included in a warning message has been shown to be a primary motivator that drives which actions a person takes when faced with a threat and their confidence to be able to perform such actions (Coombs 2009; Frisby et al. 2014; Milne et al. 2000; Sellnow et al. 2017). Although the inclusion of these protective actions is important in warning message design, messages often exclude them, especially in short-form messages such as those sent via Twitter (Sutton et al. 2021).

To inform the public of an imminent threat, the National Weather Service (NWS) developed a suite of experimental warning products that are automatically disseminated to the public through Twitter "bot" accounts such as @NWSTornado, @NWSSnowSquall, and @NWSDustStorm (NWS 2016; NWS 2020). These automated messages include tweet copy, or text, naming the type of hazard and the locations at risk, and a graphic containing a map, potential impacts, and populations exposed (see figure 1). These Twitter messages are designed to deliver and disseminate warning information for fast-moving hazards, such as tornadoes, snow squalls, and dust storms, to members of the public and core partners in broadcast/electronic media, emergency managers, and other government agencies. However, several of these experimental messages do not include the protective action guidance that may inform the public about what to do during hazardous conditions (Sutton et al. 2021). When a person lacks prior experience or familiarity with a threat and its corresponding actions, the exclusion of protective action information may result in their inability to take protective actions (Sutton et al. 2018).

Figure 1

An Example of an Experimental Warning Product Distributed by the NWS for Tornado



While Twitter-based tornado products were initially issued in 2016 for hazards like tornado, in 2018 the National Weather Service introduced two new experimental warning products: dust storm and snow squall. The NWS distributes these experimental warning products from their official Twitter accounts to warn the public about the approaching hazard. Although these threats existed in the past, due to the more recent development of messages for these hazards, recipients are less likely to be familiar with the appropriate actions to take when exposed to threat. Notably, dust storm and snow squall both have potential to result in significant harm. For example, in 2022, a snow squall in Pennsylvania resulted in a 50-vehicle pileup, extended closures of a seven-mile stretch of highway, and eight deaths (Cappucci et al. 2022); and in 2021, a dust storm in Utah resulted in a 20-vehicle crash leading to injuries for at least ten people and eight deaths (Firozi and Cappucci 2021).

A critical challenge for warning message designers and risk communicators is determining how best to design messages that promote understanding of the severity of the situation and motivate individuals to take action to protect themselves (Perreault et al. 2014). Limited research has been directed to identify how prior warning experience affects cognitive perceptions of warning messages, including individuals' understanding of, belief in, and decisions to take the actions prescribed in the message. This research addresses that gap by exploring the effect of prior hazard warning experience on warning message perceptions for three hazards.

2) Literature Review

a) Warning message design

Prior research on warning messages has focused on how best to construct messages that will lead individuals to take protective actions. Persuasive *message design* theories specify how message *content*, message *style*, and message *structure* can be manipulated to produce the most effective outcomes (Shen and Bigsby 2013; Sutton et al. 2021).

Message content has been defined as the "what is said" or represented in the text and graphic portions of a persuasive message (Shen and Bigsby 2013). In warning messages, there are five types of content that should be included in an effective warning message: 1) information about the hazard itself (i.e., what it is and information about the potential severity, impact, and consequences), 2) protective action guidance (i.e., what people should do to protect themselves from the threat), 3) the location of the threat and who it might impact, 4) the time to take action in response to the potential threat and the time the message expires, and 5) the message source (i.e., the organization that distributed the message) (Mileti and Sorensen 1990). Effective warning messages must convey content that tells people what to do, how to do it, while maximizing their health and safety (Janssen et al. 2006; Sutton et al. 2021).

Message style refers to how message designers use linguistic styles to present information (Shen and Bigsby, 2013), such as through hyperboles, phonetic symbolism, powerful versus powerless language, and message framing (Shen and Bigsby 2013; O'Keefe and Jensen, 2006). For warnings, message content should be presented in a style that relays certainty, is consistent, is specific, and uses language that is unambiguous (Mileti and Sorensen 1990). Scholars have indicated warning messages should be clear in wording with minimal references to jargon to explain their concepts (Wood et al. 2018). Further, internal consistency should be achieved so that information does not contradict itself within the message (Williams and Eosco 2021).

Message structure refers to how content is presented; this includes the order of contents and the format, such as if information is presented in the graphic or text of a message (Shen and Bigsby 2013; Sutton et al. 2021). Scholars have previously examined how the ordering of contents, that is, presenting the most important information at the beginning of the message versus at the end of the message, influences perceptions (Shen and Bigsby 2013). Others have examined message structure in the information presented in short vs. long-form Twitter warning alerts, and they found message perceptions were higher for the longer messages (Sutton et al. 2018). Although research has previously explored how the placement of the message contents in different types of messages, limited research has explored how the placement of protective action guidance influences perceptions of the message. One study by Sutton et al (2021), however, examined how the placement of the protective action guidance, whether in the text or the graphic, of the message influences outcomes. Their results indicated the inclusion of protective action guidance, whether in the main Tweet copy, the graphic, or both, increased the message perception outcomes (Sutton et al. 2021). However, there has not been research to examine how those with varying levels of prior experience with a hazard and the inclusion of protective action guidance in varying message structure influences the participants perceptions of the message.

b) The inclusion of protective action guidance in warning messages

The role of a warning message is to provide message receivers with information about a threat and the actions they should take to protect themselves (Mileti and Sorenson 1990; Potter et al. 2018; Ripberger et al. 2015; Cappucci 2019). However, recent research investigating the experimental Twitter product for tornado has shown that although these warning messages deliver useful information about the threat, they failed to include information about protective actions. This absence of guidance information has the potential to diminish message receivers' knowledge about and ability to undertake protective actions (Sutton and Fischer 2021).

Subsequent recent research explored the @NWSTornado experimental product via experimental design, where participants were exposed to an original message, or a message manipulated to include protective action guidance (Sutton et al. 2021). Results indicated that the inclusion of protective action guidance content elicited increased understanding, increased ability to make decisions, increased self-efficacy, and increased response-efficacy.

c) Familiarity & prior hazard warning experience

Scholars have provided empirical evidence demonstrating the importance of protective action information; however, less attention has been directed to how prior hazard warning experience affected message perception outcomes. To put it simply, prior experience has been operationalized as the idea that humans are shaped by their own previous experiences, and it impacts their ability to understand information and to make judgments and decisions. However, prior experience has been measured in a variety of ways, ranging from simplistic approaches (e.g., "have you experienced a <hazard>?" to multi-item Likert scales resulting in conflicting findings on the influence of prior hazard experience on outcomes and perceptions of risk (Demuth 2018). These differences in measurements and definitions of prior hazard experience may have influenced whether and to what extent it relates to individuals' assessments of and responses to future risks. Thus, there have been calls for more systematic and attention to the treatment of past hazard experience (Demuth 2018; Weinstein 1989; Lindell and Perry 2012; Kellens et al. 2013).

Empirical evidence does demonstrate prior experience has a powerful impact on an individuals' ability to recognize risk (Weinstein 1989), including the characteristics of the threat, the level of value or importance the person places on the risk, the emotional response to the threat, and the judgments and decisions they make when faced with the threat (Demuth 2018; Greening et al. 1996; Tversky and Kahneman 1974). When exposed to a warning message about a threat, prior experience may result in increased message salience (Brown et al. 2018; Becker et al. 2017), as well as increased understanding, ability to make decisions, and motivation to take action (Demuth 2018; Lindell and Perry 2012). Furthermore, prior experience with a hazard affects how individuals become aware of, assess, and respond to risk (Demuth, 2018), and personal experience with an event influences how people react to a message and the included protective action guidance (Perreault et al. 2014; Atwood and Major 1998). For example, for some, prior tornado experience leads to an increased likelihood to take protective action (Weinstein et al. 2000), to be attune to communication channels, and to seek out further information about the oncoming hazard (Perreault et al. 2014).

Scholars have also emphasized that geographic location and proximity to hazardous locations (i.e., living in a coastal region and experiencing hurricanes) will also shape risk perceptions and behaviors (Lindell and Perry, 2012). For example, those who live in higher risk areas tend to be more familiar with local hazards and how to protect themselves during hazardous events (Lindell and Perry, 2012). Additionally, the amount of personal experience with official threat information (i.e., being under a tornado warning, hearing tornado sirens firsthand) and news information about a threat (i.e., hearing or watching news coverage when a threat is happening) also shapes risk perceptions and judgements when individuals are confronted with new information (Demuth 2018). In the case where an individual has not directly experienced a hazard, they may have learned about the threat and its protective action behaviors through indirect channels of communication (Demuth 2018).

d) Measuring warning message outcomes

Prior empirical research has identified a series of perceptions, or message outcomes, that occur after individuals are exposed to a warning message and prior to their behavioral response. These include message understanding, believing, personalizing, deciding, milling, self-efficacy, and response-efficacy (Mileti and Peek, 2000; Mileti and Sorenson, 1990; Sutton et al. 2021).

After exposure to a warning message, the message receiver must first *understand* the message and attach meaning to the information presented. To understand the message, the receiver comprehends what the threat is, what is happening, what the potential impacts are, what population is at risk, where the location of the threat is, what they must do to protect themselves, who the sender of the message is, and the time at which and duration of protective actions that should be taken (i.e., Dash and Gladwin 2007; Mileti and Beck 1975; Mileti et al. 1975; Mileti & O'Brien 1992).

Message recipients must then *believe* the threat to be real and that a threat is coming to harm a specific area to harm the individual (Dash and Galdwin 2007; Nigg 1987; Schumacher et al. 2010). Within belief, message receivers must also perceive or believe that the message and its protective action guidance is truthful and accurate. After the receiver believes the threat to be real, individuals must *personalize* the threat – that is, the receiver must assess whether the threat will affect them personally (Wood et al. 2018), prompting action. Next, message receivers must be able to *decide* or to make a judgment of what actions to take, if any, to protect themselves from the threat. The decision to take protective action includes determining if a behavioral response is warranted in the situation and serves as a precursor to behavioral actions (Wood et al. 2018).

Throughout these message perception processes, message receivers engage in *milling,* or information seeking, to confirm that the threat is real or protective action guidance is accurate (Casteel 2016; Mileti and Peek, 2000; Perry 1979; Perry et al. 1981). The process of milling may spark individuals to seek out other information sources or interact with other people to find more information about the threat and its recommended actions (Wood et al. 2018).

More recently, researchers have included measures of efficacy in response to a warning message (i.e., self- and response- efficacy). Self- and response-efficacy are key to identifying whether message receivers, and efficacy has referred to the individual's level of confidence that the message's protective action guidance will keeping them safe. Through efficacy items, individuals must believe they themselves could take the recommended protective actions and that those actions will keep them safe (Sutton et al. 2021). Self-efficacy refers to the receiver's belief that they could perform the protective action (Bandura 2010; Witte 1996), and response-efficacy refers to the belief that taking the recommended actions would protect life safety (Bandura 2010).

3. Research Questions

The current study investigates perceptions of NWS experimental warning product Twitter messages for three hazard types: tornado, snow squall, and dust storm. We vary these messages by manipulating their content and structure through 1) the inclusion and 2) the presentation of protective action guidance, located either in the message graphic or in the text. We also examine the role of prior hazard warning experience on participants' message perceptions. This study was guided by four research questions:

RQ$_1$: How does the *type of hazard* (tornado, snow squall, or dust storm) affect message perception outcomes (understanding believing, personalizing, deciding, milling, self-efficacy, and response-efficacy)?

RQ$_2$: How does the *type of message* (control, enhanced graphic, enhanced text, and enhanced graphic and text) affect message perception outcomes (understanding believing, personalizing, deciding, milling, self-efficacy, and response-efficacy)?

RQ$_3$: How does *prior hazard warning experience* (low vs. high) affect message perception outcomes (understanding believing, personalizing, deciding, milling, self-efficacy, and response-efficacy)?

RQ$_4$: Does the type of hazard or the level of the participant's prior hazard warning experience *modify* the relationship between message type and message outcomes?

4. Methods

a) Study design

To address the research questions, this study uses a 3x4x2 between-subjects factorial experiment. The first independent variable was the *hazard type* referring to the type of hazard event presented in the message: dust storm, snow squall, or tornado. The second independent variable was the *message type*. Message type refers to how protective action guidance was included in the structure of the message. Four message types were included: 1) a "standard practice" or control message that is not enhanced with protective action guidance, 2) an enhanced graphic message, where protective action guidance was added in the graphic portion of the message, 3) an enhanced text message, where protective action guidance was added to the text portion of the message, and 4) an enhanced graphic and text, where protective action guidance was added to both the text and graphic portions of the message. The third independent variable was the participant's *level of prior hazard warning experience* with their assigned hazard, and it was categorized as low vs. high using a median split. We examined the effects of the three independent variables on the participants' perceptions of the message (i.e., understanding, believing, personalizing, deciding, milling, self-efficacy, and response efficacy). To examine the effects, the experiment used a between-subjects design where participants were randomly assigned to one hazard type and received one of the four warning messages. Afterwards, the participants answered questions about their perceptions of the message, their perceptions of self- and response- efficacy, prior hazard warning experience, and demographic information.

b) Participants and sampling procedures

Data were collected from 1,050 adult participants through an online, third-party company (Qualtrics research panels), to obtain a non-probability, opt-in sample of residents in three locations: Atlanta, Georgia; Buffalo, New York; and Phoenix, Arizona. These three locations were selected because they had each recently received an NWS hazard warning message for the three hazards of interest (Atlanta, tornado; Buffalo, snow squall; and Phoenix, dust storm) and had similar population characteristics and sizes.

Participants were recruited through Qualtrics research panels. Qualtrics, a third-party recruitment firm, obtains participants through actively managed market research panels and social media platforms. To verify unique responses and ensure validity, Qualtrics employed digital fingerprinting technology and internet protocol (IP) address checks. Power analysis

(Power = .80, α = .05) was conducted using G*Power software assuming small-to-medium effect sizes (f = .15), which determined a minimum sample size of N = 990.

Our sample encompassed approximately one-third of the participants in each location for a final sample size of N = 1,050 (i.e., n = 363, 35% in Atlanta, n = 326, 31% in Buffalo, and n = 361, 34% in Phoenix), which was verified through ZIP Code identifiers. To ensure variability in prior hazard warning experience, the participants in each location were randomly assigned to receive a type of message hazard type: Atlanta sample (n = 141, 40%, tornado; n = 95, 27%; snow squall; n = 116, 33% dust storm); Buffalo sample (n = 112, 32% snow squall; n = 119, 34% tornado; n = 121, 34% dust storm); Phoenix sample (n = 124, 36% dust storm; n = 119, 34% snow squall; n = 103, 30% tornado). Additionally, we developed quotas for the sample to match census demographics for age (ages 18-34: 30%, ages 35-54: 32%, and ages 55+ 38%) and gender (approximately 50% who identified as a woman, approximately 50% who identified as a man, and non-binary natural fallout). Respondents who did not match these quotas were disqualified from participation and omitted from the study. Table 1 displays the demographic data on all study participants.

Table 1

Demographic Characteristics of the Respondents

Demographic Variable	*f*	%
Age		
18-34	350	33%
35-54	350	34%
55+	350	33%
Ethnicity		
Caucasian	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%

c) Independent Variables

Three independent variables were included in this study: hazard type, message type, and prior hazard warning experience. Below, we discuss each of these independent variables.

i) Hazard Type

Hazard type refers to the type of hazard presented in the message: tornado, snow squall, or dust storm. These three hazards were selected by the NWS because they were recently adopted into the suite of experimental products and lacked empirical testing with populations that may be alerted or warned in future events.

ii) Control

Currently, NWS Weather Forecast Offices (WFOs) distribute experimental warning products to the public through Twitter and Facebook. These messages were chosen due to the study’s design to test the visual aspect of a warning, and how the structure of the message and the contents located in this structure influence message outcomes. The control or “standard practice” messages used for this study were direct replicas of NWS experimental warning products that had been recently distributed by NWS in Atlanta, Buffalo, and Phoenix. Each of the standard messages included a tweet with text copy that stated the location of the hazard and the duration the warning in effect (i.e., tornado – Tornado Warning including Atlanta, GA, North Atlanta, GA, Decatur, GA until 11:15 AM EDT) and an attached graphic (Figure 2). The attached graphic included the type of warning, a large map with a polygon depicting the areas at risk, and a sidebar that provided details about the threat information and population exposed. At the bottom left corner of the message was a smaller, inset map, which oriented the viewer to the broader geographical context. To replicate the messages, the researchers chose messages from each of the three locations and manipulated the time and date to match the study parameters.

Figure 2

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


Standard Practice Message
NWS Atlanta
@NWSAtlanta
Tornado Warning including Atlanta, GA, North Atlanta GA, Decatur GA until 11:15 AM EDT.
Tornado Warning
NWS Buffalo
@NWSBuffalo
A snow squall warning is in effect until 4:45 PM EST for I-190, I-290, I-90, I-990 near Buffalo, NY.
Snow Squall Warning
NWS Pheonix
@NWSPheonix
A dust storm warning is in effect until 8:45 PM MST for I-10 between mile markers 159 and 210 in Arizona, I-8 between mile markers 120 and 178 in Arizona, US-60 between mile markers 152 and 168 in Arizona.
Dust Storm Warning
Enhanced Text Message
TORNADO WARNING including Atlanta, GA, North Atlanta GA, Decatur GA until 11:15 AM EDT.
To protect yourself TAKE COVER NOW! Move to an interior room. Stay away from windows.
A SNOW SQUALL WARNING is in effect until 4:45 PM EST for I-190, I-290, I-90, I-990 near Buffalo, NY.
AVOID OR DELAY TRAVEL! If on the road, turn on your headlights and hazard lights. There's no safe place on a highway in a snow squall.
A DUST STORM WARNING is in effect until 8:45 PM MST for areas along I-10, I-8 and US-60 in South Central Arizona.
PULL ASIDE STAY ALIVE! Park your vehicle with all lights off until storm passes.
Enhanced Graphic Message
Combined Format Message

ii) Enhanced Graphic Message

The first manipulation is to the structure of the graphic portion of the message. We focused on manipulating the structure of the message to include protective action guidance in the graphic. The "enhanced graphic" messages include protective action content within the graphic, while retaining the text copy from the standard practice message (highlighted in yellow, Figure 2). Members of the research team consulted with practitioners from the NWS Storm Prediction Center and NWS regional offices on content manipulations. Information about the potential exposure to populations in the black sidebar area was removed and replaced with a warning icon and protective action information under the heading "Safety Precautions." The description about the safety precautions for each type of message are as follows: Tornado − Move to an interior room of the lowest floor of a sturdy building. Stay away from windows; Snow Squall −Avoid or delay travel. If on the road, turn on your headlights and hazard lights. There's no safe place on a highway in a snow squall.; Dust Storm − Pull aside and stay alive. Park your vehicle with all lights off until storm passes.

iv) Enhanced Text Message

The second manipulation is to the tweet copy portion of the message. To manipulate the structure of this message, the "enhanced text" messages include protective action content within the text copy while retaining the graphic from the standard practice message (highlighted in blue, Figure 2). Members of the research team consulted with practitioners from the NWS Storm Prediction Center and NWS regional offices on content manipulations in the tweet copy. In addition some text was presented in capital letters or imperative tense (TAKE COVER NOW!, AVOID or DELAY TRAVEL!, and PULL ASIDE. STAY ALIVE!) to draw the message receiver's visual attention.

v) Combined Format Message

The third manipulation is to both the graphic portion and the tweet copy portion of the message by including protective action guidance content as detailed above. The combined format message is presented in Figure 2.

d) Prior Hazard Warning Experience (HW Experience)

Prior hazard warning experience, hereafter referred to as *HW Experience*, was measured using four items that indicated the extent to which participants had warning experience with their assigned hazard (adapted from Demuth, 2018). The items were: 1) I have been under a (tornado, snow squall, dust storm) warning, 2) I have received (tornado, snow squall, dust storm) warnings (not as a test) firsthand, 3) I have heard or watched live news coverage on radio, TV, or online of (tornado, snow squall, dust storm) as it was happening, and 4) I have seen news coverage about the aftermath of a (tornado, snow squall, dust storm). Respondents indicated their agreement with each statement using a standard 5-point Likert scale (1 = *Strongly disagree, 2 = Somewhat disagree, 3 = Neither agree nor disagree, 4 = Somewhat agree,* and 5 = *Strongly agree)*. Table 2 reports the Chronbach's α, means, standard deviations, and medians for Experience by each hazard type.

Table 2
Means, Medians, and SD's Prior Hazard Warning Experience by Hazard Type

Prior Hazard Warning Experience	*α*	*Mean*	*SD*	*Median*	*N*
Tornado Warning Experience	.77	3.49	1.15	3.48	363
Snow Squall Warning Experience	.92	3.24	1.46	3.39	326
Dust Storm Warning Experience	.89	2.96	1.14	2.95	361
Total	-	3.23	1.37	3.25	1050

e) Dependent variables

Message perceptions were measured via five primary dependent variables (understanding, belief, personalization, deciding, and milling) (Sutton et al. 2018; Sutton et al. 2021; Wood et al. 2018). Perceptions of self-efficacy and response-efficacy were also measured to determine participants beliefs about their ability to complete and confidence in the recommended protective actions (Sutton et al., 2021). These measures were drawn from Protective Motivation Theory (Rogers and Prentice-Dunn 1997) and the prior research from Sutton et al. (2021). For all the dependent variables, participants indicated their agreement with corresponding statements using a standard 5-point Likert scale (1 = *Strongly disagree, 2 = Somewhat disagree, 3 = Neither agree nor disagree, 4 = Somewhat agree,* and 5 = *Strongly agree)*.

i) Understanding

Understanding (Chronbach's α = 0.88) was measured using seven items: *"*After viewing this message, I understood: 1) What is happening, 2) The risks (impacts), 3) What to do to protect myself, 4) What location is affected, 5) Who the message is from, 6) When I am supposed to take action to protect myself, and 7) How long I am supposed to continue taking actions to protect myself."

ii) Belief

Belief (Chronbach's $\alpha = 0.83$) was measured using five items: "After viewing this message, I would believe that: 1) The threat is heading my way, 2) The message is reliable, 3) I know when I will be in danger, 4) I should take action to protect myself and, 5) Taking protective action will make me safer."

iii) Personalization

Personalization (Chronbach's $\alpha = 0.91$) was measured using seven items from Wood et al. (2018): "After viewing this message, I think that: 1) I might become injured, 2) People I know might become injured, 3) People I do not know might become injured, 4) I might die, 5) People I know might die, 6) People I do not know might die, and 7) The message was meant for me."

iv) Deciding

Deciding (Chronbach's $\alpha = 0.91$) was measured with three items: "After viewing this message, I believed: 1) It will be easy to decide what to do, 2) I will be able to decide what to do quickly, and 3) I can decide what to do with confidence."

v) Milling

Milling (Chronbach's $\alpha = 0.90$) was measured with three items: "Before following the information in the message to protect myself, I would look for additional information about… 1) What is happening, 2) What to do, 3) How to perform the actions."

vi) Self-Efficacy

Self-efficacy (Chronbach's $\alpha = 0.90$) was measured with three items: "1) I know what actions I should take after reading this warning, 2) I am confident I can follow the information described in this message, and 3) I am capable of following the information advised in this warning."

vii) Response-Efficacy

Response-efficacy (Chronbach's $\alpha = 0.88$) was measured with three items: "After viewing this message, I feel: 1) The information in this message will keep people safe, 2) Following the information in this message will be successful for reducing harm, and 3) Following the information in this message will be effective in keeping me safe."

f) Procedure

To complete the study, the invited participants were first asked to read and electronically provide informed consent. Next, the participants were randomly assigned to a type of hazard (i.e., tornado, snow squall, or dust storm) and one of four message types (i.e., control, enhanced text, enhanced graphic, or enhanced text and graphic). After exposure to the message, participants answered a series of questions about their perceptions of the message, their perceptions of self- and response- efficacy, their prior HW Experience, and their background/demographics. The data reported in this study are part of a larger study; however, the data reported in this manuscript were analyzed independently from the other variables. The questionnaire took approximately 15 to 20 minutes to complete. Participants received incentives through Qualtrics to thank them for their time.

Data were analyzed using IBM SPSS Statistics Version 28. Data were reviewed and cleaned prior to analysis. Composite variables were created for each construct (mean). Additionally, we recoded prior HW Experience using a median split where 1 = *low prior HW Experience* and 2 = *high prior HW Experience*. Descriptive analysis included frequency, mean, median, and standard deviation. Inferential analysis included analysis of variance (ANOVA) to examine main and interaction effects with significance where $p < .05$. Post hoc tests (Bonferroni) were conducted to identify statistically significant differences (main effects, interaction effects, and Bonferonni post hoc comparisons) between the specific message types.

4. Results

A series of ANOVAs (Analysis of Variance) were used to determine the effects of the hazard type (tornado, snow squall, or dust storm), message type (control, enhanced graphic, enhanced text, and enhanced graphic and text), and prior HW Experience level on the participants' perceptions of the given message (understanding, believing, personalizing, deciding, milling, self-efficacy, and response-efficacy). First, we discuss the main effects for the ANOVA by hazard type. Second, we discuss the main effects for the ANOVA by message type. Third, we discuss the main effects for the ANOVA by prior HW Experience. Finally, we describe the interaction effects for all two-way and three-way interactions. The two tables below provide the results for the Estimated Marginal Means (EMM) and Standard Errors (SE) (Table 3) between-subjects effects (Table 4) and for message outcomes by message type and HW Experience. The Raw Means (M) and Standard Deviations (SD) for message outcomes by hazard type, message type, and prior HW Experience are also included in the Appendix (Table A.1).

Using thresholds by Cohen (1988), we interpret magnitudes for effect sizes (partial eta-squared) as .01 = “small”, .06 = “medium”, and .14 = “large.”

Table 3

Estimated Marginal Means (M) and Standard Errors (SE) for message outcomes by message type and prior HW Experience

Message Type	*Prior Hazard Warning Experience*	**Understand.**		**Belief**		**Personal.**		**Deciding**		**Milling**		**Self-Efficacy**		**Response-Efficacy**	
		EMM	SE	EMM	SE	EMM	SE	EMM	SE	EMM	SE	EMM	SE	EMM	SE
Control	Low	3.76	.07	3.81	.07	3.10	.10	3.60	.08	3.68	.11	3.66	.07	3.75	.08
	High	4.24	.07	4.26	.07	3.18	.10	4.26	.08	3.82	.11	4.31	.07	4.23	.08
	Total	4.01	.05	4.04	.05	3.14	.07	3.93	.06	3.75	.08	3.98	.05	3.99	.05
Graphic	Low	3.97	.06	3.99	.07	3.17	.09	3.94	.08	3.84	.11	4.12	.07	4.04	.07
	High	4.38	.06	4.32	.07	3.40	.09	4.50	.08	3.64	.11	4.51	.07	4.37	.07
	Total	4.18	.05	4.15	.05	3.28	.06	4.22	.05	3.74	.07	4.31	.05	4.20	.05
Text	Low	4.11	.06	4.12	.07	3.23	.09	4.05	.08	3.58	.10	4.27	.07	4.05	.07
	High	4.54	.07	4.45	.07	3.38	.10	4.42	.08	3.42	.11	4.61	.08	4.46	.08
	Total	4.32	.05	4.29	.05	3.31	.07	4.23	.06	3.50	.08	4.44	.05	4.28	.05
Both	Low	4.34	.07	4.22	.07	3.30	.09	4.23	.08	3.57	.11	4.36	.07	4.22	.07
	High	4.48	.07	4.36	.08	3.28	.10	4.47	.09	3.53	.12	4.59	.08	4.44	.08
	Total	4.41	.05	4.29	.05	3.29	.07	4.35	.06	3.56	.08	4.48	.05	4.33	.06

Table 4
Effects of Hazard Type, Message Format, and Hazard Warning Experience on Warning Message Outcomes

Dependent Variable Source	Type III SS	*df*	MS	*F*	*p*	Part. (η^2)
Understanding						
Hazard Type	2.017	2	1.009	1.81	.16	.004
Message Type*****	23.856	3	7.952	14.27	<.001	.040
HW Experience *****	33.993	1	33.993	61.003	<.001	.056
Hazard Type x Message Type	3.909	6	.652	1.169	.32	.007
Hazard Type x HW Experience	1.072	2	.536	0.961	.38	.002
Message Type x HW Experience ǂ	4.114	3	1.371	2.461	.06	.007
Hazard Type x Message Type x HW Experience	2.914	6	.486	0.872	.52	.005
Error	571.728	1026	.557			
Corrected Total	642.241	1049				
Belief						
Hazard Type	1.901	2	.951	1.529	.22	.003
Message Type*****	11.169	3	3.723	5.988	<.001	.017
HW Experience *****	24.989	1	24.989	40.189	<.001	.038
Hazard Type x Message Type	3.037	6	.506	0.814	.56	.005
Hazard Type x HW Experience	1.325	2	.662	1.065	.35	.002
Message Type x HW Experience	2.91	3	.970	1.56	.20	.005
Hazard Type x Message Type x HW Experience	3.751	6	.625	1.005	.42	.006
Error	637.964	1026	.622			
Corrected Total	687.678	1049				
Personalization						
Hazard Type**	15.587	2	7.794	6.948	.00	.013
Message Type	4.619	3	1.540	1.373	.25	.004
HW Experience	3.195	1	3.195	2.848	.09	.003
Hazard Type x Message Type	1.864	6	.311	0.277	.95	.002
Hazard Type x HW Experience	4.959	2	2.479	2.21	.11	.004
Message Type x HW Experience	1.938	3	.646	0.576	.63	.002
Hazard Type x Message Type x HW Experience	5.124	6	.854	0.761	.60	.004
Error	1150.918	1026	1.122			
Corrected Total	1189.749	1049				
Deciding						
Hazard Type	3.862	2	1.931	2.426	.09	.005
Message Type*****	23.022	3	7.674	9.643	<.001	.027
HW Experience *****	53.324	1	53.324	67.006	<.001	.061
Hazard Type x Message Type	4.19	6	.698	0.878	.51	.005
Hazard Type x HW Experience	1.591	2	.796	1	.37	.002
Message Type x HW Experience *	6.687	3	2.229	2.801	.04	.008

Hazard Type x Message Type x HW Experience	6.086	6	1.014	1.275	.27	.007
Error	816.508	1026	.796			
Corrected Total	910.482	1049				
Milling						
Hazard Type	8.672	2	4.336	2.886	.06	.006
Message Type*	12.759	3	4.253	2.831	.04	.008
HW Experience	1.058	1	1.058	0.704	.40	.001
Hazard Type x Message Type	11.282	6	1.880	1.252	.28	.007
Hazard Type x HW Experience	5.528	2	2.764	1.84	.16	.004
Message Type x HW Experience	4.527	3	1.509	1.005	.39	.003
Hazard Type x Message Type x HW Experience **	27.584	6	4.597	3.06	.01	.018
Error	1541.339	1026	1.502			
Corrected Total	1614.315	1049				
Self-efficacy						
Hazard Type	2.229	2	1.115	1.636	.20	.003
Message Type***	36.86	3	12.287	18.037	<.001	.050
HW Experience***	40.872	1	40.872	60.002	<.001	.055
Hazard Type x Message Type	2.964	6	.494	0.725	.63	.004
Hazard Type x HW Experience	1.349	2	.675	0.99	.37	.002
Message Type x HW Experience *	6.048	3	2.016	2.96	.03	.009
Hazard Type x Message Type x HW Experience	5.762	6	.960	1.41	.21	.008
Error	698.896	1026	.681			
Corrected Total	791.461	1049				
Response-efficacy						
Hazard Type	2.345	2	1.173	1.668	.19	.003
Message Type***	15.65	3	5.217	7.421	<.001	.021
HW Experience ***	32.754	1	32.754	46.599	<.001	.043
Hazard Type x Message Type	5.057	6	.843	1.199	.30	.007
Hazard Type x HW Experience	0.582	2	.291	0.414	.66	.001
Message Type x HW Experience	2.413	3	.804	1.144	.33	.003
Hazard Type x Message Type x HW Experience	3.634	6	.606	0.862	.52	.005
Error	721.176	1026	.703			
Corrected Total	779.951	1049				

Note.—SS = Sum of Squares; MS = Mean squares, effect size = $\eta 2$ or partial η^2

ǂ indicates approaching significance for interaction effects only

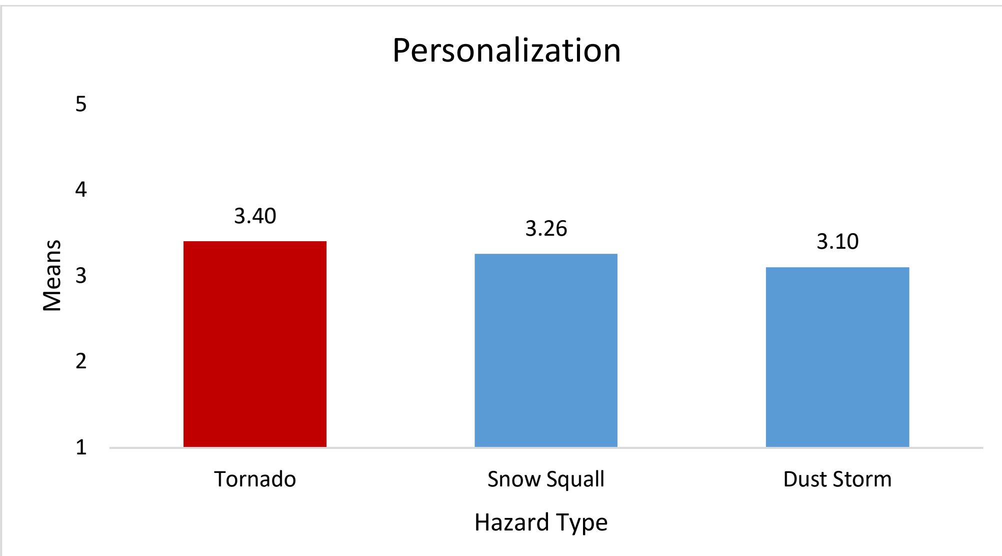
a) The Main Effects of Hazard Type on Message Perception Outcomes

RQ1 investigates how the type of hazard presented in the message affects message perception outcomes. As seen in Table 4, we found no significant main effects for hazard type *except* for personalization, suggesting participants' levels of understanding, believing, deciding, milling, self-efficacy, and response-efficacy are not significantly different depending on the type of hazard the messages reflected.

We did find a significant main effect for personalization, $F(2, 1026) = 6.95$, $p = .001$, $\eta^2 = .013$ (small effect size). Bonferroni post hoc comparisons found differences in the levels of personalization based on the hazard type portrayed in the message (i.e., tornado, snow squall, dust storm). Figure 3 demonstrates the tornado group ($M = 3.40$) has significantly higher levels of personalization as compared to the dust storm group ($M = 3.10$; $p < .001$).

Figure 3.

Main effects of personalization on hazard type.

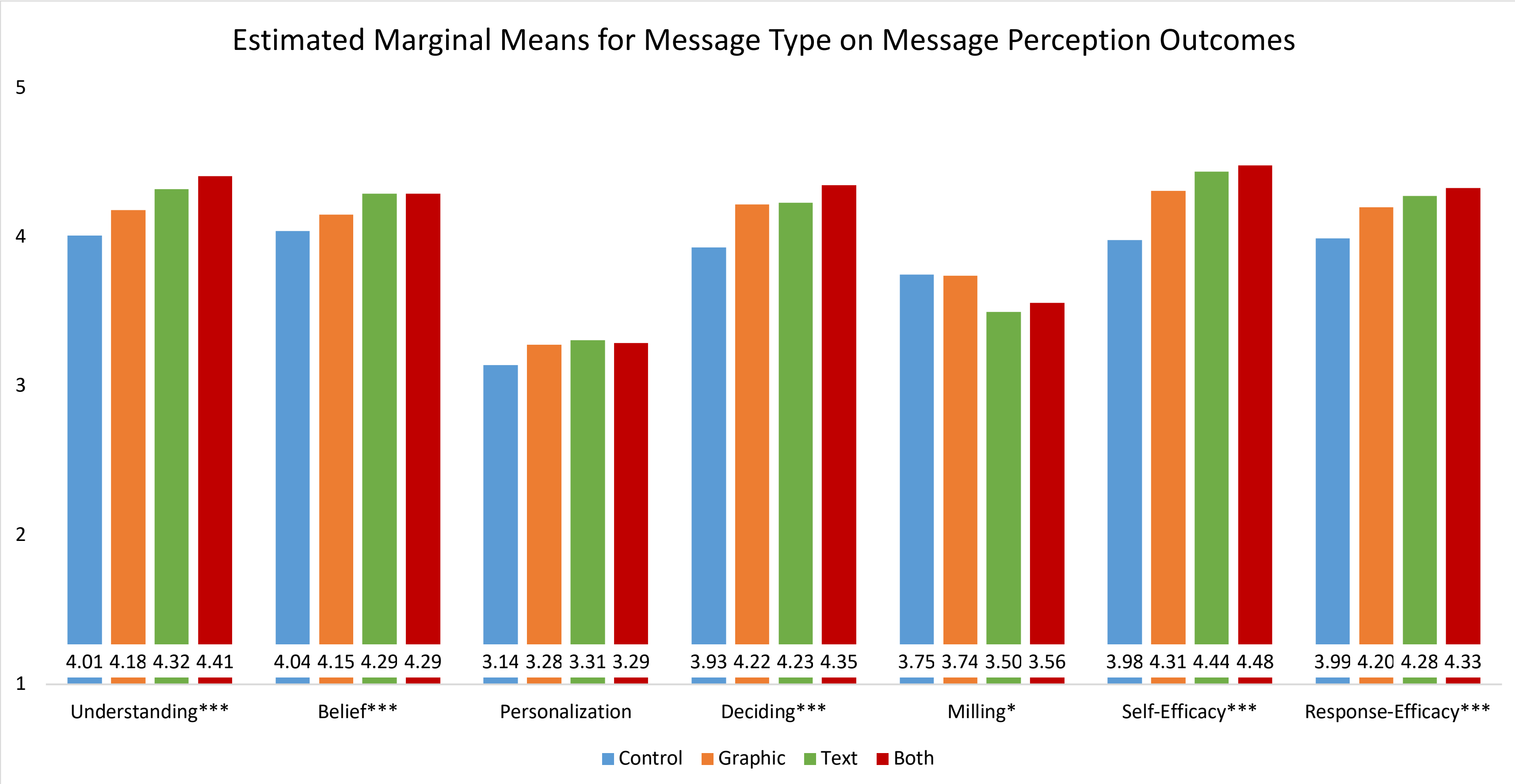


b) The Main Effects of Message Type on Message Perception Outcomes

RQ$_2$ investigates if the type of message (control, enhanced graphic, enhanced text, and the combined format) affects the message perception outcomes. As shown in Table 4, we found significant main effects between the message type in levels of all outcome variables except personalization. This includes significant main effects for message type on understanding, $F(3, 1026) = 14.27$, $p = .001$, $\eta^2 = .04$; believing, $F(3, 1026) = 5.99$, $p =.001$, $\eta^2= .017$; deciding, $F(3, 1026) = 9.64$, $p =. 001$, $\eta^2 = .027$; milling, $F(3, 1026) = 2.83$, $p =.04$, $\eta^2= .008$; self-efficacy, $F(3, 1026) = 18.04$, $p < .001$, $\eta^2 = .050$; and response-efficacy, $F(3, 1026) = 7.42$, $p =.001$, $\eta^2 = .021$. We present the estimated marginal means of the Bonferroni post hoc comparisons for message type on message perceptions in Figure 4.

Figure 4

Estimated Marginal Means for Message Type on Message Perception Outcomes



Note: Outcomes with Significant Main Effects for Message Type indicated by *** $p < .001$, ** $p < .01$, * $p < .05$ on x axis

i) Message Type and Understanding

The Bonferonni post hoc comparisons (Table 3, Figure 4) show the respondents who received the message with both enhanced graphic and text ('combined format') had significantly higher levels of understanding ($M = 4.41$) compared to those who received the standard practice or 'control' ($M = 4.01$; $p < .001$) and the enhanced graphic ('graphic') message ($M = 4.18$; $p < .01$). Those who received the enhanced text ('text') message ($M = 4.32$; $p < .001$) and the enhanced graphic ('graphic') message ($M = 4.18$; $p < .05$) also showed significantly higher levels of understanding compared to those who received the standard ('control') message. While the mean for the message containing both enhanced graphic and text ('combined format') is higher than the enhanced text message (by .9), the difference was nonsignificant.

ii) Message Type and Belief

The Bonferonni post hoc comparisons (Table 3, Figure 4) show the 'combined format' message ($M = 4.29$; $p < .01$) and the 'text' message ($M = 4.29$; $p < .01$) resulted in significantly higher levels of belief as compared to the 'control' message ($M = 4.04$).

iii) Message Type and Deciding

The Bonferonni post hoc comparisons (Table 3, Figure 4) show the 'combined' format message ($M = 4.35$; $p < .001$), 'text' message ($M = 4.23$; $p < .001$), and the 'graphic' message ($M = 4.22$; p < .01), resulted in significantly higher levels of deciding as compared to the 'control' ($M = 3.93$).

iv) Message Type and Milling

The Bonferonni post hoc comparisons (Table 3, Figure 4) show the 'text' message ($M = 3.50$) showed significantly lower levels of milling compared to 'control' message ($M = 3.75$; p < .05) and the 'graphic' message ($M = 3.74$; p < .05).

v) Message Type and Self-Efficacy

The Bonferonni post hoc comparisons (Table 3, Figure 4) show the 'combined format' message ($M = 4.48$; $p < .001$), the 'text' message ($M = 4.44$; $p < .001$), and the 'graphic' message ($M = 4.31$; $p < .001$) had significantly higher levels of self-efficacy compared to the 'control' message ($M = 3.98$).

vi) Message Type and Response-Efficacy

The Bonferonni post hoc comparisons (Table 3, Figure 4) show the 'combined format' message ($M = 4.33$; $p < .001$), the 'text' message ($M = 4.28$; $p < .01$), and 'graphic' message ($M = 4.20$; $p < .05$) result in significantly higher levels of response-efficacy as compared to the standard, or control message ($M = 3.99$).

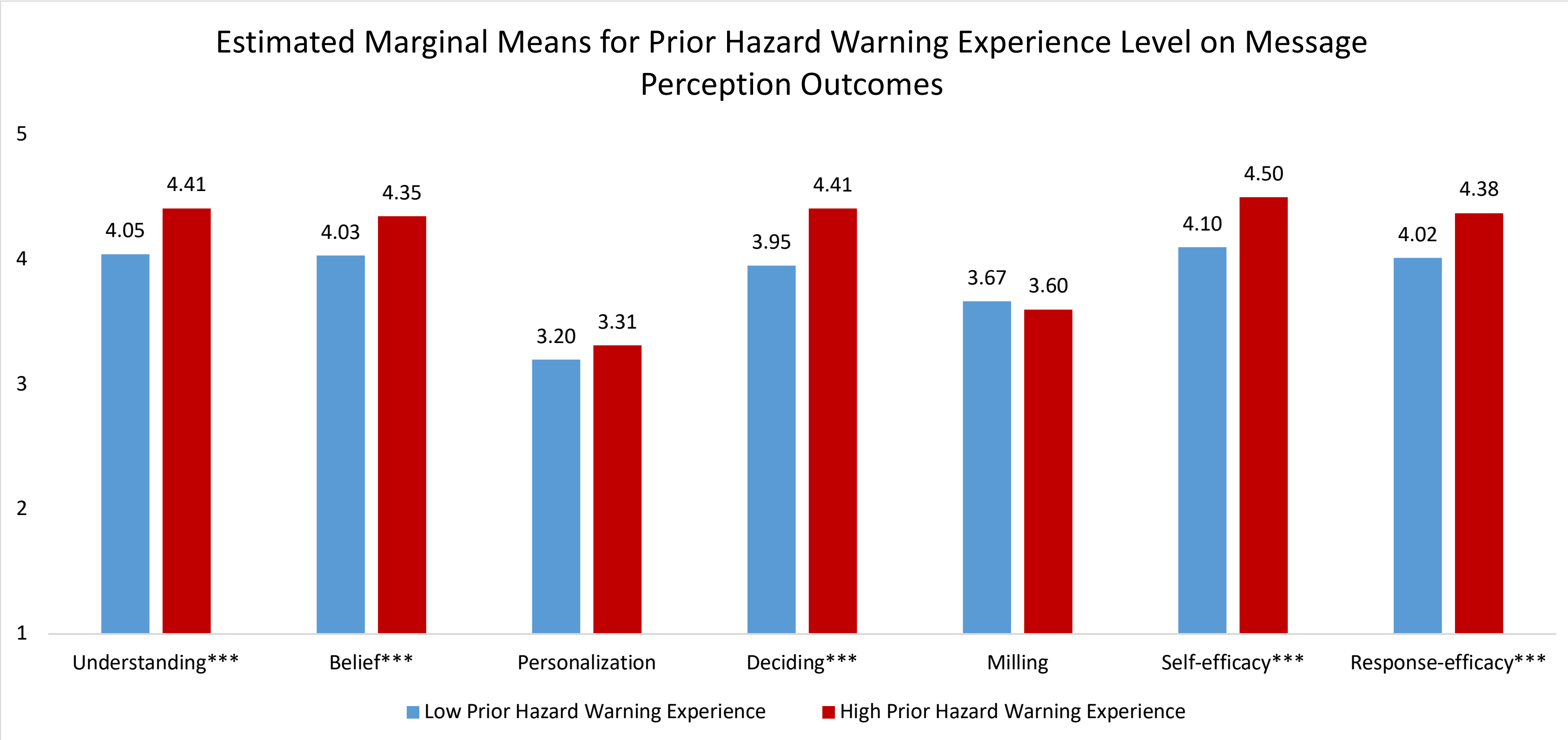
c) The Main Effects of Prior HW Experience on Message Perception Outcomes

RQ$_3$ investigates if the level of prior HW Experience affects the message perception outcomes. We found significant main effects for prior HW Experience levels on each of the message perception outcomes except personalization. Specifically, we found significant differences in participants' levels of understanding, $F(1,1026) = 61.00$, $p = <.001$, $\eta^2 = .056$; believing, $F(1, 1026) = 28.13$, $p =.001$, $\eta^2 = .038$); deciding, $F(1, 1026)= 67.006$, $p = .001$, $\eta^2 = .061$); self-efficacy, $F(1, 1026) = 60.00$, $p < .001$, $\eta^2 = .055$; and response-efficacy, $F(1,1026) = 46.60$, $p = .001$, $\eta^2 = .043$ based on their prior HW Experience .

Bonferonni post hoc comparisons (Figure 5, Table 3) demonstrated understanding to be higher for those with high HW Experience ($M = 4.41$) as compared to those with low HW Experience ($M = 4.05$, $p < .001$). Perceptions of belief were also higher for those with high HW Experience ($M = 4.35$) as compared to those with low HW Experience ($M = 4.03$, $p < .001$). Deciding was higher for those with high HW Experience ($M = 4.41$) as compared to those with low HW Experience ($M = 3.95$, $p < .001$). Similarly, among both efficacy outcomes, we found that self-efficacy was higher for those with high HW Experience ($M = 4.50$) as compared to those with low HW Experience ($M = 4.10$, $p < .001$), and response-efficacy was higher for those with high HW Experience ($M = 4.38$) as compared to those with low HW Experience ($M = 4.02$, $p < .001$).

Figure 5

Estimated Marginal Means for Prior Hazard Experience Level on Message Perception Outcomes



Note: Outcomes with Significant Main Effects for Prior HW Experience indicated by *** $p < .001$, ** $p < .01$, * $p < .05$ on x axis

d) Message Type, Hazard Type, and Prior HW Experience

RQ_4 investigates whether either the type of hazard or the participants' level of prior hazard warning experience modifies the relationship between message type and the message outcomes.

i) Does hazard type modify the relationship between message type and message outcome?

As shown in Table 3, there were no significant two-way interactions for *hazard type* x *message type* (understanding, $p = .32$; believing, $p = .56$; personalization, $p = .95$; deciding, $p = .51$; milling $p, = .28$; self-efficacy, $p = .63$; response-efficacy, $p = .30$) or *hazard type* x *prior HW* Experience (understanding, $p = .38$; believing, $p = .35$; personalization, $p = .11$; deciding, $p = .37$; milling, $p = .16$; self-efficacy, $p = .37$; response-efficacy $p = .66$) for any of the outcome variables.

ii) Does prior HW Experience modify the relationship between message type and message outcome?

Next, we explore potential interaction effects among message type and prior HW Experience to understand whether the former's effect on message perceptions varies across levels of prior HW Experience (see Table 3).

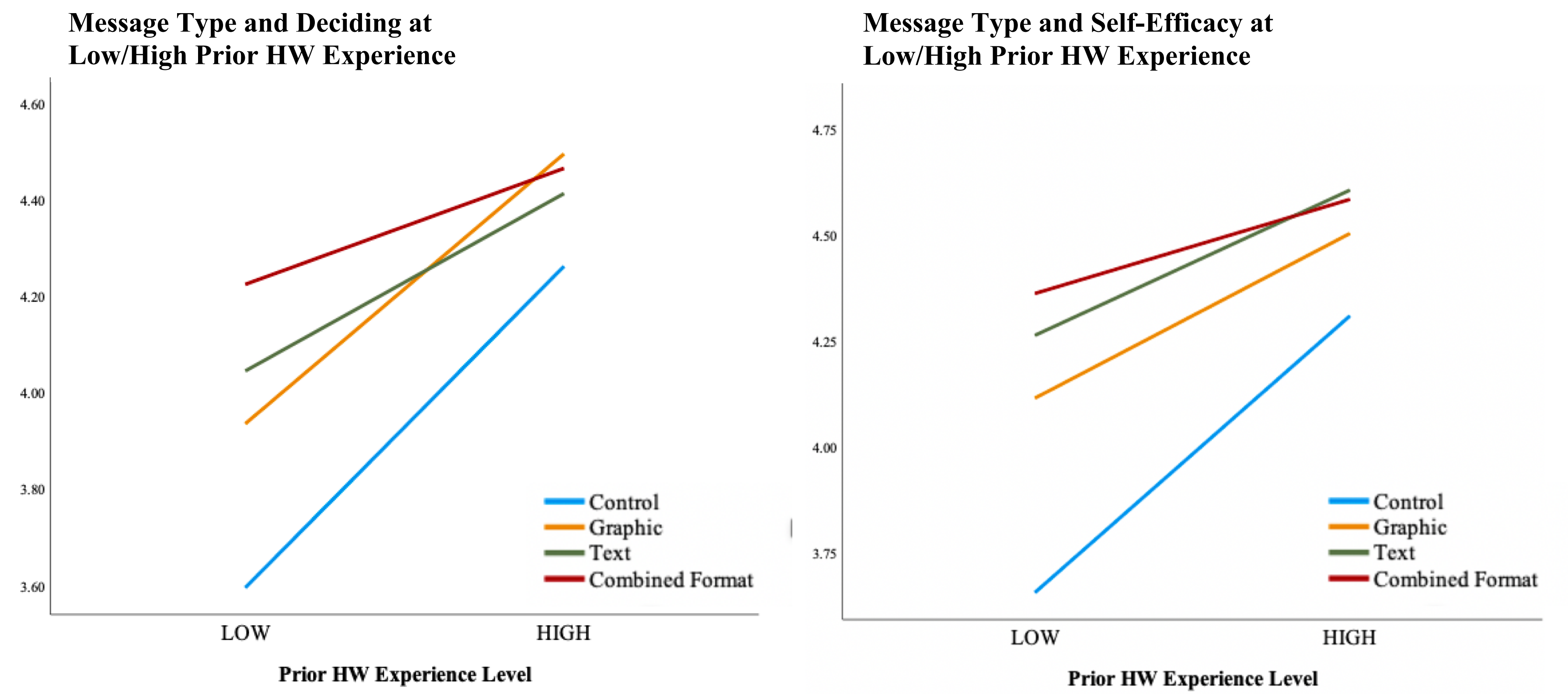
As shown in Table 3, we found significant interaction effects for *message type* x *prior HW Experience* on deciding, $F(3, 1026) = 2.80$, $p = .04$, $\eta^2 = .008$, and self-efficacy, $F(3, 1026) = 2.96$, $p = .03$, $\eta^2 = .009$. However, we found non-significant interaction effects for message type x prior HW Experience on understanding, $F(3, 1026) = 2.46$, $p = .06$, $\eta^2 = .007$; believing: $F(3, 1026) = 1.56$, $p = .20$, $\eta^2 = .005$; personalization: $F(3, 1026) = 0.58$, $p = .63$, $\eta^2 = .002$; milling: $F(3, 1026) = 1.01$, $p = .39$, $\eta^2 = .003$; and response-efficacy: $F(3, 1026) = 1.14$, $p = .33$, $\eta^2 = .003$.

The results from a series of Bonferroni comparisons and simple slopes plots show for deciding and self-efficacy, prior HW Experience modified the effect of message type on message perception outcomes. The effect of message type, for each message type except the 'combined format' message, was found to be different depending on the level of prior HW Experience participants possessed. Specifically, when receiving the 'control', 'graphic', or 'text' message, the participants with lower prior HW Experience showed significantly lower levels of deciding and self-efficacy than those with higher prior HW Experience. However, no differences were seen when those with a lower level of prior HW Experience received the 'combined format' message. As Figure 6 demonstrates (dark red flatter line), the 'combined format' message produced the highest levels in deciding and self-efficacy for recipients regardless of their prior experience level.

In summary, prior HW Experience significantly modified the relationship between message type and deciding, self-efficacy, understanding, belief, and response-efficacy. The results suggest the 'combined format' message elicits the highest levels in these perceptual outcomes for the most people, despite their experience with the hazard or whether the messages are warning for tornadoes, snow squalls, or dust storms. We also report three-way interaction information in the Appendix B.

Figure 6

Interaction Effects of Message Type X Prior HW Experience on Significant Message Perception Outcomes



Note: Multiple Pairwise Comparisons conducted on significant outcomes only.

6. Discussion and Conclusion

The results of our study provide insights relating to the type of hazard warned in a message, the inclusion of protective action guidance, and its placement, in a message, and the influence of prior HW Experience on message perceptions. We first determined that *hazard type* did not have meaningful effects on participant message perceptions, suggesting that participants rate outcomes similarly regardless of the type of hazard these messages are designed for. Thus, NWS experimental message products in their existing form may serve as an effective tool to inform the public about a hazard during an imminent threat event. This is particularly important for communicating about hazards that have more recently designed experimental products, such as dust storm and snow squall (NWS 2020), or when a population is exposed to unfamiliar hazards. Our research may suggest these NWS experimental products may help to provide content that informs participants, regardless of prior hazard experience, about the hazard and its impacts.

Second, we determined that *message type*, or the structure of the message, affects message perception outcomes. Our findings suggested the messages that were enhanced to include protective action guidance in either the graphic portion, text portion, or in both portions of a message, elicited higher levels of participant understanding, believing, ability to decide, perceived self-efficacy, and perceived response-efficacy, and decreased milling in comparison with the standard or control message. Importantly, we found that message perception outcomes were higher for messages that included the manipulated structure of the enhanced text and messages that include both enhanced text and graphic in comparison with the message that included only the enhanced graphic or control. This finding differs from Sutton et al. (2021)'s work, who indicated the inclusion of the protective action guidance, whether in the text, graphic, or both, influenced message perceptions. Our findings suggested minimal differences between the control and the enhanced graphic. Perhaps, more details are needed in the enhanced graphic or more icons and visuals to help explain about the threat.

Prior warning research has not taken into account the effect that participant prior HW Experience has on warning message perceptions (Sutton et al. 2021; Wood et al. 2018). In this study we found that for all message types, higher levels of prior HW Experience leads to higher message perception outcomes. That is, participants with high levels of prior HW Experience had significantly higher message understanding, believing, deciding, and self- and response-efficacy, and less milling than those with low HW Experience. Prior experiences with a hazard have a powerful impact on how people respond to risk and risk information (Demuth 2018; Greening et al. 1996; Lindell and Perry 2012; Weinstein 1989). Scholars have provided evidence that those with higher levels of experience tend to have stronger reactions to risk-based messages, and tend to have an increased understanding, ability to make decisions, and motivations to take action (Demuth 2018; Lindell and Perry 2012).

Our results indicated the message including protective action content in the 'both message' elicited the greatest understanding, believing, deciding, self-efficacy, and response-efficacy, for the participants with lower HW Experience. The 'text', 'graphic' and 'control' messages instead tend to better serve those with high HW Experience. It is possible that the repetition of protective action guidance in both the structure of the text and the graphic of the message reinforces information to unfamiliar audiences. Thus, we recommend that messages include protective action content in both the text and the graphic portion to inform and motivate individuals who have both high hazard warning experience and low hazard warning experience.

The effect sizes for message type and most of the message perception outcomes were small to medium. It is important to note that small effects can make large differences in the numbers of people who may be able to act when exposed to a warning message in response to an imminent threat such as a tornado, dust storm, or snow squall, a finding that is consistent with those identified in previous research (Sutton et al. 2021). The largest effect size was found for self-efficacy, and it suggests that exposure to protective action guidance information leads to greater confidence in one's ability to protect themselves during these hazard events. Larger effect sizes were found for main effects of prior HW Experience (largest for deciding), which our findings also suggest modifies the relationship between message type and numerous outcomes, and thus may serve as a potential confounder in message manipulation studies.

a) Theoretical Implications

This research contributes to warning response theory by including prior HW Experience and varying hazard types as independent variables. Additionally, this work extends prior research by investigating how manipulations of message structure affect message perceptions based on hazard type and prior HW Experience levels. We found that the inclusion of protective action guidance information elicits higher message perceptions for understanding, deciding, believing, self-efficacy, and response-efficacy. However, for those who lack prior HW Experience, it is critical to deliver information in both the text and graphic format. Through this study, we found that messages that include informative protective action guidance, lead to the highest understanding, deciding, believing, self-efficacy, and response-efficacy – demonstrating that a *well written message will work well, regardless of hazard type or prior HW Experience*.

b) Practical Implications

The National Weather Service has continued to develop experimental products to communicate to the public about imminent threats disseminated through Twitter (the most recent additions including dust storm, snow squall, and high wind). Social media channels include technological affordances that allow for the inclusion of graphical information. With this, there is an opportunity to both inform the public about severe weather conditions as well as to motivate appropriate protective actions. From this research, we recommend that the NWS Storm Prediction Center modify existing and future experimental warning products to include protective actions in *both* the graphic and the text portions of a tweet.

c) Limitations

Non-probability samples have bias and limitations (e.g., potential exclusion, selection, and participation bias), and readers should be cautioned when attempting to generalize the findings of this study to larger populations. Although the sample for the study was intended to match census characteristics for age, gender, and race, members of the population may be excluded, which is a limitation of non-probability sampling and online surveys. However, through the use of experimental design, multiple hazard types, varying levels of prior HW Experience, and clear effects of the inclusion of protective action guidance suggest these findings are likely to be replicated in future studies. It is also important to address that we did not measure for behavioral responses, nor do we measure for behavioral intent; however, our study addresses key motivators leading to important behavioral outcomes, message perceptions, and efficacy. Another limitation of this study was the design and use of Twitter messages to disseminate risk information. While online survey respondents tend to be more communication-savvy, this study was not about how these respondents interact with Twitter. Instead, we focused on how the respondents perceive these messages and if they believed the messages provided enough information to take protective actions. Finally, we recognize ecological validity of the messages themselves as a limitation for this study. For example, if people are driving at the time where there is a tornado, snow squall, or dust storm, they should not be reading Twitter. However, our results have less to do with the timing of the delivery of the message via Twitter and more to do with how the design of the message affects message receiver perceptions.

d) Future Research

Warning response research should continue to examine how messages persuade the public to take action in response to message exposure in real life conditions. Thus, future post-event survey and field research should include accounts of messages received by warned populations. Future research may also explore why the message with enhanced content in both the text and the graphic was the most effective with those with low prior HW Experience. Although our population was matched to census demographics for the three cities (Atlanta, Buffalo, and Phoenix), we recommend expanding the population to those who might not be included in these areas. Perhaps future research could attempt to collect survey data through mail in surveys and/or by phone. These different survey techniques may expand the scope of the population to non-communication savvy groups and older generations. To investigate this further, we suggest using eye tracking methods that will capture what facets of a message affects visual attention for populations with both high and low HW Experience. Additionally, the enhancement to these messages focused on the inclusion of content; future research should manipulate other design elements such as color, use of icons, types of maps, and other placement options. Finally, it will be important to understand the extent to which experimental products are utilized by the public versus those who are within NWS partner organizations and may make use of population exposure information contained in the graphic portion of the standard message. While a single warning product cannot be all things to all people, a tweet has the potential to serve the purposes of many audiences and motivate protective actions that can save lives.

Acknowledgements

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Data Availability Statement

Anonymized data may be made available upon request.

Appendix A

Table A.1
Raw Means (M) and Standard Deviations (SD) for Message Outcomes by Hazard, Condition, and Prior Hazard Warning Experience

Hazard Type	Message Type	Prior HW Exp.	N	Understand. *M*	Understand. *SD*	Belief *M*	Belief *SD*	Personal. *M*	Personal. *SD*	Deciding *M*	Deciding *SD*	Milling *M*	Milling *SD*	Self-Eff. *M*	Self-Eff. *SD*	Resp. Eff. *M*	Resp. Eff. *SD*
Tornado																	
	Control	Low	35	3.58	.83	3.85	.85	3.08	1.07	3.31	1.15	3.67	1.09	3.48	.98	3.52	1.01
		High	58	4.21	.77	4.29	.71	3.55	1.04	4.18	.96	4.03	1.07	4.29	.76	4.17	.79
		Total	93	3.97	.85	4.13	.79	3.37	1.07	3.86	1.11	3.89	1.08	3.98	.93	3.92	.93
	Graphic	Low	49	4.08	.94	4.13	.91	3.21	.99	3.98	.97	3.80	1.25	4.16	.86	4.16	.87
		High	48	4.42	.55	4.33	.70	3.65	1.09	4.42	.82	3.60	1.36	4.59	.56	4.44	.62
		Total	97	4.25	.79	4.23	.81	3.43	1.06	4.20	.92	3.70	1.30	4.37	.75	4.30	.77
	Text	Low	46	4.02	.88	4.13	.99	3.42	.97	3.93	1.06	3.35	1.42	4.16	1.01	3.91	.94
		High	51	4.50	.52	4.31	.60	3.51	1.05	4.27	.91	3.07	1.41	4.55	.60	4.37	.66
		Total	97	4.27	.75	4.23	.81	3.46	1.01	4.11	.99	3.20	1.41	4.36	.84	4.15	.83
	Both	Low	40	4.41	.70	4.19	.83	3.30	1.07	4.23	.93	3.80	1.31	4.40	.87	4.11	.96
		High	36	4.45	.62	4.37	.64	3.52	1.03	4.45	.78	3.04	1.42	4.60	.62	4.36	.87
		Total	76	4.43	.66	4.28	.74	3.40	1.05	4.34	.86	3.44	1.41	4.50	.76	4.23	.92
	Total	Low	170	4.04	.89	4.09	.90	3.26	1.02	3.89	1.06	3.65	1.29	4.08	.98	3.95	.96
		High	193	4.38	.64	4.32	.66	3.56	1.05	4.32	.88	3.48	1.36	4.49	.65	4.32	.74
		Total	363	4.22	.78	4.21	.79	3.42	1.04	4.12	.99	3.56	1.33	4.30	.85	4.15	.87
Snow Squall																	
	Control	Low	44	3.82	.89	3.72	.99	3.19	1.01	3.64	1.16	3.76	1.08	3.63	1.13	3.73	1.13
		High	34	4.47	.53	4.45	.63	2.98	1.05	4.53	.63	3.89	1.04	4.56	.64	4.40	.65
		Total	78	4.10	.81	4.04	.92	3.10	1.02	4.03	1.06	3.82	1.06	4.03	1.05	4.03	1.00
	Graphic	Low	34	3.95	.85	3.96	.96	3.26	1.10	3.96	1.00	4.19	.86	4.15	.93	3.93	1.09
		High	43	4.40	.67	4.27	.75	3.25	1.08	4.50	.64	3.41	1.31	4.50	.75	4.29	.77
		Total	77	4.20	.78	4.14	.85	3.25	1.08	4.26	.86	3.75	1.19	4.34	.85	4.13	.94
	Text	Low	43	4.20	.71	4.23	.73	3.24	1.03	4.09	.97	3.81	1.08	4.36	.78	4.15	.89
		High	34	4.70	.38	4.66	.44	3.54	1.09	4.63	.53	3.66	1.42	4.77	.41	4.50	.63
		Total	77	4.42	.64	4.42	.65	3.37	1.06	4.33	.85	3.74	1.24	4.54	.67	4.30	.80
	Both	Low	41	4.29	.74	4.20	.80	3.33	1.10	4.18	.93	3.50	1.17	4.44	.68	4.32	.73
		High	53	4.48	.61	4.40	.65	3.26	1.04	4.43	.72	3.89	1.17	4.54	.60	4.43	.72
		Total	94	4.40	.67	4.32	.72	3.29	1.07	4.32	.82	3.72	1.18	4.50	.64	4.38	.72
	Total	Low	162	4.07	.82	4.03	.89	3.25	1.05	3.97	1.04	3.80	1.08	4.14	.95	4.03	.99
		High	164	4.50	.58	4.43	.64	3.26	1.07	4.51	.64	3.72	1.24	4.58	.62	4.40	.70
		Total	326	4.29	.74	4.23	.80	3.26	1.06	4.24	.90	3.76	1.16	4.36	.83	4.22	.87

Dust Storm																
Control	Low	47	3.87	.93	3.86	1.00	3.02	1.09	3.83	.98	3.61	1.28	3.87	1.17	3.99	.96
	High	39	4.05	.63	4.04	.63	3.01	1.17	4.08	.84	3.54	1.09	4.09	.90	4.13	.72
	Total	86	3.95	.81	3.94	.85	3.02	1.12	3.94	.92	3.58	1.19	3.97	1.06	4.05	.86
Graphic	Low	61	3.87	.93	3.87	.91	3.04	1.00	3.87	.97	3.53	1.14	4.04	.93	4.02	.91
	High	45	4.33	.75	4.35	.75	3.29	1.15	4.58	.56	3.90	1.15	4.43	.78	4.38	.71
	Total	106	4.06	.88	4.07	.88	3.15	1.07	4.17	.89	3.69	1.15	4.20	.89	4.17	.85
Text	Low	54	4.11	.87	4.00	.95	3.04	1.05	4.12	.93	3.57	1.23	4.28	.87	4.10	.94
	High	40	4.41	.65	4.39	.60	3.10	1.13	4.34	.73	3.53	1.20	4.50	.74	4.52	.65
	Total	94	4.24	.79	4.16	.83	3.07	1.08	4.21	.85	3.56	1.21	4.37	.82	4.28	.85
Both	Low	49	4.31	.81	4.26	.81	3.26	1.02	4.27	.98	3.41	1.29	4.25	.96	4.24	.91
	High	26	4.52	.44	4.31	.50	3.07	1.05	4.51	.64	3.67	1.43	4.62	.59	4.51	.59
	Total	75	4.39	.71	4.28	.71	3.19	1.03	4.35	.88	3.50	1.33	4.38	.86	4.34	.82
Total	Low	211	4.04	.90	3.99	.93	3.09	1.03	4.02	.97	3.53	1.22	4.11	.99	4.09	.93
	High	150	4.31	.66	4.27	.65	3.13	1.13	4.37	.72	3.67	1.20	4.39	.79	4.37	.69
	Total	361	4.15	.82	4.11	.83	3.10	1.07	4.16	.89	3.59	1.21	4.23	.92	4.21	.85
Hazard Combined																
Control	Low	126	3.77	.89	3.81	.95	3.10	1.05	3.62	1.10	3.68	1.16	3.67	1.11	3.77	1.04
	High	131	4.23	.69	4.26	.68	3.24	1.11	4.24	.86	3.85	1.08	4.30	.79	4.22	.74
	Total	257	4.01	.83	4.04	.85	3.17	1.08	3.94	1.03	3.76	1.12	3.99	1.01	4.00	.93
Graphic	Low	144	3.96	.91	3.98	.92	3.15	1.02	3.93	.97	3.78	1.14	4.11	.90	4.04	.94
	High	136	4.38	.65	4.32	.73	3.41	1.11	4.50	.69	3.64	1.28	4.51	.70	4.37	.70
	Total	280	4.17	.82	4.14	.85	3.27	1.07	4.20	.89	3.71	1.21	4.30	.83	4.20	.85
Text	Low	143	4.11	.82	4.11	.90	3.22	1.02	4.05	.98	3.57	1.26	4.26	.89	4.05	.92
	High	125	4.52	.54	4.43	.57	3.39	1.10	4.39	.77	3.38	1.36	4.59	.61	4.45	.65
	Total	268	4.30	.73	4.26	.78	3.30	1.06	4.21	.90	3.48	1.31	4.42	.79	4.24	.83
Both	Low	130	4.34	.75	4.22	.80	3.29	1.05	4.23	.94	3.56	1.26	4.36	.85	4.23	.87
	High	115	4.48	.57	4.37	.61	3.30	1.05	4.46	.72	3.57	1.35	4.58	.60	4.43	.74
	Total	245	4.41	.68	4.29	.72	3.30	1.05	4.34	.85	3.56	1.30	4.46	.75	4.32	.82
Total	Low	543	4.05	.87	4.03	.91	3.19	1.04	3.96	1.02	3.65	1.21	4.11	.97	4.03	.96
	High	507	4.40	.63	4.34	.65	3.33	1.09	4.40	.77	3.61	1.28	4.49	.69	4.36	.71
	Total	###	4.22	.78	4.18	.81	3.26	1.06	4.17	.93	3.63	1.24	4.29	.87	4.19	.86

Appendix B

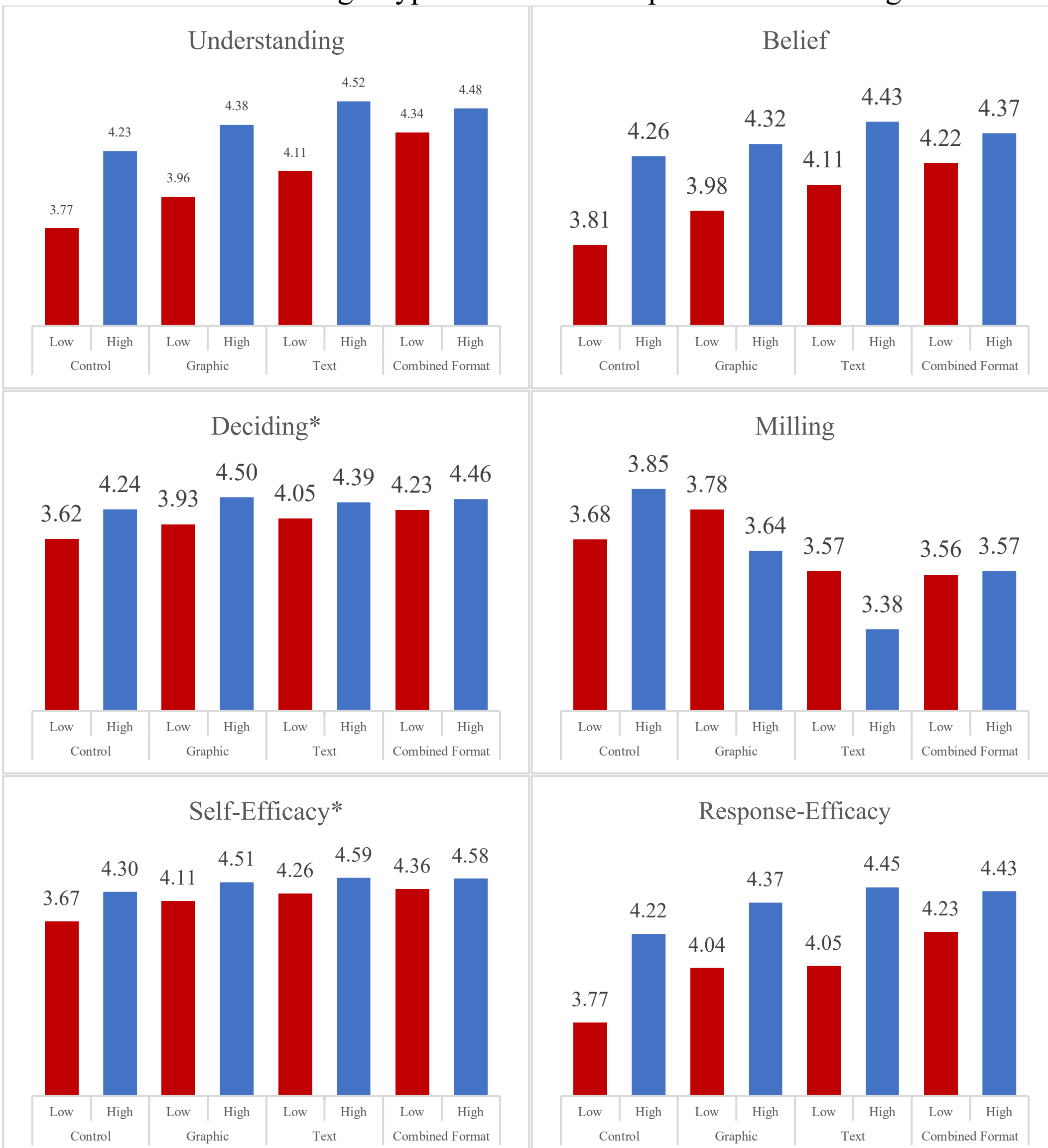
Below, we provide a full, detailed write up describing how does the type of hazard or the level of the participant's prior hazard warning experience *modify* the relationship between message type and message outcomes?

1) Interaction Effects: Message Type and Prior HW Experience

We explore potential interaction effects among message type and prior HW Experience to understand whether the former's effect on message perceptions varies across levels of prior HW Experience (see Table 3, Figure A.1, and Table A.1). Below, we report the interactions and Bonferonni adjusted comparisons for each outcome separately, excluding personalization (p = .63) and milling (p = .39).

Figure B.1

Interaction Effects: Message Type X Prior HW Experience on Message Outcomes



*Significant interaction effect at *p* < *.05*

a) Message Type x Prior HW Experience on Understanding

We found interaction effects between *message type* x *prior HW Experience* to be non-significant, $F(3, 1026)= 2.46$, $p =.061$, $\eta^2 = .007$. However, Bonferonni post hoc comparisons revealed at *low* levels of prior HW Experience (red bars), the 'combined format' message ($M = 4.34$) results in significantly higher levels of understanding as compared to the 'control' ($M = 3.76$; $p < .001$) and the 'graphic' message ($M = 3.97$; $p < .001$). At low HW Experience, the 'combined format' message also shows higher levels of understanding (M = .23) than the 'text' but the difference was only approaching significance (M = 4.11; p = .074). At *high* HW Experience (blue bars), we see only the 'text' message (M = 4.54) resulting in significantly higher means of understanding than the 'control' message (M = 4.24; p = .013).

In addition, the Bonferonni post hoc comparisons demonstrated that prior levels of HW Experience (i.e., high/low) drove differences in participants ratings of understanding within each message type (except for the 'combined format' message), where the 'control' message showed significantly lower levels of understanding for those with low HW EXPERIENCE (M = 3.76) as compared to those with high HW Experience (M = 4.24; p < .001). Those who received the 'graphic' and had low HW Experience (M = 3.97) showed lower understanding compared to those with high HW Experience (M = 4.38; p < .001). Similarly, the 'text' message showed significantly lower levels of understanding for the low HW Experience group (M = 4.11) compared to the high HW Experience group (M = 4.53; p < .001). We found no significant differences for those who received the 'combined format' message across low/high HW Experience levels, where the entire HW Experience group rated understanding collectively high.

b) Message Type X Prior *HW Experience on* Belief

The interaction effect of *message type* x *prior HW Experience* on belief was nonsignificant (p = .198). However, we further investigated the Bonferonni post hoc comparisons of message type at each level of HW Experience, which showed clear evidence for an effect of message type on belief at low levels of HW Experience, $F(3,1026) = 6.43$, p = .001, $\eta^2 = .018$, but not high levels of HW Experience , $F(3,1026) =1.33$, p = .265, $\eta^2 = .004$.

As seen in Figure A.1, Table 3 and Table A.1, for the low HW Experience group, the 'combined format' message (M = 4.22) and the 'text' message (M = 4.12; p < .01) resulted in a significantly higher level of belief as compared to the 'control' (M = 3.81; p < .001). Moreover, comparing belief scores within each message type, we again found those with low HW Experience and who received the 'control' (M = 3.81); the 'graphic' (M = 3.99), and 'text' messages (M = 4.12) rated belief significantly lower than those receiving the same respective message, instead with high HW Experience (Control *and* High HW Experience E ; M = 4.26, p < .001) (Graphic *and* High HW Experience: M = 4.32, p < .001) (Text *and* High HW Experience: M = 4.45, p < .001). However, we again see no significant difference between the low (M = 4.22) and high HW Experience groups (M = 4.36) for the 'combined format' message

(p = .17) on levels of belief, which are similarly high for both HW Experience groups (.14 difference).

c) Message Type X Prior HW Experience on Deciding

Significant interaction effects for *message type* x *prior HW* Experience were found for deciding, $F(3, 1026) = 2.80$, $p = .039$, $\eta^2 = .008$. As seen in Table 3, Figure A.1, and Table A.1, at *low* levels of HW Experience, we found the 'combined format' (M = 4.23) message results in significantly higher levels of ability to decide as compared to the 'control' (M = 3.60; $p < .001$) and the 'graphic' message (M = 3.94; $p < .05$). The 'text' (M = 4.05; $p < .001$) and 'graphic' (M = 3.94; $p < .05$) messages also result in significantly higher ability to decide when compared to the 'control' (M = 3.60) at low HW Experience. At *high* HW Experience, we found no significant differences in ability to decide across the message types.

When comparing the average levels of deciding within each of the message types at high/low HW Experience, our results showed a series of significant interaction effects. Similar to the previous outcomes, we found the 'control' message showed significantly lower levels of deciding for those with low HW Experience (Low HW Experience: M = 3.60) as compared to those with high HW Experience (High HW Experience: M = 4.26; p < .001). Those who received the 'graphic' and had low HW Experience (Low HW Experience: M = 3.94) also had significantly lower levels of deciding compared to those with high HW Experience (M = 4.50; p < .001). While those who received the 'text' or 'combined format' message showed higher scores in deciding combined (across HW Experience groups), those who received these enhanced messages and had low HW Experience(Text *and* Low HW Experience: M = 4.05) (Both *and* Low Exp: M = 4.23) also showed significantly lower levels in deciding compared to their counterparts who received the same message and had high HW Experience(Text *and* High HW Experience: M = 4.41; p < .001) (Both *and* High HW Experience: M = 4.47; p = .04). Again, the perceived ability to decide are highest for both HW Experience groups for the 'combined format' message (Low HW Experience: M = 4.23; High HW Experience: M = 4.47), suggesting that the 'combined format' message elicits the highest levels of deciding for the most people, despite their experience with the hazard warning.

d) Message Type X Prior HW Experience on Self-Efficacy

As shown in Table 3, Figure A.1, and Table A.1, we found significant interaction effects for *message type* x *prior HW Experience* on differences in self-efficacy, $F(3, 1026) = 2.96$, p

= .03, η^2 = .009. At *low* levels of prior HW Experience, the ‘combined format’ (*M* = 4.36) message produces significantly higher levels of self-efficacy as compared to the 'control' (*M* = 3.66; $p < .001$), and the 'graphic' (approaching significance, *M* = 4.12; $p = .09$). The 'text' message (*M* = 4.26) also has significantly higher perceived self-efficacy when compared to the ‘control’ ($p < .001$). At *high* HW Experience, we found significant differences in self-efficacy between the ‘text’ message (*M* = 4.61) as compared to the ‘control’ (*M* = 4.31; $p = .029$) and approaching significant differences between the ‘combined format’ message (*M* = 4.59) as compared to the ‘control’ (*M* = 4.31; $p = .07$).

When comparing the average levels of self-efficacy within each message type at high/low HW Experience, our results again showed a series of significant differences. At low HW Experience, the ‘control’ message (Low HW Experience: *M* = 3.66) shows significantly lower levels of self-efficacy as compared to the high HW Experience group that received the same meessage (High HW Experience: *M* = 4.31; $p < .001$). A similar trend is found for all the enhanced messages, with scores of self-efficacy being lower for those with low HW Experience and who received the ‘graphic’ message (*M* = 4.12), ‘text’ message (*M* = 4.26), and ‘combined format’ message (*M* = 4.36), compared to those with higher HW Experience receiving the same respective messages (Graphic *and* High HW Experience: *M* = 4.51; $p < .001$) (Text *and* High HW Experience: *M* = 4.61; $p < .001$) (Both *and* High HW Experience: *M* = 4.59; $p = .04$). While these differences are significant, overall, perceived self-efficacy is highest for both Experience groups for the ‘combined format’ message (Low Exp: *M* = 4.36; High Exp: *M* = 4.59), suggesting that the ‘combined format’ message elicits the highest levels of self-efficacy for the most people, despite their Experience with the hazard or whether the messages are warning for tornadoes, snow squalls, or dust storms. The ‘control’, ‘graphic’ and ‘text’ messages have higher perceived self-efficacy for those with high levels of experience.

e) Message Type x Prior HW Experience on Response-Efficacy

Although the interaction effects for message *type* x *prior HW Experience* were nonsignificant ($p = .33$) for response-efficacy, we again consider that there is not a global effect of message type at all levels of prior HW Experience. Thus, we further investigated the Bonferonni post hoc comparisons, of message type within each level of HW Experience, which showed clear evidence for an effect of message type at low HW Experience, $F(3,1026) = 6.96$, $p = .001$, $\eta^2 = .020$, but not high HW Experience, $F(3,1026) = 1.81$, $p = .143$, $\eta^2 = .005$) on response-efficacy. To further illustrate these differences, Figure A.1 presents the marginal means for the low HW Experience groups next to the high HW Experience groups by message type. As shown, for the low HW Experience group, the 'combined format' message ($M = 4.22$) produced a significantly higher level of response-efficacy as compared to the 'control' message ($M = 3.75$; $p < .001$). The 'text' message ($M = 4.05$; $p = .019$) and the 'graphic'($M = 4.03$; $p = .036$) message also generate higher response-efficacy than the 'control' ($M = 3.75$) message.

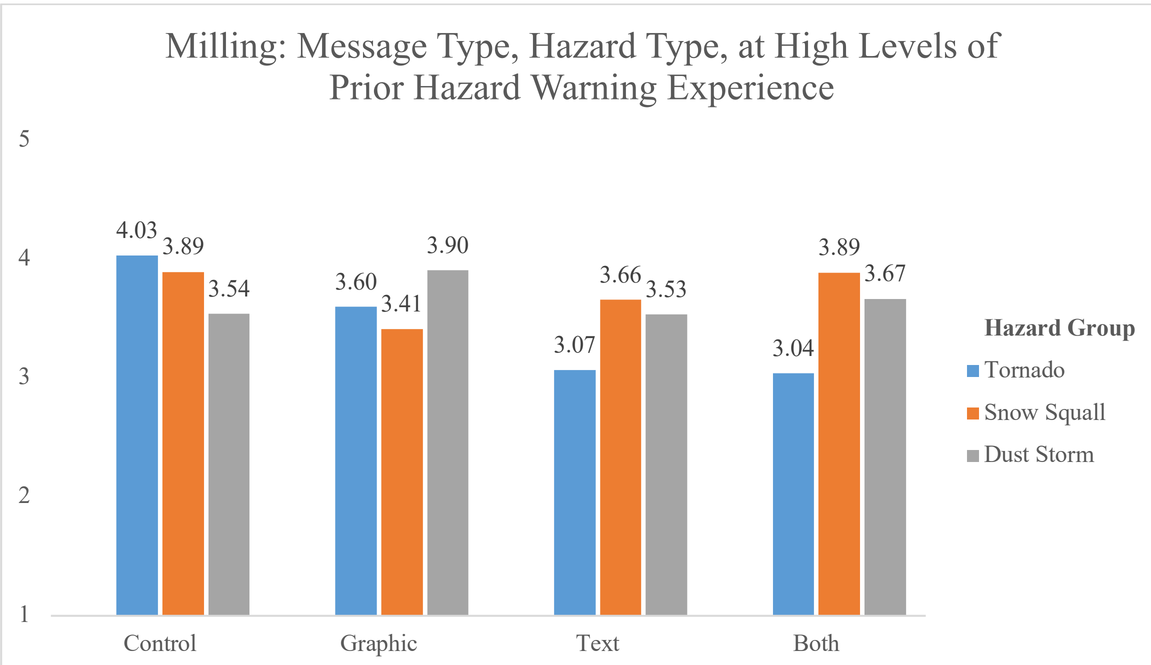
When comparing the average levels of response-efficacy within each of the message types, our results again showed a series of significant differences: Specifically, those with lower levels of prior HW Experience and who received the 'control' message ($M = 3.75$) showed significantly lower levels of response-efficacy as compared to those with higher levels of HW Experience ($M = 4.23$; $p < .001$). For the enhanced messages, those with low HW Experience and who received the 'graphic' ($M = 4.03$;) and the 'text' ($M = 4.05$) messages showed significantly lower levels of response-efficacy as compared their counterparts with high HW Experience (Graphic *and* High HW Experience: $M = 4.37$; $p < .001$) (Text *and* High HW Experience: $M = 4.46$; $p < .001$). The difference within the 'combined format' message is approaching significance, with the low HW Experience group ($M = 4.22$) showing slightly lower average in response-efficacy than the high HW Experience group ($M = 4.44$; $p = .056$). While the differences between the means within the 'control', 'graphic', and 'text' messages are much larger for the high HW Experience group than the low HW Experience group (on average M = .40 difference), the difference within the 'combined format' message is about half the size as compared to the other message types. These findings suggest that for the 'combined format' message, perceptions among both low and high HW Experience groups are most similar and highest in ranking response-efficacy. Thus, the 'combined format' message generates the highest amount of response-efficacy for the most people, regardless of the hazard. The 'text', 'graphic' and 'control' messages instead tend to better serve those with high HW Experience.

f) Three-Way Interaction

As shown in Table 3, we find the three-way interaction to be significant for perceptions of milling, $F(6, 1026) = 3.06$, $p = .01$, $\eta^2 = .018$. For interpretation, we isolated the three-way interaction and found it is only significant under high levels of prior HW Experience and for those in the tornado hazard type/group $F(3, 495) = 7.216$, $p < .001$, $\eta^2 = .042$. As seen in Figure A.2, the results show that participants with high levels of prior tornado warning experience, who received the standard or control message had significantly higher milling intention ($M = 4.03$) than those who instead received the enhanced text message ($M = 3.07$; $p < .001$) and the message with both enhanced text and graphic ($M = 3.04$; $p < .01$).

Figure B.2

Interaction Effects: Message Type X Prior HW Experience x Hazard Type on Milling



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