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Show Me and What Will I Remember? Exploring Recall in Response to NWS Tornado Warning Graphics

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Show Me and What Will I Remember? Exploring Recall in Response to NWS Tornado Warning Graphics

Abstract

It is critical that organizations deliver timely, effective communication about potential risks and life-saving information. The National Weather Service (NWS) developed a suite of messages known as "experimental graphic products" to be automatically distributed through their local official Twitter accounts at the onset of fast-moving, severe weather events such as tornadoes. However, recent research has suggested messages need to be carefully constructed for audiences to place attention to the content, remember the content, and later act in response to the content. The purpose of this study is to explore what people recall of the NWS Twitter message. We used an online survey instrument, distributed via Qualtrics, to investigate participant responses to three open-ended questions about the message. We performed a quantitative analysis to summarize the frequency of message features recorded by participants, and a qualitative analysis to identify themes that provide a deeper description of what was recalled. We found that participants encoded the hazard type, the time the message was sent and would expire, and the types of impacts that might occur. Graphic design cues elicited attention as they "stood out" to the participants. When asked about importance and what they would tell others, respondents described protective action, indicating participants may have activated prior knowledge of the threat, as it was not included in the message. Risk, disaster, and science communicators can draw guidance about communicating during a disaster. It provides a lens for researching message construction, and the importance of communicating protective action guidance during severe weather events.

Keywords

Recall, Limited Capacity Model of Motivated Mediated Message Processing, Disaster Communication, Natural Resources

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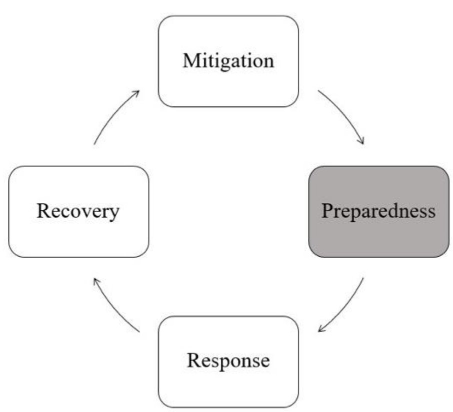
Introduction and Literature Review

The 2020s are no stranger to catastrophic disasters resulting from severe weather events. Recent severe weather events include extreme heatwaves, droughts, and forest fires in the western United States, deadly hurricanes across the Gulf states, destructive tornadoes across the Southeast, and winter storms in climates that are typically warm and immune to such weather events (NOAA, 2022). According to the National Oceanic and Atmospheric Administration's National Centers for Environmental Information (2022), "In 2021, there were 20 weather/climate disaster events with losses exceeding $1 billion each to affect the United States."

Federal agencies have identified rising global temperatures and climate change as a main contributor to changing and more severe weather patterns. Specifically, the Environmental Protection Agency (EPA) stated, "rising global average temperature is associated with widespread changes in weather patterns. Scientific studies indicate that extreme weather events such as heat waves and large storms are likely to become more frequent or more intense with human-induced climate change" (EPA, 2021, para. 1). Due to increases in the number and severity of storms, it is critical that response organizations and Federal agencies provide information to ensure publics and stakeholders are aware of and understand the risks and the associated actions they can take to protect themselves before they are exposed to a hazardous event.

Disaster communication is a complex phenomenon requiring a multi-phased communication approach to help publics effectively mitigate against, prepare for, respond to, and recover from hazardous events. Although communicators must develop strategies for each phase of the disaster lifecycle, enhancing the message strategies about the potential risk *before* a disaster occurs could result in long term learning leading to protective actions when they are most needed. Disaster communicators must develop key strategies and messages to provide impactful, timely information during each of the key stages of a disaster (see Figure 1): 1) mitigation: taking actions to prevent or reduce the cause, impact, and consequence of a disaster; 2) preparedness: planning, training, and education activities for events that cannot be mitigated; 3) response: actions that occur immediately after the disaster to reduce harm; and 4) recovery: long-term restoration efforts (FEMA, 2021).

Figure 1
Disaster Communication Stages Model (FEMA, 2021)



Within the agricultural science and natural resources literature, much of the focus has been on organizational communication strategies in the *response* and *recovery* stages of the disaster lifecycle. Extension and other natural resources community-based organizations have played a critical role in distributing information regarding how to cope with limited resources (i.e., lack of power and water). For example, Ali et al. (2020) identified the types of commination activities of county extension directors after Hurricane Irma. Their findings suggested the role of Extension was to relay timely and useful information from Federal agencies to their stakeholders through phone, face-to-face, and social media in these response and recovery phases. Mike et al. (2020) identified how Extension could be a resource for the community during and after a disaster and identified the types of communication channels used by Extension directors during the recovery stage during Hurricane season. Irlbeck and Moore (2020) described the communication efforts made and lessons learned from agricultural and natural resources communicators during the *response* and *recovery* stages of severe wildfires in Texas, Oklahoma, and Kansas. However, limited agricultural communications research has focused on risk messages communicated during the *preparedness* stage. The current study investigates how risk messages viewed prior to a hazardous event (i.e., during the preparedness stage) can lead to long term learning and affect short term information processing under conditions of imminent threat, or during a warning.

The National Weather Service

One organization that delivers life-saving information (i.e., guidance on how to take action during a potential threat) to the public during the *preparedness* stage of disasters is the National Weather Service (NWS) (Liu et al., 2020). During ‘routine weather’ days, the NWS engages the public by providing information about daily forecasts, historical data, events, and operational activities (Olson et al., 2019). During non-routine weather, such as severe weather events, NWS Weather Forecast Offices (WFOs) distribute warnings via webpages, social media, and wireless emergency alerts for the protection of life and property (Olson et al., 2019; Liu et al., 2020; NWS, 2020). Governmental agencies, such as the NWS, are central to the distribution of information in a clear, timely manner, and the public relies on these messages to make informed decisions (Liu et al., 2020).

The NWS has developed a series of experimental graphic products designed to be automatically distributed through local Weather Forecast Offices (WFO) official Twitter accounts at the onset of a severe weather event allowing for rapid dissemination of critical live-saving information for short-fuse threats (such as tornado, thunderstorm, dust storms, flashflood, etc.) (NWS, 2016; NWS, 2020). The current study will focus specifically on the Tornado graphic. As seen in Figure 2, these messages include text above the graphic, identifying the hazard, location of threat, and the time at which the message expires. Below the text is a graphic that includes a large main panel depicting the warning area, county boundaries, selected community names, and highways. On the left of the graphic is content about the time and date of the threat; the threat (i.e., size and type of hail), and populations that may be affected (i.e., potential exposure). The graphic also includes icons, used as a visual cue to depict potential impacts, and an inset map that orients the message receiver to the larger geographical area (NWS, 2016; NWS, 2020).

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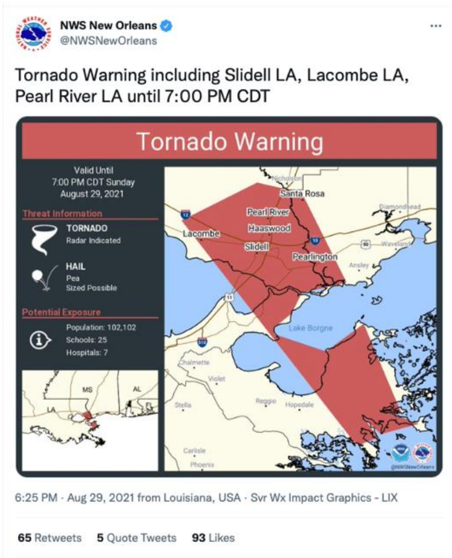
Figure 2

Example Tornado Warning Graphic Distributed to the Public via Twitter from the NWS



These products are routinely sent via Twitter to increase accessibility and amplification across social media platforms and on mobile devices (NWS, 2016; NWS, 2020). According to the NWS (2016, 2020), the audience for these messages is members of the public and NWS Core Partners in broadcast/electronic media, emergency management, and other governmental agencies. However, messages that are sent via social media are amplified across personal social networks, which suggests there is a possibility that even those who are not at risk will be exposed to these messages over time. When viewers are exposed and place attention to this message, it is possible that the individual will retain information as they cognitively process the message, and they, therefore, may learn from the information (Fisher et al., 2018). Although the goal of a warning is to alert publics to an imminent threat and motivate them to take action, multiple exposures to warnings over time may aid individuals to gain knowledge of a threat, its potential impacts, and the recommended protective actions.

Tornadoes frequently pose a risk that requires fast decision-making among exposed populations. Warnings, such as these Twitter messages, deliver information that informs audiences about the potential severity of the threat and identifies audiences exposed to risk. However, recent research has suggested that the design and construction of these messages needs to be carefully considered and developed if the goal is for the message receiver to attend to the content, remember the content, take action in response to the threat (Sutton & Fischer, 2021), and learn from this information.

Message Construction

In order to effectively communicate with key publics, practitioners must construct messages with the audience in mind to persuade them to do a specific task. Prior literature has identified *message content, message structure, and message style* as three components to consider when constructing messages (Shen & Bigsby, 2013; Mileti & Sorensen, 1990).

Message content relates to the what is said or represented in the message (Shen & Bigsby, 2013), both in text and in graphics, such as in icons or maps. Warning scholars have identified five primary content areas that increase the likelihood that message receivers will take protective action. These are information about *the hazard* (what it is, the severity, impact, and movement), *protective action guidance* (what people should do to protect themselves), *the location of the threat* (including the population at risk), *time* (by which a person should take action), *and the message source* (the organization or individual sending the message) (Mileti & Sorensen, 1990).

While the inclusion of content information is critical in warning messages, the *message structure*, or the presentation of the data or the claim (i.e.where content is placed or presented in the structure of the message), is also a critical piece of the message construction framework (Shen & Bigsby, 2013) in persuading audiences to act. In addition to the order of content, such as preceding or following an argument, message structure relates to where information is presented in the visual design of the message (Sutton et al., 2021). In one experimental study, the researchers manipulated the placement, or the structure, of protective action information by adding protective action guidance to the text copy of a Tweet, the graphic copy of the Tweet, or both (Sutton et al., 2021). The results of this study suggested that the inclusion of protective action guidance, whether in the text copy or the graphic, resulted in higher levels of self- and response-efficacy, or the belief that they could perform the prescribed actions (Sutton et al., 2021).

Message style concerns the way information is presented linguistically (Shen & Bigsby, 2013). Prior scholars have examined message style through a variety of linguistic techniques such as the use of hyperboles, phonetic symbolism, powerful versus powerless language, and message framing (Shen & Bisby, 2013; O'Keefe & Jensen, 2006). For example, O'Keefe and Jensen's (2006) meta-analysis concluded that specific use of language impacted the persuasiveness of a communications material.

Message Design

Although Shen and Bigsby's (2013) message construction framework identifies how a communicator presents information, it fails to address how the use of visual and graphic design are presented in a message. *Message design*, such as the use of colors, fonts, images, and shapes, is also an important aspect of message construction that serves to attract visual attention and impact understanding (Wogalter et al., 2002). Message construction should also use graphic design elements (i.e., the display and interaction of font, color, images, shapes, and text) to communicate and build visual salience (i.e., the use of design elements included to elicit attention to specific parts within the message) (Sutton & Fischer, 2021).

Message designers may incorporate graphic design techniques to improve warning messages (Wogalter et al., 2002) and capture the attention of viewers (Pieters & Wedel, 2007). For example, Sutton and Fischer (2021) found in an eye-tracking study that color was a crucial element to providing contrast to emphasize information in maps; the use of all capital letters (i.e., TORNADO WARNING) provided contrast to sentence case text-based information; and the use of punctuation (i.e.,!) indicated an important aspect of the text-based content. These researchers concluded that the use of design elements in warning messages must be used intentionally to elicit visual attention. The placement of information in graphical format and the use of graphic

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design elements may trigger attention allocation to specific elements and later increase processing of the information (Sutton & Fischer, 2021).

Recent research investigating the NWS Twitter messages has turned to eye-tracking and think-aloud methods to learn where participants allocated attention and what they thought as they viewed the message (Sutton & Fischer, 2021). One gap identified was how viewing patterns and attention allocation affected memory of the warning messages. In this study, we focus on message recall, investigating the construction and design elements of the message that participants remember from the Twitter tornado warning.

Recall and Information Processing

Recall has been defined by scholars as the mental process of retrieving information from the past (Lang, 2000; Fisher et al., 2018). Aspects of recall help to uncover the mental processes that occur in message processing, such as whether participants are able to remember aspects of the message accurately, how the use of colors or fonts draw their attention, and what kind of contents are most memorable.

One theory that informs understanding of recall is the Limited Capacity Model of Motivated Mediated Message Processing (LC4MP). LC4MP describes an individual's mental interaction with communication messages and the stages in the cognitive information processing system (Fisher & Weber, 2018; Lang, 2000, 2009; Lang et al., 2012). The model asserts that when an individual is exposed to a mediated message, they will allocate cognitive resources in three key stages: encoding, storage, and retrieval (Fisher & Weber, 2018; Lang, 2000, 2009; Lang et al., 2012).

Encoding has been described as the initial stage of perceiving and learning information (Lang, 2000, 2009; Lang et al., 2012) by creating a mental representation of a stimulus or message. Information that is encoded is subconsciously chosen from the vast information environment for further processing (Lang, 2000, 2009; Lang et al., 2012). In this subconscious process, individuals will select or encode information that is made visually salient by the message designers (i.e., colors, text, font that draw attention to elements or 'pop' out), information that is motivationally salient to the individual viewer (i.e., information that is in line with prior viewing habits and viewer motivations), or information that aligns with the individual viewers' prior experiences and beliefs. Encoding has been previously studied by asking participants "what do you remember from the scenario or message," and assists researchers in understanding what pieces of the message the individuals have selected from their information environment (Fisher et al., 2018).

Storage refers to maintaining encoded information and storing it in working memory over time (Lang, 2000, 2009; Lang et al., 2012; Fisher et al., 2018). In this stage, individuals will attempt to make sense of the information by mentally linking the new information to previously stored, old information, and creating a mental schema (Fisher et al., 2018). This storage phase is the repository of information individuals have collected over time that will be retrieved at a later date to make judgments (Fisher et al., 2018).

Retrieval refers to taking previously stored information and using that information to make judgements and arrive at a decision (Lang, 2000, 2009; Lang et al., 2012; Fisher et al., 2018). In the LC4MP, retrieval is the conscious recollection, or the action of remembering a piece of information that was stored and using this information during a task (Fisher et al., 2018).

Although there is no research using the LC4MP with warning messages, to the authors current knowledge, the LC4MP has been used to study other goal-directed communication, such as health communication (Clayton et al., 2017) and political messages (Bradley et al., 2007), among other social marketing topics. In their study on designing effective cancer communication messages, Lang (2006) posits that motivationally relevant topics and message structure affects the encoding, storage, and retrieval of information. A major area of importance in LC4MP, and particularly when dealing with disaster preparedness, is understanding how to build and design messages that ensure important parts of a message are encoded, stored, and later retrieved (Fisher & Weber, 2018; Lang, 2000, 2009; Lang et al., 2012). The LC4MP asserts under different motivational circumstances, such as preparing for an approaching hazard, individuals will be intrinsically and pre-consciously motivated to recall, (retrieve) messages that have been stored and encoded in long term memory.

Free recall was chosen to capture this contextual process, as opposed to cued recall which prompts the participant to recall certain pieces of the message (Hunt, 2016). Cued recall starts a specific memory retrieval process, while free recall prompts recollection of any salient message components. The current study measures if the participants encode enough information for individuals to retrieve (remember) so they can appropriately respond to the severe weather event by asking a series of open-ended recall, or memory, questions. In the time of a real threat, individuals will not be prompted to remember salient components of the warning message; instead, they will instead ideally receive the message, remember certain parts, decipher what is important, share with friends and family members, and act in accordance with it. While NWS Twitter tornado messages are designed to trigger protective action at the time of imminent threat, exposure to these messages may also promote learning for the future (i.e., what did the participants recall). This is a hallmark of preparedness --- learning in such a way as to be prepared for future events (FEMA, 2021). Further, these messages distributed by NWS are also designed to be shared via social media (NWS, 2020). First, the public is more likely to share information with their social media followers that they place importance upon (whether it be their personal relevance to a topic, or important information in a specific moment like a disaster) (Dong et al., 2021; Liu et al., 2017). Second, scholars have suggested information sharing will only occur if the information aligns with their followers viewing habits and needs (Liu et al., 2017). Thus, if message designers seek to promote learning and the sharing of information on social media, they must be aware of how and why the public finds messages to be of the importance to be shared.

Purpose and Research Questions

The purpose of this study was to explore what people recall from the NWS Tornado Warning Twitter experimental product. In this study, we investigated recall of the tornado warning message using the lens of Shen and Bigsby's (2013) message construction framework. We explore what participants remember about the message content and the design features to learn what they find to be most memorable and most important and to learn what participants would tell others about the warning message. To achieve this purpose, the following research questions guided the study:

> **RQ1**) What *message content* features did study participants remember, find important, and what would they tell others?

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RQ2) What *message design features* did study participants remember, find important, and what would they tell others?

Methods

To collect data on what the participants' remembered, found important, and would tell others about the NWS Tornado Warning Twitter message, we used a survey instrument, distributed online via Qualtrics, to investigate participant responses to three specific open-ended questions after exposure to the message. This study was approved by the university IRB (Protocol Number: 56007). We performed a descriptive quantitative analysis to summarize the frequency of content and style features that were recorded by participants (Krippendorff, 1980), and a qualitative analysis to identify themes that provide a deeper description of what participants recalled about the message (Altheide & Schneider, 2012; Wimmer & Dominick, 2014)

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Participants

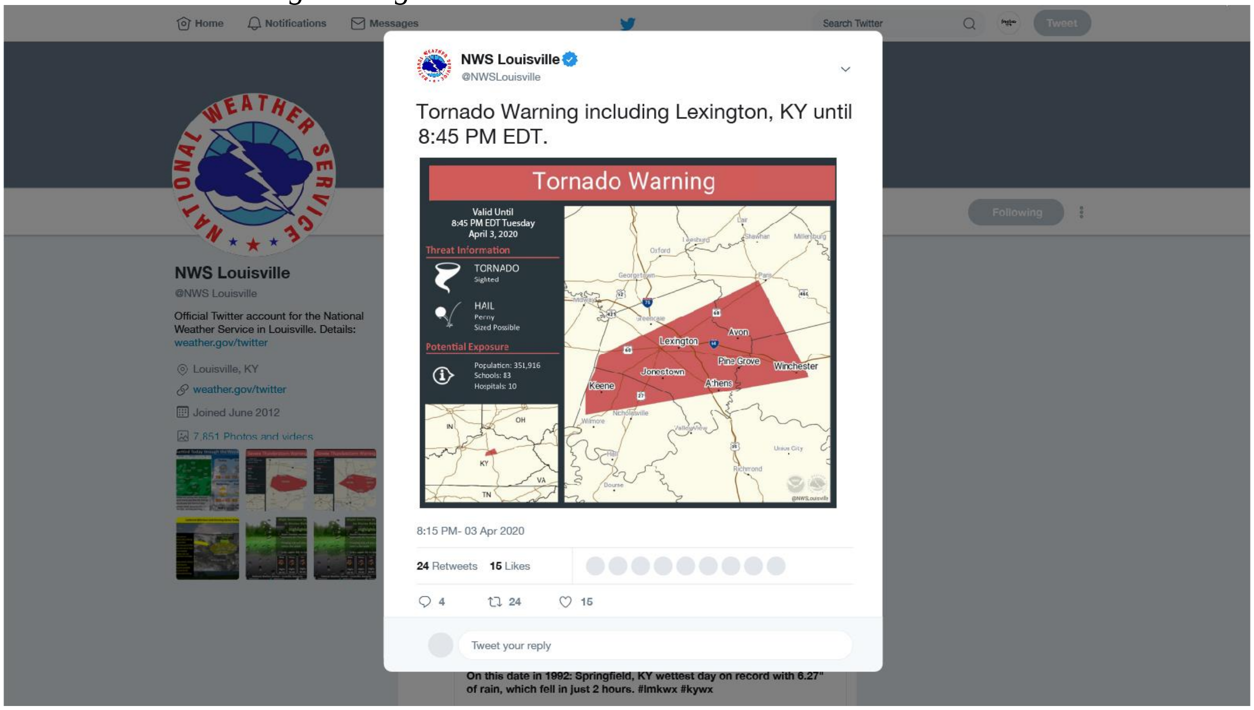
We recruited undergraduate students from a large southeastern university from courses within a college of communication and information to participate in an online Qualtrics study regarding a tornado warning message. Students earned course credit for their participation in the study. We collected responses from 71 undergraduate students; however, 5 participants were removed from the sample due to incomplete responses throughout the entire survey. Thus, we had a total sample size of 66, which is appropriate for descriptive research. The data reported in this manuscript were part of a larger study, and data were analyzed independently from other variables collected through the survey instrument and collection procedures.

Seventeen of the participants were freshman (26.2%), 17 were sophomores (27.7%), 13 were juniors (20.0%), 17 were seniors (27.7%), and 1 participant did not answer this question. Forty-five participants (n = 69%) were white, 10 participants (15.4%) were Black or African American, 4 participants were Hispanic/Latino(a) (6.2%), 2 participants (3.1%) were Asian, 1 participant was Native Hawaiian or Pacific Islander (1.5%), and 2 participants preferred not to answer.

Research Procedures and Questions

After the informed consent process, participants were instructed to "please take a moment to read and review the message. After, you will be asked to reflect upon the tweet that you see below" and were presented with a mockup of a Twitter message that replicated a tornado warning message previously distributed by NWS Louisville (Figure 3).

Figure 3
NWS Tornado Warning Message



After viewing the message, to increase ecological validity, participants were then asked to watch a 90 second distraction video about cats (Wimmer & Dominick, 2014). Next, to achieve the purpose of the study and understand what participants recalled, open ended free recall questions were employed. In free recall, participants are asked to recall any information they can remember from the tweet that they viewed (Aue et al., 2016). In this case, the participants were instructed, "Now think about the tweet that you viewed before watching the video. Please take a moment to write everything that you remember about the message. Including things like the written words, colors, symbols, placement, etc." To assess what participants specifically found to be *most important*, they were asked, "Please take a moment to share what you think is the most important information from the message." Finally, the participants were asked, "What would you tell other people about what was in this message." For each question, participants were asked to enter their responses into a blank text box (Hunt et al., 2016).

Data Analysis

Data was analyzed both quantitatively and qualitatively to identify the frequency of what specific features were encoded (i.e., retrieved from short term memory) and to characterize why specific contents and features were remembered (i.e., encoded and stored). We applied content codes at the sentence level that were drawn from prior literature on warning messages (Mileti and Sorensen,1990). Codes included terms associated with the threat type (i.e., tornado, hail, penny sized hail, tornado sighted), threat level (i.e., warning, tornado warning), potential exposure (i.e., potential exposure, population, schools, hospitals), location (i.e., Kentucky, Lexington, counties), time (i.e., date, time), and guidance (i.e., take cover, shelter in place). Message design of the warning message was also coded quantitatively. In this section, we coded for mention of message design features identified by participants such as colors (i.e., black, red,

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white, yellow), maps, icons, shapes (i.e., polygons, sidebar), and changes in fonts (i.e., ALL CAPS, bold letters) that were described in the open-ended responses. Researchers entered each open-ended response into a spreadsheet, then each response was coded for the content and features described above, using *1 = present* or *0 = absent* into a second Microsoft Excel spreadsheet.

To ensure consistency and reliability were reached, coder training was conducted using the open-ended responses from two participants. After the initial coder training, the two coders analyzed 10% of the data independently. The data were then entered into Microsoft Excel and uploaded to ReCal2, a free web-based service, that calculates intercoder reliability. In the first phase of intercoder reliability, we found a few discrepancies. Thus, the coders then met to review the codebook, discuss and redefine these variables and discrepancies. After the second phase of preliminary coding, we found an acceptable threshold of intercoder reliability using Krippendorff's alpha (Wimmer & Dominick, 2014). All variables had an acceptable threshold of 0.779 or higher and were deemed acceptable based on Wimmer and Dominick (2014) thresholds.

For the qualitative analysis to determine the why statements were retrieved, the researchers used a deductive, top-down approach (Erlandson et al., 1994). In this approach, the researchers used the same codebook variables and assigned passages of the text to the pre-determined codes. A detailed audit-trail and peer debriefing were used to ensure confirmability and dependability of the qualitative data (Erlandson et al., 1994).

Findings

After exposure to the NWS Tornado Graphic, participants were asked to recall 1) what they remembered from the message, 2) what they found important, and 3) what they would tell others about the message. Below, we provide the findings from participants' recall of the message content features and the message design features.

Message Content Features

Throughout the analysis, the five most prevalent message construction themes that emerged from the data were the 1) the level of the threat (warning), 2) the date and time of the threat, 3) location of the threat, 4) types of hazards included, 5) the potential exposure to the storm, and 6) the need to take action. Table 1 provides details of the frequency and percent of the participants' recall of the content of the NWS Tornado Warning Graphic and Tweet, and we describe the qualitative findings in the narrative below.

Table 1
Summary of the Participants Recall of the Message's Content of the NWS Tornado Warning Graphic and Tweet

	Remembered		**Found Important**		**Tell Others**	
Emergent Theme	**n**	**%**	**n**	**%**	**n**	**%**
Level of the Threat (Warning)						
Warning	50	75.76	38	57.58	40	60.60
Tornado Warning	41	61.12	26	39.40	33	50
When the Threat was Occurring						
Date	11	16.67	6	9.09	2	3.03
Time	30	45.45	24	36.36	18	27.27
The Location of the Threat						
Location	56	84.85	34	51.51	47	71.21
Lexington	41	62.12	12	18.18	27	40.91
Kentucky	14	21.21	3	4.55	9	13.64
Regions, Counties, Cities	9	13.3	2	3.03	2	3.03
Types of Threats						
Severe weather/bad weather	27	40.91	26	39.39	20	30.30
Tornado	21	31.81	21	31.82	16	24.24
Tornado Sighted	6	9.09	6	9.09	4	6.06
Hail	17	26.0	4	6.1	8	12.0
Penny Sized Hail	6	9.09	1	1.52	3	4.55
Potential Exposure						
Population	10	15.51	0	0	1	1.52
Schools	11	16.67	1	1.52	0	0
Hospitals	7	10.61	2	3.03	1	1.52
Source of the Message						
NWS	6	9.09	1	1.51	0	0
NWS Louisville	5	7.58	1	1.51	0	0
How to Take Action	0	0	5	7.57	12	18.18

Level of Threat (Warning)

Throughout the responses, it was clear that participants remembered that the message included the term "warning." More than half of the participants remembered information regarding a warning (n = 50, 75.76%), found the warning to be of importance (n = 38, 57.58%), and would tell others a warning was occurring (n = 40, 60.60%). For example, one participant wrote, "I remember it was issued from an account in Louisville and the warning was in effect until 8:24." Another participant stated, "The most important information is that it states the warning for Lexington will last until 8:45 p.m." One participant stated they would tell others that, "there was a warning for our area and to be mindful of their locations and activities."

Fewer participants included the specific terminology "tornado warning" (n = 41, 62.12%), found the tornado warning to be important (n = 36, 39.40%), and would tell others the message said "tornado warning" (n = 33, 50%). These participants were more specific in their language. One participant wrote simply that they remembered, "there was a tornado warning."

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One responded, "the most important info from the tweet was the tornado warning…" When asked what they would tell others, "I would tell people that there is a tornado warning in the Lexington area."

When the Threat was Occurring

The participants also recalled the time of the threat occurring. Thirty participants (45.45%) freely recalled the time of the warning, and 11 participants (16.67%) freely recalled the date of the warning. Some participants (*n* = 24, 36.36%) also stated that the time in the message was important and that they would tell others about the time (*n* = 18, 27.7%). However, only six participants found the date (9.09%) to be important (*n* = 6, 9.09%), and only two (3.03%) indicated they would tell others about the date.

The qualitative analysis revealed that participants were interested in when the tornado warning was in effect. For example, several participants recalled specific dates and times, writing "the warning was effective until April 3rd" and "the tornado warning lasted till 8:45 p.m." Others were less specific. One participant wrote they found when the threat to be occurring important when they wrote, "the most important information is…on what date and what time." Another participant included, the "most important information was the map of where the tornado warning is happening and how long it is in place." Several participants (*n* = 24, 36.36%) wrote that it was important to tell others about the timing of the tornado warning. One participant indicated they would tell others, "The time of the tornado warning." Another participant wrote, "That a tornado warning was in effect until the posted time."

The Location of the Threat

Participants indicated the location of the threat was a primary point they remembered, found important and would tell others. Fifty-six participants (84.85%) recalled the specific names of cities at risk such as Lexington (*n* = 41, 62.12%), and the state of Kentucky (*n* = 14, 21.21%). Others described geographical areas more broadly, using words such as regions, counties, or cities (*n* = 9, 13.3%). For example, the specific names of the town or state were mentioned by one participant who wrote, "there was a map that showed the route of the tornado that covered Lexington and counties to the east and west." Others, instead, gave general information about the location of the tornado. One participant stated, "the tweet highlighted all the possible regions impacted."

Thirty-four (51.51%) participants wrote that the most important information centered on the location of potential impact. For example, one participant wrote, "where the tornado is located within the counties, how close the tornado is to the affected counties." Another wrote, "the most important [part of the] message would be to understand the areas that the tornado is coming in contact with to ensure safety." Forty-seven participants (71.21%) wrote that they would tell others about the warning, "if their county was in the warning" and "where the storm was currently."

The Types of Threats Included

From the quantitative analysis, participants tended to recall specific threat information such as severe weather (*n* = 27, 40.91%), hail (*n* = 17, 26.0%), tornado (*n* = 21, 31.81%). Some participants included specific information in their open-ended response such as, “it gave a threat information list, which said there was penny-sized hail possible.” One participant wrote, “it said tornado sighted and possible penny sized hail.” One participant recalled the specific information about the tornado such as, “gave information about tornado: talked about hail and other characteristics of a tornado.”

In response to the question “what was important,” participants described the degree of the threat, that is, the potential severity, and used adjectives such as severe weather and bad weather (n = 26, 39.39%). For example, one participant wrote, “I think that this was showing that this was a severe issue and that the viewers needed to take precaution and take it seriously.” Another wrote, “The most important was there was very bad weather that was coming and to take shelter.” Another wrote there was, “…hail in Lexington and other neighboring cities.”

Similarly, when asked what they would tell people, participants suggested they would tell people about the severity or possible impacts from the weather that was coming (n = 20, 30.30%), One wrote, “I would tell people… there could be hail damage.” Another participant wrote, “…there might be hail.”

Potential Exposure

Participants also wrote about the population (n = 10, 15.5%), schools (n = 11, 15.15%), and hospitals (n = 7, 10.61%) that were potentially exposed to the tornado hazard and other threats. For example, one participant wrote, “at the bottom left corner it said what would be affected by the tornado, and it gave numbers of how many schools and hospitals.” Another participant wrote, “it also gave the population of Lexington, the total number of schools in Lexington, and total number of hospitals.”

However, only 1 participant indicated that information about population exposure was important and that they would tell others writing, “I would tell other people that the greater Lexington area had a tornado warning and over 380,000 people were in the path. I would tell them this in particular because it is not every day a tornado hits a big urban area, and when it does it is usually very destructive.”

The Source of the Message

Details about the source of the message, the sender, was not commonly included in the open-ended responses. Six participants (9.09%) wrote about the message source either by mentioning NWS, NWS Louisville, or the word “source.” For example, one participant wrote, “the tweet was produced by NWS Louisville.” Another wrote, “first, I checked the validity of the source from which this information was coming from, which was the National Weather Service in Louisville.”

Additionally, the message source was only found to be important by 1 participant (1.51%), and it was not something any of the participants indicated that they would tell others.

How to Take Action

Notably, the message that participants viewed did not include information regarding the actions a person should take to keep them safe during a tornado event. We also found that none of the participants recalled information about protective action information. However, many

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participants wrote that "taking action" was either important (n = 5, 7.57%) or something they would tell others (n = 12, 18.18%).

One participant wrote, "I think that the most important information is the location where the tornado is expected to hit. This is the most important because those people needed to get to a safe area underground due to the strong possibility of a tornado hitting them." Another participant wrote, "The severe weather should lead to people to take shelter," "The most important was there was very bad weather that was coming and to take shelter." Another participant wrote, "I would tell people that there is a tornado warning and that we all need to take the right process to stay safe" and, "I would tell them there is a tornado warning in your location (if it pertained to them) and take the necessary precautions."

Message Design Features

The five themes that emerged from the data regarding the message design: 1) colors, 2) emphasis through bold letters or ALL CAPS, and 3) visual shapes (including polygons and icons). Table 2 details the frequency and percent of the participants recall of the design of the NWS Tornado Warning Graphic and Tweet, and we describe the qualitative findings in the narrative below.

Table 2

Summary of the Participants Recall of the Message Design Features of the NWS Tornado Warning Graphic and Tweet

	Remembered		**Found Important**		**Tell Others**	
Emergent Theme	**N**	**%**	**n**	**%**	**n**	**%**
Colors						
Background colors						
White	6	9.09	0	0	0	0
Blue	12	18.18	0	0	0	0
Red	46	69.70	9	13.64	2	3.03
All Caps & Bold Fonts	10	15.15	0	0	0	0
Visual Shapes						
Maps	29	49.93	11	16.67	0	0
Polygon/Highlighted Area	30	45.45	13	19.69	2	3.03
Sidebar	13	19.70	0	0	1	1.51
Icons	5	7.58	0	0	0	0

Colors

Colors drew attention to specific items. While only a few participants wrote about the background colors [found on the map/sidebar] such as white (n = 6, 9.09%) and blue (n = 12, 18.18%) more than half of the participants wrote about the colors used on the map (n = 46, 69.70%).

These colors were recalled by the respondents. For example, one participant wrote that the locations were "highlighted," explaining "the tweet was an image that had a map on the right with the places affected by the tornado highlighted in a red outline and then on the left there was information on what the warning includes." Another participant wrote, "there was a red box enclosing the areas that had the warning issued to them." Another participant recalled, "There was a covered area on the map [that] was in red that was included in the tornado warning that included areas surrounding Lexington."

Although the participants freely recalled this information, few indicated that color was important or something that they would tell others about. The *white and black background colors* were not found important or something they would tell others (White: $n = 0$; Blue: $n = 0$); however, 9 participants (13.64%) found *red* to be important and 2 participants (3.03%) would tell others about the color red in the message. In response to the question "what was most important," many referenced areas that were in red, suggesting that it indicated a level of importance to message viewers. For example, one participant wrote, "I think the most important is where the chunk of red was because it told you where the warning was at." Another participant wrote, "the most important information was the areas in red that would be affected."

Emphasis through big, bold letters or ALL CAPS

Similar to the colors, the participants were more likely to recall the information that was written in ALL CAPS or **big bold** letters (n = 10, 15.15%). One participant wrote, "I remember TORNADO WARNING in bold letters at the top of the screen." Another participant wrote, "the tornado warning is in effect the words: WARNING in big letter[s] at the top of the screen." However, they did not indicate that this was important or something about the message that they would tell others.

Visual Shapes

Participants wrote about specific information pertaining to visual shapes such as icons, polygons/highlighted areas, graphics, and maps in the message. Twenty-nine participants (43.94%) wrote about a map in the message, 30 participants (45.45%) wrote about a polygon area (sometimes described as a highlight, a covered area, shape, or an outline on the map), 13 participants (19.69%) wrote about the sidebar area and 5 participants wrote about the inclusion of icons.

Maps Twenty-nine participants (43.93%) wrote about the [large] map featured on the tweet. Participants wrote about the map of Kentucky and the areas the tornado may affect. The following quotes describe this theme. One participant wrote, "there was a covered area on the map was in red that was included in the tornado warning that included areas surrounding Lexington." Another wrote, "the map was in the center of the tweet." One participant wrote, "I also remember a map and a red shape indicating where the tornado warning was issued."

Many participants also found the map to be important. 11 participants (16.67%) indicated that the map was important to them. One stated, "I think the most important information from that tweet was the image showing where the tornado warning was." Another participant wrote, "I think the most important info on the warning was what areas would be affected and the map of the highlighted area was the most effective on saying where it would hit as well as the message saying tornado warning."

Polygon/Highlighted Area The participants also wrote about the polygon directing attention to the map (n = 30, 45.45%). For example, one participant wrote, "The map was mostly neutral tones, with points indicating the location of common cities, and a red polygon marked the

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zone that the warning applied to." Another participant wrote about a highlighted area, "The area was highlighted by a red square." A participant stated shapes helped to highlight important areas, "… a highlighted area of where the counties would be affected."

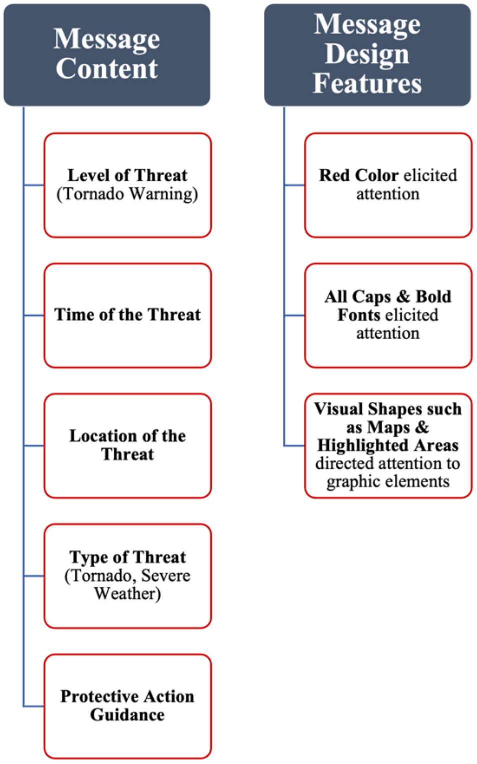
Sidebar and Included Icons Participants also wrote about the sidebar (n = 13, 19.70%) and the icons (n = 5, 7.58%) depicting various impacts. One participant wrote, "the information was placed off to the left including the info that a tornado had been spotted and penny sized hail was possible." Another stated, "There was a chart on the side that showed a graphic or symbol of a tornado and hail." One participant wrote, "On the left there was information on what the warning includes. There were warnings saying tornado and hail." However, the participants did not find this to be important nor would they tell others.

Conclusions, Discussion, and Recommendations

This study explored what elements of message construction and design participants wrote about in their free recall answers about what they remembered, what was most important, and what they would tell others. The act of writing about the message is a demonstration of recall showing what pieces of information were encoded and retrieved in the participants short term memory (Fisher et al., 2018; Lang, 2006). The findings of this study are useful for NWS Weather Forecast Offices and scientific, risk communicators as they identify how to improve message construction, that is, the contents, structure, style and design features, when communicating about warning and risk information. The theoretical model of the LC4MP provided a lens for the design of the study, and the message construction framework developed by Shen and Bigsby (2013) provided a lens for the analysis of the responses (Fisher & Weber, 2018; Lang, 2000, 2006, 2019). The free response questions invited participants to identify what had been encoded (i.e., what did they remember), and what they retrieved (i.e., what did they find important, and what did they tell others).

First, we analyzed what participants wrote about remembering (recall) or 'encoded' regarding the message content presented in the NWS Tornado Graphic. Mileti and Sorensen (1990) found the most effective warning messages will include content about the hazard, time by which a person must take action, the location of the threat, protective action guidance, and the source of the message. The participants were able to recall key information from the message such as the hazard type (a tornado warning), the timing of the message, and the types of threats that might occur (hail, wind). Participants also identified key contents of the warning message and wrote that the location, the duration, and the severity of the threat were important pieces of information that they would tell others. Figure 4 provides a visual summary of the message content and message design features participants recalled from the message.

Figure 4
Visual Summary of Elements Recalled from the NWS Graphic



Importantly, the tornado warning message provided by the NWS did not include information about the actions participants should take to protect themselves. However, 18% of the participants voluntarily retrieved information that suggested that they would tell others to take action (i.e., take cover, find shelters, stay safe). It is possible that the participants remembered previously stored information (i.e., prior experiences, memories of protective action guidance), and when they viewed the warning message, they associated the previously stored information with the newfound information on the warning message (Lang, 2006). This finding may be attributed to the information processing framework of LC4MP (Lang, 2006; Lang, 2012).

Regarding the message design features, a red polygon was used to draw attention to the location of the threat, the tornado warning was shown in big, bold ALL CAPS letters, and icons and graphics were used to communicate “tornado warning.” These graphic design elements helped parts of the message to “stick out” to the participants. This finding is consistent with the findings from Sutton and Fischer (2021) that used eye tracking and think aloud methods to learn how graphic design elements such as colors, text emphasis, and icons draw viewers’ attention.

This study was descriptive in nature; however, it holds potential insights for risk communicators who construct hazard messages, regardless of where they fall within the disaster lifecycle. Our findings suggest the participants recalled risk information that has been previously identified as key to motivating protective action in response to a warning. These include threat duration, location, and type of threat. However, in this case, participants also made connections to their encoded information on what to do during a tornado warning. Absent recommendations about protective actions in a warning message, however, some participants could draw from prior learning and memories to integrate their knowledge with the message that they viewed the message. Importantly, the NWS graphic included information related to potential exposure (i.e.,

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the population at risk, number of schools/hospitals at risk). While some participants recalled this information, only one participant indicated the potential exposure information was important. Due to these findings, we recommend the NWS include information on protective action guidance (i.e., take shelter in a sturdy room in a building, stay away from windows, etc.) in warning messages. There is some indication that warning messages will prompt learning among those who are not truly at risk. When necessary, message receivers can retrieve learned information and integrate it with recently encoded content; therefore, when communicating about a potential threat, protective action information should be provided for the benefit of those immediately at risk as well as to reinforce future preparedness. Further, risk, disaster, and science communicators can draw key findings from this study, such as the importance of communicating during severe weather and to be sure to include protective action information to guide the public.

Future studies should use experimental design to test public perceptions of the NWS Twitter warning message. Researchers could explore the connection between recall and message perceptions (i.e., if they are able understand the message, make decisions from the information presented in the message, etc.). Future research can further operationalize the *storage* construct of the LC4MP by offering cued recall questions that prompt the participant to think about certain message aspects. Often, participants have successfully stored content and perhaps would access it under heightened motivation (i.e., a real disaster) but do not *retrieve* it when asked to respond to the free recall question (i.e., Lang, 2006). Furthermore, researchers interested in the salience of Mileti and Sorensen's (1990) message characteristics could operationalize the constructs (information about the hazard, protective action guidance, location of the threat, time, and message source) to more sensitively measure if these pieces were encoded and stored but not independently retrieved via cued recall questions prompting recollection of these areas (Fisher & Weber, 2018).

Because the sample is limited to university undergraduate students, we are cautious to generalize this study beyond our sample. However, the design of the study shows clear trends related to how the public may view and response to message content and design elements presented within in a message. Additionally, while undergraduate students may be more communication savvy, this study was not about how they interacted with social media, rather, it focused on what message elements they were able to recall and tell others. In regard to expanding the results of the current study, it would be of interest to replicate this study with other hazards and varying populations. The current study focused on one type of threat, tornadoes; however, it may be interesting to explore how participants recall information from messages focused on threats with less familiarity such as snow squalls and dust storms. Perhaps, with threats with less familiarity, the participants may be drawn to elements that are highlighted through graphic design techniques. It may also be of interest to include eye tracking methods for data collection. Eye tracking will allow researchers to identify what components of the message elicited attention. Further, visual attention has been connected to recall, and researchers could connect and determine if visual attention allocation predicts recall when exposed to messages. Further, some participants had knowledge of what to do an emerging tornado warning. However, when faced with an unfamiliar threat for which they have limited knowledge, how would they respond? It may be of interest to conduct future research to determine how prior knowledge and experience of a threat influences recall of message design, construction, and understanding.

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