What Does It Mean to Stand Out? How Visual Design and Presentation Affect Attention and Memory in a Warning Message

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(Manuscript received 22 November 2023, in final form 21 September 2024, accepted 9 December 2024)

ABSTRACT: In emergency communication, it is essential to call attention to key information that can be interpreted quickly and remembered easily. Individuals possess a limited number of cognitive resources to allocate to message processing in an emergency. Because of this, they are more likely to allocate attention to messages they are motivated to care about or to message attributes that stand out. In this study, we focus on how warning messages are attended to when they are viewed in a busy media environment and ask the question: "What does it mean to stand out?" To address the research questions, we used a sequential explanatory design, mixed-methods approach. We employed eye tracking, a memory exercise, and think-aloud interviews to investigate visual attention, memory, and perceptions in response to warnings communicated via Twitter and Wireless Emergency Alerts (WEAs) for snow squall (SS) and dust storm (DS) hazards. Our findings revealed insights to assist message designers as they develop warning messages without burdening the message receiver with contents that require additional cognitive load. Colors help to draw attention to key elements and evoke a feeling of risk. Icons also draw attention and can serve as a signal that catches the eye, especially when actively viewed in a busy messaging environment. Additionally, techniques to make key text stand out through bold or the use of ALL CAPS may reduce effortful processing and eliminate the need for conscious fixations while resulting in easily remembered content.

SIGNIFICANCE STATEMENT: Visual risk communication messaging is often used to provide individuals with quick decision-making and protective action information in response to hazards. As messages increase in length and complexity, a burden is placed on risk communicators to capture the attention of message receivers. This study uses eye tracking, a memory exercise, and think-aloud interviews to investigate what factors influence visual attention, memory, and perceptions in response to warning messages over different channels. These methods allow us to not only answer questions about where people look, what they remember, and what draws their attention but also recommend tactics such as using ALL CAPS, colors, symbols, and icons, that can be used by message creators to maximize message effectiveness.

KEYWORDS: Communications/decision making; Emergency preparedness; Societal impacts

1. Introduction

As messages get longer, alerting authorities need to know how to call attention to key information that can be interpreted quickly and remembered easily. Choosing what to attend to is difficult due to issues related to cognitive load and the overwhelming amount of content that people are exposed to daily. It is estimated that the average person spends 2 h and 27 min on social media every day and checks their mobile device 159 times a day (Howarth 2024). Therefore, the average person is exposed to new information in a near-constant feed of visual stimuli. This has the potential to pose problems for those who need to be alerted to imminent threats in their environments. Theoretical and empirical research on the process of motivating a person to take a protective action has demonstrated that the initial step includes receiving and attending to a cue from the environment, other people, or an information source in the form of a warning (Lindell and Perry 2012). Mileti and Sorensen (1990) identified warning message receipt as the first step in their Warning Response Model (WRM), a step that initiates message interpretation. Receiving the warning means that the message, in some form, is delivered and captures their attention in the mid of all of the other competing sounds, sights, and feelings in the physical environment (Mileti and Peek 2000). Because individuals possess a limited number of cognitive resources to allocate to message processing, they are more likely to allocate attention to content they are preemptively motivated to care about (Lang 2000, 2009; Lang et al. 2012). Additionally, they will direct these resources to things that stand out—that is, features that are visually salient or different from the neutrally presented text (i.e., lower case, nonitalicized, and nonbold) and images (i.e., static and lacking color). Therefore, the presentation of content in a warning message takes on the dual task of communicating risk and urgency (Fischer et al. 2022), which can motivate a person to process the message while directing attention to the most salient content (Lang 2000, 2006, 2009; Lang et al. 2012). This means breaking through a very "noisy" and crowded media environment, as well as mental environment.

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DOI: 10.1175/WCAS-D-23-0140.1

Some warning channels have technological affordances that elicit attention to important information using visual cues to highlight key information for viewers. For example, social media platforms allow users to include static and animated images with and without video, both of which have been shown to increase message saliency (Sutton et al. 2015). Investigations of attention to these visuals showed colors, fonts, and icons or symbols drew individual gaze to key information when viewed in a laboratory setting (Sutton and Fischer 2021). In contrast, channels such as opt-in Short Message Service (SMS) alerts or Wireless Emergency Alerts (WEAs) are presently limited to text content for warning messages (with some use of emoji). WEAs are limited to 90 and 360 characters of text and include a single symbol (a yellow triangle containing a red exclamation point near the words EMERGENCY ALERT) at the top of the message. Many studies have been conducted on message comprehension related to the contents of WEA messages, including what should be included (Sutton and Kuligowski 2019; Sutton et al. 2024) and in what order (Bean et al. 2014) to optimize message perception outcomes. However, how WEAs are attended to visually, and how this may differ from warnings that present content in text and visual format, has not yet been studied.

In this study, we focused on how warning messages are attended to when they are viewed in a busy media environment and asked the question: What does it mean to stand out? To do so, we investigated responses to two types of warning messages that are issued by the National Weather Service (NWS): the warning tweet and the Wireless Emergency Alert. We selected two hazard types that are both relatively new to the NWS suite of alerts: snow squall and dust storm. We investigated visual attention using a mixed-methods approach where we collected demographic information and eye-tracking data and asked participants to elaborate on their thoughts about the message they viewed in a memory task and think-aloud interview. A better understanding of how message design affects the ways audiences view and remember key content can help to inform future visual design strategies. Importantly, these messages may be the primary cue that signals a person to take protective action.

2. Background and literature

a. Visual attention

Within information processing frameworks, visual attention allocation plays a critical role in information processing. Simply put—humans are constantly inundated with information and messages, and the human mind has a limited capacity to process incoming messages and new information (Zillman and Bryant 1985; Lang 2000; Duchowski 2007; King et al. 2019). When a viewer first looks at a stimulus, they will begin to identify specific areas or regions within the message that attract their immediate attention—this is like scanning the landscape. After this scan, the viewer will prioritize which areas of an image or message to inspect more carefully (Duchowski 2007; Gong and Cummins 2020). Theoretically, visual attention has been described as the process of allocating cognitive and mental resources to a component of a message (Duchowski 2007). It has been operationalized as an eye movement that is stationary over an object (measured in s and ms) and the number of times (frequency count) the eye was stationary (Duchowski 2007).

The selection of regions to prioritize in their visual inspection will depend on two types of salience: 1) motivational or 2) visual. Motivational salience refers to items that capture visual attention due to an individual's intrinsic motivation—it can be goal oriented (i.e., they have been assigned a task, so they look for things that help them to do the task), or it can relate to their prior knowledge or experience (i.e., I look for information that aligns with my prior knowledge and beliefs) (MacInnis and Jaworski 1989; Fischer et al. 2020; Gong and Cummins 2020). In contrast, visual salience refers to items in the visual search field that stand out and can be interpreted by a receiver (Lang 2000, 2009; Lang et al. 2012; Fisher and Weber 2020; Fischer et al. 2022). Visual salience has been described as components of a message that "pop out" from their surroundings, can be detected from other components of the message, and garner visual attention (Yantis 1993; Pieters and Wedel 2007; Sutton and Fischer 2021; Fischer et al. 2022). Graphically, message designers use contrasting colors, new color additions, the edge of objects, novelty, motion, symbols, and emojis, to help draw visual attention (Yantis 2005; Bruce and Tsotsos 2009; Zhang and Lin 2013; Sutton and Fischer 2021).

Textually, message designers can manipulate text to elicit visual salience through effects such as the use of all capital letters ("ALL CAPS") or the use of italics, bold, or colored fonts which can draw attention to an important word or phrase (Edworthy and Hellier 2006; Frascara 2006; Vos et al. 2018; Sutton and Fischer 2021). Designers may also make use of punctuation like an exclamation point (!), which may draw attention to important sentences (Edworthy and Hellier 2006; Frascara 2006; Vos et al. 2018; Sutton and Fischer 2021). Visual salience has been found to drive attention, and if items elicit attention, there is a higher chance that they will be processed and later interpreted by the viewer (Yantis 1993; Pieters and Wedel 2007; Fischer et al. 2022).

Previous research, including studies by Fischer et al. (2022) and Sutton and Fischer (2021), has explored the design of tornado warning messages, particularly those disseminated via Twitter, now known as X, through the use of think-aloud interviews and eye-tracking methods. Fischer et al. (2022) found that within Twitter warning messages, design elements such as bold and ALL CAPS letters, icons, and graphics enhanced the visibility of certain message features. Similarly, Sutton and Fischer (2021) made use of eye-tracking methods to examine how these elements capture visual attention within tornado warnings, specifically identifying which features most effectively attract viewers' attention. The current study expands this scope of research by analyzing visual attention to warnings for dust storm and snow squall sent via Twitter and Wireless Emergency Alert, allowing us to understand how visual attention to these features varies across message media.

b. Message processing

In this study, we utilize the Limited Capacity Model of Motivated Mediated Message Processing (LC4MP) (Lang 2006; Fisher and Weber 2020), to operationalize the cognitive processes related to message viewing, including "encoding," or selecting the components of the message to view, "storing" memories about message contents, and mentally "retrieving" or remembering the information obtained following message exposure. The LC4MP outlines three phases of cognitive resource allocation upon message exposure: encoding, storage, and retrieval. Encoding represents the information a receiver views and selects to process when exposed to a message. Next, if cognitive resources allow, information is then stored or logged into the accessible memory. Then, in the retrieval stage, individuals will access, or retrieve, the knowledge (i.e., remember). The allocation of cognitive resources to the memory storage process is determined by the individual's motivation to process the message and surrounding environmental stimulation (Fisher and Weber 2020), as well as message-related variables like message length, content density, and the medium, or channel, through which a message is received (Lang 2000).

c. Eye-tracking approach overview

The use of eye-tracking technology allows researchers to effectively explore where participants focus their gaze across various stimuli. As noted by Duchowski (2007) and discussed by Sutton and Fischer (2021), this method can effectively pinpoint locations within the visual field that capture individual attention, while also identifying the elements of visual stimuli that are most salient. By identifying and isolating specific components that command the highest levels of attention, particularly in the context of risk communication message design, we can establish which are the most engaging and impactful. Additionally, the combined use of eye tracking with follow-up think-aloud interviews enhances our understanding of the effectiveness of these components.

d. Study purpose and research questions

As noted in the WRM, publics must receive and attend to a message prior to preparing to take action (Mileti and Sorensen 1990). We argue that attention to a warning message also allows us to understand what components of the message elicit encoding, storage, and remembering of message content, which helps to facilitate protective action taking. Therefore, in this study, we investigated what people remembered about a warning message's content and features as a proxy for where they placed their cognitive attention and why. We used memory to identify any potential differences between eye-tracking data that measured what information individuals spent time looking at and what information or message features individuals actually remembered shortly after message exposure.

Additionally, think-aloud interviews, or asking a person to verbalize their opinions as they view a message, also provide insight into why participants allocated visual attention (see Bean et al. 2014; Sutton and Fischer 2021). By verbally describing what stands out in a message while looking at the message, viewers dedicated additional cognitive effort alongside visual scanning and attention. In other words, they became aware of what drew their attention as they are looking and describe what and why they see it. This may differ from what a viewer describes when asked what they remember about a message as well as what a viewer actively fixates on during eye tracking (Lamme 2003).

By exploring eye-gaze tracking, memory, and think-aloud interviews, researchers can more fully understand the relationship between what people attended to in a message, what they remember about the message, and what elements and features attract their attention. Where users focus their attention and simultaneously reflect on what they are thinking can give insight into cognitive processing (Clive et al. 2021). Additionally, the message features that are remembered most clearly can provide insight into what factors drew their attention and why. Therefore, we ask the following questions:

RQ1: Where do participants allocate visual attention when viewing a WEA and Twitter message about an approaching hazard in their location?

RQ2: What do participants remember about a WEA and Twitter message about an approaching hazard in their location shortly after viewing the message?

RQ3: What visual features do participants say draw their attention in a WEA and Twitter message about an approaching hazard in their location?

3. Methods

To address the research questions posed in this study, we used a mixed-methods approach using sequential explanatory design (Creswell and Clark 2007), investigating responses to warnings communicated via Twitter and WEAs for snow squall (SS) and dust storm (DS) events. In the first phase of this study, we collected eye-tracking data including fixation frequency and fixation duration as a measure of visual attention. Next, we conducted a memory exercise, where participants were asked about what contents and features in each message type were the most memorable and attention grabbing. Following this, we conducted think-aloud interviews, where participants reviewed a WEA or Twitter message and were asked to describe what features stood out to them and why. Finally, we asked participants to complete a short questionnaire to understand their prior hazard experience and collect demographic information.

a. Participants

Our participants included college students at two large public universities: one located in the northeast United States, assigned to messages focusing on a snow squall, and one in the southwestern United States, assigned to messages focusing on a dust storm. Participants were recruited using university listserv email lists and were offered a $20 gift card incentive in return for their time. In each location, 20 participants completed the study for a total of 40 participants. Eye-tracking studies typically have relatively low numbers of participants

TABLE 1. Sociodemographic characteristics for participants.

	Northeast University (SS)		Southwestern University (DS)	
	$n = 20$		$n = 20$	
Characteristic	*n*	%	*n*	%
Gender				
Male	15	75	6	30
Female	5	25	14	70
Race/ethnicity				
White	13	65	20	100
Black or African American	7	35	0	0
Asian	1	5	0	0
Indo-Caribbean	1	5	0	0
Class year				
First year (freshman)	1	5	0	0
Sophomore	0	0	4	20
Junior	10	50	10	50
Senior	7	35	6	30
Graduate student	2	10	0	0
Training in map reading				
Yes	14	70	0	0
No	5	25	19	95
Unsure	1	5	1	5
Training in meteorology				
Yes	1	5	0	0
No	18	90	19	95
Unsure	1	5	1	5
Hazard experience (mean)	3.49/5.00		4.35/5.00	
Age (mean)	21.7		20.7	

(King et al. 2019; Sutton et al. 2020), especially those focusing on the usability of websites or other online technologies (King et al. 2019). In descriptive research studies, prior research indicates smaller samples, often fewer than 20 participants, are adequate for understanding patterns of viewing behavior (Jacob and Karn 2003). Because this study provides descriptive trends involving visual attention and features that affect it, the number of participants was evenly split between the two hazards and the two message types of interest. Participants were randomly assigned to one of the two conditions programmed for their geographical area.

At the northeast university, the participants were diverse in ethnicity, predominantly male, and had an average age of 21.7. Many of the participants indicated they did not have any formal training in map reading or meteorology. In contrast, the participants in the southwestern university all described themselves as white, were majority female, and had an average age of 20.7. Most of the southwestern participants indicated that they did not have any formal training in map reading or meteorology. See Table 1 for the participants' full sociodemographic breakdown.

In both locations, the participants were found to have high levels of prior experience with their assigned hazard condition: SS or DS. Experience was measured using methods similar to Demuth (2018), identifying hazard experience using a five-point scale. In the SS location, which had just experienced an SS event 2–3 weeks before data collection (Schneider 2023), the mean experience level with SS events was determined to be 3.49. In the DS location, which had just experienced a significant dust storm location only 6–7 weeks prior to data collection (Lozano 2023), the mean experience level with DS events was determined to be 4.35.

b. *Eye-tracking data collection*

1) EYE-TRACKING PROCEDURE

The goal of eye-tracking data collection is to objectively measure the areas where the participant fixates their eyes (fixation counts) and the amount of time allocated to viewing each portion of the message (fixation duration). Eye-tracking data were collected in an on-campus research laboratory at their respective university location. Upon arrival at the laboratory, participants were introduced to the study activities and then completed informed consent. Participants began the study session sitting in front of a computer screen for an eye-tracking procedure that used a Tobii Pro Fusion device to monitor their eye movements and gaze patterns (Sutton and Fischer 2021). This noninvasive eye-tracking method measures pupil movement, fixations, and viewing patterns by emitting infrared light into the eyes of participants (Sutton and Fischer 2021). Prior to beginning the eye-tracking activity, participants performed a calibration procedure where they fixated on moving objects on the screen to ensure accurate data capture.

After the eye-tracking calibration, the laboratory researcher asked the participants to imagine they were members of the

public living in the city respective to where the study was being performed. They were told that they were scrolling through Twitter when they stopped to look at some messages. Participants were advised to view each image on the computer screen at their own pace and to press the spacebar when they were done to move on to the next message to mimic scrolling through a Twitter feed. The laboratory researcher remained present during the eye-tracking activity to ensure that participants remained still and to observe each participant's response as they viewed the stimuli. Time spent viewing the stimuli varied by location with approximately 78 s for participants in the northeast and 57 s for participants in the southwest.

2) STIMULI

The study consisted of four primary stimuli and four "foils." The primary stimuli included two Twitter-style messages (one for DS and one for SS) and two messages in the form of Wireless Emergency Alerts (one for DS and one for SS) that have been posted in a Twitter stream. Each message was designed to mimic real messages issued by the National Oceanic and Atmospheric Administration Storm Prediction Center (SPC) and NWS Weather Forecast Offices. Foils or "filler images" that were shown during the experiment served as a distraction from the primary stimuli. They were designed to simulate generic Twitter content that a college student might normally encounter when scrolling through a Twitter feed. See appendix C for a sample foil image.

(i) Twitter warning message

Twitter-style warning messages include two distinct components: the textual content of the tweet and an accompanying graphic image (see Fig. 1). The tweet text contains information pertaining to the hazard, its timing, location, and recommended protective actions. Text presented in ALL CAPS in our given stimuli includes the name of the hazard and the primary protective action guidance.

In the graphic portion of the tweet, the image includes a banner with the name of the hazard warning; a large map with a red polygon displaying the area at risk; a smaller inset map showing the risk area relative to a broader geographic area; and a box, in black, containing text and icons describing the hazard and safety information. Additional information that is common to Twitter posts was also included for realism including the account information, date/time of tweet, and engagement metrics.

(ii) Wireless Emergency Alerts

The WEA replicates the exact text contained in WEAs issued for SS and DS events but is displayed in a Twitter stream (see Fig. 2). A real WEA would be delivered directly to an individual's phone and would appear as a text-type message on the home screen until the receiver dismissed the message (i.e., a "push" notification). Each WEA is comprised of text and includes the name of the source, the hazard, time, and protective action recommendations. WEAs also include a small icon and the words EMERGENCY ALERT in ALL CAPS. For the purpose of this experiment, the WEA message is posted

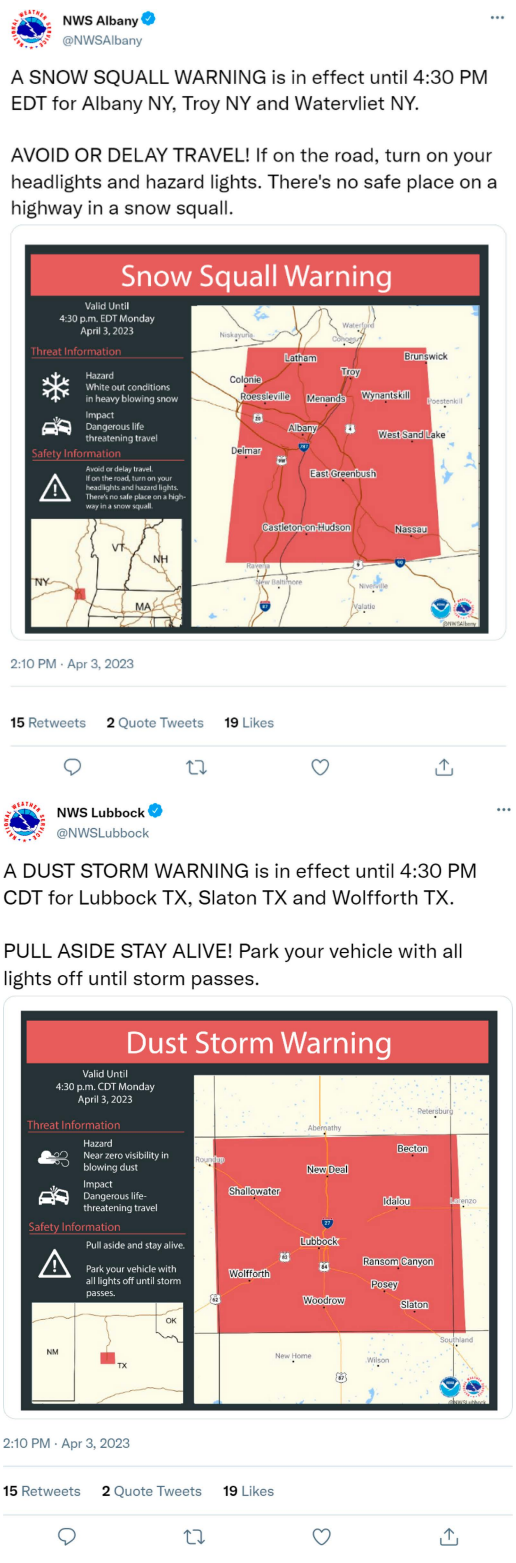

FIG. 1. Twitter warning message for (top) SS and (bottom) DS.

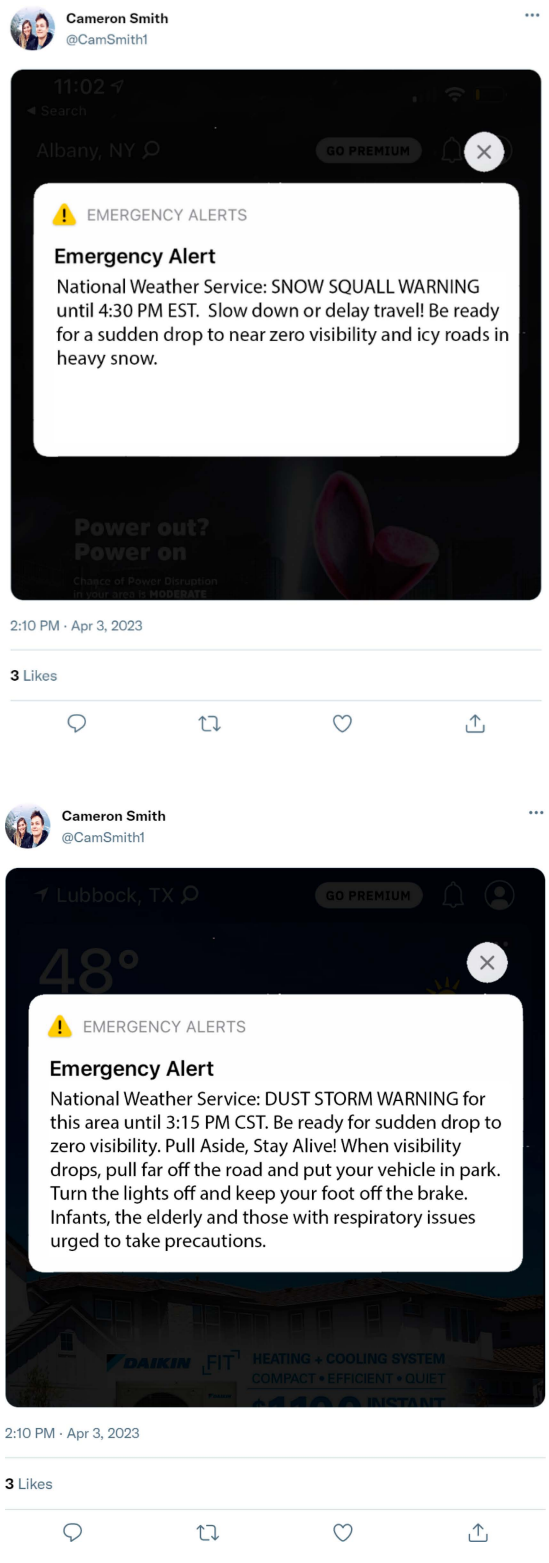

FIG. 2. (top) SS WEA and (bottom) DS WEA posted to a Twitter stream.

to a fictitious Twitter account and includes the time of posting and engagement metrics.

(iii) Foils

Four foils, or filler messages, served as a distraction from the target image and were designed to represent the type of messages that a college student might normally encounter when scrolling through a Twitter feed (see appendix C). Foil topics included a recently released movie, a humorous tweet about dogs and cats, an advertisement for a streaming service, and content about an upcoming university event. The tweet for the university event varied by the location of data collection. Each foil included a brief text component and an image; all were issued by organizations.

(iv) Areas of interest

Each stimulus image was segmented into multiple areas of interest (AOIs) that varied depending on message content (see Fig. 3). AOIs represented defined regions or elements within each image, encompassing components such as text, objects, images, or other graphical and visual components (see appendixes A and B for full descriptions of the AOIs). The use of AOIs enabled a granular analysis of participant gaze and visual attention allocation to components or features within an overall message. In short, AOIs allowed us to identify components or features of the image that participants most and least often contribute to their visual attention.

c. *Eye-tracking analysis*

Eye-tracking data were analyzed using Tobii Pro Laboratories software tools. After creating AOIs, all eye-tracking data collected via Tobii were downloaded as an interval-based tab-separated values (TSV) file, opened, and analyzed using Microsoft Excel. We measured the total number of fixations on the entire image and across each AOI. Fixation duration was measured for the overall image and each AOI and presented in seconds. Our results present the calculated frequencies and percentages for the fixation counts and the calculated means and standard deviation in seconds for the fixation duration per the overall message and specific areas of interest.

d. *Interview data collection*

Interviews were conducted to gain insights into the contents and features of each message the participants remembered, what features drew their attention, and why attention was directed to specific regions. Interviews were conducted in two parts: first as a memory task and later as a think-aloud interview. Both are described next.

1) MEMORY TASK PROCEDURE

The memory task focused on what participants could remember from the warning image they viewed among the set of Twitter images. Using a semistructured interview guide, the researcher asked the participants to describe message contents and features that they could remember from the warning message to which they were previously exposed. For both the tweet and the WEA, participants were asked to describe what

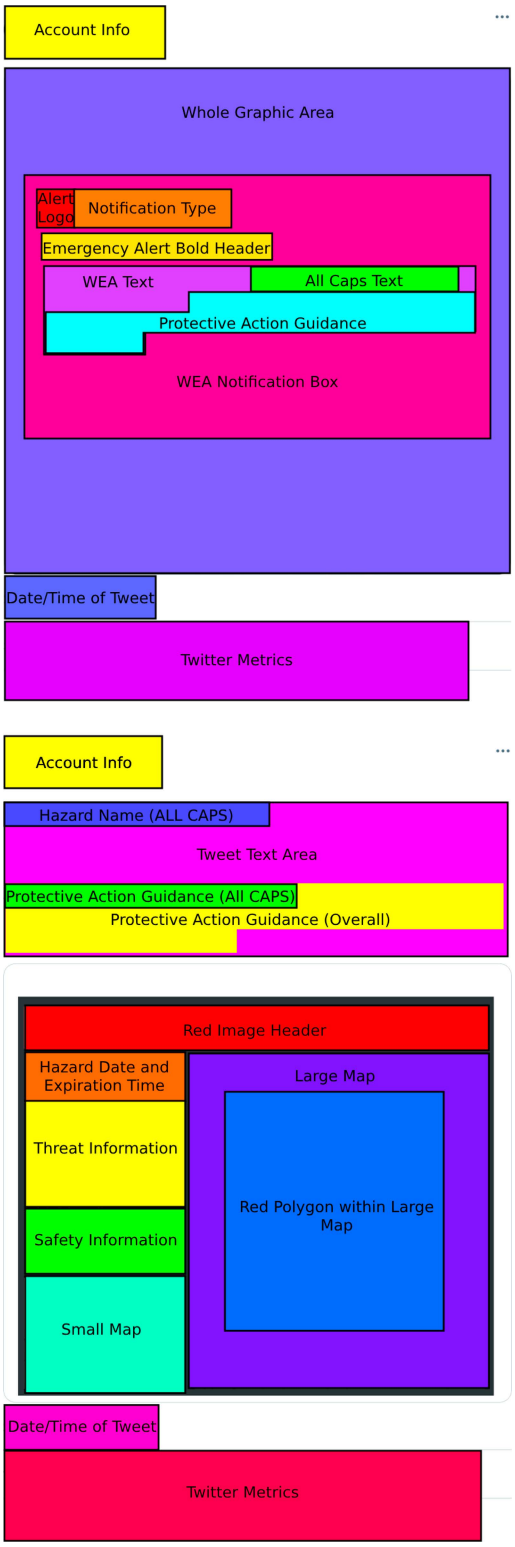

FIG. 3. AOIs outlined within (top) Twitter warning message stimuli and (bottom) WEA message stimuli.

they remembered about the written words, colors, symbols, placement of features, and general information from the message.

2) THINK-ALOUD PROCEDURE

Following the memory task, the participant was shown the warning message a second time and asked to describe the message features that stood out or drew their attention. They were also encouraged to state their initial reaction to the message and discuss parts of the message that they liked or disliked. Think-aloud interviews ranged from 11 to 28 min with an average of 16.6 min (northeast) and 5–20 min with an average of 8.8 min (southwest).

e. Interview data analysis

To ensure the trustworthiness of the data, each interview was audio recorded and uploaded into Otter.ai, an online audio transcription tool, and transcribed (Guest et al. 2006; Otter.ai 2024). After processing, transcripts were checked for accuracy by laboratory researchers and imported into Microsoft Excel for coding and analysis. Participant responses were organized by interview questions, and coding was performed on a question-by-question basis. Responses to each question were later grouped together and organized by topic.

The coding process began with the primary researcher performing a manual transcript analysis of each participant interview absent a predefined codebook. Reviewing each transcript, the researcher identified and generated inductive codes based on emergent themes in the participants' responses. Specific message features highlighted or mentioned by participants, such as the presence of icons, the name of the sending organization, text formatting such as ALL CAPS, or color, were documented in a coding spreadsheet (see Tables 8, 12, 15, and 18 for identified codes). The process was iterative; upon identifying a new theme, the researcher revisited all other analyzed responses to assess the presence or absence of that theme across the entire dataset (Aurini et al. 2021). As the analysis progressed, the researchers were able to identify the most prevalent themes found in participant responses, quantifying their occurrence across interviews. To ensure the dependability and confirmability of the results, two researchers met and utilized a peer debriefing process (MacQueen et al. 1998; Erlandson et al. 1993). During the peer debriefing, the two researchers discussed and debriefed the codebook, code formation, and code definitions. The debriefing led to consistent codes and definitions, thus increasing the confirmability and dependability of the results (MacQueen et al. 1998).

4. Results

a. Visual attention

We first examined participants' allocation of visual attention to the messages. For each of our eye-tracking measures, we present the number of participants who viewed each stimulus, the AOI, the average fixation duration (mean and standard deviation), the percentage of time they looked at the AOI, and the mean number of fixations.

TABLE 2. Descriptive results from eye-tracking data for SS and DS NWS tweets. Mean and standard deviation data are presented in s.

	Viewed by No. of participants	Mean (s)	SD (s)	Percent of overall viewing time	Average No. of fixations	Viewed by No. of participants	Mean (s)	SD (s)	Percent of overall viewing time	Average No. of fixations
Content feature	Snow squall					Dust storm				
Tweet image component										
Overall graphic	10	10.07	5.4	47.40%	32.1	10	7.85	3	48.70%	21.6
Large map	10	2.86	2.2	14.10%	10.3	10	2.75	2.1	17.10%	7.2
Red polygon within large map	10	2.26	1.69	11.00%	7.9	10	2.21	1.01	13.70%	5.3
Threat information	10	2.78	2.43	12.70%	7	9	1.56	0.96	9.70%	3
Safety information	10	1.94	2.33	8.10%	5	9	1.49	1.34	9.20%	4.2
Red image header	10	0.69	0.37	3.50%	3.2	9	0.42	0.29	2.60%	2.2
Hazard date and expiration time	7	0.58	0.76	2.70%	1.9	9	0.82	0.64	5.10%	1.9
Small map	10	0.84	0.68	4.30%	3.2	10	0.54	0.28	3.40%	1.6
Tweet text										
Tweet text area	10	8.01	2.75	42.70%	35.1	10	6.97	2.63	43.20%	29
Protective action guidance (overall)	10	3.99	2.02	20.50%	17.7	10	2.12	1.56	13.10%	9.3
Hazard name (ALL CAPS)	9	1.12	1.01	5.90%	4.4	9	0.81	0.44	5.00%	3.4
Protective action guidance (ALL CAPS)	9	0.28	0.31	4.10%	3	9	0.91	0.7	5.60%	4
Twitter UI features										
Twitter metrics/UI	6	0.29	0.38	1.80%	1.3	3	0.16	0.29	1.00%	0.8
Date/time of tweet	6	0.28	0.26	1.40%	1.2	6	0.15	0.13	0.90%	0.7
Account info	3	0.17	0.38	0.80%	1	7	0.46	0.47	2.80%	1.3

1) VISUAL ATTENTION TO THE TWITTER WARNING MESSAGE

In response to the Twitter warning message (see Table 2), we found visual attention was highest for the overall graphic portion of the Twitter warning message for both SS (M = 10.07 s) and DS (M = 7.85 s). Within the graphic, most attention was directed to the large map (SS: M = 2.86 s; DS: M = 2.75 s), followed by the red polygon within the large map AOI (SS: M = 2.26 s; DS: M = 2.21 s).

Visual attention to the tweet text area garnered the second highest viewing time, with similar lengths of time allocated to text across both groups (SS: M = 8.01 s; DS: M = 6.97 s). Within the text area, participants who viewed the SS message looked at the protective action guidance AOI for a greater overall amount of time than those who viewed the DS message, varying from a mean of 3.99 s (SS) to 2.12 s (DS), respectively. While viewing time was longer for the tweet image component, there was a higher average number of fixations on the tweet text area, especially on the protective action guidance. Visual attention directed to the Twitter user interface (UI) features was considerably less in terms of an average number of fixations as well as the overall viewing time.

2) VISUAL ATTENTION TO THE WIRELESS EMERGENCY ALERT

In response to the Wireless Emergency Alert image (see Table 3), we found participants' visual attention across both groups was highest in the whole graphic area (SS: M = 11.76 s; DS: M = 14.99 s). Participants visual attention in this area was particularly focused on the WEA notification AOI (SS: M = 9.07 s; DS: M = 13.50 s).

Within the notification AOI, participants directed most of their visual attention to the WEA text (DS: M = 6.98 s; SS: M = 10.50 s) and the protective action guidance (DS: M = 3.46 s; SS: M = 5.90 s) AOIs. Attention was also placed on the ALL CAPS portion of the text (DS: M = 1.20 s; SS: M = 0.75 s). Noticeably, only one participant out of 40 fixated on the alert logo AOI.

b. Memory task

1) NWS TWEET—MEMORABLE FEATURES

In their description of the warning tweet, participants most commonly remembered information about the location (included in the content of the message) and the presence of a map. Location was noted by all participants (n = 10) in the SS group and a majority (70%; n = 7) of those in the DS group, in many cases by referencing the included map (see Table 4). For example, one participant stated they remembered, "the affected areas and if you are stuck in one what you should do." They continued by saying, "and then there was a map about where it would . . . was gonna strike." Another participant stated they remembered the severity of the hazard relative to the location, saying the hazard "was in the Lubbock

TABLE 3. Descriptive results from eye-tracking data for SS and DS WEA tweets. Mean and standard deviation data are presented in s.

	Viewed by No. of participants	Mean (s)	SD (s)	Percent of overall viewing time	Average No. of fixations	Viewed by No. of participants	Mean (s)	SD (s)	Percent of overall viewing time	Average No. of fixations
Content feature	Snow squall					Dust storm				
WEA tweet image										
Whole graphic area	10	11.76	6.46	87.80%	50.8	10	14.99	6.13	90.70%	63.1
WEA notification box	10	9.07	4.54	72.50%	39.5	10	13.5	6.04	81.60%	56.7
WEA text	10	6.98	3.86	57.10%	29.7	10	10.5	4.33	63.50%	44.8
Protective action guidance	10	3.46	2.25	29.40%	15.1	10	5.9	2.4	35.70%	25.9
All caps text	10	1.2	0.74	8.90%	5.3	8	0.75	0.51	4.50%	2.9
Emergency alert bold header	9	0.57	0.58	3.80%	2.4	10	0.93	0.78	5.60%	4
Notification type	5	0.33	0.52	2.40%	1.5	9	0.73	1.05	4.40%	2.6
Alert logo	1	0.02	0.06	0.20%	0.1	0	0	0	0.00%	0
WEA tweet UI features										
Account info	7	0.81	0.94	6.20%	2.5	8	0.75	0.71	4.50%	2.7
Date/time of tweet	7	0.42	0.57	3.00%	1.4	8	0.31	0.25	1.90%	1.4
Twitter metrics/UI	5	0.2	0.29	1.50%	1	5	0.27	0.49	1.60%	1.3

area and around the towns around Lubbock, and that it seemed pretty severe."

Another feature commonly remembered across both the DS and SS groups was the use of color within the messages. 90% ($n = 9$) of participants in the SS group and 70% ($n = 7$) of participants in the DS group mentioned the use of color (see Table 5). One participant noted, "they had it covered in red, which caught my eye," and another mentioned, "the redded out area of the map was the most impactful since it gave just the easy . . . like easy information to read from the map." Others mentioned other colors such as white text and the black background of the image.

Notably, when comparing across hazard groups, more participants in the SS group ($n = 8$) mentioned the name of the hazard and the inclusion of protective action guidance within the message when compared to the DS group ($n = 4$; see Tables 6 and 7). For example, one SS interviewee emphasized specific protective action guidance saying, "well, I remember it said that there is no safe place in a snow squall. That you should delay or not travel at all," and another participant said,

TABLE 4. Interview participant quotes referencing "location."

Hazard	Participant	Quote
Snow squall	SS1	"also the areas affected . . . Albany, and a few other surrounding"
	SS2	"I think it's like Troy, Albany, and Watervliet . . . or something like that."
	SS3	"today in Albany, Troy, and a third city."
	SS4	"And I also remember it was around the Albany area, primarily."
	SS5	"Okay, yeah. It's in Albany, New York as well."
	SS6	"I remember first visually there's a big map with a red . . . red area for area of impact."
	SS7	"I know it's affecting like the Capital Region area . . . And then went all the way down towards the city a little more."
	SS8	"then there was a map about where . . . they think . . . it was gonna strike."
	SS9	"warning for the Albany area."
	SS10	"I think Albany was in like the middle of it."
Dust storm	DS2	"It was in the Lubbock area and around the towns around Lubbock"
	DS3	"covered all of the county a little bit to the east, there was a small section that I mentioned."
	DS5	"see what was coming and the Lubbock area was all red."
	DS6	"just west of Lorenzo all the way down to Slayton and back over to Wolfforth. And back up . . . covered all of Lubbock, basically little sub areas."
	DS7	"It was based in Lubbock, Texas."
	DS8	"It said that it would affect the Lubbock. I think, what was it, Slayton and Wolfforth, something like that area."
	DS10	"the West Texas panhandle area. And then closer in on Lubbock County, I guess."

TABLE 5. Interview participant quotes referencing "color."

Hazard	Participant	Quote
Snow squall	SS2	"showing the areas that will be affected the most with like, color indicators. I think red is the most severe area."
	SS3	"with the area that would be affected with a red square"
	SS4	"The red . . . red labels definitely did draw your attention to like exactly where the area was. And kind of obviously reds like a color that issues danger."
	SS5	"So, I remember that there was red around the areas that were . . . would be affected by, by these weather conditions, and the other areas were gray."
	SS6	"Definitely the redded out area of the map was the most impactful."
	SS7	"Yeah, so I know that like the areas being affected were like we're in red."
	SS8	"varied in color based off how high the chances were it would strike, and it was a red or . . . reddish color."
	SS9	"I remember, the warning area was red."
	SS10	"Well, like I said, there's the red for the warning area."
Dust storm	DS2	"They had it covered in red, which caught my eye."
	DS3	"It was a lot of red. And so, it was a big red square that cover all of the county."
	DS5	"The area was in was red."
	DS6	"Well, here's the red box."
	DS7	"I remember the colors like kind of like an orangey. Like, nude, like nude orangey kind of color."
	DS8	"I think it was tan background, red in the areas that be affected by the storm."
	DS9	"that portrayed a sense of definitely like urgency with the dark red."

"they really made sure to emphasize that, that if you stay like stay put, then you're gonna stay alive. So that was interesting."

The remaining contents and features were less commonly discussed by both participant groups (see Table 8 for other identified codes). For example, less than half of each condition mentioned the inclusion of information about the time, the hazard conditions, and the source of the message. In addition, only one person in each group noted the differences in the use of font style to emphasize some words in the text.

2) WEA—MEMORABLE FEATURES

There was variation in what was remembered in the Wireless Emergency Alert message depending upon which hazard a participant was exposed to. Across both hazards, the most frequently remembered content was information about the time. 80% (n = 8) of participants in the SS group discussed the inclusion of a timing aspect in the message, while this was mentioned by 50% (n = 5) of DS participants (see Table 9). For example, one participant stated they remembered "when [the hazard] was happening, when it was taking place"; another participant recalled that the message, "specified the time of the dust storm."

The next most frequently remembered feature when summed across both hazards was the name of the hazard (n = 12). However, this was mentioned by DS interviewees far more often (n = 9) than SS interviewees (n = 3; see Table 10).

The third most frequently remembered feature of the WEA was the inclusion of the yellow emergency alert symbol as part of the header of the WEA. This symbol was mentioned by seventy percent (n = 7) of SS interviewees and forty percent (n = 4) of DS interviewees (see Table 11). When discussing this feature, one participant stated,

The symbol represented a caution kind of scenario where it's a very serious situation for residents in the area. So,

TABLE 6. Interview participant quotes referencing "snow squall/dust storm."

Hazard	Participant	Quote
Snow squall	SS1	"no safe place during a snow squall."
	SS2	"no safe place in a snow squall."
	SS3	"National Weather Service about a squall, snow squall."
	SS4	"I remember it was a warning issuing snow squalls, which could present whiteout conditions."
	SS7	"It was like a snow squall warning."
	SS8	"what to do in case you are in a snow squall . . . Squall."
	SS9	"was a snow squall warning."
	SS10	"stay inside because there's gonna be a snow squall."
Dust storm	DS1	"Normally, if they have a dust storm"
	DS5	"The dust, I was like, something's gone terribly wrong."
	DS6	"It's, I mean, it's just a dust storm. It's not hazardous, if you know how to live through one, I guess."
	DS9	"And when I read it, it's like, okay, dust storm."

TABLE 7. Interview participant quotes referencing "guidance."

Hazard	Participant	Quote
Snow squall	SS1	"to turn on your hazards and that's it to be safe if you must be outside."
	SS2	"There is no safe place in a snow squall. That you should delay or not travel at all."
	SS5	"And they were advising people to restrict their travel"
	SS6	"there was instructions for hazard stuff."
	SS7	"it also gave like tips and things about like how to like prepare for a snow squall, like what to look out for, just like warning signs."
	SS8	"The message had tips on what to do in case you are in a snow squall . . . if you are stuck in one, what you should do."
	SS9	"The main thing it gave some like, tips on what to do."
	SS10	"it's not good to go out during one, so stay inside or go inside if you're not inside already."
Dust storm	DS1	"They really made sure to emphasize that, that if you stay like stay put, then you're gonna stay alive. So that was interesting."
	DS3	"There was a small section that I mentioned. Pull aside stay alive."
	DS6	"Basically, little sub areas to pull over, stay live something like that. Yeah, pull aside, stay alive."
	DS10	"And then on the left side, it had a lot of important information about what to do if you're driving, how to stay safe, different warnings"

they're trying to warn them in a sense to make them alert of the weather conditions in the area and make sure that they're on point of not causing any injuries to themselves or anyone else.

Other contents, such as message source, hazard location and population at risk, hazard conditions, and protective action guidance, were mentioned infrequently. Only three out of the 20 interviewees mentioned the use of font differences (use of ALL CAPS) to call attention to individual words (see Table 12 for other identified codes).

c. *Think-aloud interviews*

1) TWEET

During think-aloud interviews, participants described features that captured their attention while viewing the tweet message. The most discussed feature across both participant groups was the color red, as stated by all participants ($n = 10$) in the SS group and eighty percent ($n = 8$) of those in the DS group (see Table 13). One participant said they noticed the color red, explaining, "I think the colors are associated with, certain feelings, or emotions. The colors aren't necessarily a coincidence." Another participant explained the use of color similarly, saying, "also red, right, is like warning, it's danger. It's anything that's warm tone. In the sense, it seems more urgent than cooler tone colors."

Interviewees in both hazard groups also noted that the map caught their attention (SS: $n = 5$; DS: $n = 4$). However, similar to the mention of color red on the graphic of the text, participants frequently pointed to the red area of the map (the polygon) as the section that drew attention the most (see Table 14). Participants less frequently discussed the use of capital or bold letters, the heading of the message, and the time (see Table 15 for other identified codes).

TABLE 8. Content features of the NWS tweet remembered by participants from both the SS and DS groups.

Feature mentioned	SS ($n = 10$)	DS ($n = 10$)	Total ($n = 20$)
Location	10	7	17
Map	10	7	17
Color	9	7	16
Guidance	8	4	12
Snow squall/dust storm	8	4	12
Time	4	3	7
Conditions	4	2	6
Twitter UI	4	2	6
Source	3	2	5
All caps	1	1	2

2) WIRELESS EMERGENCY ALERT

While viewing the WEA message again, participants in both the SS and DS groups most discussed the use of capital letters or ALL CAPS within the message (see Table 7). 80% ($n = 8$) of participants in the SS group and 40% ($n = 4$) of those in the DS group made specific reference to the change in text as attention grabbing (see Table 16). For example, one participant said they looked at "the capital snow squall warning . . . Because it's in capital. So, I see it first looking at it."

Another commonly discussed content feature that captured attention was the emergency alert hazard symbol. 60% of participants across both the SS ($n = 6$) and DS ($n = 6$) groups noted that this feature was effective in capturing their attention when viewing the message (see Table 17). One participant said they noticed "the caution icon next to emergency alerts, cause that shows something is serious." Another participant explained how color and differences in font were both important for capturing attention, saying:

The exclamation point in the yellow is the first thing that my eyes are drawn to and then the big bolder words, emergency alert. And then obviously, the all caps are where my eyes go after that.

Less frequently mentioned contents and features included the message heading, the use of bold letters, and the inclusion of time (see Table 18 for other identified codes).

TABLE 9. Interview participant quotes referencing "time."

Hazard	Participant	Quote
Snow squall	SS1	"also something about around 4:30 am is when it will get worse."
	SS2	"I believe it said it was going to occur at 4:30 I believe."
	SS3	"And I read to see when that was happening, when it was taking place."
	SS4	"and it said it was coming around I think 4:30, like 5 pm."
	SS6	"and believe it was within the next 24 hours."
	SS7	"the time that it's supposed to end it was like two hours. So, two hours"
	SS8	"I forgot what time but for whatever time. Um, on the top left had the time, it was 11 o'clock for the screenshot."
	SS10	"the snow squall was going to be at 4:30 or around then."
Dust storm	DS1	"until like 3:15 pm."
	DS2	"And it specified the time of the dust storm."
	DS4	"There was a time I think it was 3:15 pm."
	DS6	"till I think 3:15."
	DS8	"I remember I believe it's a 3:15 pm."

5. Discussion

In this study, we investigated participants' visual attention, memory, and verbalized thoughts toward two different types of warning messages, Twitter and WEA, for two different hazards, snow squall and dust storm. We collected eye-tracking data to identify where visual attention was allocated to the messages. We also conducted a memory task to understand what individual participants remembered about the message and followed this with a think-aloud interview to identify why message contents and features drew the attention of each individual. We addressed three primary research questions: Where do people look, what do they remember, and what draws their attention? The overarching question focuses on alert and warning message design and asks, What does it mean to stand out? Across all research questions, our findings were broadly aligned with previous research which focused only on Twitter warning messages for tornado. Our research extends beyond the scope of these previously performed studies, incorporating the examination of two new hazards, dust storm and snow squall, as well as WEA messages.

RQ1 investigated where people allocated visual attention when viewing a WEA and a Twitter message about an approaching hazard in their location. We found consistent patterns across both hazard types for each message. For the tweet, we found that most visual attention is allocated to the graphic portion of the message, with the focus placed on the map. The text portion of the message also received visual attention, as evidenced by the time allocated as well as the number of fixations on the words. However, there was limited visual attention directed to the words in ALL CAPS. These findings align with those seen in previous research focused on the use of Twitter warning messages in emergency communications (Fischer et al. 2022; Sutton and Fischer 2021). However, we are unaware of prior research that uses eye-tracking methods to measure visual attention to contents in a WEA. We found most visual attention was allocated to the guidance within the message, with some visual attention to the words presented in ALL CAPS. Notably, only one participant fixated on the alert logo and for only a fraction of a second.

RQ2 investigated what people remembered about a WEA and Twitter message about an approaching hazard in their location shortly after viewing the message. Here, we found consistent patterns across both hazard types for the tweet, but less consistency for the WEA. For the Twitter warning, participants described remembering the color—in the banner of the graphic portion of the message and the polygon on the map. Fewer described remembering the recommended protective

TABLE 10. Interview participant quotes referencing snow squall/dust storm.

Hazard	Participant	Quote
Snow squall	SS6	"about the snow squalls?"
	SS8	"saying that there's a snow squall alert."
	SS10	"That it . . . at . . . the snow squall was going."
Dust storm	DS1	"there was going to be a dust storm warning."
	DS2	"The message was a warning about a dust storm."
	DS4	"And it says dust storm warning in all caps."
	DS5	"And there was a dust storm in Lubbock."
	DS6	"that there was a dust storm warning."
	DS7	"And it said, dust storm advisory, right?"
	DS8	"there's certain ones like, Dust storm as well."
	DS9	"what the severe weather or it was like dust storm."
	DS10	"I remember there being like severe dust storm warning."

TABLE 11. Interview participant quotes referencing "emergency alert symbol."

Hazard	Participant	Quote
Snow squall	SS1	"The symbols represented a caution kind of scenario"
	SS2	"it was a warning sign, but it was yellow like a triangle with a black exclamation mark."
	SS3	"I remember it being like . . . I remember the triangle on it. So, I was like, oh that must be an emergency."
	SS5	"So, the biggest thing that I remembered about the message was definitely the warning sign. The like yellow triangle with the exclamation mark, in the middle of . . . that was the first thing that caught my mind. Or caught my attention."
	SS6	"had the yellow warning, exclamation mark."
	SS7	"We had a caution sign, yellow caution. So, it kind of draws attention."
	SS10	"And a yellow triangle that was like a warning sign."
Dust storm	DS2	"Kind of looked like an Amber Alert, but more so like the weather alert. I remember there was yellow and gray."
	DS7	"And I remember like seeing like the flag logo, like high advisory."
	DS9	"I think it was like yellow messaging, like the little logo thing, to severe weather alert."
	DS10	"I remember there being a yellow icon on it, like probably like of high importance or like danger."

actions included in the messages; however, those who viewed the snow squall tweet described remembering protective actions nearly twice as much as those who viewed the dust storm tweet. Only one person said they remembered the use of ALL CAPS to call attention to specific words in the guidance portion of the message. Again, these findings are consistent with those seen in similar research on Twitter messages performed previously (Sutton and Fischer 2021; Fischer et al. 2022).

In response to the WEA, both participant groups remembered the time at which the hazard was occurring, but snow squall participants described remembering it twice as frequently as dust storm. Both groups also remembered the hazard type, but it was described three times more frequently by the dust storm participants. We also found that more than half of the participants who viewed a WEA described remembering the inclusion of the warning logo. Less than half the participants described the protective action guidance included in the message, and approximately 10% ($n = 4$) described remembering the use of ALL CAPS to call attention to specific words in the message. We are unaware of any prior research focused specifically on remembering the content included in a WEA message.

TABLE 12. Content features of the WEA remembered by participants from both the SS and DS groups.

Feature mentioned	SS ($n = 10$)	DS ($n = 10$)	Total ($n = 20$)
Time	8	5	13
Snow squall/dust storm	3	9	12
Emergency alert symbol	7	4	11
Color	3	7	10
Source	5	4	9
Location	3	5	8
Guidance	2	6	8
Conditions	2	3	5
Twitter UI	3	1	4
Population	1	3	4
All caps	2	1	3

The underlying reason for the differences in content remembered between the different hazard types remains unclear. Notably, the content of the snow squall WEA was significantly briefer (170 characters) than the dust storm WEA (355 characters), which contained additional details about the hazard. This suggests that the amount of content included in a WEA message may affect how much detail is remembered. These observations highlight a need for future research to explore differences in message length and its influence on remembering information in emergency communications.

RQ3 investigated what visual features participants say draw their attention in a WEA and Twitter message about an approaching hazard in their location. Here, we again found consistency within message types and across hazards. Participants who viewed the tweets described the importance of color because it stands out and represents feelings of warning, danger, and urgency. They also stated that the use of ALL CAPS captures their attention because it stands out in contrast with other texts. Participants who viewed the WEA also indicated the importance of contrast by identifying the use of ALL CAPS, the use of bold text for the header of the message, and the inclusion of a symbol to signify alert. This finding is again consistent with prior research conducted by Sutton and Fischer (2021), which found that, across different hazard types, participants tend to focus on differences in text such as those seen with the use of ALL CAPS.

While there was general consistency across the eye tracking, memory task, and think-aloud interviews for the message types and across hazards (with the exception of remembering for the WEA), we do find that what "stands out" may not be the same as what receives visual attention allocation. In this case, the features that were described as being remembered following the initial observation of the warning and the features that stood out during the think-aloud interviews were not always consistent with features that were fixated on during the eye-tracking activity. For example, visual attention was more frequently allocated to the tweet text than to the guidance presented in ALL CAPS, but the text in ALL

TABLE 13. Interview participant quotes referencing "color red."

Hazard	Participant	Quote
Snow squall	SS1	"and the red, alert. It's not as bright red."
	SS2	"I mean the color red."
	SS3	"The Red. That shaded red map of the area affected."
	SS4	"Primarily the red"
	SS5	"The red colors. So, whatever is highlighted in red initially caught my attention."
	SS6	"and the Big Red Box of area of effect."
	SS7	"because it's in red, like it's red."
	SS8	"also, the picture of the Red Square showing."
	SS9	"the large red warning."
	SS10	"The red, the the area it's in."
Dust storm	DS1	"probably be this big red square."
	DS2	"Definitely the red on the dust storm."
	DS3	"Definitely the large red areas."
	DS4	"I mean, Red's my favorite color anyways? Red, I don't know."
	DS5	"The big bold, red highlight"
	DS7	"and then the color like it being like that reddish orange color."
	DS8	"and the red colors."
	DS10	"And then also red, right, is like warning, it's danger."

CAPS was both remembered and, later, discussed during think-aloud interviews. In other words, while text in ALL CAPS did not require fixation to be remembered by the viewer, it drew attention and was identified as salient without additional cognitive effort in tweets and WEA messages.

Similarly, for those who viewed the WEA message, only one person out of 20 allocated visual attention to the alert logo, but seven participants reported remembering it and 12 said that it was an important feature during think-aloud interviews. Furthermore, 19 out of 20 participants viewed and fixated on the WEA emergency alert header that was presented in bold, but none described remembering it when discussing the message.

This suggests a rather complicated relationship between visual attention allocated through eye fixations, remembering, and active viewing. Prior research has demonstrated the limitations associated with measuring visual attention to visual features through eye tracking alone because attention allocation signals deeper cognitive processing. Measuring eye fixations does not provide a reason for that level of effort (Duchowski 2007; King et al. 2019), which would leave researchers to wonder if visual attention allocation is due to confusion, interest, or some other reason. Through the use of active viewing interviews, similar to think-aloud interviews implemented by Sutton and Fischer (2021), we can learn why attention was placed on specific features. The addition of memory interviews adds new information. In the case of the messages examined in this study, we find that the allocation of visual attention did not consistently result in memories of that content. Instead, we find that some message elements that received little to no fixation time were easily remembered and described. Furthermore, during active viewing, our participants clearly identified the elements that drew their attention at that moment; however, these same elements did not lead to eye fixations when they viewed the warnings earlier.

Neuroscientists explain this puzzle as an instance where components of stimuli, such as an alert icon, are fully attended to but not perceived (Lamme 2003). This means that individuals may process a symbol, text, or other sensory inputs without having been consciously aware of them being present in a message. Some elements do not require fixation or cognitive effort to remember (Lamme 2003). Similarly, there may be parts of a message that are attended to, but it does not reach awareness. That is, a message receiver may fixate on different parts of the message, but it does not reach working memory.

TABLE 14. Interview participant quotes referencing "map."

Hazard	Participant	Quote
Snow squall	SS3	"The map . . . that shaded red map."
	SS4	"The map. The red highlighting in the map."
	SS7	"But then I guess the second thing that would pop out to me is just like the red affecting areas surrounding it."
	SS8	"Then also the picture of the Red Square showing you which roads are . . . the big big roads are affected and towns."
	SS10	"Obviously, the whole diagram over the words but definitely the red area.
Dust storm	DS1	"I'm like, Okay, I would say in like in a general area would probably be this big red square."
	DS2	"And the map catches the attention the most"
	DS3	"And the map was helpful."
	DS7	"Probably the picture map first."

TABLE 15. Content features of the NWS tweet that were noted as capturing the attention of participants.

Feature mentioned	SS (n = 10)	DS (n = 10)	Total (n = 20)
Color red	10	8	18
Map	5	4	9
Capital letters	5	2	7
Snow squall/dust storm warning	3	3	6
Bold lettering	2	2	4
Heading	0	1	1
Time	0	1	1

Stimuli that are visually salient, such as bright colors and animated graphics, are processed more efficiently without the need for deep cognitive effort (Lamme 2003). Visual design experts endeavor to create imagery that reduces effortful processing. This is especially important for the design of content meant to be viewed, processed, stored, and retrieved under conditions of heightened stress. Those elements that can be more easily identified with little effort may be more likely to also be retrieved.

For those who design alert and warning messages, these findings lead to a few suggestions to increase visual attention and memory without burdening the message receiver with contents that require additional cognitive load. Colors help to draw attention to key elements and, for some, evoke a feeling of risk. Icons also draw attention and can serve as a signal that catches the eye, especially when actively viewed in a busy messaging environment, but perhaps it is the use of techniques to make key text stand out through bold, italics, underline, or the use of ALL CAPS that reduces effortful processing and, in fact, may eliminate the need for conscious fixations while resulting in easily remembered content. This is an important detail for risk communicators and message designers and one that should be investigated further as we continue to consider what it means to stand out.

6. Limitations and future research

This study focused on two messaging channels—the tweet and the WEA—for two hazards—snow squall and dust storm. Participants were drawn from university populations in areas where they had recently experienced the hazards represented in the messages. The university student research population represents a convenience sample and is not representative of the overall population. Furthermore, while the sample sizes for eye-tracking studies are historically quite small for descriptive and exploratory research (King et al. 2019; Sutton et al. 2020), we recognize that the results of this study are not generalizable to other hazards or other populations. However, this research does lay a foundation for future research, especially as it relates to cognitive load and the strategies that can be used to increase visual saliency in bodies of text that are continuous. The results of this research assist researchers in understanding patterns of what stood out to the participants via eye tracking and qualitative insights from the interviews pertaining to why it stood out. This is especially important for messages that are issued and received under conditions of heightened stress, when the cognitive effort is limited but also required for action. Future research should include experiments that provide statistical and inferential comparisons between message formats and manipulated elements.

The findings of the current study provide unique insights into what elements of a message stand out; however, we find some visually salient areas were not remembered (i.e., warning icon). This finding lends itself to future research. One technique that we have not explored yet is the visual path participants take when viewing a message. We suggest future research should explore participants' scan paths across a message.

We also recognize that the AOIs identified in this study were drawn to represent a computer screen that might be viewed on a laptop computer. Therefore, their size makes it difficult to truly assess the accurate allocation of visual attention in some of the regions of each image. Future research should take this into account and manipulate messages to increase the size of AOIs and the space between the respective AOIs. Measuring visual attention on a smaller screen, such as a handheld device using eye-tracking goggles, would also provide insight into how viewers interact with warnings that are delivered in a mobile context.

While the layout and design of the messages we tested were ecologically valid, representing the same kinds of messages issued by NWS, we did not vary the presentation of content to

TABLE 16. Interview participant quotes referencing "capital letters."

Hazard	Participant	Quote
Snow squall	SS3	"and like anything in caps caught my attention."
	SS4	"I would say the capital letters."
	SS5	"And the big bold black caps, letters."
	SS6	"and then the all capital snow squall warning."
	SS7	"Maybe the cap . . . the capital words."
	SS8	"The capital letters? Yeah."
	SS9	"The snow the Capital like snow squall warning. It . . . because it's in capital."
	SS10	"and the snow squall warning like it's capitalized."
Dust storm	DS4	"The first thing I saw was dust storm warning in all caps for sure."
	DS6	"Dust storm warning in caps, capital letters."
	DS9	"and then obviously, the all caps are where my eyes go after that."
	DS10	"I think putting things in all caps was also a vitality."

TABLE 17. Interview participant quotes referencing "hazard symbol."

Hazard	Participant	Quote
Snow squall	SS1	"The caution, like icon next to emergency alerts, cause that shows something is serious."
	SS3	"Probably the hazards sign. Yeah, probably the hazard sign."
	SS5	"The first thing is still the the symbol, the hazard symbol."
	SS6	"Definitely the alert symbol in the top left hand."
	SS7	"and the caution icon."
	SS10	"The, the yellow triangle with the exclamation mark."
Dust storm	DS1	"I think first my eye is drawn to this yellow caution symbol emergency alerts first."
	DS3	"and then the little caution sign, the front at the top of it."
	DS5	"um other than that, and maybe like the yellow, like, caution sign"
	DS9	"The exclamation point in the yellow is like the first thing that my eyes drawn to"
	DS10	"I think the little icon as well, for some reason. Yeah, I mean, I think having that there is definitely good touch."

account for other potential designs. Furthermore, because we embedded the WEA in a tweet message, it was not presented in a format that would be displayed on the screen of a digital device. Future research should examine visual attention to WEAs delivered on cellular devices.

7. Conclusions and practical implications

This study delves into the dynamics of visual risk communication and furthers insights into what tends to draw attention within this form of messaging, as well as why those contents draw such attention. These findings can guide visual risk communication writing practices and not only increase visual salience within messaging but also enhance message perception and comprehension, ultimately influencing decision-making for message recipients. As such, this work yields some practical implications that can be used in designing these forms of visual messaging across diverse message distribution channels such as Twitter and WEA and offers guidance on how to capture recipients' attention and enhance information retention.

Design techniques, such as making use of ALL CAPS, prove to be effective in calling attention to specific words that warrant recipients' attention. The use of ALL CAPS serves to make information stand out, capturing attention within a busy information environment. Similarly, the strategic use of color within messages allows message writers to emphasize either textual components or graphic components of visual messages, thus working to make them more visually salient and memorable to message receivers. The color red, for instance, invokes a sense of urgency when seen within a message. Thus, the use of this color can make specific, important components of the message pop out from others, providing a more effective presentation of critical message information. The incorporation of symbols and icons can further amplify the effectiveness of messages, allowing urgency and severity to be visually noted in a concise and consistent fashion.

Designers of visual risk communication messaging should practice care and balance when making use of these techniques. Overuse of techniques such as ALL CAPS can dilute their effectiveness. As such, it should be reserved for genuinely crucial message information that should be attended to and remembered. Similarly, the use of other techniques such as the incorporation of colors, symbols, and icons within messaging should be carefully balanced to avoid potential confusion.

Looking ahead, the advancing capabilities of systems such as WEA open opportunities for enhancing message content, potentially introducing features such as maps, icons, and emojis. In designing messages, the full scope of these capabilities should be employed. The use of these items within WEA messaging can help draw recipient attention, leading to heightened participant attention and information retention.

TABLE 18. Content features of the WEA that were noted as capturing the attention of participants.

Feature mentioned	SS (n = 10)	DS (n = 10)	Total (n = 20)
Capital letters	8	4	12
Hazard symbol	6	6	12
Snow squall/dust storm warning	4	2	6
Heading	1	4	5
Bold lettering	2	1	3
Time	1	2	3
Exclamation mark	1	0	1

Acknowledgments. This research was funded by NOAA Grant NA21OAR4590124 to Dr. Jeannette Sutton and Dr. Laura Fischer. The results and recommendations are those made by the authors and may not reflect those of the funder.

Data availability statement. Anonymized data included in this study can be made available upon request to the corresponding author.

APPENDIX A

Area of Interest Descriptions for Twitter Warning Messages

Table A1 outlines the AOIs that were identified for the Twitter warning messages shown as stimuli. Identified are the AOI names, the color of the AOI as seen in Fig. 3, and a short description of the AOI.

TABLE A1. Descriptions of AOIs in the tweets.

AOI	Color	Description
Twitter UI		
Account info	Yellow	Twitter account owner's name and profile photo
Date/time of tweet	Pink	Date and time information for when tweet was sent
Tweet metrics/UI	Red	Information about retweets, quote tweets, and likes
Tweet text area		
Hazard name (ALL CAPS)	Dark blue	Text identifying the hazard within tweet text presented in all capital letters (ALL CAPS)
Tweet text area	Pink	AOI encompassing entire area that Twitter presents tweet text
Protective action guidance (ALL CAPS)	Lime green	Text identifying the protective action guidance within tweet text presented in all capital letters (ALL CAPS)
Protective action guidance (overall)	Yellow	Text encompassing all protective action guidance in the tweet text (including ALL CAPS)
Image/graphic		
Red image header	Red	Header/title of visual/image portion of tweet
Hazard date and expiration time	Orange	Information about the date and time of message expiration present in the visual/image portion of the tweet
Threat information	Yellow	Further information about hazard characteristics and impact in the visual/image portion of the tweet
Safety information	Lime green	Further protective action guidance presented in the visual/image portion of the tweet
Small map	Light blue	Small map showing zoomed-out view of hazard area in relation to surrounding states
Large map	Purple	Large map showing zoomed-in view of hazard area in relation to surrounding towns
Red polygon within large map	Dark blue	Red polygon within the large map showing boundaries of hazard area

APPENDIX B

Area of Interest Descriptions for Wireless Emergency Alerts

Table B1 outlines the AOIs that were identified for the Twitter warning messages shown as stimuli. Identified are the AOI names, the color of the AOI as seen in Fig. 3, and a short description of the AOI.

TABLE B1. Descriptions of AOIs in WEAs.

AOI	Color	Description
Twitter UI		
Account info	Yellow	Twitter account owner's name and profile photo
Date/time of tweet	Dark blue	Date and time information for when tweet was sent
Twitter metrics/UI	Purple	Information about retweets, quote tweets, and likes
Image/graphic		
Whole graphic area	Dark blue	Entire visual/image portion of tweet
Alert logo	Red	Small yellow hazard icon with exclamation point signifying an alert
Notification type	Orange	Text accompanying notification, indicating the type of notification received
Emergency alert bold header	Yellow	Bold header/subject text indicating an emergency alert
WEA text	Purple	AOI outlining all text present in the body portion of the emergency alert notification
All caps text	Lime green	Text within WEA that is presented in all capital letters (ALL CAPS)
Protective action guidance	Light blue	Protective action guidance within WEA text
WEA notification box	Pink	AOI encompassing entire white box area of the WEA notification

APPENDIX C

Foil Images

Figures C1–C4 show the various foil images that were presented to participants. In each respective study location, all participants were shown identical images. Figure C4 includes the two location-dependent images that were shown.

FIG. C1. Movie tweet.

FIG. C2. Humorous tweet.

Hulu
@hulu

Us running back to our ex.

2:10 PM · Apr 3, 2023

16 Retweets **8** Quote Tweets **124** Likes

FIG. C3. Advertisement tweet.

University at Albany
@ualbany

Stop by and check out the new game room in the Campus Center!

2:10 PM · Apr 3, 2023

2 Retweets **3** Quote Tweets **48** Likes

Texas Tech University
@TexasTech

Don't forget about Food Truck Wednesday, happening every Wednesday this semester in Memorial Circle from 10:30 am to 2 pm.

2:10 PM · Apr 3, 2023

2 Retweets **1** Quote Tweet **80** Likes

FIG. C4. Campus tweets.

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