USING THE TORNADO TALES SURVEY TO MEASURE WARNING RECEPTION AND RESPONSE DURING EVENING AND NOCTURNAL EVENTS

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ABSTRACT

Nocturnal tornadoes are extremely hazardous weather events. Despite this, little is known about how people receive and respond to tornado warnings during the overnight hours. This survey uses data from the Tornado Tales web application, a voluntary online survey of people who have experienced a tornado, tornado warning, or severe thunderstorm capable of producing a tornado. Three events were selected from this data based on timing of the events and statistical significance of the response number. Quantitative data were analyzed using the chi-square test, while qualitative data were analyzed for common themes related to the Protective Action Decision Model, milling, and aspects of transformative learning. The proportion of people receiving warnings was greater during the evening events compared to the early morning event. This may be due to a majority of people being asleep in the early morning. Out of all warnings received, automated text alerts were the most commonly reported warning source, followed closely by sirens. The automated nature of these warning sources could increase the likelihood that they are received. When warning reception is accounted for, there is little difference in the proportion of people taking protective action, suggesting that complacency was not an issue during these events. Furthermore, moving oneself and one's family to a secure location were the most commonly reported protective actions, which indicates that the public understands proper sheltering techniques. Overall, these findings suggest that lack of warning response could be attributed to issues with warning reception, rather than issues with complacency.

1. INTRODUCTION

Tornadic events that occur during the overnight hours are widely identified as a major hazard. Nocturnal tornadoes have been found to cause a higher percentage of deaths and injuries in comparison to daytime events than previously thought (Simmons and Sutter 2005). Ashley et al. found that not only are nocturnal tornadoes disproportionately fatal events, with nocturnal events representing 6.6% of all tornadic storms but 12.7% of storms that result in fatalities, but the percentage of deaths related to overnight tornado events, "has *increased* from 32.4% (35.9%) during the 1960s to 63.0% (52.9%) from 2000 to 2007" (2008 pp.799-800). This is despite the fact that tornado warnings have improved significantly since the introduction and widespread use of Doppler radar systems for detecting tornadic rotation (Simmons and Sutter 2005). Warnings with lead times below 15 minutes have been found to significantly decrease the percentage of potential deaths and injuries during tornadic events (Simmons and Sutter 2007). Warnings with longer lead times were found to be associated with higher fatality rates, which may be due to stronger events being identified and warned earlier than weaker, less harmful events (Simmons and Sutter 2007).

One possible explanation for this occurrence is a failure in the communication of warnings. Lindell and Perry's Protective Action Decision Model (PADM) suggests that individuals must obtain some type of input from the outside world to begin deciding which response, if any, is appropriate for the situation (2012). A tornado

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warning might be considered a type of outside influence that starts the decision-making process. However, as noted by Lindell and Perry (2012), the decision-making process cannot begin unless a warning is received. Thus, those who do not receive warnings are unlikely to take protective action, as they are unaware of the threat. This could prove to be an issue, especially at night, as surveys of the public have revealed that people are far less confident in their ability to be notified of a tornado warning during the overnight hours (Krocak et al. 2021; Mason et al. 2018).

However, even if individuals do receive a warning, warning reception does not guarantee warning response. The PADM indicates that individuals must actively choose to listen to and must be able to recognize the meaning of the warning (Lindell and Perry 2012). A survey of residents of Oklahoma, Texas, and California conducted by Powell and O'Hair (2008) found that nearly three-quarters of respondents aged 25 and older were able to correctly define and differentiate between a tornado watch and tornado warning, while just over half of respondents under 25 were able to do so (2008). This leaves approximately 25% of people over 25 and nearly 50% of people under 25 who were not able to define or did not know the difference between tornado watches and tornado warnings. Further, evidence suggests that the Dunning-Kruger effect, which occurs when people with low levels of understanding of a topic tend to overestimate their knowledge, has an influence on people's perception of their severe weather knowledge (Casteel 2023; Nunley and Sherman-Morris 2020). Thus, they may be less likely to seek out additional sources of information. This lack of knowledge could not only prevent individuals from understanding the warning being received, but it can also have an impact on their decision-making during severe weather.

The PADM suggests that, to complete the decision-making process, individuals must be able to convince themselves that the potential hazard is an actionable threat, then determine the best course of action (Lindell and Perry 2012). Individuals who scored poorly on a survey of severe weather knowledge were also found to be more likely to make poor sheltering decisions when given an example warning (Casteel 2023). This could be due in part to a lack of understanding of the hazardous nature of a tornadic storm. Another potential barrier to protective action is the "false-alarm effect" or the idea that individuals who live in areas with high rates of unsubstantiated warnings may become complacent, which could also play a role in individuals' choices during tornado warnings (Ripberger et al. 2015; Simmons and Sutter 2009; Trainor et al. 2015). However, the extent to which "false alarms" are perceived by the public and influence sheltering choices is still in question (Ripberger et al. 2015; Simmons and Sutter 2009; Trainor et al. 2015). Even if an individual understands the risk that a tornado poses, they may not be knowledgeable about the best sheltering practices. For example, planning for severe weather has been linked to a higher likelihood of sheltering during a tornadic event (Cong et al. 2014). But if individuals do not fully understand the hazards associated with tornadic events, who believe themselves to have adequate knowledge, or who believe that the threat is minimal may not have the information or desire to plan ahead for severe weather.

Further, individuals who lack the means to take shelter may be more at risk of death and injury. While discussing how location and demographic identity influence people's ability to cope with natural disasters, Cutter et al., (2003) posits that "...vulnerability to environmental hazards means the potential for loss" (p. 242). A major factor influencing social vulnerability is housing type and quality, with residents of mobile and manufactured homes generally thought of as having increased social vulnerability compared to residents of more substantial housing (Cutter et al. 2003; Flanagan et al. 2011). Interviews conducted by Demuth et al. indicated that, while individuals often want to take protective actions, they may lack awareness of what constitutes adequate shelter or lack adequate shelter in their homes or within a reasonable distance (2022). Findings by Balluz et al. suggest that individuals who are not able to move to an adequate shelter are less likely to take action during a warning (1997). This could be because a lack of adequate shelter prevents those individuals from being able to decide the best course of action, especially if they are not able to think beyond their lack of shelter. This issue is compounded for residents of mobile and manufactured homes, many of whom believe that their homes are sufficient shelter from tornadic storms (Ash et al. 2020). Both mobile/manufactured and stick-built, "permanent" homes can be insufficient shelter from tornadic storms, with 71.3% of tornado-related deaths happening inside the home (Ashley 2007 p.1223). Add this to the higher percentage of people being home during the overnight hours (as seen in Figure 1b of Lee et al. (2017)) and the fact that many types of possible shelters outside the home, such as churches, libraries, and other public buildings, are likely to be closed overnight, and the comparably high fatality rate of tornadoes begins to make sense. Thus, it is known that nocturnal tornadoes have comparably higher fatality rates (and are therefore more dangerous) than daytime events, that confidence in the ability to receive warnings decreases during the overnight hours, and that decision-making around sheltering can be affected by a lack of sheltering options. However, there is a lack of investigation into the intersection between warning reception and response during nocturnal tornadic events.

This study seeks to understand the effect of nocturnal time periods on warning reception and response by utilizing quantitative and qualitative responses from the first iteration of the Tornado Tales survey to draw comparisons between three tornadic events that occurred in the evening/early morning hours. In this study, the three events of interest and specify the criteria used for selection are introduced, the data-gathering process of the Tornado Tales web application alongside the methods used for data analysis are discussed, the results of said analysis are presented and possible explanations are explored, and concluding remarks about the utility of Tornado Tales as a measure of warning reception and response are offered.

2. EVENT SUMMARIES

Responses to the first iteration of Tornado Tales (April 2022–April 2023) were analyzed for statistical significance (number of responses per event) and event timing (evening or overnight events). Three events were found to match these criteria. Responses from these events were isolated from the data for further analysis. The event summaries below describe the most significant tornadic events that took place for the date and location of interest.

April 29th, 2022

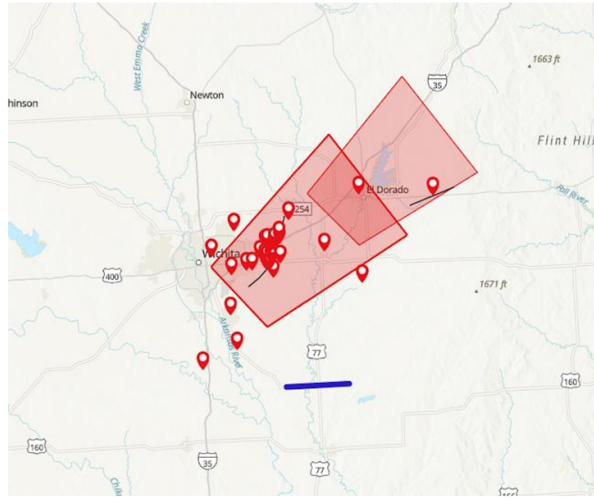

Figure 1. Map of tornado paths (thin lines), tornado warning areas (polygons), and respondent locations (pins) for the April 29th, 2022, event. A 10-mile length (thick line) is shown for scale. Tornado track data courtesy of NOAA. Tornado warning data courtesy of the Iowa Environmental Mesonet of Iowa State University.

At 8:10pm CDT (local time) April 29th, 2022, an EF3 tornado touched down approximately km south-southwest of Andover, KS (NOAA). A tornado warning was issued at the same time as touchdown (Iowa Environmental Mesonet of Iowa State University). The storm tracked north-northeast through the town of Andover, carving a 20.7km path that ended 2 km southeast of the town of Benton, KS 21 minutes after touchdown (NOAA). Winds were reported to be up to 155 mph (NWS Wichita, KS.). The storm caused three injuries, with no fatalities reported (NWS Wichita, KS.). A second tornado warning was issued at 8:51 pm for a tornado near El Dorado (Iowa Environmental Mesonet of Iowa State University). At an EF-1, this tornado was much weaker than the Andover event (NWS Wichita, KS).

June 8th, 2022

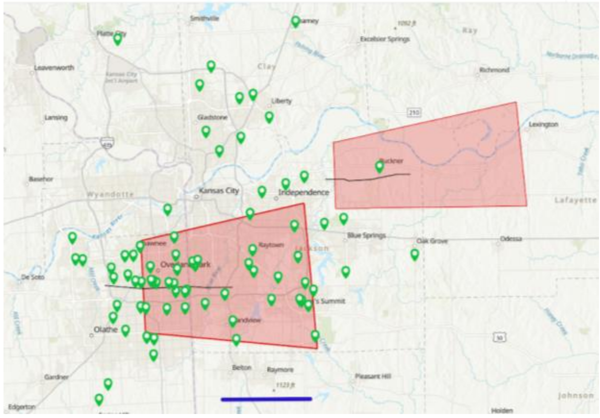

Figure 2. Map of tornado path (thin lines), tornado warning areas (polygons), and respondent locations (pins) for the June 8th, 2022, event. A 10-mile length (thick line) is shown for scale. Tornado track data courtesy of NOAA. Tornado warning data courtesy of the Iowa Environmental Mesonet of Iowa State University.

In the early morning of June 8th, 2022, two tornadoes tracked through Jackson County, Missouri within 30 minutes of each other (NWS Kansas City/Pleasant Hill, MO.). The first, which occurred at 1:10 am CDT (local time), took a 23 km track south of Kansas City from Lenexa, KS, across the Kansas–Missouri border (NOAA). A tornado warning for Johnson County,KS and Jackson County, MO was not issued until 1:21 am CDT (Iowa Environmental Mesonet at Iowa State university). The tornado's path ended approximately 6 km north of Grandview, MO (NOAA). The storm left a damage path nearly 115 m wide (NOAA). The event was categorized as an EF1 by NWS surveyors (NWS Kansas City/Pleasant Hill, MO.). The second tornado, which touched down at 1:37 am CDT, took a 15 km path just south of Buckner, MO, leaving a damage path approximately 183 km wide (NOAA). A tornado warning for Jackson, Lafayette, and Ray counties was issued four minutes later at 1:41 am CDT (Iowa Environmental Mesonet at Iowa State University). This storm was rated an EF2 (NWS Kansas City/Pleasant Hill, MO.).

February 26th, 2023

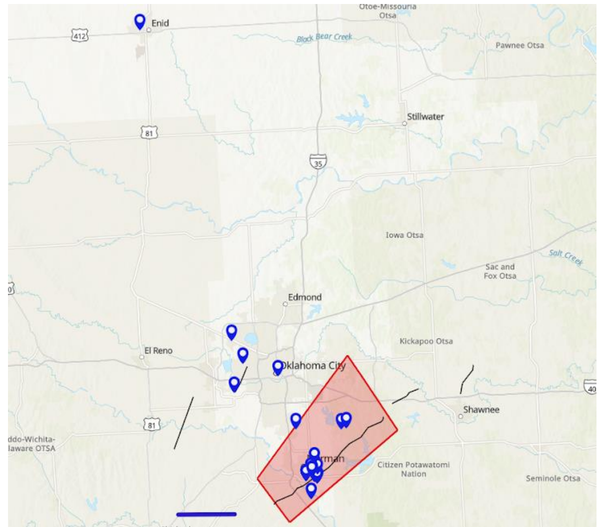

Figure 3. Map of tornado path (thin lines), tornado warning areas (polygons), and respondent locations (pins) for the February 26th, 2023, event. A 10-mile length (thick line) is shown for scale. Tornado track data courtesy of NOAA. Tornado warning data courtesy of the Iowa Environmental Mesonet of Iowa State University.

At 9:13 pm CST on February 26th, 2023, an EF2 tornado touched down approximately 2.5 km northeast of Cole, OK (NWS Norman, OK.; NOAA). Tornado warnings were issued for McClain, Cleveland, and Oklahoma counties at 9:15 CST (Iowa Environmental Mesonet of Iowa State University). The storm moved northeast, passing just south of the University of Oklahoma's main campus in Norman, before coming to an end approximately 26.3 km east of Moore, OK at 9:35 pm (NWS Norman, OK.; NOAA). The storm was reported to have a maximum width of 640m (NOAA). Twelve injuries were reported, with no reported fatalities (NOAA).

3. DATA AND METHODS

Data were derived from the NOAA NSSL Tornado Tales web application, a voluntary online survey that is continuously open to the public via the web page: https://inside.nssl.noaa.gov/tornado-tales/. Participants in the survey are asked a variety of questions about their experience during a reported tornado, tornado warning, or severe weather event, including questions about their ability to receive warnings and the protective action decisions they made when the warning was issued. Question types included yes/no (e.g.,

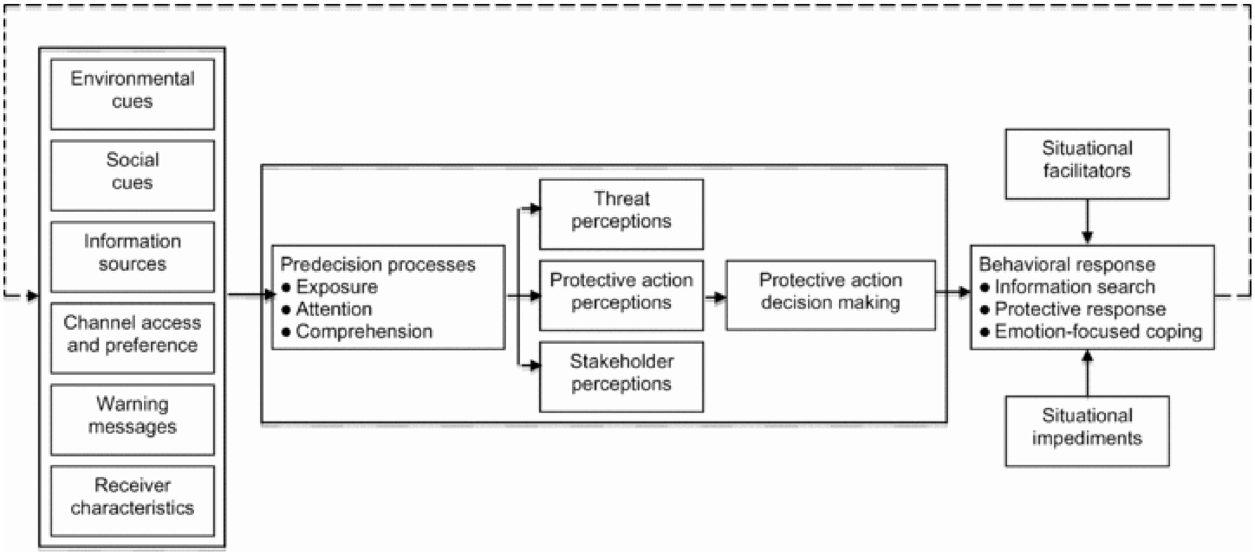

Figure 4. The Protective Action Decision Model. Figure courtesy of Lindell and Perry (2012).

whether a warning was or was not received), multiple choice (e.g., type of home), Likert scale (e.g., level of confidence in warning), and open-ended. Questions also included the geographical location of participants and the time during which they experienced the event. Responses were then recorded from the web application to a spreadsheet.

The first iteration of Tornado Tales was live from April 2022 to April 2023 and collected 598 reports during that time. The entries were analyzed to remove repetitive and/or false reports, which resulted in the elimination of 115 responses, leaving 483 total. From these responses, three events were selected for further analysis due to the number of reports allowing for statistical significance. Responses were limited to +/- 1 day of the event to account for issues with time and date recall. They were also limited to the states in which the events took place to eliminate reports of outside events. After these steps, there were 43 responses for the 29 April 2022 Andover event, 74 for the 8 June 2022 Overland Park, KS and Buckner, MO event, and 28 for the 26 February 2023 Norman, OK event.

Warning types and warning actions were automatically coded using a 1/0 system (1 for a response, 0 for no response). All other quantitative data were 1/0 coded manually. The survey data were then evaluated for their relevance to the focus of the study. The data determined as relevant were: the number of respondents receiving warnings, reception rates of warning sources, number of respondents who took protective action during the warning, and types of protective actions taken. For the purposes of the study, a protective action was defined as one or more of the following: monitoring the situation, moving to the most secure area at one's location, moving one's family to a secure location, taking cover in a designated storm shelter, sheltering at a nearby location, driving away from the tornado, or other actions that respondents decided to take in response to the warning, regardless of the effectivity. Statistical analysis was done via chi-square testing for homogeneity and independence at a 95% confidence level. A chi-square test for independence allows for the determination of the level of variable association while the test for homogeneity allows for the determination of differences between the groups of interest (Franke et al. 2012). During chi-square testing a "null hypothesis", an "alternative hypothesis," and a level of significance (e.g., 95%) are set (Franke et al. 2012; Ugoni and Walker 1995). The data are then compared using the chi-square test equation, which produces a result which is compared to a statistical table (Ugoni and Walker 1995). If the resultant number is larger than that indicated on the table for the level of significance of interest, the result is said to be statistically significant, and the null hypothesis is discarded (Ugoni and Walker 1995).

A qualitative approach was used to analyze answers to the open-ended question. To begin, responses were read in their entirety. Keywords and phrases related to warning reception, warning response, receiver characteristics, and tornado damage were highlighted. The PADM (Lindell and Perry 2012) was utilized to create categories into which answers could be sorted (e.g., answers that reported seeing the tornado were sorted into "Environmental Cues"). The PADM is a model of human decision making during potentially harmful events, in which an individual receives a warning about a potential hazard, compares the new hazard and potential protective responses to prior experiences, and decides on an appropriate reaction to the hazard (Lindell and Perry 2012). This model provides a useful framework for the analysis of the open-ended question because its warning reception–information processing–warning response structure matches well with the narrative nature exhibited by many of the answers. Responses were recorded via their survey ID, a number assigned to a response based on its input order relative to the others (the first response was number 1, etc.), which allowed each response to be traced through the model. Additionally, answers which indicated both a warning reception and a response were further evaluated individually to determine which, if any, other steps of the PADM were present.

The open-ended responses were also analyzed for common themes that fit within the concept of the protective action decision-making process. Categories included "Siren Issues", "Environmental Cues", "Lack of Knowledge/Comprehension", and "Milling/Checking for Confirmation." Portions of responses were identified and quoted for each of these categories (Table 1). An example of the analysis process is depicted below, where the bolded words in brackets are analysis:

"The Tornado app went off for our location at 8:10pm. [**Information sources, Warning messages, Exposure]** We immediately exited our 2nd floor apartment to head to a safer place to take shelter **[Protective action perception, Protective Response]** (a friend's home/basement 1 mile away, as previously discussed, due to the possibility of severe weather). It was at this time that we actually heard the local tornado sirens sounding. **[Information source, Warning messages]** The tornado was already within a mile of our apartment [**Threat Perceptions]**, it could be seen from our windows [**Environmental cues]**, so we ended up staying at the apartment complex, seeking shelter under an interior stair well(sic.) of a 1st floor neighboring apartment [**Protective Response]**. We lost power and debris was hitting our apartment complex within 2-3 min of my Tornado app going off. The YMCA 0.6 miles away from our apartments was destroyed at 8:13 pm, and my sons(sic.) grade school was severely damaged, as well. It was very scary, considering we got only a couple minutes notice to take shelter before the EF3 tornado was upon us and destroying surrounding homes and establishments." - Female, 44, 232

In this quote, a narrative structure can clearly be seen as the respondent relates her experience sequentially, beginning with receiving a warning via an app. After being exposed to the warning, the respondent appears to have understood the risk, and decides to take a protective action. She also demonstrates protective action perception, in deciding that a secondary location was a better shelter location than her other options. The respondent then indicates that she received a secondary warning via a siren and an environmental cue seeing the tornado herself, which changed her perception of the threat, thus changing her view of the safest course of action and causing her to take a different protective action than what she had originally planned.

4. RESULTS

Location

A majority of participants reported being at home during the tornado warning (80% of respondents for the April event, 99% for June, and 89% for February. Of these, a majority (80% of respondents at home for the April event, 82% for June, and 68% for February) were living in a stand-alone structure (defined as a "(detached) permanent structure such as a house"). Other housing types, such as condos, apartments, and mobile homes, were reported with substantially less frequency. Location data was also plotted on an online map using ArcGIS. The ArcGIS StoryMap associated with this work can be found at: https://storymaps.arcgis.com/stories/f1487ab53e9c4c239225a4fc1b65ca10.

Qualitative Analysis

While none of the open-ended responses, including the example provided in the previous section, perfectly aligned with all of the elements of the PADM, many included at least one aspect that matched an element from the model. The most common elements found in the open-ended responses came from the beginning (receiving the message) and ending (taking an action) stages of the model, while elements from the decision-making process itself were not as widely reported. Issues arising with siren and automated text reception were common complaints, especially for the June event.

Another common theme throughout the open-ended responses was people's need for more information or confirmation of the threat before taking a protective action. For example, a 43-year-old woman who experienced the April 29th, 2022, event reported: "I asked my husband, is that the sirens? He looked out the back of our house and saw a rope tornado and said, yes!" This type of behavior is typically defined as milling, an activity in which people seek information from others before acting on warning information (Wood et al. 2018; Doermann et al. 2021). Other methods of confirmation, such as looking outdoors for the tornado or turning on the local news for more information, were also common.

A third theme that was discussed by some of the respondents was transformative learning. Transformative learning is a process in which an adult's perception of the world is fundamentally altered via life experience (Mezirow 1997; Mezirow 2003). There has been discussion of the importance of transformative learning in disaster risk reduction contexts (Sharpe, 2016; 2021). Specifically, that transformative learning is key to enabling adaptation and resilience to disasters allowing individuals, groups and communities to undergo deeper questioning of habits of mind as part of a wider conscientization (e.g., Freire, 1970) through critical reflection (Sharpe, 2016). This fundamental change in thinking was exhibited by respondents who mention taking or planning actions that may help them receive and respond to future weather events. For example, a 43-year-old woman who experienced the April event reported that she "..plan[s] to get a fire box to keep under the stairs for important documents…", while another woman, who experienced the June event, explained her thoughts by writing "Obviously we are going to get a weather radio now, but our experience with an older one is not a positive one, so cannot rely on that." Both examples indicate that these respondents have thought about their level of preparedness for the event that they experienced and have realized that there are further actions they can take to increase their preparedness. This could indicate that their lived experiences did not align with their previous perceptions of tornadic events and that they felt

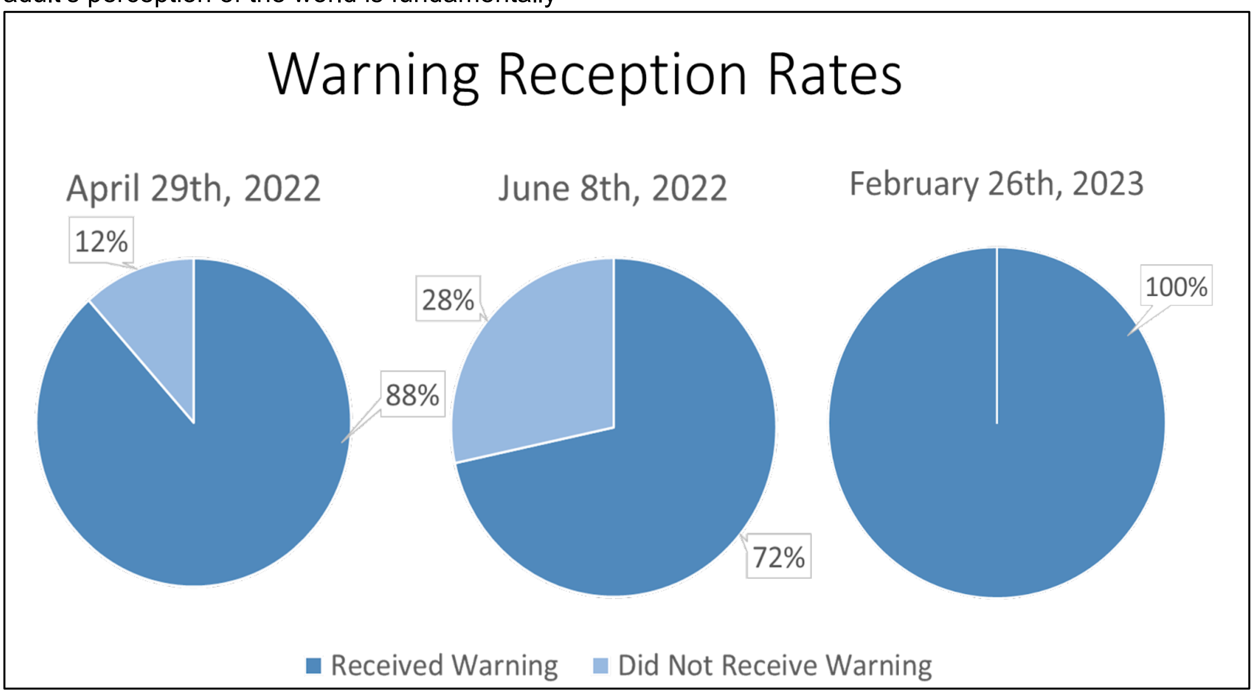

Figure 5. Pie charts depicting the percentage of people who did or did not receive warnings during each event.

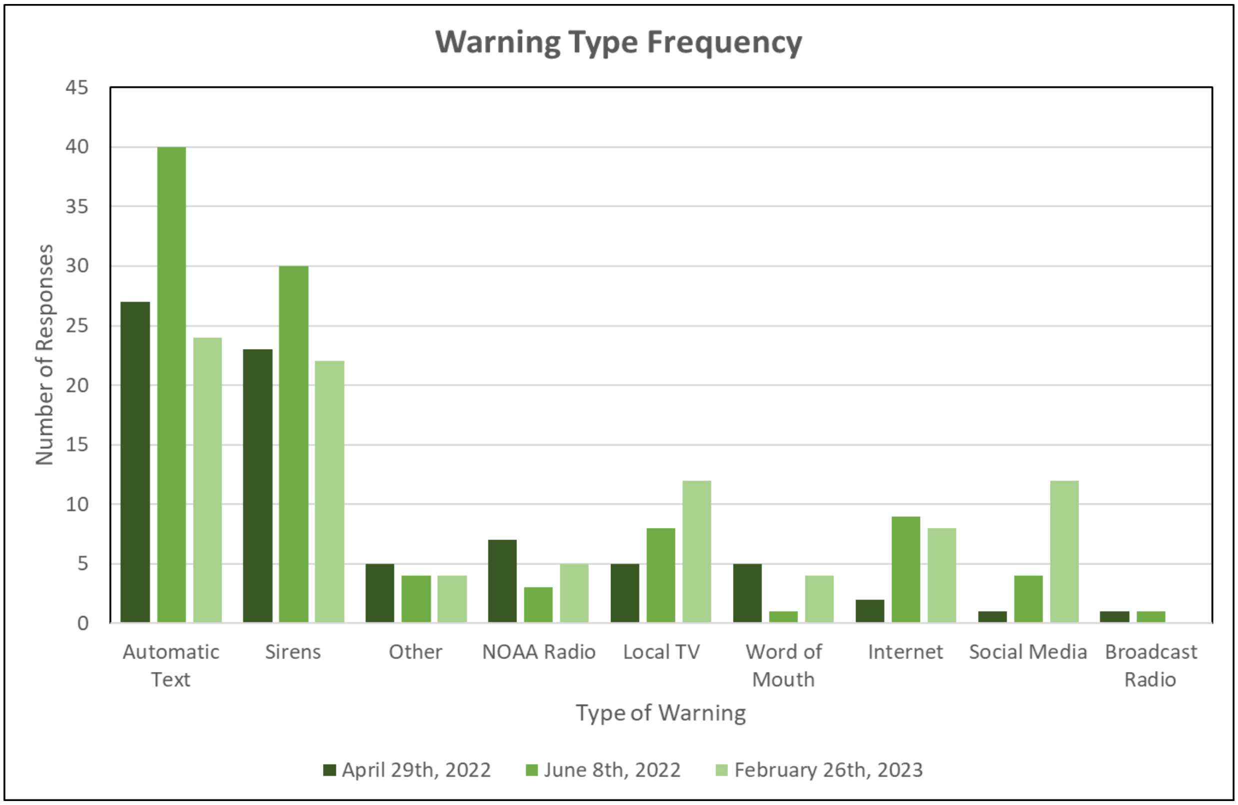

Figure 6. Clustered column chart depicting the frequency of warning reception via each warning type.

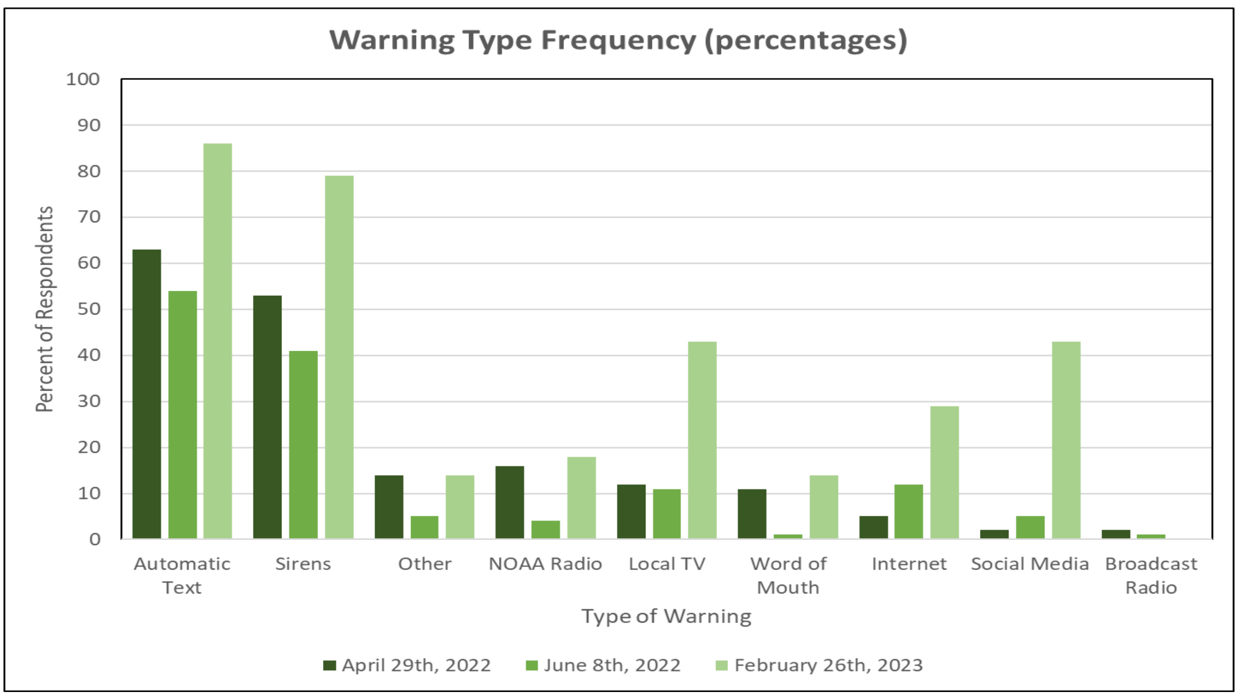

Figure 7. Clustered column chart depicting the percentage of respondents who received warnings from each warning source.

themselves inadequately prepared for possible future events. By increasing their level of preparedness for future events, these participants have increased their disaster resilience.

Warning Reception

The difference between the proportion of people receiving warnings during each event was found to be statistically significant at the 95% level (chi-square: 13.44136, d.f.: 2). Further, the difference in proportion of people receiving warnings during the evening events (April and June) and the proportion of people receiving warnings during the nocturnal June event was found to be statistically significant at the 95% level (chi-square: 11.99878, d.f.: 1). Eighty-eight percent of participants who experienced the April event reported receiving a tornado warning from at least one source, 72% of June participants received a warning, and 100% of February participants received a warning (Figure 5).

During the Tornado Tales survey, participants were asked to select the method or methods by which they received warnings. Automated texts were the most frequently reported manner of warning message reception, alerting 63% of participants during the April event, 54% of participants during the June event, and 86% of participants during the February event. The second most frequently reported warning source was sirens, as 53% of April respondents, 41% of June respondents, and 79% of February respondents reported hearing sirens. Despite being the third most frequently reported warning source for February (tied with social media) and the fourth most frequently reported warning source for June and April (tied with "other" methods), local TV news and weather channels were not very common sources for tornado warnings. Only 12% of April respondents, 11% of June respondents, and 43% of February respondents reported using local TV as a warning source (Figure 6; Figure 7).

The difference between the number of warning sources participants received during each event (chi-square: 38.94173, d.f.: 4), as well as the difference between the number of warning sources received in the evening (April and February) compared to early morning (June) (chi-square: 18.53196, d.f.:3), were found to be statistically significant at the 95% level, with June respondents reporting fewer warning sources than April or February respondents. Seven percent of April/February respondents indicated that they received no warnings, in comparison to 28% of June respondents. In contrast, 42% of April/February respondents reported receiving warnings from more than two sources, in comparison to only 16% of June respondents.

Protective Actions

When considering the three events as a group, the association between receiving a tornado warning and taking protective action was

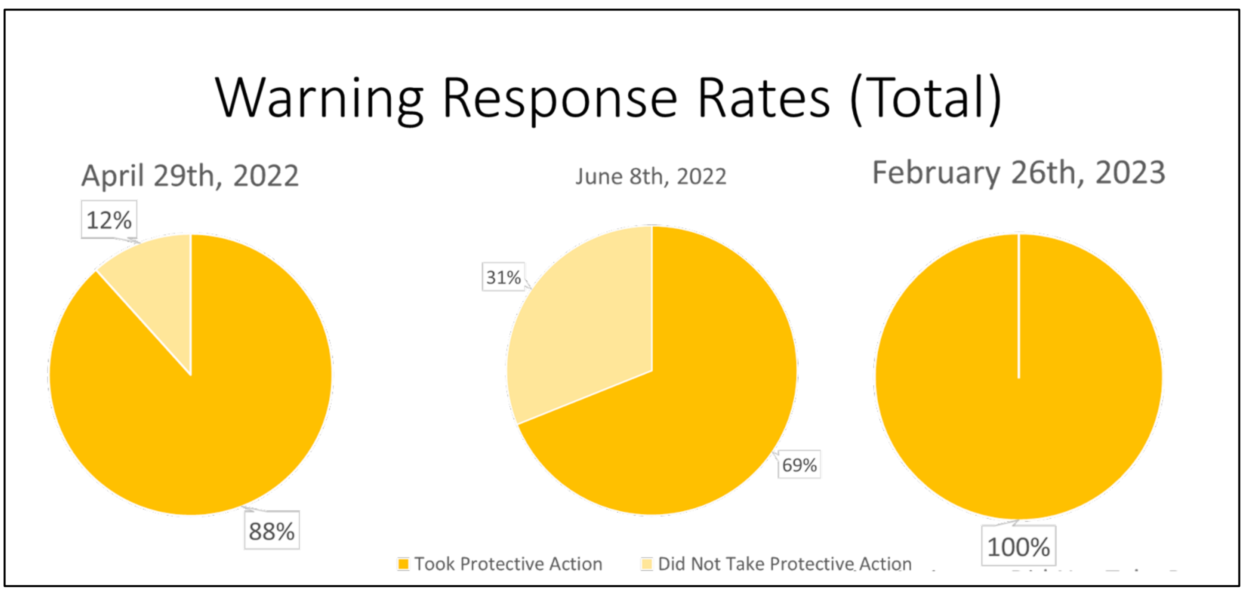

Figure 8. Pie charts depicted protective response rates for all respondents during each event.

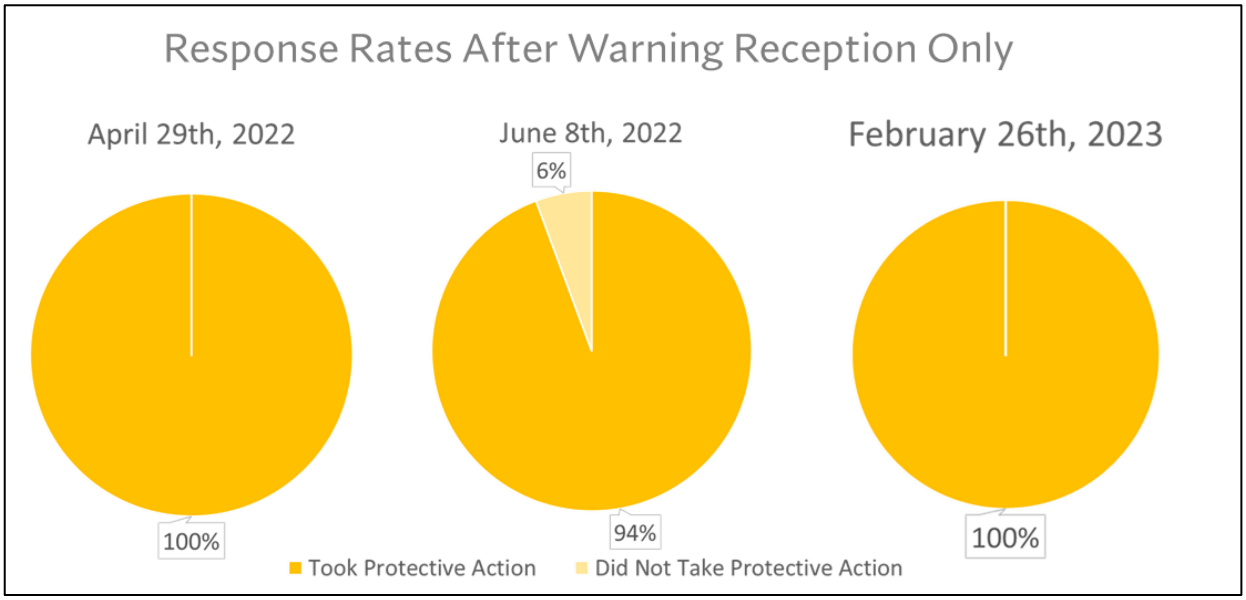

Figure 9. Pie charts depicting protective response rates of participants who received warnings during each event.

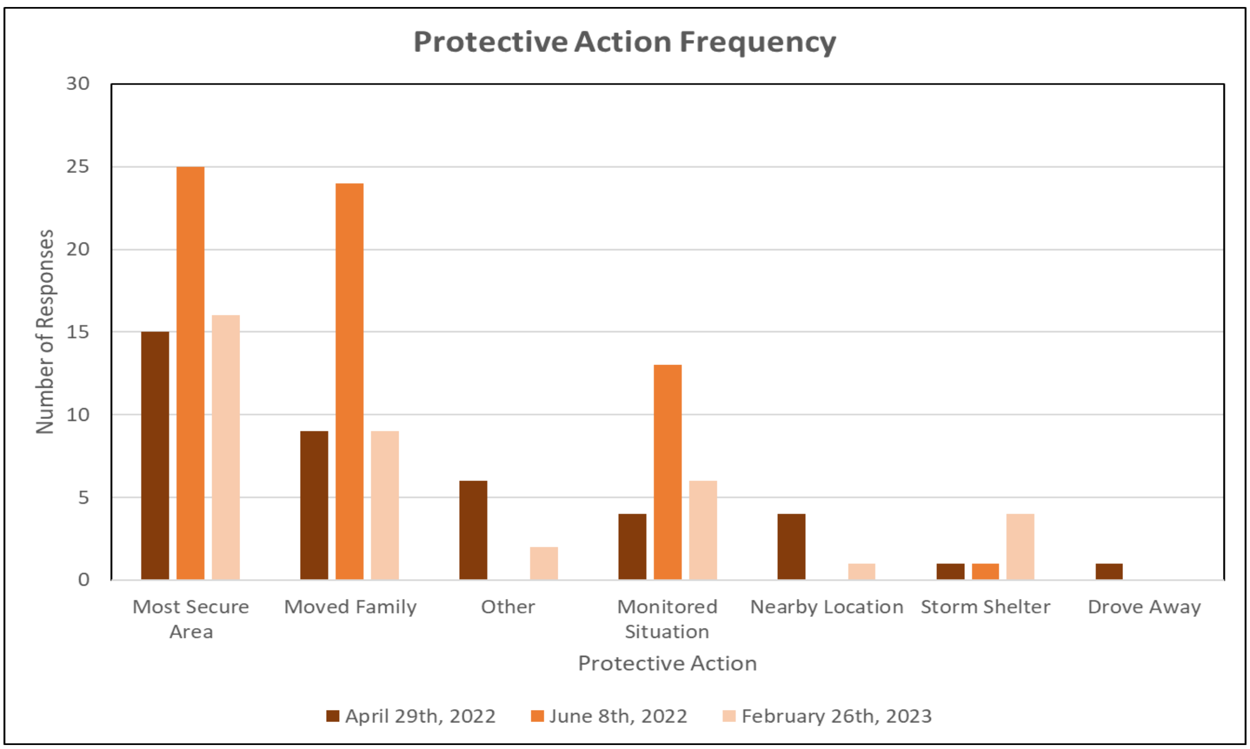

Figure 10. Clustered column chart depicting the frequency of protective response types.

significant at a 95% level (chi-square: 120.6056, d.f.:1).

The difference between the proportion of people who took protective action during each of the three events (chi-square: 14.60481, d.f.: 2), as well as the difference between the proportion of people taking action during the evening events compared to the overnight event (chi-square: 14.34248, d.f.: 1), was found to be significant at the 95% level. 86% of respondents reported taking some type of protective action during the April event, alongside 69% of June respondents and

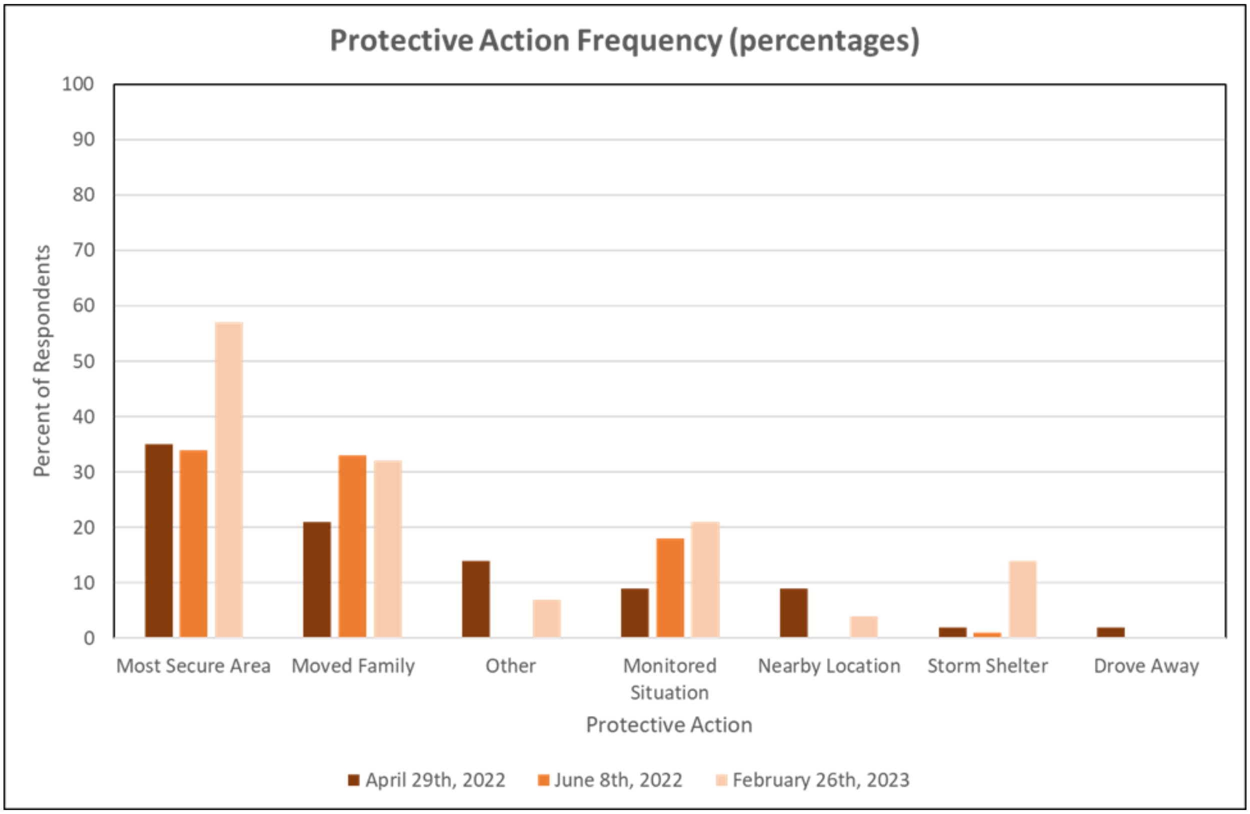

Figure 11. Clustered column chart depicting the percentage of respondents in each event who took each type of protective action.

100% of February respondents (Figure 8). Isolating only those respondents who received warnings, 100% of April participants took some type of protective action, alongside 94% of June participants, and 100% of February participants (Figure 9).

Participants were asked to report which protective actions, if any, they took during the events. Moving to the "most secure area" in one's location was the most frequently reported protective action across all events. 35% of participants reported taking this action during the April event, while 34% reported doing so in June, and 57% reported doing so in February. The second most frequently reported action was moving family and other loved ones to shelter, which was reported by 21% of April participants, 32% of June participants, and 32% of February participants (Figure 10; Figure 11).

5. DISCUSSION

Location

It is possible that timing is the reason why most people were at home as well as the reason for the differences in proportion of people at home during each event. Findings by Lee et al. (2017) support this idea, as their "activity journal"-based study indicates that the proportion of people participating in a home-based activity, including sleeping, is highest between around 5:00 pm local time and around 6:00 am, while activity outside of the home, including school and work, is highest from 7:30 am to 7:30 pm. Thus, it would make sense that the earliest event (April 29th, 2022 at 8:10pm local time) has the lowest proportion of people at home (80%) while the latest event (June 8th at 1:10 am and 1:37 am local time) has the highest proportion of people at home (99%).

Warning Reception

A possible reason why automated texts are so prevalent in the responses is their ability to reach a wide audience. In theory, anyone who owns a smartphone and is within range of a participating cell tower should be able to receive a warning (FEMA). Unlike sirens, whose range is only as far as they can be heard and therefore offer only sporadic coverage, automated text alerts should be able to reach a majority of people in the warning area. Another possible reason why automated text alerts were frequently reported could be the automatic nature of the alerts themselves. With local TV, broadcast radio, social media, and the internet, individuals need to be actively using a device and paying attention to the information source to receive a warning. An automated text can alert someone even if they are not actively using their phones. Under the same reasoning, it would be reasonable for sirens to be the second most commonly reported source of warnings. Like automated text alerts, sirens are operated without direct action by the end user, and thus may be more likely to be received.

One factor that likely played a role in the issue of fewer people receiving warnings during the overnight (June) event in comparison to the evening (April and February events) is participant’s sleep schedules. Most people are asleep generally between the hours of 10:30 pm and 7:00 am local time (Lee et al. 2017). This is evident in the responses to the open-ended question from participants who experienced the June event, which occurred between 1:00am and 2:00am. For example, one 42-year-old woman noted: “My husband and I slept thru (sic) the sirens.”, while another woman recalled that: “The sound of the alarms didn’t wake us up.” Beyond simply not receiving warnings via siren or automated text, people who are asleep will not be checking for information from other warning sources, such as local TV news, social media, and the internet. This severely limits the number of warning sources available to them. Thus, one potential reason people were receiving warnings from fewer sources during the June event in comparison to the April and February events could be that they were simply asleep and therefore not paying attention to information sources. This relative inability to receive nocturnal warnings supports findings by Krocak et al. (2021) and Mason et al. (2018), which suggest that people are less confident in their ability to receive warnings at night.

Further, there were numerous reports from the June event that warnings were not received until after the storm had passed. As indicated by the tornado track and warning polygon data displayed in Figure (2) above, a significant portion of the Overland Park tornado's path was unwarned. This is further confirmed by the 11-minute gap between tornado touchdown and warning issuance for the Overland Park tornado (NOAA; Iowa Environmental Mesonet of Iowa State University). Similarly, there was a four-minute gap between tornado touchdown and warning issuance for the Buckner tornado (NOAA: Iowa Environmental Mesonet of Iowa State University). People in the unwarned areas were not alerted to the storm at all, while those who lived on the western portion of the warning areas likely had very little notice of the approaching storm.

Warning Response

The difference in warning response between the three events is likely directly related to the difference in warning reception. Of the three participants who did receive warnings but chose not to take action during the June event, one was asleep during the storm and did not receive a warning until nearly five hours later, one indicated that they did not have time to take shelter before the storm struck, and one indicated that they received warnings during and after the storm but did not indicate that they took protective action. These findings align with those of Demuth, et al. (2022), whose interviews of tornado survivors revealed almost universal action among participants.

The most frequently reported actions for each event were moving to a secure location and moving family and friends to a secure location. These relatively high rates of sheltering could be due to successful efforts by the National Weather Service and other public safety officials to educate the public on how to protect oneself from tornadic storms, as sheltering in a secure location is the general recommendation made by these groups (NWS). They may also be a result of experience with sheltering drills conducted at school or experience sheltering with others during past events. Storm shelters, while fitting into the sheltering narrative, were reported relatively infrequently. This may be due to a lack of purpose-built or designated storm shelters at home.

6. SUMMARY AND CONCLUSIONS

In this study, responses from the first iteration of the Tornado Tales survey were analyzed to identify trends in the data. Three events (two in the evening and one early morning) were determined to have a statistically significant number of responses. Qualitative and quantitative data from these events were analyzed via chi-square testing and narrative analysis with comparison to the PADM, respectively. Four overarching conclusions were reached from this analysis.

First, a higher proportion of participants received warnings during the evening events compared to the early morning event. This suggests that there is some type of impediment preventing the receipt of warnings during the June event. Two potential reasons were suggested for this discrepancy: Some respondents may have slept through the warning, or the relatively large gap in time between tornado touchdown and warning issuance meant that some respondents experienced the tornado before the warning was issued. Given the varied responses to the open-ended question for this event, it is likely that both reasons played a role.

Second, automated text alerts were the most frequently cited source for warning information for each event, followed by sirens. This could be due to the automatic nature of these warning systems.

Third, when adjusted for warning reception, there was little difference between the proportion of people who took protective action during each event. This suggests that warning reception is an overriding factor in warning response. Further, the near-100% response rate to warnings across the three events suggests little complacency among respondents.

Finally, moving to the most secure area at one’s location was the most frequently reported protective response for each event. This could suggest that efforts by the NWS and other public-safety entities to emphasize the need to shelter during a tornado warning have been successful.

In sum, the larger proportion of fatal nocturnal events compared to those that occur during daylight hours may be more strongly influenced by issues with warning reception during the overnight hours, rather issues related to complacency or lack of understanding about best sheltering practices. This suggests that there is more work to do when it comes to disseminating warning messages to the public during these nocturnal events.

The Tornado Tales survey is a rich source of data related to people’s real-world experiences with tornadic events. With a complete first iteration dataset and an ongoing (as of July 2023) second iteration currently gathering responses, there is great potential for future studies. For example, the potential for a relationship between watch and warning reception fell outside the scope of this study, however, the data needed to investigate this avenue of research is present in the current dataset. The open-ended responses in particular may be useful in determining the rate of success in warning dissemination, as many mention issues with warning reception.

Further, it is the authors’ intention that additional ArcGIS StoryMaps will be created for additional iterations of Tornado Tales to increase transparency about how responses are used and to encourage further awareness of and participation in the survey.

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APPENDIX A:
Table 1. A portion of the table used for open-ended question analysis.

Key Concepts	Milling/Checking for Confirmation	Siren Reception Issues	Automated Text Reception Issues	Critical Reflection
April 29th, 2022	"When my phone alert went off I knew it was serious. My husband and I stepped out on our deck and observed the tornado in the southwest moving right toward our location." -Female, 133 "We took video of the tornado from our driveway before taking shelter." - Male, 49, 148 "I asked my husband, is that the sirens? He looked out the back of our house and saw a rope tornado and said, yes!" - Female, 43, 156 "...suddenly both our phones went off with a Tornado Warning. She got up from her chair and went around the corner of our building, this is when she screamed at me. I ran to her and saw the tornado was already in the neighborhood to our southwest." - Male, 39, 167	"Sirens sounded with the phone alert however the were powered down for several minutes while tornado was on the ground." - Female, 41, 120 "Our weather alerts happened on our phone after the tornado had formed, and it seemed that those weather alerts on our phone occurred before the tornado siren itself." - Female, 34, 152 "The main issue I had was that our power went off and the sirens turned off." - Male, 30, 194 "We could NOT hear the tornado sirens where we are"- Female, 51, 209	"Did not receive alert on phone as many others on my area did." - Male, 42, 135 "Our weather alerts happened on our phone after the tornado had formed..." - Female, 34, 152 "No weather alerts received on my phone. ... I rely on my phone alerts due to hearing loss in one of my ears. I never received any that evening" - Female, 40, 153 "Never recieved Tornado emergency notification on my cell phone." - Female, 178 "I did not receive an alert to my phone for the tornado warning or watch." - Female, 30, 180	"My experience informed me that tornado response will always be messy (in terms of debris), it will get harder after dark, and it will take a large amount of resources to respond to events even if they're geographically small." - Male, 30, 103 "I plan to get a fire box to keep under the stairs for important documents. ... I now see the importance of a weather radio as I was having trouble with phone/text service. ... Also, I reactivated the National alerts on my phone after that night." - Female, 43, 156
June 8th, 2022	"I was first alerted to the tornado via my cellphone & a push warning. Next, I turned on TV to get a better sense of the location of the tornado which turned out to be just 4 blocks north of my house so, I began to move towards going to the basement." - Female, 49, 299 "Received the warning after the tornado was already on the ground and out of our area as we turned on the news while getting our cats into their crates and were advised that the tornado was already past our area." - Female, 33, 366	"... we d jui d not heat sirens." - female, 62, 274 "Read on weather.com tornado was on the ground before hearing sirens." - Male, 275 "Our siren failed to go off but one was heard slightly in the distance." - Female, 34, 279 "We did not receive the warning siren in our neighborhood until several minutes after the potential tornado had passed." - Female, 39, 281 "But Gladstone Missouri sirens never went off and we never ever got an alert on our phones." - Female, 21, 282	"Concerned because my phone alert did not go off...." - female, 62, 274 "...no phone or weather radio alert at all." - Male, 49, 284 "Phones need to have more of a warning nothing comes through on my phone when there is a tornado" - Male, 287 "...NONE of my alerts (radio or phone alert) went off when event occurred."- Female, 53, 288 "I received an emergency notification on my smart phone (Android pixel 6), similar to an	"Obviously we are going to get a weather radio now, but our experience with an older one is not a positive one, so cannot rely on that." - Female, 44, 347

Table 2. Questions and response options from the Tornado Tales Survey.

Question	Response Options
Where were you when the event occurred?	At home At work At school At a business (such as a store or restaurant) In a vehicle (such as a car, truck, or bus) Other I don't recall
If at home: Which of the following describes your current primary residence?	Stand-alone (detached) permanent structure such as a house Condominium, town-house, or duplex that is attached to another structure Apartment or dormitory room that is part of a larger residential complex Mobile home (whether placed on a permanent foundation or not) Other
If at work: Which of the following categories best describes your work setting?	Single-story Building Multi-story Building Big Box Store, e.g., Lowes, Home Depot, Walmart Shopping Mall Industrial of Construction setting Other
If at a business: Which of the following categories best describes the business?	Single-story Building Multi-story Building Big box Store, e.g. Lowes, Home Depot, Walmart Shopping Mall Other
How safe did you feel in this structure when the event occurred?	Not at all safe Only slightly safe Somewhat safe Moderately safe Very safe
Did you receive a tornado warning? A Tornado Warning is issued by the National Weather Service when a tornado is imminent. Did you receive a tornado warning for your area?	Yes/No
If warning received: How did you learn about the tornado warning? Please select all that apply.	Broadcast Radio Weather Radio(National Weather Service radio) Television Siren or other alarm Internet Social media such as Twitter or Facebook Word-of-mouth (including telephone or text messages, email, etc.) from family, friends, neighbors, employers, co-workers, etc.) Automated text of phone notifications Other

	I don't recall
If warning received: When you received the tornado warning, did you need to seek additional information on actions you could take to stay safe?	Yes/No/unsure
If warning received: What did you do when you got the tornado warning? (select all that apply)	Nothing; continued my daily activities Monitored the situation, but did not move to shelter Moved to the most sheltered part of the building, but did not leave the building Moved family or friends to the most sheltered part of the building, but did not leave the building Moved to a specially constructed storm shelter in the building Moved to a nearby location or building that provided safer shelter Left the building and drove away from the tornado warning area Something else
Did you receive a tornado watch? A Tornado Watch is issued by the National Weather Service when tornadoes are possible in and near the watch area. Did you receive a tornado watch for your area? (select one option)	Yes/No/Don't Recall
If watch received: How did you learn about the tornado watch? (check all that apply)	Broadcast radio Weather Radio (National Weather Service radio) Television Siren or other alarm Internet Social Media such as Twitter or Facebook Word-of-mouth (including telephone or text messages, email, etc.) from family, friends, neighbors, employers, co-workers, etc. Automated text or phone notification Other source I don't recall
If watch received: What did you do when you got the tornado watch? (select all that apply)	Nothing, continued my daily activities Checked emergency supplies Bought emergency supplies Made sure NOAA radio was on an charged/plugged in Had Local TV News/Weather on Had local radio News/Weather on Checked my weather App on my phone frequently (NOAA weather radio, etc.) Called friends and family nearby to warn them Sought information on tornado safety Something else I don't recall
What is your gender?	Male Female Other/Prefer not to Answer

What is your age?	Number fill-in-the-blank
What other information would you like us to know about this event? (This can be anything you want to share about your experience with this tornado)	Open-ended
Participants were also asked to select their location at the time of the event from a map or enter an address.	
Participants were also asked to enter the date and time at which they experienced the event.	