Severe Weather Forecasts and Public Perceptions: An Analysis of the 2011 Super Outbreak in Tuscaloosa, Alabama

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ABSTRACT

This paper uses the “Super Outbreak” of 2011 as a case study to examine the potential gaps between the dissemination of severe weather warnings and the public’s behavioral response to this information. This study focuses on a single tornado track that passed through Tuscaloosa, Alabama. The tornado caused massive damage and destruction and led to a total of 62 fatalities. The threat of severe storms was known days in advance, and forecasts were disseminated to the public. Questions were raised about the forecasts, warning lead times, and the perception of the warnings among residents. This paper examines the potential gaps that exist between the dissemination of tornadic warning information and citizen response. The analysis of data collected through a mixed-method approach suggests that, regardless of weather forecast accuracy, a significant chasm exists between the dissemination of warnings and the personalizing of risks, which results in limited use of protective measures in the face of severe weather threats.

SIGNIFICANCE STATEMENT

The tornadoes of 2011 caused hundreds of fatalities during a time in which severe weather forecasting had made great improvements in accuracy. This study aims to understand what the potential gaps are between forecast dissemination and protective-action responses. Perceptions of risk from a tornado remain low among participants even with ongoing exposure and confirmed receipt of tornado warning messages. In many cases, participants needed to personalize the threat before protective actions were prompted. These findings suggest an increased need for improved communication of risks. Future work should investigate risk perceptions and protective-action prompts for other severe weather phenomena among diverse populations.

1. Introduction

On 27 April 2011, the United States experienced one of the deadliest tornado outbreaks in modern history. The potential increase in the occurrence of extreme weather events makes it imperative for the weather and emergency management enterprises to better understand the

public’s response to forecast warnings. The 27–28 April “Super Outbreak” spanned 14 states and resulted in 316 deaths—the highest number of tornado-related fatalities experienced in the nation in over 70 years (NWS 2011). Before this event, no other tornadic outbreak resulted in 50 or more deaths since 1974 (Simmons and Sutter 2012b). Recent research finds that the frequency of tornado outbreaks is increasing, and extreme outbreaks are

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FIG. 1. Map of tornado tracks and ratings through Alabama (NWS Birmingham). Numbered track 44 is the tornado track examined in this study.

increasing at an even higher rate (Tippett et al. 2016). Further, there has been a decrease in the number of days per year with tornadic activity, but since the 1970s there has been an increase in the number of days with multiple tornadoes (Brooks et al. 2014) like the Super Outbreak in April of 2011. With the potential for a rise in the number of tornado outbreaks, understanding the public's response to weather threats becomes increasingly important as risk communication "influences how people perceive and act on risks" (Bostrom et al. 2018). Similarly, Losee et al. (2017) argues that improvements to forecast message content are as important as improving forecast message accuracy. Extreme weather resiliency requires both improved weather prediction and improved public response strategies.

The 2011 Super Outbreak presents dozens of tornado tracks (see Fig. 1) in multiple counties that could be investigated to understand the links between weather prediction and the public's response to weather alerts. This study focuses on the Tuscaloosa–Birmingham (Alabama)

track that touched down in the afternoon. The National Weather Service (NWS) Birmingham Weather Forecast Office confirmed uncommonly large numbers of long-lived, violent (enhanced Fujita scale category EF4 or EF5) tornadoes with pathlengths over 60 mi (~100 km) throughout the entire outbreak. This tornado track was selected because of its high intensity, long pathlength, and high fatality rate for a single-track tornado.

Aside from the damages caused by the storm, this tornado track is favorable for analysis because forecast information about a potential tornado outbreak was shared with the public days before the event, and its daytime occurrence reduces the likelihood of residents being unaware of the risk while asleep. This paper examines the potential gaps that exist between receiving tornadic warning information and subsequent response. Specifically, the study addresses the following research questions: 1) What weather forecast information was conveyed to the public about the Super Outbreak? 2) How did members of the public

perceive the forecasts? 3) Did the perceptions of tornado risk affect the public's response to severe weather alerts?

2. Literature review

Numerous studies have examined how the public responds to severe weather forecasts and related alerts (e.g., [Cameron and Shah 2012](#); [Elliott and Pais 2006](#); [Enarson and Morrow 1998](#); [Perry and Lindell 1991](#); [West and Orr 2007](#)). Studies specifically examining the response to tornadoes have focused on a few potentially associative factors. The source of information (e.g., radio station, local television news program, social media) obtained about the risk of tornadoes has been examined by several scholars. Studies reveal that television news media is a primary source of weather information for the public ([Ashley et al. 2008](#); [Hammer and Schmidlin 2002](#)) and, not surprisingly, has influenced protective responses ([Brown et al. 2002](#)). When considering weather-related information, [Mills et al. \(2017\)](#) found that traditional media sources were preferred over social media sources, and most respondents consider traditional media to be more beneficial. However, for 19–24-year-old residents, Facebook is included with television as a top choice for weather-related information ([Stokes and Senkbeil 2017](#)). Despite the evidence that the public takes cues from the news media, [Sherman-Morris \(2010\)](#) finds that people are confused by the terminology used when conveying a threat (e.g., “tornado watch,” “tornado warning,” or “sheltering in place”), which may further complicate the perception of the risk. Additional research finds that message receivers generally know and are confident in their knowledge that there is a difference between a tornado watch and a tornado warning, but when asked to define these terms or express which actions to take in their own words, correctness is lower ([Schultz et al. 2010](#)). A similar phenomenon is seen with other weather terminology, even by experts in the field ([Stewart et al. 2016](#)).

Regardless of the level of understanding of public advisories, research suggests that people often seek to substantiate the information received through social (e.g., watching the behaviors of others) and environmental (e.g., listening for sounds and looking for physical signs of an approaching tornado) cues ([Lindell and Perry 2012](#); [Balluz et al. 2000](#); [Comstock and Mallonee 2005](#); [Jauernic and Van Den Broeke 2017](#)). Previous experience with tornadoes also appears to significantly increase threat appraisals and personal responsibility ([Mulilis et al. 2003](#)), as well as preparedness ([Comstock and Mallonee 2005](#); [Mulilis et al. 2003](#)). However, other studies suggest that previous experience with tornadoes

may not engender appropriate behavioral responses ([Nagele and Trainor 2012](#)). [Senkbeil et al. \(2012\)](#) found that 53% of their survey participants who experienced the tornado outbreak in 2011 had no shelter plans in place at the time of the outbreak. However, participants indicated that they would do something different in the future; unfortunately, 69% of these respondents did not know what their plan would be. Those who reported having developed sheltering plans were more likely to be Latino or previously had their homes destroyed during the previous tornado event. Additional research suggests that overexposure to reoccurring threats that do not materialize or personally verify can lead to what is referred to as the “cry wolf” syndrome, in which exposure to reoccurring threats leads some to become desensitized to subsequent alerts about potential hazards. Hence, repeated warnings that result in minimal or no personalized impact are often viewed as problematic because complacency develops among the population exposed to the repeated alerts ([LeClerc and Joslyn 2015](#); [Simmons and Sutter 2011](#)). While this may be problematic for tornadoes, it is possible that the impact of repeated alarms is affected by which hazard is being warned; other research involving hurricanes indicates no direct effects on threat perceptions given repeated warnings ([Dow and Cutter 1998](#)). Further, false alarm ratios can vary by region and season, and [Lim et al. \(2019\)](#) find that the perception of false alarms from residents of the southeastern United States does not match actual false alarm rates nor do they help to predict protective actions.

Although threat perceptions have been linked to response to tornado alerts, some argue that the force of a storm can be so strong that the best defense is getting people out of the storm's path—that is, they should evacuate ([Simmons and Sutter 2012a](#); [Mason and Senkbeil 2014](#)). [Hammer and Schmidlin \(2002\)](#) discovered that close to one-half (47%) of their sample chose to flee their homes during an impending tornado, and none of those that fled suffered injuries. This response choice is particularly important for individuals who live in mobile homes or apartments or are outdoors, where the proportion of deaths among injured persons is higher than in permanent homes ([Comstock and Mallonee 2005](#); [Senkbeil et al. 2012](#)). Nonetheless, it is important to note that this type of protective action can become problematic, especially for those with limited mobility ([Clarke et al. 2015](#)) or those who have not received and heeded a warning message quickly.

Conceptual model of risk communications

In addition to the previously discussed literature, further research has sought to explicate how people react to severe weather alerts. The model of hazard risk

communication, heavily influenced by [Mileti and Sorensen \(1990\)](#) outlines a series of stages individuals go through leading up to taking protective actions. [Blanchard-Boehm \(1998\)](#) succinctly describes the stage sequence as hearing, understanding, believing, confirming, and responding to messages and refers to it as the general model of risk communication. Researchers in the field of risk communication have presented slight variations of this model, but all generally include similar components beginning with receiving the information, through understanding the information, to taking protective action ([Blanchard-Boehm 1998](#); [Bostrom et al. 2018](#); [Mileti and Sorensen 1990](#); [Lindell and Perry 2012](#)). For the remainder of this paper, this will be referred to as the general hazard risk communication model. The model used for this project includes six major components, with each one affecting the others, ranging from receiving the warning through taking protective action. Each of the six components has the potential to influence the likelihood of taking protective actions. Each component is described in a specific order, but it is possible for phases to occur at any point for an individual or to not occur at all.

The first component of the general hazard risk communication model is receiving the warning through various communication channels (e.g., in-person communication, television, radio, mobile device, or social media). Understanding the warning is the second component. Will residents know the difference between the issuance of a “tornado watch” versus a “tornado warning”? Are there any language barriers? Is the resident familiar with the phenomenon that is about to occur? The third component is believing the warning. Is there a reason for the receiver not to believe the message? There may be low confidence in the local meteorologist or other environmental cues that conflict with the related warning. The previous steps lead to the fourth component: confirming the threat. Confirming the threat can include hearing the warning across multiple media platforms (e.g., radio, television, social media, and word of mouth).

The fifth component is personalizing the threat. Personalizing can be a large hurdle to cross for warning receivers. Once dark clouds or flying debris are personally seen, or a phone call from a close relative or friend is received, the threat is more easily personalized ([Collins et al. 2017](#); [Howard et al. 2017](#)). Once personalization of the threat is reached, the final step is to take protective action. This final step can become significantly more difficult if the time between warning dissemination and personalization of the threat extends. Once someone has decided to take protective actions, they must evaluate the feasibility of available actions and determine which action to take. Options for a tornado warning include but are not limited to

sheltering in place, seeking shelter at a remote location, and evacuation (e.g., driving away from perceived threat). This process can be even more difficult if there are any physical disabilities, personal mobility hindrances, or other social vulnerabilities ([West and Orr 2007](#)).

In summary, a person must receive information about a potential threat, understand the information, believe the warning, confirm the threat, personalize the threat, and take protective action. This study will use this theoretical model to guide the interpretation of the findings.

According to the review of literature and the general hazard communication model, several factors influence the protective actions taken or not taken during the threat of a tornado event. As noted earlier, to reduce the question of forecast accuracy or whether the information was shared with the public, a long-track tornado that passed through populated and more rural areas in the late afternoon was chosen for this study. From a forecasting stance, the potential for an outbreak was seen up to a week in advance, and the threat of tornado activity was widely known throughout the forecasting community. Having advanced notification of the storm and tornadoes during daylight hours reduces the increased danger and higher fatalities associated with nocturnal tornadoes ([Ashley et al. 2008](#)). Residents of Alabama are generally expected to be aware of the threat of tornadoes since they reside in a historically tornado-prone area ([Ashley et al. 2008](#); [Coleman and Dixon 2014](#); [Dixon et al. 2011](#)). The area experiences a high number of tornadoes each year, with over 100 tornadoes in the two years prior and 59 in 2011 before the Super Outbreak ([Kazek 2010](#)). This type of exposure should help to reduce the number of residents that are unfamiliar with tornadic processes. However, because of the false alarm rates of 2011, it could have also led to the previously mentioned cry-wolf syndrome ([Atwood and Major 1998](#); [LeClerc and Joslyn 2015](#); [Lim et al. 2019](#); [Simmons and Sutter 2011](#); [Trainor et al. 2015](#)). This paper explores these concepts guided by the general hazard risk communication model.

3. Background

a. Description of the meteorological conditions and forecast of the event and how it was communicated to the public

A brief overview is given of the meteorological conditions of the case, the weather forecasts, and alerts that were communicated to the public. For thorough and detailed meteorological analysis of the entire 2011 Super Outbreak, see [Knupp et al. \(2014\)](#). This outbreak is characterized as three distinct episodes, separated by their time of occurrence: early morning, midday, and

FIG. 2. Day 1 outlook preliminary reports validation for 27 Apr 2011 (SPC).

afternoon into the evening. The initial mesoscale convective system (i.e., the complex of thunderstorms) that became a quasi-linear convective system (QLCS) (i.e., a semilinear line of thunderstorms) occurred very early in the day between 0200 and 0800 local time. The second episode, a smaller QLCS, occurred midday. The final, and most devastating episode—characterized by a high number of discrete supercells—occurred after the system reintensified from daytime heating in the late afternoon and carried on through the evening. Because of the disruption to the power and communication infrastructure from the earlier storms (e.g., over 200 000 customers experienced electric power outages), the public's exposure to risk during the later storms was heightened (Samenow 2011). This study focuses on just one of the long-lived, high-intensity tornadoes of the outbreak.

On 27 April 2011, there were a total of 199 confirmed tornadoes, which is the highest in a 24-h period since 21 March 1932 (NOAA 2012). The tornado under investigation in this study was just 1 of 62 confirmed tornadoes to touch down in the state of Alabama. Of the hundreds of fatalities that occurred, the single tornado under examination impacting Tuscaloosa and Birmingham accounted for 62 of the deaths. The NWS Storm Prediction Center (SPC), published convective outlooks, outlining this event several days in advance. In addition to the weather service, local newspapers and television meteorologists communicated the high threat for significant tornado outbreaks in the days preceding the outbreak. Warning polygons were issued covering the majority of central Alabama, indicating a

high proportion of residents were at risk. These forecasts were later verified as illustrated in Fig. 2.

Local meteorologists utilized their airtime and social media platforms to advise viewers and readers to take caution. Figure 3 is an example of the type of messages that were communicated from the NWS to local broadcasters and made available for web users. One local meteorologist, J. Spann, was awarded for his broadcasting during the event and was singled out in the focus group interviews conducted in this study. Through his internet “blog,” he advised readers to remain attentive to weather information and to pass the message along to as many other people as possible, stating, for example, “This means potential for large hail, damaging winds, a few violent, long-track tornadoes. This is a dangerous weather setup” (Spann and Simpson 2011). This is one example of broadcast meteorologists pushing out messages of precaution and advising residents to remain actively aware. The entire weather community shared the same sentiment of urgency to prepare for this severe weather threat. The high confidence of this forecast and the resulting extensive media coverage of the threat mean that risk communication leading up to this event was likely optimal relative to other tornadic cases. As such, this study will focus on analyzing gaps related to risk communication and risk perceptions as a factor in decision-making to take protective action during this event.

b. The storm's impact

The tornado track under examination remained on the ground for 80.68 mi (129.84 km), and the intensity

STRONG SLY SURFACE FLOW AHEAD OF THE FRONT INCREASING TO 80 TO 100 KT FROM THE SW AT MID LEVELS WILL PROVIDE SHEAR HIGHLY FAVORABLE FOR VERY INTENSE/LONG-LIVED ROTATING UPDRAFTS. THIS -- COMBINED WITH FAVORABLE THERMODYNAMIC ENVIRONMENT...APPEARS SUPPORTIVE OF SIGNIFICANT LONG-TRACK TORNADOES AND -- DEPENDING UPON STORM MODE -- THE THREAT FOR WIDESPREAD/VERY DAMAGING WINDS ALONG WITH LARGE HAIL. ATM...GREATEST POTENTIAL FOR TORNADOES APPEARS TO EXIST ACROSS TN/KY/VRN MS AND VRN AND CENTRAL AL...WHILE POTENTIAL FOR WIDESPREAD WIND DAMAGE -- ALONG WITH TORNADO THREAT -- WILL EXTEND NNEWD ACROSS THE OH VALLEY TOWARD THE LOWER GREAT LAKES REGION AHEAD OF THE FRONT.

FIG. 3. Forecast discussion, produced on 26 Apr 2011 by SPC.

ranged between EF0 and EF4 with maximum wind speeds reaching 190 mi h^{-1} (85 m s^{-1}), in the eastern part of Tuscaloosa. The impacted area along a tornado track is relatively small in comparison to other natural hazards (e.g., floods, hurricanes), hence the destruction was quite localized. Unfortunately for residents, the highest intensities and most damaging wind speeds occurred in densely populated areas. Across the state of Alabama, 23 553 homes were either damaged or destroyed according to the American Red Cross. The Alabama Center for Real Estate reported that in Tuscaloosa alone 5144 homes were damaged or destroyed, and, according to the county coroner's report, 42 fatalities resulted from a direct impact. To better understand who was affected, and potentially why, the demographic characteristics of the fatality victims are examined. This allows a sense of what types of people were most at risk of being fatally injured. According to a review of the fatality data, considerably more women were victims (67%) than would be expected given that women made up 52% of the population in 2011 (Fig. 4). More than one-half of the fatality victims fell into two age groups, over 50 years old (16 victims) and between 21 and 29 years of age (12 victims): 38% and 28.5%, respectively (see Fig. 5). The average age of the fatality victims aged 21–29 in Tuscaloosa is proportionate to the age distribution when compared with census data (28.6% and 29.8%, respectively), but the figures for the population under the age of 30 is higher than what is generally reflected in the literature (Ashley 2007; Simmons and Sutter 2011), in which fatality victims are older. The spike in those between 21 and 29 years old is estimated to be caused by the proximity of the University of Alabama and the high potential for university-aged students living in the surrounding area to be victims of this storm. The racial breakdown of the fatalities was only slightly inconsistent with the number of victims, as the U.S. Census Bureau (2010) reports that Whites account for 54% of the population, followed by Blacks at 41%, and Other at 5%. The analysis of victims gives a racial breakdown of 50% Whites and 50% Black.

FIG. 4. Gender distribution of fatalities in Tuscaloosa.

The review of tornado-related deaths showed that at least 69% were inside a home of some type, rather than outdoors or in a commercial location.¹ The number of deaths that occurred in permanent homes was more significant than has been previously reported in the literature (Simmons and Sutter 2011, 2012b).

4. Methods

While the meteorological background provides information on the weather experienced during the outbreak, the sociological data provide insights on the response to the weather forecast and the impact of the event on the residents. This data collection included focus groups of residents in the affected areas. Two focus groups were conducted in autumn of 2012 in Tuscaloosa. There are a variety of ways in which focus groups can be conducted, but the method predominantly used for this study was a moderator-led group discussion. The participants were asked questions regarding 1) the extent of their knowledge of tornado alerts, 2) their perceptions of the weather forecast issued prior to and during the 2011 tornado outbreak, 3) their behavioral reactions to the alerts prior to and during the outbreak, and 4) their experiences with the disaster.

Two focus groups were conducted. The first was composed of nine graduate students and one faculty member at the University of Alabama who recalled their individual experiences of 27 April 2011, during the tornado outbreak. Nearly all members of this focus group were White (9 of 10), 70% were female, and all except one were under 30 years of age. All had education exceeding bachelor's degree. Nine of the 10 participants in this group had been at the university for less

¹ This percentage could be higher, but the locations could not be confirmed for fatality victims in both affected counties. Note that exact locations were validated for 68% of the fatality victims.

FIG. 5. Age distribution of fatalities in Tuscaloosa.

than four years, but 80% were from Alabama. This focus group was primarily composed of graduate students who are able to represent a link between the younger segments of the population and the older faculty and staff members. This allows responses from members of similar age groups to those with highest fatalities during the outbreak.

The second focus group was composed of five adults who lived and worked in a community near the university and who lived in Tuscaloosa for several years, with most having lived there for over 10 years. All members of this focus group were female; 80% were African American, and most were between 40 and 55 years of age (4 of 5). This focus group was conducted to assure that the data collected reflected the experiences of both long-term residents and short-term residents and younger and older members of the community. It was deemed appropriate to conduct two focus groups because the members of each group represented the population under examination, and there were no dominant voices in the focus groups, as all of the members of each of the groups were active participants in the discussion.

In general, because participants in focus groups are self-selected, they may not be representative of the population under examination. However, the responses of the group remain salient.

Although one focus group is entirely female, and the other majority female, women represent the most vulnerable segments of a community during a disaster (Bateman and Edwards 2002; Enarson and Morrow 1998; Enarson et al. 2007; Salvati et al. 2018; Seager 2012). Since women and minorities are more vulnerable during natural disasters and differences in perceptions can have dire consequences, the responses of participants can fill a research gap for an at-risk group. Aside from the predominance of women in the focus groups, the participants reflect a sizable portion of the Tuscaloosa population. In addition, the relatively small geographic impact of tornadoes carries its impact through specific

neighborhoods, each of which may not match the diversity of the larger community.

While a wide range of definitions may exist for the concept of protective action, for this study, a protective action is broadly defined as any attempt deliberately taken to protect oneself from imminent danger. Protective actions include seeking shelter—regardless of the type, inside or outside of the home—and searching for additional information about how to survive the event. People can take shelter in a different home or building, or portion of the house (e.g., closet, bathroom, hallway), or tornado shelter. Information seeking may range from asking a neighbor/classmate, searching the internet, watching television reports, or listening to local or weather radios. The data from the focus groups were compared, and core themes were identified.

Study limitations

There are a few limitations associated with the data used in this project. This project focused on only one tornado track out of the dozens that occurred during the outbreak. Hence, it is possible that the findings are reflective of the impacted communities under examination and therefore has limited generalizability. In addition, this study relies on a small sample size, which also minimizes its generalizability. It is important to note that there are limitations associated with focus group data. Dominant members of the group can seriously influence the focus groups and may serve to suppress the opinions of others and thus impact the data collected. Potential contradictions in views may also be suppressed during focus group discussions because of the fear of conflict (Smithson 2000). Understanding the potential possible limitations of focus groups, the moderator worked to minimize the risks. In addition, the focus groups oversample women. While this does not reflect the gender breakdown found in census data for the Tuscaloosa area, because women are often disadvantaged and at a higher risk during disasters, their responses can be especially salient for understanding the challenges faced during a disaster (Chiu et al. 2013; Enarson and Morrow 1998; Enarson et al. 2007; Neumayer and Plümper 2007). Everyone was encouraged to disclose their real opinions and participate fully in the dialogue.

5. Results

As indicated above, two focus groups were conducted to examine the impact of risk perceptions on response to weather forecast information during the Super Outbreak. The groups are referenced as the “college group” and the “community group.” As specified in the research

approach section, the participants were asked a series of questions regarding the relevant concepts associated with the general hazard risk communication model under examination, specifically, information-seeking behaviors, perceptions of weather forecasts, reactions to weather forecasts, as well as other relevant contextual factors (e.g., previous experience with disasters and projected reactions to further tornado threats).

When considering participant knowledge of tornadoes and alerts, most of the participants reported that they had not, before the Tuscaloosa–Birmingham tornado, had any direct experience with a tornado touching down within their community. However, several participants indicated that they had previous experience with tornado threats as most were from the state of Alabama. Many residents report having heard tornado warnings before and understand the difference between a tornado watch and a tornado warning.

a. College group results

Within the college group, a lack of knowledge about what to do and how to proceed in order to stay safe during this type of natural hazard was expressed. As one student stated, “In a building filled with adults none of us knew what to do” (college group participant 2012). Of all the students in the college group, only one reported knowing what to do during the storm. This finding is surprising, given that all but two of the students were from Alabama, and most noted that the university has safety protocols in place for the students. The one student who indicated they knew what to do had participated in emergency preparedness training before the tornado outbreak. It is also a possibility that the college experience is the first time that they were required to make protective decisions without guardians or family members alongside them to make the decision.

When the members of the college group were asked to describe their perceptions of the day of the storm and the information disseminated, the majority noted that they watched a local news program for information, with a specific reference to one local weather forecaster. However, a few of the participants stated that they relied on social media sources for information. Members of this group mentioned hearing news about the risk of tornadoes at least a day in advance.

While the majority noted relying on television news reports for information, accounts of their behavioral actions in response to the warnings demonstrated that they either did not take the forecast seriously or they did not understand how to correctly respond to the warnings that were issued. Some noted that they did not take protective actions until they saw visible signs of the tornado headed their way, a component of confirming

and personalizing the threat. As one student stated, “[I’ve] experienced tornadoes but not as prepared as [I] should have been . . . kind of numb to these things now.” The participant went on to describe her information-seeking practice in which she “sat in front of the Weather Channel for 12 hours straight.” Unfortunately, because of the extensive threat of severe weather in Alabama, not everyone experiences a direct impact, and she later expressed disappointment with prior experiences by stating, “you get really excited and nothing happens.” Others noted that the resident assistants in the dorms did not provide leadership or guidelines on what to do as they were “crying and screaming” during the incident. This indicates that although members of this group heard about the threat of tornadic activity, they did not fully understand and or believe that they were personally at risk, and those who did were not able to effectively act to protect themselves. Notwithstanding, the University of Alabama has in place a communication and information dissemination system that contacts faculty and student via email and text message. While this alert system was in place students reported not receiving these messages on account of power outages and cellular issues likely from severe weather earlier in the day. Participants report mimicking the behaviors of others around them, and, as noted earlier, almost all reported relying on environmental cues. As one participant stated, “I watched other people’s behavior.” The participant expanded and gave the example that squelched her fears: “My dorm mate said it’s okay we have tornadoes all the time in north Alabama; my roommate took a nap I thought it was okay. [I] only looked outside after hearing the sirens.” A sizable number of participants reported confirmation- and personalization-seeking behaviors, such as calling their parents for advice before the storm was in view. As another participant noted, “I trust my grandma’s and mother’s warning system.”

Although the students reported seeking and confirming behaviors, several students reported not knowing what to do and having minimal direction on campus in dormitories, and the students that lived off campus reported having the same experience. Those who lived off campus reported watching national news programs as their primary source of information on when they might need to take immediate protective actions. For instance, as one student noted, actions were not taken until the power in her residence went out, and she checked a window and could see the tornado on the ground. The student stated, “I realized it [the risk] right during the disaster . . . I saw debris flying around.” The participant described witnessing and needing to personally confirm the threat and later stated that this visualization “reinforced that it was as bad.” Fortunately, she was able to take action relatively quickly. However,

not everyone closely watched the developments of the tornado threat. One participant described largely ignoring the threats because of her uncertainty in how to respond appropriately when living in an apartment.

b. Community group results

Similar to the college group, most of the members of the community group indicated that they had prior experience with tornado threats as they were all from Alabama and have lived in Tuscaloosa for an extended period. The members of this group reported that they heard about the risk before the outbreak. This group also relied on the local news station and a favored local meteorologist denoted by the college group for information during the day of the tornado outbreak. He is well respected by the community, as one person noted, “James Spann respect him I do, he’s just a man, others praise him like he’s the Lord.” None of these participants noted using social media to obtain, relay, or verify weather data, but more than half the student participants indicated or agreed that they called family members and friends to confirm the risk information they received and pass along information. One participant emphasized, and others agreed, that the local television stations were preferred over social media, as one person stated, “TV station . . . they did a good job before and after . . . volunteers set up a Facebook page and Twitter page, social media is here to stay but I hate it.”

Interestingly, the response patterns between the members of the community group and the college group were similar on multiple questions. There is a difference between hearing a message and understanding the nature of the risk. The responses concerning the degree to which the study participants of this group understood and or believed they were at risk indicate that they were not fully aware of the risk. A few of the members of this group stated that they did not pay much attention to the warnings that were issued, and the majority reported dependence on environmental cues. Most indicated that they took for granted an assumption that the storm was not going to impact them directly and hence did not take protective actions in response to hearing the warnings. However, the participants reported taking warnings seriously after their experience with the Super Outbreak. One person reported saying to herself when there are tornado warnings, “[G]et the wine bottle and go to the closet.” Hence, the experience of the Super Outbreak made them more prone to pay attention to tornado warnings and take protective actions in response to the warnings.

Although both university and community residents claim that they wish they had been better prepared or

had been given additional information, there was a great deal of praise for the mitigation actions that were taken on the part of weather forecasters. Perception of risk for focus group participants was low despite constant exposure to warnings and faith in a local forecaster. A local meteorologist in the area has been credited with giving people understandable and useful information on the severity of this storm and its potential for massive destruction. Some even confess to not following his specific advice while realizing it would have proven successful had they done so. Nonetheless, focus group participants believed that the emergency managers, local news media, and social media users spread the word of the possibility of threats during this time. None of the respondents during the focus groups or interviews stated that they were completely unaware of the chance for tornadoes.

The focus group data provided valuable insight into how people lived through this phenomenon differently: what weather information they received, how they processed the news, what they saw during the outbreak, how they reacted, and what they might do differently if faced with a similar threat. The data reveal that people received information about the tornado threats through different communication channels—with young people using both traditional and nontraditional sources, such as social media, and the older population relying solely on traditional news media, with both groups declaring their faith in one meteorologist. The participants also reported having an awareness of the threat of tornadoes, but some reported that they were not as concerned as one would think because they believed they would not be a victim of the storm for a variety of reasons (i.e., observing other people’s responses, previous experiences of threats bypassing their community). Previous experience with tornado alerts that did not pose direct threats appeared to have diminished the perceptions of risks of tornadic activity—an indication of the cry-wolf syndrome. However, almost all except a few of the participants sought to validate the information they received about the tornado risk through checking other sources—the majority called a loved one to verify or cross-check the information. Despite the awareness of the threat of severe weather, almost all the participants did not take protective actions until being directly confronted with the threat. The analysis of the focus group data informs us that although people can hear and understand the information given, they may not believe it; more specifically, they may not personalize it on their own. Responses reveal that verification of the information is sought, sometimes extensively, and individuals may not take the appropriate actions

despite hearing, understanding, and confirming the messages.

6. Discussion

The primary impetus for this project was a desire to understand what led to the high number of fatalities associated with the 2011 Super Outbreak in Alabama. Forecasters knew of the potential threat days in advance and worked with local media to alert the public as the event evolved. So, why were the casualty rates so high? It was believed that an examination of the connection between the dissemination of weather information and the public's perception and response to the threats would provide valuable insights. The findings suggest that there is a difference between knowing that there is an elevated risk of tornadic activity and believing that there is actually a risk of danger to you personally.

According to the hazard risk communication model, residents are required to receive the warning, understand it, believe it, personalize it, which in turn impacts how one responds to the warning messages. All study participants noted that they were aware of the threats of tornadic activity days before the Super Outbreak. Consistent with prior research (e.g., [Ashley et al. 2008](#); [Hammer and Schmidlin 2002](#)) the data reveal that regardless of age and gender, most of the residents relied on traditional media sources—television weather broadcasts the day of the outbreak. However, the younger participants also referenced using the internet and social media, like the findings of [Stokes and Senkbeil \(2017\)](#). Different than the findings of [Sherman-Morris \(2010\)](#), this study found that none of the study participants indicated they had problems understanding the warnings issued. However, like [Nagele and Trainor \(2012\)](#) and [Senkbeil et al. \(2012\)](#) found, it appears that the participants' prior experience with tornado threats influenced their perceptions of the risks associated with the predicted forecast. Previously mentioned studies found no significant relationship or predictors respective to protective actions or shelter plans. In this case, participants with prior experience with tornado threats had not been directly impacted. They were unaware of their lack of knowledge regarding what to do or how to respond. This lack of a direct hit likely gave participants a sense that they did not need to personally worry about the imminent tornado threat. Thus, almost all of the participants did not personalize the risks of the severe tornado outbreak. Further lack of personalization was evidenced by some of the focus group participant responses that suggested they did not take the weather forecast seriously and similar to the work of [Barnes et al. \(2007\)](#) and [LeClerc and Joslyn \(2015\)](#) the

focus group data also pointed to the impact of the over-saturation of previous exposure to tornado warnings—cry-wolf syndrome.

Notwithstanding the lack of personalization of the threat of tornadic events, close to one-third of the participants in each of the focus groups reported confirming the warnings issued the day of the Super Outbreak. The residents sought to verify the warnings they were exposed to with some other source of information, like changing the channel or checking the internet and social media, or through their social networks. These forms of confirmations are not questionable, however, similar to the findings in other research (e.g., [Balluz et al. 2000](#); [Jauernic and Van Den Broeke 2017](#)), many of the college group study participants reported relying on social (e.g., mimicking the behavior of others) and environmental cues (e.g., waiting to see physical evidence of the approaching storm). Therefore, based on focus group findings, the most challenging step in the process of taking protective action appears to be confirming the threat. While relying on social and environmental cues would not appear to be necessarily problematic for a discrete weather threat, waiting could pose problems for those taking refuge in structures that cannot withstand a violent tornado.

Perceptions of risks for focus group participants remained low despite constant exposure to warnings and faith in local forecaster. Despite the broadcasts, the lack of urgency residents expressed initially having suggests that improvements can be made in the dissemination of information. Although highly informative products are disseminated by the NWS, it is important to question whether the entirety of information disseminated, and the extended timeline of the threat made risk information overwhelming for general utilization. The current state of the science and technology limits prediction of precise time and location of the touchdown and path of tornadoes to minutes ahead of their impact. Watch and warning notifications cover large areas of the potential threat, that are often too broad for some residents to discern the level to which they are personally at risk. Hence, it is one thing to know that there is a high threat for a wide area, but it is another thing to know precisely when and where a discrete event will occur. Additional specificity would increase the degree to which citizens can recognize their risk levels.

Forecasting capabilities and tornado detection have improved significantly over the years yet, more specific temporal and geospatial information on the communities at highest risk may prompt more people to take protective actions ([Hammer and Schmidlin 2002](#); [Klippel et al. 2010](#); [Rothfus et al. 2018](#)). While the United States has made a great deal of meteorological progress

(Coleman et al. 2011), additional work is needed to ensure the information is conveyed and digested in ways that will make it more likely for citizens to personalize the threat and engender high confidence in decision-making at these timeframes. Additional research is needed to discern the best ways to convey the information that is available in a manner that will compel people to take threats seriously regardless of the number of times they have been exposed to similar threats. Perhaps further investigations into the risk information and processing model will yield useful results.

This study finds support for the stages highlighted by the general hazard risk communication model. The data yielded from the focus groups illustrated that Tuscaloosa residents received and understood the warnings issued through various news outlets, but most did not take them seriously. Additionally, they struggled to personalize the threat, and except for seeing physical evidence of the tornadoes, most took minimal to no protective actions. Notwithstanding these findings, it is important to highlight that when confronted with direct evidence of an approaching tornado, residents took as many protective actions as they could: they sought shelter and stayed indoors. However, in numerous cases for Tuscaloosa County residents, the housing structures were insufficient to withstand 190 mph winds. According to the Federal Emergency Management Agency Mitigation Assessment Team report (FEMA 2012, p. 10-2), residential buildings in Alabama, which are vulnerable to wind damage, did not have the current version of building codes, and the state of Alabama does “not require individual communities to adopt a residential building code.” For these residents, shelter options [e.g., sheltering in place in interior rooms or basement(s), evacuating to building(s) with strong foundations] were inadequate to withstand the high wind speeds. Research conducted by Hammer and Schmidlin (2002) suggests that the best option for survival may be to evacuate out of the path of the storm. This option could save lives, particularly for people who live in mobile homes (Edwards 2012), as studies suggest that these residents have the highest risk for fatal injuries (Brooks and Doswell 2002; Ashley 2007). Sadly, a study conducted on mobile home residents by Schmidlin et al. (2009) found that most had not investigated available shelter options.

The option of fleeing the current location in pursuit of a safer one should be publicized more since reports of injuries sustained by those who evacuate are low (Hammer and Schmidlin 2002). According to the Alabama State Council, many residents did not realize before the outbreak that they had access to public shelters. Other policy changes that have proven successful in other areas, and even in Alabama public schools, are mandates on

structural standards. After the storm, new storm shelters were open in Tuscaloosa, including at the University of Alabama and the public schools, but public shelters remain less of an option for mobile home parks (Bynum and Martin 2017). Efforts should be made to incentivize the acquisition of storm shelters and make additional publicly available storm shelters.

This paper underscores that improvements in forecast accuracy have occurred since 2011 but have not yet made their full impact on the behavioral response of the public during tornado events. The study’s finding that the public’s understanding of risk for tornadic activity does not translate into taking protective actions until environmental cues are confirmed is disconcerting. The findings highlight the need for continued expansion of social-behavioral research to how message recipients may respond to high-risk severe weather events. Furthermore, the findings add voice to the existing calls to improve forecast messaging.

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