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Perceptions of Tornadoes, Tornado Warnings, Safety Actions, and Risk: Effects on Warning Response Among Undergraduates in Nebraska

Sabrina T. Jauernic
University of Nebraska-Lincoln, sjauernic@huskers.unl.edu

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PERCEPTIONS OF TORNADOES, TORNADO WARNINGS, SAFETY ACTIONS, AND RISK: EFFECTS ON WARNING RESPONSE AMONG UNDERGRADUATES IN NEBRASKA

By:

Sabrina Twyla Jauernic

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PERCEPTIONS OF TORNADOES, TORNADO WARNINGS, SAFETY ACTIONS, AND RISK: EFFECTS ON WARNING RESPONSE AMONG UNDERGRADUATES IN NEBRASKA

Sabrina Jauernic, M.S.

University of Nebraska, 2015

Advisor: Matthew Van Den Broeke

Few studies show how university students perceive and respond to tornado warnings, or how they gain tornado-related knowledge. Lacking in the literature are investigations of how perceptions of tornado risk may influence actions. Using two separate surveys and two large samples of undergraduates enrolled in the University of Nebraska, the author determined significant relationships between student demographics, perceptions, and response actions. Incorrect perceptions were found, such as overpasses and southwest corners of buildings being safe, and cities being invulnerable to tornadoes. International students, especially, assumed cities were safe from tornadoes. Students had a tendency to confirm their risk instead of initially sheltering. Females and international students sheltered relatively often, but chose unsafe locations. Those who used traditional auditory warning sources and perceived lower false alarm rates sheltered more often. Prior experience did not significantly influence actions, but it did influence risk perception. Parents and school were the most popular knowledge sources for domestic students, while friends were popular for international students. Parents may establish better knowledge and safety habits, while friends and popular culture as knowledge sources may result in students sheltering less often and perceiving a higher false alarm rate. Most

domestic students correctly identified safe areas in which to shelter, and correctly knew warnings were issued by meteorologists, but less knew who was responsible for sounding sirens or the precise meaning of a warning polygon. International students who reported having some tornado education made safer sheltering decisions and were more likely to have safety plans. These results, combined with students themselves claiming a need for better tornado information, implies more thorough tornado education on university campuses is warranted. Personalization of risk, dispelling local myths, and education of those new to tornado-prone locations should be emphasized.

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MULTIMEDIA OBJECTS

Chapter 1. Introduction

In spite of greater tornado warning lead times, better detection, and more warning sources, there are still many injuries and fatalities due to tornadoes. As a result, in recent years the weather enterprise has taken increased interest in education and safety preparedness. The National Oceanic and Atmospheric Administration (NOAA) has formed an outreach program whose goal is to have a completely 'Weather-Ready Nation'. An overarching aim of this initiative is to build community resilience, especially to high-impact weather. Part of this involves the National Weather Service's (NWS's) StormReady® campaign. To be deemed a StormReady® institution, universities are required to meet certain criteria set by the NWS, such as having hazardous weather plans, and having numerous ways to receive and relay warning information to the school's population. At the time of this writing, 180 universities nationwide have been designated as StormReady® (NWS 2015a). It is crucial to keep this number growing, as recent events on college campuses have shown. One example is Union University in Jackson, Tennessee. During the evening of 5 February 2008, the campus was struck by an EF-4 tornado, damaging numerous dorms on campus (NWS 2008). There were no fatalities, though 51 students were hospitalized and 9 received serious injuries. Few studies outside of Sherman-Morris (2009), Lovekamp and McMahon (2011), and Ash et al. (2014) show how university students perceive and respond to tornado warnings. No research, to the author's knowledge, has related actions taken during real warnings to student knowledge sources and warning sources. None have investigated how perceptions of (i) tornadoes, (ii) tornado risk, and (iii) tornado warnings may influence actions taken by university

students when under a tornado threat. Among this population, international students in particular have seldom been studied regarding their perceptions of tornadoes and actions taken during warnings. With an estimated 22 million students on university campuses in 2015 (DoE 2015), it is critical to know how these students obtain, perceive, and respond to tornado-related information. With a centralized avenue of sending out mass emergency communication via emails and text messages, university campuses can often act independently from the larger city within which they are located, and university administrators often feel a responsibility to protect those on campus (Baldwin 2008, Nichols 2012). These two characteristics make a university population a unique study sample.

There is evidence that nationality, gender, and length of residence in a particular locale all influence safety actions during warnings (Wong and Yan 2002, Paul et al. 2014, Ripberger et al. 2015). How these factors pertain to university students in particular will be investigated. Other factors such as prior experience, the presence of safety plans, knowledge sources, and warning sources will also be investigated to determine any relationship with safety actions. Psychological factors such as optimism bias, perception of risk, and perception of tornado warnings should also theoretically influence warning response actions. Investigating how these factors influence actions taken among university students will add to the body of literature regarding disaster warning response. In this thesis these relationships were explored through the use of two separate surveys conducted at the University of Nebraska – Lincoln. In the first survey any relationships between student knowledge, safety perceptions, and actions taken during warnings were

explored. The second survey focuses more on tornado warning perception, as well as relating past experience and gender to warning response.

Chapter 2. Background

I. Tornado Knowledge and Safety Practices

One key aspect of tornado knowledge is the public's knowledge of the difference between a tornado watch and tornado warning. Much of the general public can correctly distinguish between watches and warnings, or at least recognize the increasing level of severity with a warning (Balluz et al. 2000, Mitchem 2003, Chaney and Weaver 2008, Schultz et al. 2010). However, there are exceptions (Donner et al. 2012), when respondents are asked to define a watch and warning in open response format. With an open response question, respondents are allowed to supply their own answer. It has been shown (Dudaite 2003) that students tend to perform better with multiple choice than with open response questions. However, open response questions may more accurately portray one's perceptions and knowledge. With no influence from given choices, open response questions 'include the possibility of discovering the responses that individuals give spontaneously' (Reja 2003).

Even if individuals understand the difference between a watch and a warning, they may believe a few common tornado-safety myths. These include sheltering under highway overpasses or in the southwest corner of a building, opening windows before a tornado arrives, and the idea that certain places are 'protected' from tornadoes (Grazulis 2001). The first myth gained popularity after the 1991 Kansas turnpike video. This video shows a family successfully sheltering from a relatively weak tornado under a unique overpass which had a small crawl space and girders for handholds. However, it is consensus in the scientific community that overpasses are a poor sheltering option due to

the wind-tunnel effect and stronger wind speeds higher off the ground (NWS 2009). To seek shelter underneath an overpass, a person would usually have to climb above ground level, exposing themselves to flying debris. The ‘opening windows’ and ‘basement corner’ myths came to prevalence from 1950’s era educational documentaries which misinformed the public to open windows to equalize the pressure inside and outside the home (YouTube 2013). The same video also gave the simple explanation of ‘since many tornadoes come from the southwest direction, that corner should be the safest.’ We now know these perceptions to be false. If inside during a tornado warning, the current NWS recommendation is to seek shelter in a small, windowless, interior room on the lowest possible level of a well-built structure. Covering up with mattresses, blankets, or other material as protection from flying debris and glass is also recommended (NWS 2015b). Some sources, such as a private weather corporation, advise seeking shelter in a corner room to minimize the risk of material from above collapsing down onto the lower levels. This is shown below in a direct quote from their website (AccuWeather 2012):

“If you live in a house with a finished basement, corner rooms or bathrooms and closets offer extra protection. The more concrete walls or plumbing around you, the better. This reduces the risk of your home caving in on you and better protects you from flying debris.”

Despite discrepancies such as these, there is agreement in the weather enterprise that mobile homes should never be used as sheltering options even in weak tornadoes, and cars should generally be used only as a last resort. If nearby sturdy shelter is not available, and if conditions do not allow driving at right angles to the tornado’s motion, there are generally two options recommended by the NWS as a last resort: 1) Staying

buckled in inside the vehicle, with one's head down below the windows, and covered with hands and/or a blanket and 2) Exiting the vehicle and seeking shelter by lying flat in a ditch lower than the roadway (NWS 2015b). The best option pursued is situationally dependent on proximity to the tornado, road network, hail, and flash flooding risk, among other hazards.

II. Safety Plans

Many people indicate they feel prepared for a tornado, and when asked if they had a plan to keep themselves or their family safe, anywhere from 60 to 75% of respondents report knowing what to do and where to go to be safe (Legates and Biddle 1999, Chaney and Weaver 2008, Schultz et al. 2010). Even with a safety plan in place, however, people do not always seek shelter. Tiefenbacher et al. (2001) surveyed 31 households on the periphery of a tornado track in the small town of Siren, Wisconsin. Although none of these participants were directly impacted by the tornado, they resided only a few blocks away from the damage path. This study found that although 81% had a safety plan, only 57% followed through with this original plan. The remaining people were either not at home, sheltered in a different location than they originally planned, went outside to watch the storm, or were not aware of the threat. Determining if student populations have safety plans and act on them remains to be seen.

III. Sources of Tornado Warnings

A review of the literature shows that a majority of people receive tornado warnings primarily from television, with sirens running a close second (Legates and Biddle 1999, Balluz et al. 2000, Brown et al. 2002, Hammer and Schmidlin 2002, Paul et al. 2003,

Comstock and Mallonee 2005, Chaney and Weaver 2008). NOAA weather radios have been seldom used even though they are arguably the most reliable source for warnings (NOAA 2015). More sophisticated technology has led to many more warning sources, including the internet, campus alert systems, text messages, and numerous applications on mobile devices. Schultz et al. (2010) found that older age groups rely more heavily on traditional warning sources such as local TV stations and radio, while younger generations show an increased use of newer technology. A national poll of 2,455 U.S. adults showed increased internet usage for weather forecasts in younger generations, with 25% of those aged 18 to 30 using the web, compared to about 12% of those over the age of 43 (Harris 2007). This is consistent with a study of one Mississippi university that had a recent brush with a tornado (Sherman-Morris 2009). The majority of students surveyed reported receiving warnings from the campus emergency alert system through text and email. In a study conducted in Hong Kong (Wong and Yan 2002), 72% of respondents received weather-related warnings from televisions and radio, with fewer reporting receiving warnings coming directly from others, the web, or telephone services.

IV. Warning Response Process

Mileti and Sorensen (1990) reviewed ways in which the general public responds to weather warnings, and factors affecting the response process. People typically do not hear hazard warnings and immediately panic or respond as some people may assume. There is a sequence of mental events that most people undergo upon receipt of a warning. The person must hear and personally attach meaning to the warning by fully understanding it. They must next believe it to be true and personalize the risk attached to

the warning to their own situation. Personalization of risk is an important step, and is based upon the subjective conclusion of whether or not the person will be affected. Those warned typically do not passively await updated information about the threat, but often instead actively seek out additional information from additional sources. This information-seeking behavior has been coined *risk confirmation*, and has been found in other studies in tornado-warning response (e.g., Chaney and Weaver 2008, NWS 2011). Risk confirmation may be the most important thing people do to believe, personalize, and ultimately respond to a threat. The decision to act or not and which, if any, safety actions to implement are the final steps in the warning-response model proposed by Mileti and Sorensen (1990). This response process is part of a larger 'web' of factors which all influence how people act when under a warning (Fig. 1).

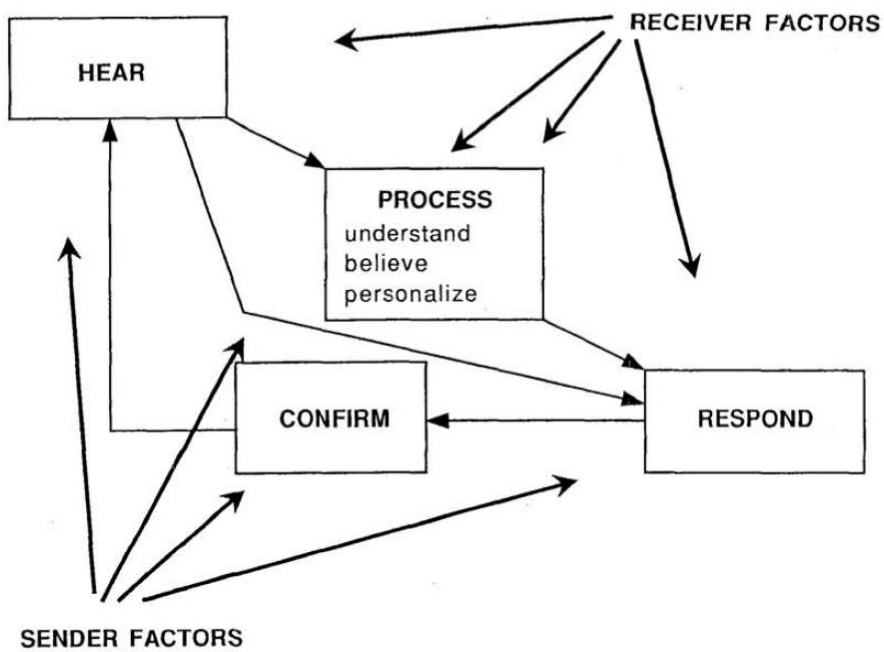


Fig. 1 Mileti and Sorensen (1990): Factors influencing warning response process.

In addition to the process of understanding, believing, and personalizing the threat, other factors that affect response to warnings are ‘sender’ and ‘receiver’ factors. Sender factors include warning source and dissemination channel, warning message content, and warning frequency. On the receiving end, environmental and social cues, and psychological factors, also play a role in determining whether or not a person ultimately responds. Effective messages contain consistent, clear information regarding safety actions to take and locations which are at risk. Mileti and Sorensen (1990) noted that inconsistent warning information could result in public confusion. An example of this occurred in the 2011 Joplin tornado, during which sirens were initiated for a storm to the west-northwest of the city and then stopped. They were then restarted for the tornado which had touched down and started moving into the city from the southwest. The sirens were sounded independently, and coincided with the two warning polygons affecting the city. Many residents didn’t believe the sirens when they sounded the second time, due to the initial one losing credibility (NWS 2011).

V. Factors Influencing Response

Factors positively associated with taking shelter during tornado warnings include being female (Comstock and Mallonee 2005, Nagele and Trainor 2012, Silver and Andrey 2014, Paul et al. 2014, Ripberger et al. 2015), having a safety plan (Balluz et al. 2000, Nagele and Trainor 2012), and having trust in the warning system (Ripberger et al. 2015). Other factors such as prior experience, length of residence within a community, and perceived false alarm rate (pFAR) have had mixed results. As shown in the next

sections, some research suggests prior experience and pFAR have no impact on future warning response, while other research does suggest an impact.

Prior Experience: Positive Influence

Some studies have found prior experience with a tornado may make people more cautious and more likely to shelter during future warnings. Senkbeil et al. (2012) found only 47% of their Tuscaloosa, Alabama, sample had safety plans prior to the 27 April 2011 outbreak. Afterward, 62% planned on changing their sheltering plans to something they perceived as safer. Similar trends have also been observed in Canada. On 21 August 2011, an EF-3 tornado struck Goderich, Ontario, the first to impact this area in recorded history. Since no siren system or emergency alert system was in place, only eight percent of the interviewees ever received an official warning (Silver and Andrey 2014). This is substantially different than many U.S. surveys, since many cities have sirens in place. Many respondents reported visual or extreme cues prompting them into action. These extreme cues included seeing objects being thrown, trees bending or breaking, seeing the tornado, or hearing the wind, rain, and/or hail become more intense. Only 38% of residents took shelter during the initial storm on 21 August, but this increased to 56% three days later when a tornado-warned storm passed through the same area (Silver and Andrey 2014). This included 58% of respondents who were not present during the day of the tornado (Silver and Andrey 2014). This shows indirect experience, through witnessing damage and hearing personal accounts of survivors, increases warning response rate in the near term. Since only three days separated the tornadic event with a tornado-warned severe storm, the event was still at the forefront in many people's minds.

Had there been a longer stretch of time between events, these results may have been different. Another study in Canada (Blanchard-Boehm and Cook 2004) showed those who have had direct or indirect experience with a tornado tend to be more cautious, more willing to learn about tornadoes, and more willing to prepare for possible future tornadoes.

Prior Experience: No Influence

Other studies, such as Nagele and Trainor (2012) found that 'one previous experience with a tornado had no significant relationship with future safety actions.' Nagele and Trainor also said 'perhaps for prior experience to positively influence future response, the past event would have to have been an intense and direct experience.' A direct and intense impact from a tornado that affects people personally may increase their ability to personalize risk. Those who have experience with many weak tornadoes, or tornadoes that do not impact them directly, have been shown to have a decreased tendency to take shelter in subsequent events. Paul et al. (2014) found an inverse relationship between prior experience with tornadoes and compliance with warnings. Three tornadoes impacted the Joplin area since the early 1970's, and 'many communities within 20 miles of Joplin had experienced several tornadoes in the recent past' (Paul et al. 2014). However, no strong tornadoes had occurred within city limits in 38 years leading up the 22 May 2011 EF-5 tornado. This may have caused habituation to occur in long-term residents within the city. In this context, habituation refers to a decrease in responsiveness due to repeated exposure to a stimulus. Many residents in Joplin may have stopped paying as much attention to sirens once they realized many did not result in

an immediate, personal tornado threat. Paul et al. (2014) also showed those new to the city of Joplin, with no prior experience of these 'false alarms,' responded more readily to warnings by sheltering during the 22 May 2011 tornado.

Perceptions of False Alarms

There has been disagreement among researchers concerning false alarms (FAs) and their impact on future warning response. There have been laboratory studies (e.g., LeClerc and Joslyn 2015) showing that the 'cry-wolf' effect is real in *certain* circumstances. LeClerc and Joslyn (2015) conducted an experiment in which students were responsible for salting hypothetical roads based on a computer system's advice. When the system advised salting the road but no snow fell, money was lost, and this was defined as a false alarm. It was found that a higher pFAR led to distrust in the warning system, resulting in less tendency to follow future advice. Ripberger et al. (2015) also found that people who had a higher perceived false alarm rate (pFAR) held lower trust in NWS warnings; this lower trust led to a lower likelihood of taking any safety actions. Simmons and Sutter (2009) found a strong positive correlation between objective false alarm rate (FAR) and number of tornado casualties in the United States between 1986 and 2004. This study used fatalities and casualties as a proxy for pFAR. Thus, it is unknown exactly how the pFAR affected casualties and fatalities. For instance, some people may have been attempting to take shelter, but could not do so for a number of reasons.

Other studies suggest FAs have little to no impact on people's pFAR and safety responses. Dow and Cutter (1998) found that repeat experiences with FAs for hurricanes

in South Carolina did not affect resident's risk perception or future evacuation plans. More recently, Schultz et al. (2010) found that 86% of their respondents were not 'overly concerned about the cry-wolf effect,' and Donner et al. (2012) found that while FAs prolonged time spent getting to shelter, they did not stop respondents from eventually seeking shelter. As alluded to in LeClerc and Joslyn (2015), whether or not FAs negatively impact future response is likely confounded by other variables such as the number, nature, and recency of previous FAs. As Barnes et al. (2007) note, over-warned events such as severe hail, wind, and rain at a particular location in lieu of tornadoes may be perceived by the public as close calls or near misses. These events may not increase the pFAR but instead may serve as an educational opportunity. If false alarms are given explanation or more uncertainty is portrayed in warning messages, this may make the public more likely to give the warning entity the benefit of the doubt (LeClerc and Joslyn 2015).

Even with these discrepancies, it is intuitive that a cry-wolf scenario results in lower warning credibility, especially for tornado warnings. As studies have shown (NWS 2011, Paul et al. 2014, Klockow et al. 2014), there is a prevalent notion that sirens sound quite often, with tornadoes usually not resulting. After the 2011 Joplin tornado, one respondent to the Paul et al. (2014) study reported 'We hear tornado sirens all the time, and nobody pays attention to them.' In the Joplin service assessment, common responses included we are 'bombarded with [sirens] so often that we don't pay attention,' and 'sirens are sounded even for thunderstorms' (NWS 2011). The 2011 service assessment included an analysis of how often sirens had sounded in Joplin before the

tornado, and they found that most people thought they sounded much more often than they actually did. In Joplin, city policy dictates sirens sounding not only during confirmed or suspected tornadoes, but also for winds expected to exceed 75 mph (NWS 2011). Many Joplin residents may not know this, and this fact also raises the pFAR in residents' minds by raising the perceived number of repeated false alarms. This may also increase the need for long-term residents to seek out more information, or wait until the threat becomes immediately apparent before seeking shelter. Knowing if people perceive sirens as indicating an immediate tornado threat would be beneficial.

Perceptions of Warning Polygons

Ash et al. (2014) studied 501 students at the University of South Carolina and investigated their perceptions of warning polygons. Students' perceptions of the standard storm-based warning polygon in use today was compared with two different probabilistic tornado warnings. One of these was a red gradient, with darker shades of red collocated with the highest probable location of a tornado. This red-hued gradient was meant to give guidance about tornado risk probability in different regions of the warning polygon. Indeed, this probabilistic warning resulted in higher values of fear and presumed safety actions near the region with highest hypothetical tornado threat. However, the original design in use today resulted in the highest reported fear and hypothetical safety actions near the geographic centroid of the polygon. Since there was no gradient to influence perceptions of risk, there was a trend to view the polygon as dichotomous (e.g., there was relative safety outside of the polygon, and relative danger inside of it.) As noted by Ash

et al. (2014), this demonstrated students producing their own idea of uncertainty regarding tornado location in the absence of guidance given by a hue gradient.

International Differences: Warning Information and Response

In China, there are severe weather warnings in place for thunderstorms, heavy rain, and tropical cyclones. These are usually displayed as graphics on the bottom of television screens and verbally through public radio. Although these warnings give the type of severe weather expected, other valuable warning components such as time of issuance, duration, and recommended safety action are not given (Wong and Yan 2002). In their study, conducted in Hong Kong, 72% (n = 231) of respondents received warnings from televisions, radio, or newspapers. Even though over 99% of the participants reported knowing what different symbols indicate, it was found that many only had basic and vague knowledge rather than a deep understanding of different warnings. Only 31% (n = 98) of respondents reported usually responding to warnings, with females and elderly people being more likely to respond.

Optimism and Normalcy Biases

An individual’s risk perception heavily influences their actions during disaster warnings. A key element here is optimism bias. This refers to the mistaken belief that one is less at risk for negative events than one's peers (Weinstein 1980). This bias in perception, where people feel immune to disasters, has been shown to be prevalent in tornado warning response (Sherman-Morris 2009, Lovekamp and McMahon 2011, Donner et al. 2012, Suls et al. 2013, Klockow et al. 2014, Paul et al. 2014). Many survey respondents that were affected by tornadoes in 2011 showed optimism bias prior to being

affected. Residents in Joplin seemed to share a feeling of immunity or a ‘local’ optimism bias with regards to the city. Even though severe weather is a normal spring occurrence in southwest Missouri, many felt that ‘storms always blow over and miss Joplin,’ or that ‘there’s always rotation, just never in Joplin’ (Paul et al. 2014). Klockow et al. (2014) found that residents in Tuscaloosa, Alabama, held the popular opinion of ‘I’ve always thought it’ll happen somewhere else and not to me.’ These beliefs cause those at risk to become complacent, and possibly not heed warnings.

In addition to overcoming optimism bias, if a person is to ultimately heed a warning, a major shift in their risk perception needs to take place. This shift needs to be from a perception of safety and normality to one of acute personal risk. People conducting every-day business have a natural tendency to believe themselves safe (Mileti and Sorensen 1990). As stated by Donner et al. (2007) a common response to any disaster is normalcy bias. This is the conviction that events should continue on as they do normally, since there is no *real* danger. Without extreme environmental cues to act as ‘proof’ of danger, some people initially react to warning messages with denial. Interviewees impacted by tornadoes in New Orleans, Louisiana, and Springfield, Missouri, ‘admitted that warning information, in many cases, triggered almost immediate disbelief that storms would generate tornadoes’ (Donner et al. 2007). This bias might be one reason why risk confirmation and information-seeking behavior is prevalent in disaster warning response.

Even if those warned do personalize the risk, the duration of time since an event influences this risk perception in the future. Suls et al. (2013) found a positive effect of

time increasing respondents' levels of optimism following a tornado. Their study found that community residents felt significantly less at risk one year after a tornado compared to six months afterwards. As the event receded further into memory, it was not as prevalent in their minds, and the memories of specific emotions and risk they felt regarding the tornado faded.

Place Attachment and Local Myths

Optimism bias is usually paired with local myths of tornado behavior. Even with knowledge of prior tornadoes that have tracked close to their location, residents still may not believe their home is particularly vulnerable. This is due to the prevalent idea that tornadoes may preferentially hit certain places and travel along repeatable paths. Klockow et al. (2014) showed that if a tornado tracked just north or south of residents' locations or 'on the outskirts of town,' people believed later tornadoes would follow this same path. Many people, especially in urban areas, do not perceive tornadoes as a particularly threatening event, which gives a false sense of security (Mitchem 2003, Schultz et al. 2010, Van Den Broeke and Arthurs 2015). Even in smaller cities such as Joplin, there is a prevalent belief that there is a protective bubble around the city. Many people think tornadoes will preferentially occur in rural areas, not considering the fact that cities simply represent smaller targets than surrounding rural area. Reasons why university students perceive Lincoln, Nebraska as less vulnerable was found in Van Den Broeke and Arthurs (2015). These reasons include the city being at a locally lower elevation, few historical tornadoes, too many tall building, or too much heat or friction produced by the city. Many people also believe tornadoes cannot occur in certain

regions, regardless of urban or rural location, or that surface features such as hills, mountains, or bodies of water can affect tornado motion (Donner et al. 2012, Klockow et al. 2014, Van Den Broeke and Arthurs 2015).

VI. Student Preparedness and Perception

Schmidt et al. (2011) surveyed 1,348 nursing students regarding their perceptions of disaster preparedness. Here 82% of the students surveyed were in undergraduate pre-medical school programs. While the survey only inquired about disasters and emergencies in the broadest sense, it may illuminate the general proportion of students who are prepared versus not. This pattern may or may not apply specifically to tornadoes and severe weather. The results showed slightly over 60% not knowing the disaster plans of the clinical sites they worked at, and over 66% (82%) not practicing disaster plans at school (at home). Seventy-one percent also reported faculty never informing them about what to do during a disaster at school. This may indicate that many students are not well prepared to handle disasters.

In a study conducted in the weeks following the Union University tornado, students were asked about their perceptions of risk and self-preparedness regarding tornadoes and other natural disasters (Lovekamp and McMahon 2011). Many students reported having a strong fear of tornadoes, yet still perceived their personal risk as too low to cause great concern. After viewing footage of the recent tornado affecting Union University, many students acknowledged the risk but adopted a fatalistic attitude. They felt that there wasn’t much they could do to stay safe if a tornado was to affect their campus. One student also commented ‘I have been here 3.5 years and nothing's happened

to me since. So, what's another semester?' Other students simply didn't believe 'it could happen to them,' which shows optimism bias among college students, as with the general population. Sherman-Morris (2009) found that the 'most common reason for [students] not seeking shelter [during a warning] was that they didn't believe the tornado was a serious threat.' Suls et al. (2013) showed students being similar to the general population because they reported feeling less at risk compared to their peers, even if there were no major differences between them and their peers. These students also had increased optimism with the passage of time following a tornado.

Undergraduate students on university campuses are a unique population for study. Many may eventually pass on their own beliefs and knowledge related to severe weather to the next generation. For many students, being on a university campus will be the first time they are expected to be autonomous, responsible for their own safety, and to use their own judgement in dangerous situations. A university population also offers an opportunity to gather information on international students' perceptions, knowledge, and safety actions. The influence of tornado knowledge and warning sources, disaster preparedness, and risk perception on response actions has been seldom, if at all, studied for university students. Determining how students perceive warnings, sirens, and false alarms will be crucial to relate to actions taken during severe events.

Chapter 3. Survey 1 Methods

I. Design and Implementation

The initial 24-item survey inquired about general knowledge of tornadoes, common misconceptions about tornado characteristics and behavior, safety actions taken during a tornado threat, and motivating factors to respond to a tornado warning (questions included in Appendix A). Questions were developed from common themes, which appear in the literature regarding perceptions of tornadoes or response to a tornado threat. Many questions were open-response format to get more detailed insight into student thoughts, and to have students give answers without 'priming' them with multiple choice options. As noted by Reja (2003) and Sherman-Morris (2009) there is a difference between being able to pick the correct answer from a set of given choices and providing a correct definition in open-response format. Multiple choice items may allow respondents to recall ideas or definitions faster and easier, but they may not as accurately portray a respondent's 'gut' reaction or thought process. Initial survey pre-testing was conducted on five meteorology-climatology majors and one professional meteorologist, who indicated the questions did not need further clarification.

In fall 2012, the survey was given to 613 undergraduate students at a public university in Nebraska, which is in a region of climatologically-elevated tornado risk. Total enrollment at the institution was slightly over 24,000 at this time. Survey participants were enrolled in introductory-level science courses, including General Biology (n = 236), General Chemistry (n = 127), Oceanography (n = 115), Introductory Geology (n = 104), Weather and Climate (n = 85), Severe and Unusual Weather (n = 80),

and Environmental Geology (n = 59). Most participants were non-science majors filling general science education requirement, and participants had not received tornado-related instruction in their courses when the survey was administered. Neither of the study researchers were instructors in these courses. Hard copies of the surveys were administered to all students who came to class on the survey day, who were not aware a survey would be administered. No compensation (e.g., academic credit, monetary incentive) was provided for participating. Many demographic aspects, such as year in college and gender, were not primary factors of interest and were not collected. Each survey was assigned a unique, arbitrary numerical identifier. While independently scoring the first 100 participants, a full rubric was developed and refined for scoring the remaining responses (scoring rubric available in Appendix A). Relative to this rubric, 100% intercoder agreement was eventually reached. All 613 surveys were independently coded by two researchers.

The questions for which answers were sought in the first survey using a large sample of undergraduates enrolled in Nebraska include:

1. What do students report as their primary sources for tornado warnings and tornado-related knowledge?

2. How much do students know about tornadoes and tornado safety, and does this vary by the students' geographic origin?

3. How do students perceive their risk of being affected by a tornado?

4. Do any of the above factors influence tornado warning response rate or safety actions?

5. Do university students differ from the general population regarding tornado knowledge, risk perception, or actions taken during tornado warnings?

II. Scoring Knowledge and Safety Concepts

Demographic questions determined home country or state, length of residence in Nebraska, and tornado warning and knowledge sources. Non-demographic questions were categorized as primarily focused on 'knowledge' or 'safety'. Knowledge questions were developed to estimate the thoroughness of students' factual knowledge of tornadoes in the broadest sense. Tornado knowledge questions included defining a watch and a warning, estimating wind speed in a 'very strong tornado,' possible directions of tornado movement, vulnerability of the local city compared to the surrounding region, and the interaction of tornadoes with different land surface features, such as snow, water, and topography. The questions compromising the safety score were concerned with existence of safety plans, warning response rate to all warnings received, and actions taken during hypothetical events as well as the latest warning experienced. The knowledge score consisted of 12 items (Questions 5-16; Appendix A), and the safety score consisted of 9 items (Questions 17-24; Appendix A). Knowledge questions were scored on a scale from 0 to 1, where incorrect answers were assigned 0 points and responses showing expert-like knowledge received 1 point. One question, for instance, asked "What does it mean if a tornado warning is in effect for your area?" and was scored as the following:

1 = Correct explanation; 'tornado has been spotted or inferred by radar'
0.75 = Mostly correct; 'Strong chance of tornado', 'funnel clouds spotted'
0.5 = Partially correct but generic; 'take cover', 'tornado forming signs'
0 = Incorrect; confuses watch and warning, doesn't know

Safety questions were also scored from 0 to 1, where unsafe actions were assigned 0 points, and safest actions received 1 point. Final scores for each participant were obtained by summing the total number of points earned across all items for ‘knowledge’ and ‘safety’ and reporting the percentage of earned points out of total points possible for each score (12 points possible for knowledge and 9 for safety). A low score implied relatively non-expert responses on many items. There were items that the majority of respondents answered incorrectly, such as questions asking about the process of tornado formation and the cause of strong winds in a tornado. Even though questions such as these reduced knowledge scores for many respondents, variations relative to peers were still seen in some groups. If an item was missing a response, it was assumed the participant did not know the answer. When a particular survey was missing $\geq 40\%$ of the questions making up either score, the survey was discarded for that score. This resulted in two discarded surveys for the safety score, and 39 for the knowledge score.

III. Statistical Analysis Methods

The Wilcoxon-Mann-Whitney (WMW) rank-sum test was utilized to determine if the differences in the average knowledge score, safety score, and warning response rate were statistically significant between groups with different home regions, knowledge sources, warning sources, and perceived vulnerability. This two-tailed non-parametric test indicates whether two means come from different populations, and was used because results for many questions were non-Gaussian, and some groups being compared were relatively small (Wilks 2011). The *p*-values reported for differing response rates show if a particular group’s mean was significantly above or below the mean of the entire

remainder of the surveyed sample. Dependence among categorical variables was calculated using the chi-squared statistic. Standardized residuals were utilized to determine which variables contributed most to the total statistic (Sharpe 2015), thus showing which variables were significantly different than otherwise expected.

IV. Survey 1 Limitations and Assumptions

The knowledge and safety scores were formed as aggregate measures to generally compare overall tornado knowledge and safety actions across different groups. The knowledge score was not meant to fully represent everything a student might know about tornadoes, and the safety score was not meant to represent the appropriateness of every action taken in every warning. Inherent knowledge, safety perceptions, and actions taken may be fluid in time and change from event to event, thus this survey only captured a partial and instantaneous look at what students may do. Instead, the goal of these scores was to obtain a general look of what different groups of students know about tornadoes and the safety actions they take.

Additional assumptions and biases may also have been present. The survey was given in introductory-level science courses, which may have slightly biased the results compared to a sample spread uniformly across the undergraduate population. It was assumed that self-reported events and actions were being remembered and reported accurately and honestly. Another limitation is that the survey did not ask if ‘school’ as a knowledge source referred to grade school, high school, or college coursework unless specified by the respondent; it is also unknown whether students were differentiating between dorms, classrooms, and other areas on campus when reporting having safety

plans at school. Participants' prior experience with a confirmed tornado, or prior experience with tornado warnings while actually on campus, was also not ascertained. The pilot study was conducted solely on meteorologists, and could have been improved by being offered to non-meteorologists as well.

Chapter 4. Survey 1 Results and Discussion

I. Survey 1 Demographics

Student demographics were hypothesized to influence tornado knowledge and safety actions taken during tornado warnings. Participants were thus asked to provide their home state or country, and their length of residence in Nebraska. A total of 76.7% of participants reported being from Nebraska (Fig. 4.1). For statistical comparison, the states of Texas, Oklahoma, Kansas, Nebraska, and Iowa (shaded in Fig. 4.1) were defined as the ‘Plains States’ due to the relatively high climatological occurrence of tornadoes in these states. Plains States participants made up the majority of the sample (n = 491; 81.6%). Non-Plains U.S. students accounted for 15.6% (n = 94), and international students made up 2.8% (n = 17). This sample was fairly representative of the geographic distribution of undergraduates at this institution. Foreign students were underrepresented, as university records indicated this group accounted for six percent of the university population during the given semester (UNL 2012). Most participant’s reported being in Nebraska for five or more years (79.1%), or for less than one year (11.7%).

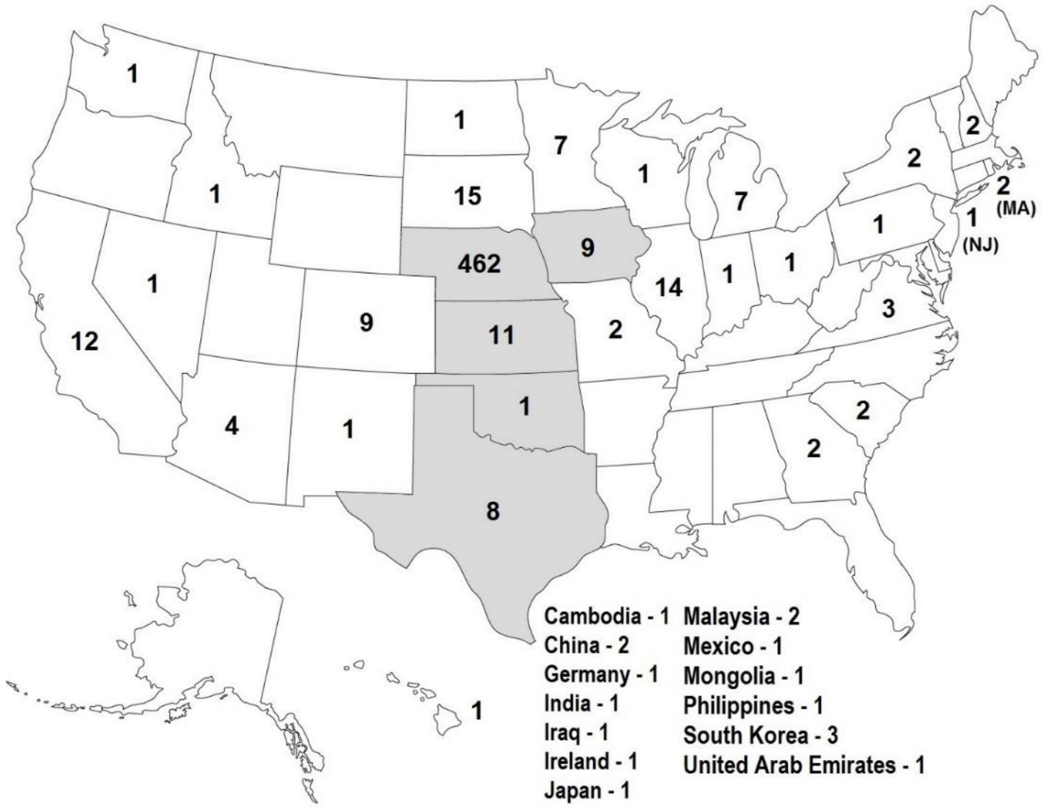


Fig. 4.1 Home state and country of students within Survey 1 sample. Gray-shaded states are defined as the 'Plains States' region.

II. Knowledge and Warning Sources

All self-reported sources of tornado-related knowledge (free response; Item 3; Appendix A) provided by 602 participants indicates the majority of students (63%; n = 381) reported general schooling as one of their sources (Fig. 4.2). Since so many students are using school to gain tornado-related knowledge, knowing what they are being taught, and investigating the knowledge of teachers would be beneficial. The next most common knowledge sources were parents and television. Other sources such as common knowledge, the internet, popular culture, and friends/peers were each listed by

less than five percent of respondents. Using the definition provided by Klockow et al. (2014) for folk science, common knowledge was defined as being 'environmental perceptual knowledge that people have developed by living in a place for a long period of time'. Participants were asked to give one source from which they learned the majority of their knowledge. However, 229 students listed more than one source. It was assumed that the most prominent source in participants' minds would be the first one listed; this was designated the primary source.

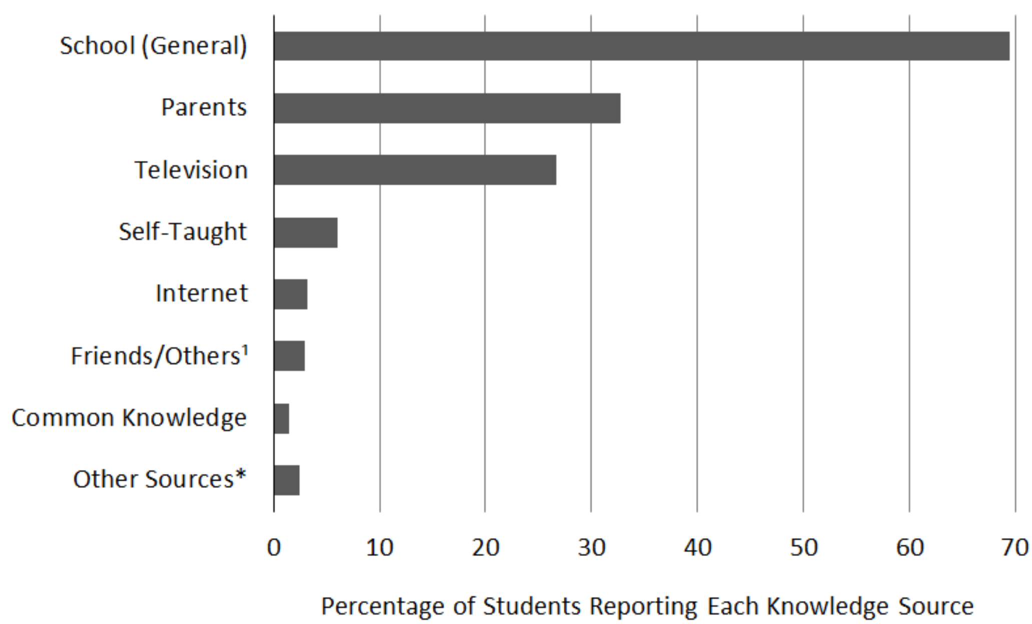


Fig. 4.2 All reported sources for tornado-related knowledge for survey 1. [1]Friends/others include any acquaintances known to the respondent. *Other knowledge sources include: public radio, NWS, and movies/popular culture.

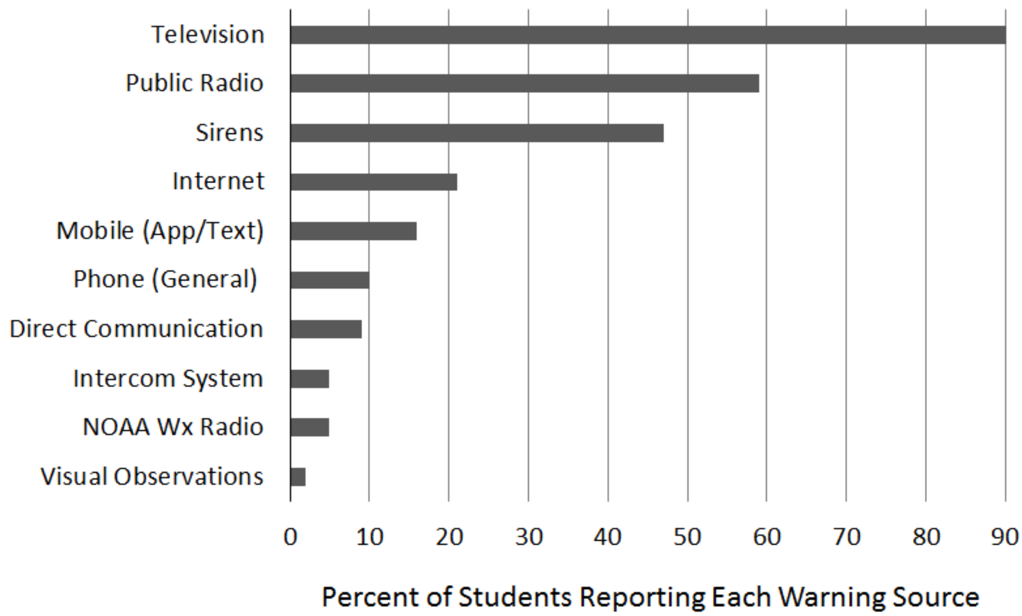


Fig. 4.3 All reported sources for tornado warnings for survey 1.

All self-reported warning sources used by 608 participants (free response; Item 4; Appendix A) indicates television was the most popular source (91%, n = 552) of students, followed by public radio and sirens (Fig. 4.3). Considering the continued popularity of television and sirens, it seems crucial to know how students are interpreting information from these sources. Other sources such as building intercom systems, weather radio, and visual observations were each used by five percent or less of respondents. Participants were asked to list their sources in order of usage. As with knowledge sources, it was assumed that the first source listed would be the most-used by the participant. It was found that the three most popular sources (television, public radio, and sirens) were listed as a first source by 86% of students. Other sources such as phones (used for either calling, texting, or mobile apps), the internet, and direct face-to-face communication were listed as primary sources approximately five percent of the time.

Nearly 90% of respondents (n = 544) reported receiving warnings from at least two sources, and 58% (n = 352) reported three or more sources.

Comparison of Sources to General Public

Students in this study received their warnings primarily from television followed by sirens, the same two sources as the general public (Legates and Biddle 1999, Balluz et al. 2000, Brown et al. 2002, Hammer and Schmidlin 2002, Paul et al. 2003, Comstock and Mallonee 2005). However, fewer participants reported visual cues of the environment as warning sources than in prior studies (Balluz et al. 2000, Comstock and Mallonee 2005). In this study, less than one percent listed it as a primary source, and only two percent listed it at all. This finding may indicate less weather awareness in younger generations. Face-to-face communication with others was also less prevalent in this population (one percent listed it as a primary source; nine percent cited it as any source) than was found in previous studies (Tiefenbacher et al. 2001, Paul et al. 2003, Comstock and Mallonee 2005, Chaney and Weaver 2008, Sherman-Morris 2009). Prior to Sherman-Morris (2009), few studies reported usage of new technology such as the internet and mobile devices. Comstock and Mallonee (2005) reported phones and pagers being used by 10% to 15% of respondents during the 1999 and 2003 Moore, Oklahoma, tornadoes. Our study shows younger generations using newer technology such as the internet, mobile application, and texts as tornado warning sources nearly 37% (n = 226) of the time. These types of sources were only listed as a *primary* source, however, by six percent of students. This may indicate that while newer technology is gaining popularity,

it is being used more as a confirmatory source and is not as prominent in the minds of respondents as traditional sources such as television, sirens, and radio.

III. Knowledge and Safety Scores

The knowledge and safety scores were developed to generally compare overall tornado knowledge and safety actions across groups of students with different backgrounds and perceptions. The average knowledge score was 0.35 out of a possible 1.0 for 574 students. When asked to define tornado watch and tornado warning (Items 5 and 6; Appendix A), many students provided generally correct, but quite generic answers, as found by Sherman-Morris (2009). Examples for tornado watch included '*a tornado may occur*,' or '*tornadoes are possible*.' For a tornado warning definition, a common response was '*a tornado has been spotted somewhere*' or '*there is a strong possibility of a tornado*.' Besides the lack of specificity, many respondents had generally good knowledge of what each term meant, and ~ 90% (n = 538) knew that a warning was more significant and/or required more urgent action than a watch. While most students had a reasonably accurate perception of these two terms, poor responses on other questions such as typical wind speed in a 'very strong tornado' (Item 7; Appendix A), tornado formation, motion, and behavior (Items 8-11; Appendix A), and the influence of surface features (Items 12-14; Appendix A) lowered overall knowledge scores. Safety scores were generally higher than knowledge scores, with an average safety score of 0.59 out of 1.0 for 611 students. This higher score was due to many students having safety plans, and reporting generally correct safety actions during the last warning received. Using

Pearson's correlation, it was found that knowledge and safety scores were only weakly positively correlated (r = 0.21).

Factors Influencing Knowledge and Safety Scores

Home region significantly impacted knowledge and safety scores (Table 4.1). Students from Plains states had significantly higher scores for both knowledge and safety (p = 0.006 and 0.0001, respectively) compared to all other respondents. Non-Plains U.S. students scored significantly lower than Plains students (knowledge p = 0.032; and safety p = 0.002). International students had significantly lower scores for both knowledge and safety than all U.S. students (p = 0.016 and 0.001, respectively). Although this result may be influenced by a smaller sample size, and a lower level of understanding of the questions among international students, this still shows a special need for this population to be educated on tornado behavior, associated risks, and safety actions when moving to a tornado-prone region. One international student who reported ignoring the last warning gave the reasoning of *'Usually [the storm] is gone after a while, so I just stay in my room.'* Tornado education designed to improve the response to a tornado threat may also benefit Non-Plains U.S. students, who may be aware that tornadoes are dangerous, yet not know the best safety practices to take during a warning. Primary knowledge source also seemed to impact overall safety measures taken by respondents. Participants who reported learning their tornado knowledge primarily from parents had significantly higher safety scores (p = 0.001; Table 4.2) than those who reported gaining such knowledge elsewhere. Students reporting school as their primary knowledge source had slightly lower safety scores (p = 0.087) than those with other sources.

Table 4.1: Influence of home region on knowledge and safety scores.

Home Region	**Knowledge Score Ave = 0.35**	**Safety Score Ave = 0.59**
Plains States (n = 465, 491)	0.36[a]	0.60[a]
Non-Plains States (n = 88, 94)	0.33[b]	0.55[a]
International (n = 12, 16)	0.26[b]	0.42[a]

[a]Significant at 1 % Confidence Interval (C.I.), [b] Significant at 5 % C.I., [Non-Plains students were only compared with Plains students]. Values of 'n' indicate number of students from each home region which had a Knowledge and Safety score, respectively.

Table 4.2: Influence of knowledge source on knowledge and safety scores

Primary Knowledge Source	**Knowledge Score Ave = 0.35**	**Safety Score Ave = 0.59**
School (n = 280, 303)	0.35	0.58[c]
Parents (n = 125, 128)	0.36	0.64[a]
Television (n = 88, 94)	0.38	0.59
High School/Univ (n = 20, 21)	0.35	0.59
Self-Study (n = 18, 20)	0.36	0.56
Internet (n = 10, 11)	0.34	0.50
Friends/Others (n = 9, 10)	0.40	0.52
Common Knowledge (n = 7, 7)	0.30	0.53

[a]Significant at 1 % C.I., [c] Significant at 10 % C.I. Values of 'n' indicate number of students with each primary knowledge source which had a Knowledge and Safety score, respectively.

IV. Safety Plans and Intended Actions during Warnings

Many students reported having safety plans in place in case of a tornado (Items 17a and 17b; Appendix A). Nearly 60% had plans at both home and school. Our findings mirror those for the general population (Legates and Biddle 1999, Chaney and Weaver 2008, Schultz et al. 2010). However, what exactly these safety plans consist of needs further exploration. More students reported having safety plans at home than at school (79% and 67%, respectively), implying that students may not know where to go if on campus during a tornado threat. Those gaining knowledge from parents were statistically more likely to have safety plans at home ($p = 0.020$). However, international students ($p = 0.057$), those from Non-Plains states ($p = 0.012$), and those who had been in Nebraska for one year or less ($p = 0.015$) were statistically less likely to have a safety plan at home, showing a need for further education about tornado risks. Among those who ignored the last warning, fewer students ($p = 0.066$) reported a safety plan in place at home than those who responded to the warning by sheltering or seeking more information. No significant factors were discovered which influenced students having safety plans at school.

When asked where to shelter in a basement if one was available (Item 18; Appendix A), many students appeared to not carefully read the question, and responded generically with '*the basement*,' yet others simply said '*a room without windows*.' While avoiding windows is a good practice, a response that would have earned full credit would also specify sheltering in a small, enclosed, central room such as a closet or bathroom. Slightly less than 26% ($n = 154$) of respondents replied in such a manner. When asked

what action participants would take if trapped outside with an approaching tornado (Item 19; Appendix A), 80% (n = 489) replied they would seek shelter in a ditch or depression. Few of these students (n = 59) additionally mentioned covering their head to protect from flying debris. It is unknown whether the rest of the respondents knew of this safety measure and simply did not report it, or if they did not know that they should protect their head. Nearly 20% of responses (n = 118) indicated unsafe actions. These included panicking, trying to outrun the tornado, not knowing what to do, and seeking shelter under a tree or overpass.

V. Perceptions and Tornado Mythology

Students were asked questions regarding perceived tornado risk and common tornado myths. Thirty-one percent (n = 190) believed that overpasses provide suitable shelter when trapped outside with an approaching tornado (Item 20; Appendix A). This was lower than found by Schultz et al. (2010) in which 45% of respondents believed this myth. No factors were discovered which significantly influenced a student's tendency to seek shelter in such a location. In addition, other myths were believed by some in the university student population. There were 24% (n = 149) who believed opening windows before a tornado arrives was advisable (Item 21; Appendix A), however this wastes valuable time better spent sheltering. Ninety percent (n = 543) of students believed at least one of the surface features of hills/mountains, rivers, and snow cover affected tornado formation and behavior. When asked how vulnerable the local city was compared to the surrounding rural area (Item 12; Appendix A), 51.3% (n = 287) believed the city was less vulnerable for various reasons. This included those students who were unsure

about the local risk. The most prevalent reasoning (believed by 21%; n = 119) was the 'bowl-effect,' which is the local notion that tornadoes cannot affect the city due to the slightly lower elevation (Van Den Broeke and Arthurs 2015). In addition to believing the local city was less at risk, many students thought that cities in general are relatively safe from tornadoes, or that tornadoes preferentially occur in open rural areas. This reiterates findings for the general public (Donner et al. 2012, Klockow et al. 2014).

VI. Response during Warnings

Self-reported actions taken during the most recent warning (Item 22; Appendix A) were available for 567 participants (Table 4.3). Of these, 69% (n = 391) reported going downstairs. The remaining 31% (n = 176) reported various relatively unsafe actions, ranging from dangerous activities (e.g., ignoring the warning, attempting to chase, or going outside to look) to safer options (e.g., watching from a window, or watching the news or radar). While watching the news or radar are not inherently dangerous, they could not be scored as a safe option, since students gave no information regarding their location. It also was not possible to confirm if these students had the knowledge necessary to determine whether they were in danger. Upon receiving a warning, some students (n = 76) took actions to confirm the risk of a tornado occurring before taking action, as has been seen in the general population (Chaney and Weaver 2008, NWS 2011). Such responses included '*I went outside to watch the storm*,' '*I went outside to look for the tornado*,' or '*I watched from the window until conditions got really bad*.'

Table 4.3: Self-reported actions taken during most recent tornado warning.

Reported action during most recent warning	n	% of total
Took shelter in basement	391	69
Information seeking or confirmatory behavior[a]	76	13
Ignored warning, continued activity, not aware of threat	72	12
Attempted to chase storm in vehicle	12	2
Stayed or moved 'indoors' with no additional information	11	2
Panicked, or was driving at time	5	1

[a] This behavior included going outside, watching from a window, or watching news and/or radar.

Seventy-two respondents reported ignoring or not being aware of the last warning that applied to them. Common answers in this category included watching television or sleeping during the warning. Other responses from this group included going to a baseball game, continuing shopping, *'[the warning] didn't bother me too much,'* and *'[I] didn't consider [the warning] a threat.'* One student from Texas replied with *'[I] wasn't too worried, [I] could see one outside once; If I was ever hurt I would change my mind.'* Another unique response was: *'[I] went to the store, I knew it wouldn't hit us.'* This particular student believed the '*heat from the city should dispel the tornado.'* Another student reported they *'didn't believe the sirens, finally went to basement in the dorms,'* even though they reported usually responding to warnings, *'especially outside of [the local city].'* These types of responses show that many students do not take the threat of a

tornado seriously, due in part to the perceived protection of cities, and the lack of recent tornadoes in and around the local city.

Trigger to Motivate Response

Information or circumstances needed to motivate a response to a tornado warning was reported by 474 participants (Item 23; Appendix A), shown in Table 4.4. Of these responses, nearly 40% (n = 184) implied that the warning itself would be sufficient motivation - this was either stated explicitly, or by indicating response to sirens or a broadcast meteorologist advising seeking shelter. Thirty-four percent (n = 163) replied that they would need more information about the exact location of the tornado, direction of movement, or urgency of the situation. One student mentioned their motivation to seek shelter would be *'if somewhere close to me got hit,'* which shows the need for confirmation of personal risk. Roughly one-quarter (n = 113) stated that visual cues such as the wind speed increasing or the sky becoming dark would initiate a response. These respondents didn't mention seeing the tornado, but instead focused on other environmental cues. Fifteen percent (n = 72) implied they would not take shelter unless they physically saw or heard the tornado. This is very similar to the proportion found by Comstock and Mallonee (2005) when sampling the general population of Moore, Oklahoma. Those who reported needing visual or auditory confirmation of a tornado were also significantly less likely to have safety plans at home ($p = 0.0001$). Finally, seven percent (n = 35) reported taking action only if others near them took action or if they were responsible for another person's safety. More than one 'trigger' which would initiate a response was indicated by 103 respondents. Many of these may be situationally

dependent as well, as some students reported combinations such as both seeing the tornado and the sirens initiating a response.

Table 4.4: Trigger needed to motivate a response to a tornado warning.

Trigger to act on Warning	**n**	**% of total**
Warning is enough	184	40
Need more information about location/severity	163	34
Visual cues other than tornado (rain/wind)	113	24
Need to see or hear tornado	72	15
Depends on others' actions or presence	35	7

Factors Influencing Actions Taken

Incorrect knowledge was associated with unsafe actions. Those who did not correctly define a tornado warning were significantly less likely to have immediately taken shelter during the last warning ($p = 0.028$). The odds of students taking shelter was 85% lower if they gained tornado-related knowledge from popular culture, friends, or 'common knowledge' compared to all other knowledge sources ($p = 0.023$). Those being warned through direct communication (by phone call or directly face-to-face), were also slightly less likely to shelter ($p = 0.058$). Instead, this group may have sought out more information after receiving the initial warning, as many in this group reported needing more than simply the warning as motivation to respond and over 76% ($n = 23$) used three or more warning sources on a regular basis. Those who reported needing visual or

auditory confirmation of a tornado before responding were significantly less likely to take shelter ($p = 0.001$). The only variable that positively influenced shelter-seeking in a slight way was having parents as a primary knowledge source ($p = 0.067$). Other factors, which may have played a role in the decision to shelter, such as gender and prior experience with tornadoes, were not assessed in this survey.

Factors Influencing Warning Response Rate

Self-reported percentage of warnings responded to (free response; Item 24; Appendix A) was provided by 583 students. The average warning response rate was 63%. The majority, 42%, (n = 242) of students reported responding to at least 90% of the warnings of which they were aware (Fig. 4.4). Twenty-six percent (n = 153) responded to a quarter or less of warnings, with 36 of these students reporting not responding to any warnings. The author's concept of a safe response may have differed from some students' conceptions of 'responding.' Responding to some may have simply meant seeking additional information by consulting other sources or confirming the threat by looking outside. Twenty participants reported responding to every warning in spite of unsafe actions taken during the most recent event (e.g., going outside to watch, chasing the storm). Whether 'responding' means actively seeking shelter, seeking additional information, or following unsafe actions remains an area for further research.

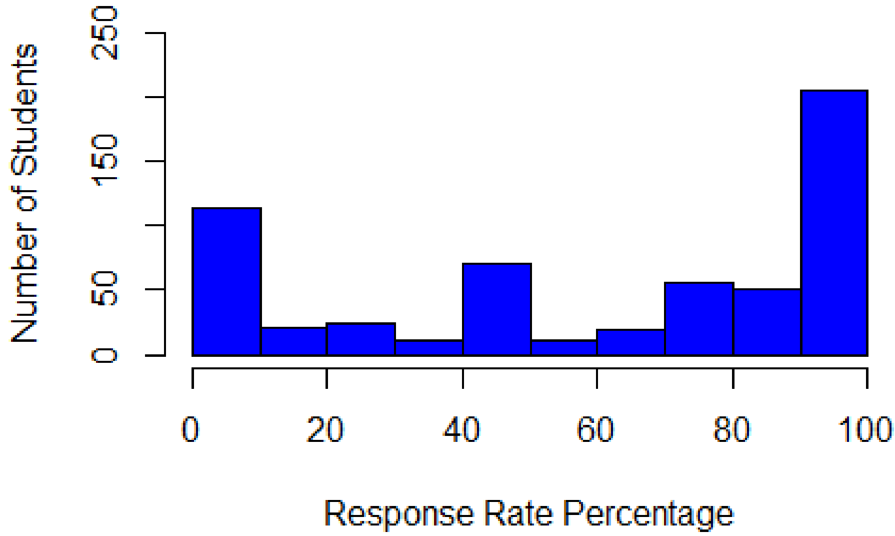


Fig. 4.4 Students' self-reported tornado warning response rate.

Warning response rate appears to be related to other factors, including perceived vulnerability of the local city, home origin, and primary knowledge sources (Figures 4.5 - 4.7). Those who felt the local city was less likely to be affected than the surrounding region responded to a significantly lower proportion of warnings (61%; p = 0.044) than other respondents. This shows an incorrect perception of tornado behavior and risk leading to unsafe actions being taken. Those who thought the local city was equally likely to be affected by a tornado as the surrounding area, which was the most expert answer, reported responding to significantly more warnings (69%; p = 0.037) than those who thought otherwise (Fig. 4.5). International students responded to fewer warnings than all U.S. students combined (50%; p = 0.089; Fig. 4.6). Many disregarded warnings and did not seem to fully realize the threat associated with tornadoes. This implies international students are not being educated sufficiently about tornadoes and tornado safety upon arrival to the United States.

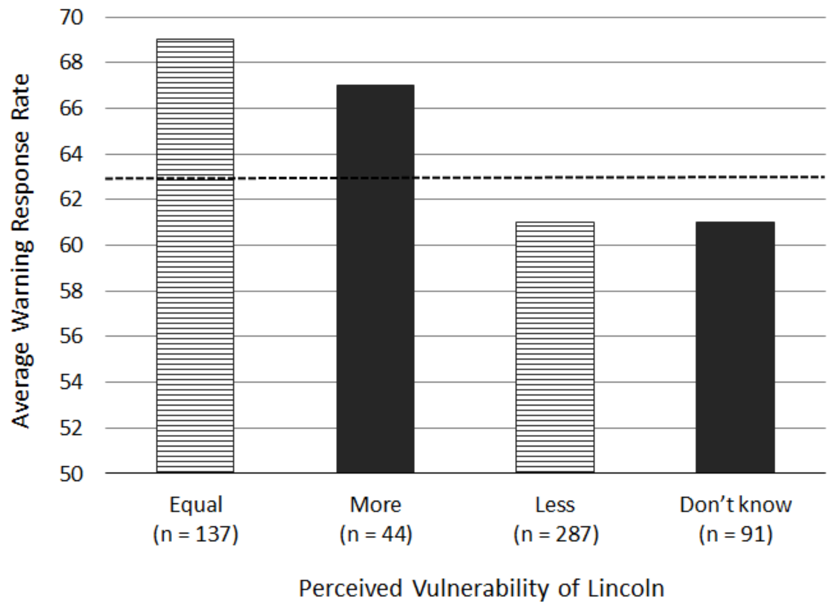


Fig. 4.5 Average tornado warning response rate as a function of perceived tornado vulnerability. Dashed line denotes overall average response rate (63%). Horizontal stripes denote significance at 5 % C.I. with respect to difference in particular group's average compared to rest of sample.

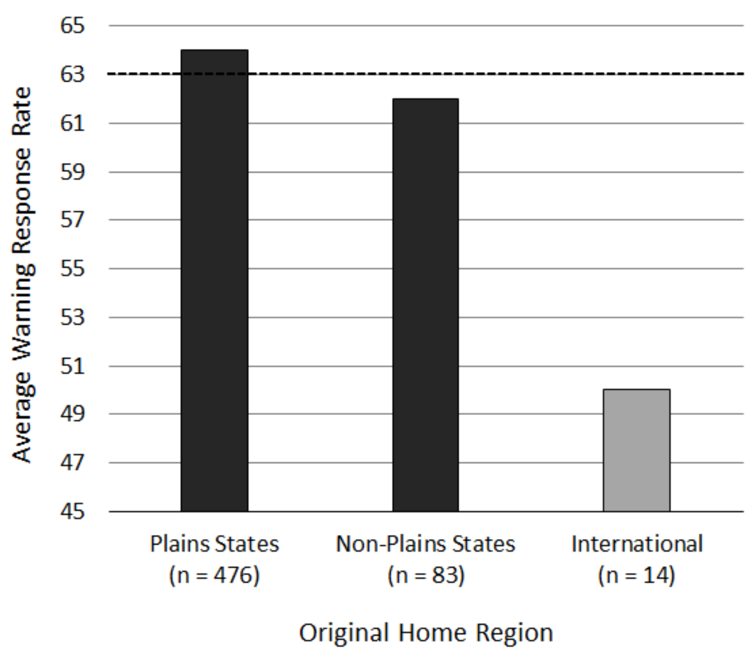


Fig. 4.6 Average tornado warning response rate as a function of original home region. Dashed line denotes overall average response rate (63%). Light gray shading denotes significance at 10 % C.I. with respect to difference in particular group's average compared to rest of sample.

Students who received their knowledge primarily from their parents (Fig. 4.7) reported a significantly higher warning response rate (70%; $p = 0.023$). This shows parents teaching their children to take notice of warnings, but specifically what perceptions of tornadoes are passed down through generations should be addressed in future research. Those reporting school or common knowledge/popular culture as their primary knowledge sources were likely to respond to fewer warnings (59%; $p = 0.0029$ and 38%; $p = 0.058$, respectively). It is hypothesized that while 17 states, representing nearly 94% of the domestic students surveyed, either encourage or require schools to conduct regular tornado drills, these drills may not instill a sense of urgency in students to motivate taking action during real events (Fig. 4.8). Nebraska began mandating drills in public schools in spring 2014. Whether ‘school’ as a knowledge source indicates respondents learned the most about tornadoes during drills or in classroom curricula remains to be confirmed. Common knowledge loosely based on local folklore of tornadoes may perpetuate common myths about their behavior, which may explain the low response rate among students citing it as their primary knowledge source. Finally, students reporting sirens as their primary warning source responded to a significantly higher percentage of warnings (70%; $p = 0.030$) than those using other sources (not shown). When not already aware of severe weather potential, sirens may startle and concern respondents, causing them to seek additional information regarding the threat or shelter.

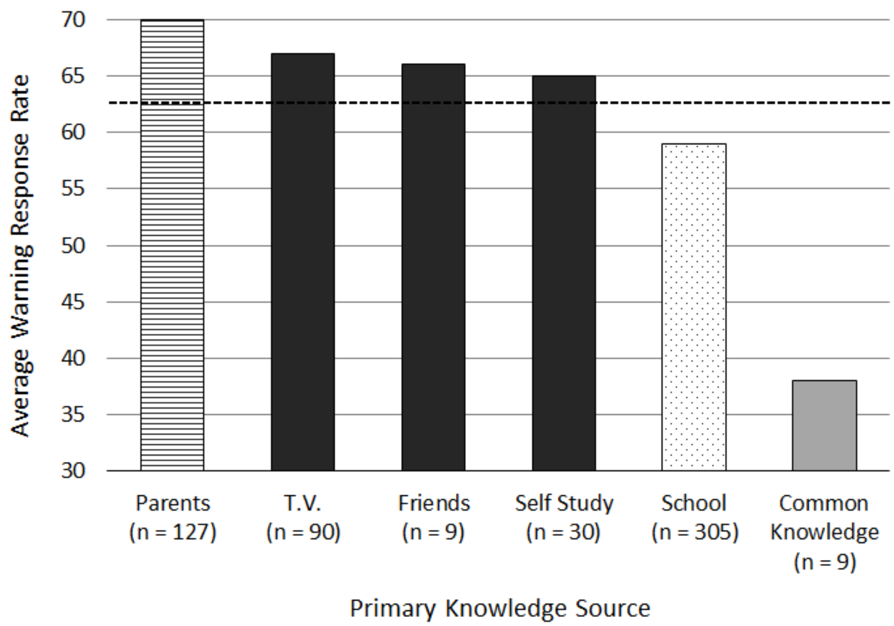


Fig. 4.7 Average tornado warning response rate as a function of self-reported primary tornado knowledge source. Dashed line denotes overall average response rate (63%). Light dotted shading denotes significance at 1% C.I. Horizontal stripes denote significance at 5% C.I. Light gray shading denotes significance at 10% C.I. with respect to difference in particular group's average compared to rest of sample.

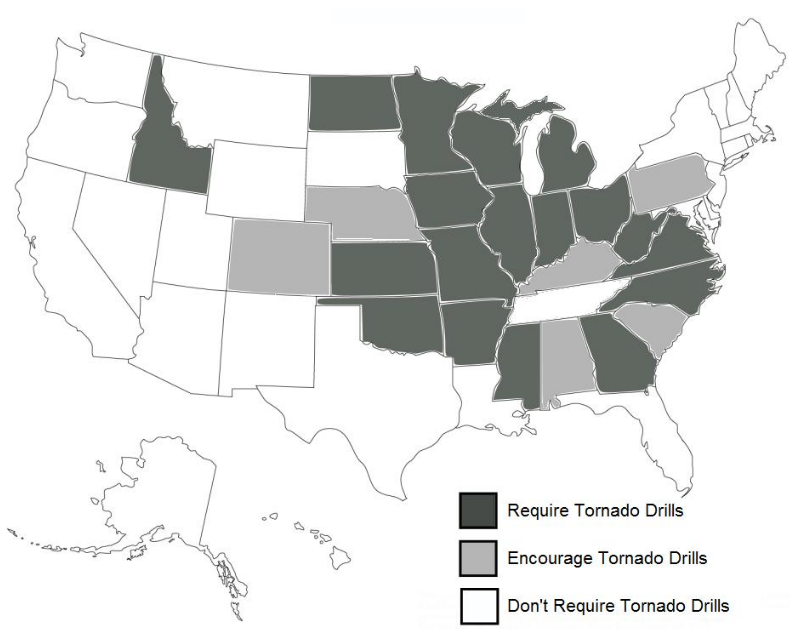


Fig. 4.8 Public school tornado drill policy by state. [Nebraska became a required state in spring 2014, after Survey 1 administration].

Chapter 5. Survey 2 Design

I. Survey Design and Implementation

The first survey left several areas for further investigation. These included determining actual sheltering rate instead of simply response rate, and gaining more detailed responses for specific mobile applications and websites used for warning sources. Gaining a larger sample of international students from which to draw stronger conclusions of perceptions and knowledge was also warranted. Gender, prior tornado experience, and tornado *warning* perceptions (instead of tornado perceptions) were also investigated in the second survey. New questions investigated in this new online survey included:

1. Are variables such as gender, prior experience, and pFAR related to actions taken by students during warnings?
2. How do students interpret radar imagery and tornado warning polygons?
3. Who do students think sound sirens and issue warnings and do these perceptions affect response actions?
4. Which factors most strongly influence warning response actions and perceptions?

Using the initial survey as a foundation, questions in the second survey focused on prior experience, perceived risk in a variety of situations, perceptions of tornadoes and tornado warnings, and safety actions taken. The revised survey was developed according to general guidelines of Dillman et al. (2000). Questions were developed with clear and concise instructions, and were formatted to be easy to answer with accurate and honest responses. Open-ended questions were used sparingly to keep motivation high for

continued participation throughout the survey. Open-ended questions were still used in cases where 'priming' might have been an issue. For instance, in the question regarding warning polygon interpretation, a student's gut reaction was desired without the possible aid of answer choices. Follow-up questions were asked on a few questions that investigated why students chose a particular answer, or from what specific source they received warnings. Choices in multiple-choice lists were randomized to minimize any effects of students picking from the first few options shown. All but two questions were forced-response types, where participants could not proceed with the survey until selecting or providing an answer. The key questions in this survey (Table 5.1) are referenced throughout the text.

Table 5.1: Summary of key questions asked in Survey 2.

Question	Type
What do you usually do first during tornado warnings?	Multiple Choice
In what percentage of cases do you end up taking shelter during a warning?	Interactive Slide Marker
Have you or anyone close to you ever been affected by a tornado?	Yes/No/Unknown
What percentage of tornado warnings do you think have been false alarms?	Interactive Slide Marker
Who do you think issues tornado warnings?	Open Response
Who do you think controls when tornado sirens sound?	Open Response
Tornadoes usually <u>cannot</u> hit cities. Including why specific response was chosen.	True/False Why: Multiple Choice
How likely is the city of Lincoln to be affected by a tornado, compared to a rural area of equal size? Including why specific response was chosen.	More/Equal/Less Why: Multiple Choice
In this basement floor plan, where would be the safest place during a tornado?	Image Selection
(Viewing radar image) How safe would you feel at the yellow star?	Likert Scale
(Viewing radar image) What does the red rectangle mean?	Open Response

Initial survey pre-testing was conducted on eight people, half of whom were of international origin. Two were professional meteorologists, four were meteorology students, and two were non-meteorologists. The 26-item online survey was developed and implemented using Qualtrics® software, which enabled the survey to be tailored by responses from students. This reduced the number of unnecessary questions being asked

which did not apply to them, in hopes of increasing the rate of full survey completion. An email invitation with a direct link to the survey was sent out to a simple random sample of 5000 American and 1665 international undergraduates enrolled at the University of Nebraska – Lincoln. To increase the perceived benefits and importance of participating, respondents were informed in the recruitment email of the value of such a survey. It was stated that information provided by respondents would help researchers know what type of material to teach students about tornadoes and tornado safety actions in the future. Response rate from this initial recruitment email was nine percent (595 students). The response rate for domestic students was deemed adequate, with a second and final reminder email sent solely to the same sample of international students approximately 3 weeks after the initial invitation email. This resulted in an additional 70 responses from international students. The international students were deliberately oversampled to draw statistical relationships between this group and domestic students. After closing the survey, 25 surveys were discarded due to a low percentage of completion, resulting in a total of 640 responses.

II. Statistical Analysis Methods

Emergent categories were used for the coding schemes for open response items. For statistical analysis, primary knowledge and warning sources were classified into larger categories as shown in Tables 5.2 and 5.3 Formal education and safety drills comprised one group. Another included sources related to self-education. Parents were left as a single group, due to size and distinct nature. A final group was comprised of knowledge sources perceived as less reliable than the first three. More traditional warning

sources were categorized together; these were sources that students' parents may have used and passed along to their children, and were mostly auditory. Newer technology was likewise consolidated. Television was not classified with either of the preceding groups, due to being a traditional source, but with a distinct visual element. When consolidating knowledge and warning sources, sizes of resultant groups was also a crucial factor.

Table 5.2: Consolidated categories of primary knowledge sources for each survey. Numbers and percentages are out of total number of primary sources listed by all students.

Group	**Survey 1 100% (n = 602)**	**Survey 2 100% (n = 551)**
Group A	**54% (n = 325)**	**34% (n = 197)**
Elem. School Drills	---	14% (n = 80)
Elem. School Classes	50% (n = 304)	10% (n = 57)
High School Classes		7% (n = 41)
Univ. EAS Classes[c]	4% (n = 21)	3% (n = 19)
Group B	**21% (n = 128)**	**19% (n = 104)**
Parents	21% (n =128)	19% (n = 104)
Group C	**21% (n =128)**	**38% (n = 208)**
Personal Experience	---	12% (n = 68)
Local News	16% (n = 95)	9% (n = 51)
Documentary	---	9% (n = 48)
Self-Edu./Internet[a]	5% (n = 33)	7% (n = 41)
Group D	**3% (n = 21**	**8% (n = 42)**
Popular Culture	<1 % (n = 2)	3% (n = 19)
Friends/Peers	2% (n = 10)	3% (n = 14)
Other[b]	1% (n = 9)	2% (n = 9)

[a] Includes NWS webpage [b] Other sources include common knowledge, public radio, non-parental family members, PBS programming, God, working in 'weather lab,' and listening to others on the bus or in restaurants. [c] Earth and Atmospheric science classes.

Table 5.3: Consolidated categories of primary warning sources for each survey. Numbers and percentages are out of total number of primary sources listed by all students.

Group	Survey 1 100% (n = 608)	Survey 2 100% (n = 572)
Group A	**37% (n = 227)**	**42% (n = 240)**
Sirens	21% (n = 128)	29% (n = 165)
Public radio	13% (n = 78)	5% (n = 28)
Visual Cues	<1% (n = 2)	4% (n = 22)
NOAA Weather Radio	1% (n = 4)	3% (n = 19)
Building intercoms	1% (n = 9)	1% (n = 5)
Face-to-Face	1% (n = 6)	<1% (n = 1)
Group B	**52% (n = 319)**	**24% (n = 140)**
Television	52% (n = 319)	24% (n = 140)
Group C	**10% (n = 62)**	**33% (n = 192)**
Weather App	---	17% (n = 99)
UNL alert	---	8% (n = 48)
Internet	2% (n = 15)	4% (n = 21)
Mobile device/Text	4% (n = 23)	3% (n = 19)
Phone call	4% (n = 24)	1% (n = 5)

As with Survey 1 the WMW rank-sum test was utilized to determine if the differences in the average sheltering rate and pFAR were statistically significant between groups with different home regions, knowledge sources, warning sources, and perceived vulnerability. Dependence among categorical variables was again calculated using the chi-squared statistic. Standardized residuals were utilized to determine which variables were significantly different than otherwise expected. Any significant variables from chi-squared analysis were used in a logistic regression, along with other variables believed a priori to affect safety behaviors and perceptions.

III. Survey 2 Limitations and Assumptions

This survey may have suffered from slight coverage error since emails were only sent to email addresses available to the Office of the University Registrar. Some of these email addresses may have no longer been in use by those particular students. The under-coverage error from students not owning personal computers or having internet access was thought to be mitigated by the availability of computers with internet access on campus. Non-response error, which is caused by non-respondents being significantly different than respondents in some way, was assumed to be small. The drop-out rate was not substantially high, as over 86% (n = 554) of participants completed the last question. Measurement error, introduced by participants not interpreting questions in the way intended, may have introduced bias in the responses to a few questions. This measurement error could have possibly been reduced through adding more non-meteorologists to the pilot study and by the author being present in the room to listen to and document respondents' thought processes while progressing through the survey. Finally, there was inherent subjectivity when categorizing the open-response items.

Chapter 6: Survey 2 Results and Discussion

I. Survey 2 Demographics

A total of 640 surveys were analyzed, with 79% (n = 507) being American and 21% (n = 133) being international (Fig 6.1). International students accounted for nearly eight times as many students in the new survey as the survey described in Chapter 4. The distribution of residence length was broader in this dataset as well. Over 38% resided in Nebraska for less than 5 years, compared to the first surveys, in which this group only accounted for 20%. Slightly over three-quarters of domestic students (n = 386) were originally from Nebraska, with roughly one-quarter (n = 121) originating in other states. In total, 29 countries and 26 states were represented. As in Silver and Andrey (2014) female students were unintentionally overrepresented accounting for 62% (n = 399) of those who completed the survey but for just under 47% of the total undergraduate population of the university at this time. Fifty-two percent (n = 69) of international students were in residence for less than one year. Among students in the state for less than one year, 59% (n = 69) were international, and 41% (n = 48) were domestic. Items 1 through 4 in Appendix B illustrate these demographic questions.

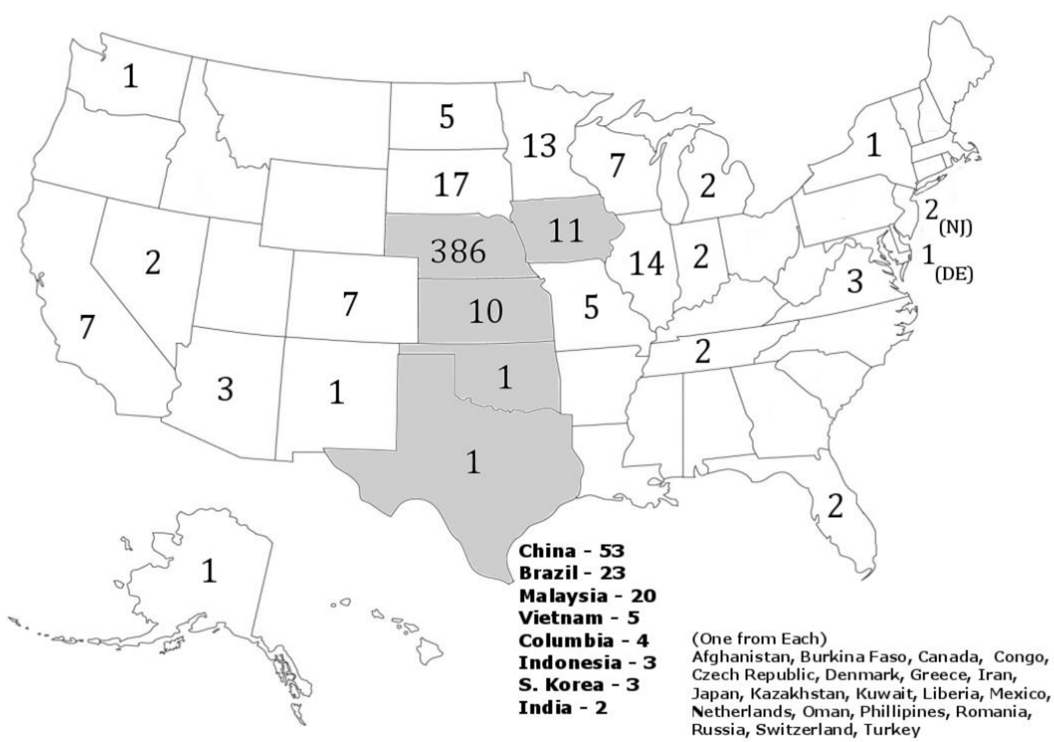


Fig. 6.1 Home state and country of students within Survey 2 sample.

II. Knowledge and Warning Sources

Participants were explicitly asked about their one primary knowledge source and any secondary sources in two separate questions (multiple choice; Items 5 and 6; Appendix B). The most popular source for domestic students was parents/guardians with 20% (n = 102), followed by elementary school drills (16%; n = 79; Fig. 6.2). University classes, friends, peers, and popular culture were rarely chosen as knowledge sources. International students were likely to learn about tornadoes from high school classes (21%; n = 10), or their friends and peers (19%; n = 9). Self-education was also popular. This shows a willingness of international students to learn more, as well as a need for education at the university level when students arrive to campus. Sources such as parents, elementary school drills, and experience were rarely chosen by international students.

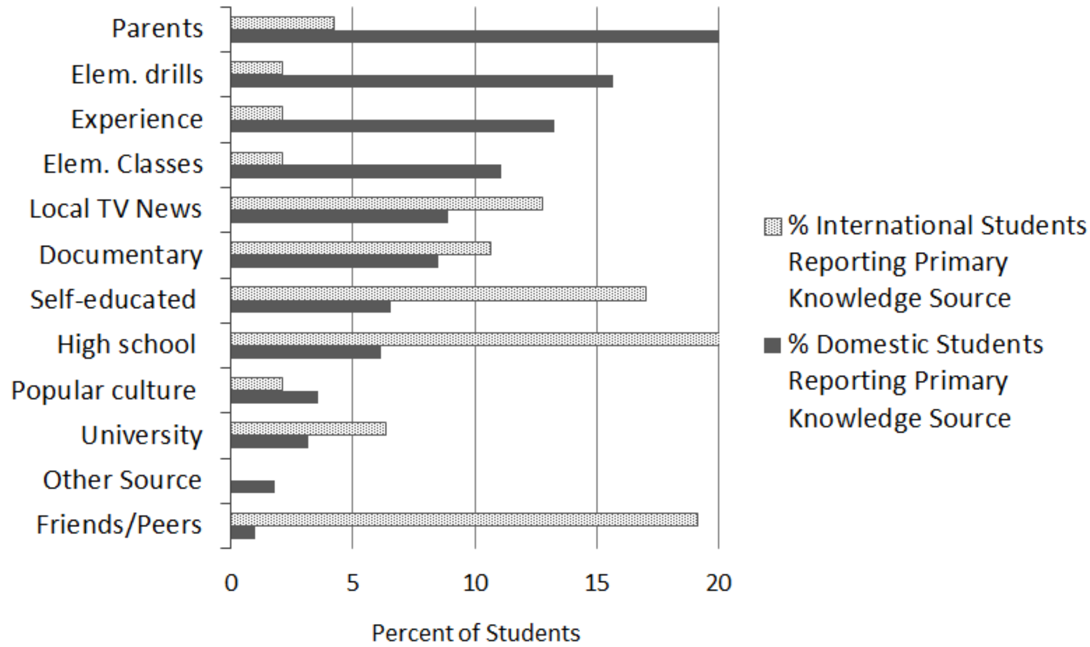


Fig. 6.2 Primary knowledge sources of domestic and international students.

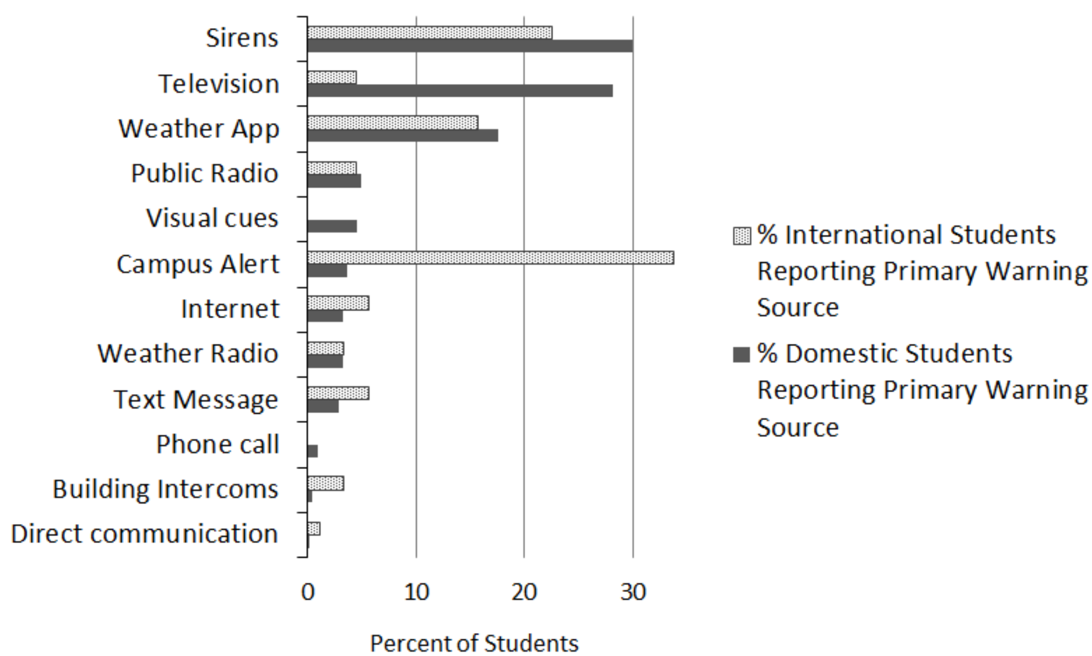


Fig. 6.3 Primary warning sources of domestic and international students.

These types of sources are likely to be less reliable or non-existent compared to areas where severe weather is common, such as the central Plains region of the U.S. The most popular secondary source for all students was local news at 63% (n = 350), illustrating again the utility in learning how students are interpreting warning messages presented to them through the television. Students, on average, reported learning from five or six different sources. International students were asked if they had learned about tornadoes before or shortly after arriving in the United States (Item 7; Appendix B), and 41% (n = 54) replied gaining such knowledge, and 59% (n = 79) reported not learning anything regarding tornadoes.

All primary and secondary sources for tornado warnings were investigated in Items 8 and 9; Appendix B. When asked about the primary method by which they receive tornado warnings, sirens (30%, n = 145) and television (28%, n = 136) were the most popular among domestic students (Fig. 6.3). Among international students, UNL alert was the most popular with 34% (n = 30). This shows a considerable amount of international students voluntarily signing up for the automated emergency communication system. One international student reported getting their weather *information* from UNL alert, which is designed to notify students of warnings only, not forecasts or other general weather information. Weather applications on mobile devices was the third most popular warning source for both groups of students (U.S. 18%, n = 85; International 16%, n = 14). Text messages (all sources) and the internet were less popular with domestic students, though they were fairly popular with international ones. The internet seemed to be favored as a secondary source, as 45% (n = 260) of all students

combined reported it when asked if there were any other sources they used. The average number of total warning sources per student was about six. Students reporting any warning source to be television, internet, text message, or weather applications on mobile devices were asked what specific source they were using (Fig. 6.4). These specific warning sources were presented as multiple choice options to aid in recall. Local news was the most popular television source (89%, n = 366), followed by the Weather Channel (33%, n = 137). The Weather Channel’s website was the most popular internet source (57%, n = 158), followed by local news websites, and the NWS. Among text-message users, most reported receiving warnings from the NWS (69%, n = 145), followed by family and friends. This is encouraging, as the NWS emergency alert messages rely on the user’s GPS location and notify the user of any watches or warnings in effect for that specific area. For mobile weather applications on smartphones and/or tablets, the most popular source was again the Weather Channel (68%, n = 225) which was used over four times as often as any other mobile application source.

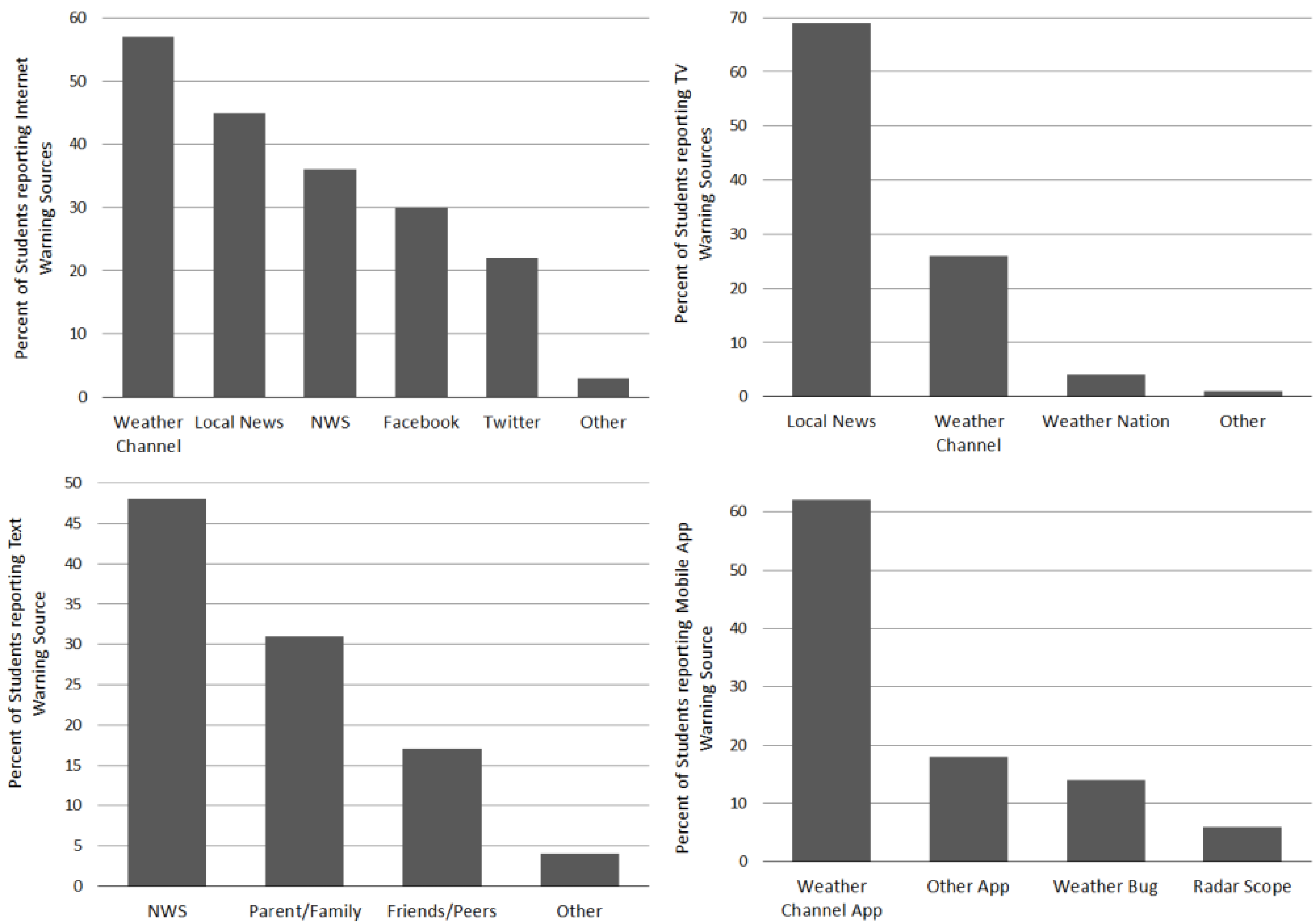


Fig. 6.4. Clockwise from top left: Warning sources for internet, TV, mobile applications, and mobile SMS.

III. Sources of Weather Information and Forecasts

Students were asked if they had ever been in a tornado warning (Item 10; Appendix B), and 91% (n = 579) stated that they had. A small percentage of students (roughly 9%), reported never being under a tornado warning (n = 50), or not knowing (n = 5). Seventy-eight percent (n = 39) of those never warned were international, and 22% (n = 11) were domestic students. Of these domestic students, five were from Nebraska, three originated from California, and one each came from New Mexico, Illinois, and Virginia. Instead of being asked about tornado warning sources, this subgroup was asked where they obtain their general weather information (Item 11; multiple choice; Appendix B). Mobile weather applications and the internet (67%, n = 36; and 22%, n = 12, respectively) were the most popular sources. Other sources such as television and public radio were seldom used. The prevalent use of mobile weather applications for general weather information is in sharp contrast to other surveys for weather information sources used by the general public. Between 44% and 70% of the general public receives weather information from local news (Harris 2007, Demuth et al. 2011). The contrast between those studies and these findings demonstrates the difference between sources of weather information between international and domestic populations, as well as the increasing use of technology for weather information and forecasts in recent years.

Comparison of Warning Sources to General Public

Students in this study received their warnings primarily from sirens first, and television second, the same two sources as the general public, but in reversed order. Many more participants used mobile warning applications than the general population. The most recent comprehensive weather information source data are from Demuth et al. (2011). Given the rapid rate at which new technology is being developed, an updated study investigating usage of weather applications on mobile devices for the general public would be beneficial. This study shows younger generations using newer technology such as the internet, mobile application, and texts as tornado warning sources from 33 to 45% of the time. These types of sources were listed as a *primary* source by 17% of students compared to the six percent of students using it as a primary source in the first survey. This may indicate newer technology is gaining popularity as a primary warning source instead of a confirmatory source, or it may simply reflect the different nature of the questions (e.g., open-response format in the initial surveys, and multiple choice option in the second set.)

IV. Experience, Preparedness, and Intended Safety Actions

Prior Experience

Students were asked if they or anyone close to them had ever been in a tornado, or had part of their home damaged by a confirmed tornado. Half the respondents (n = 300) reported direct or indirect experience, and the other half (n = 298) reported no prior experience or were unsure if they had relatives that were impacted (Item 12; Appendix B). Those with prior experience were next asked how this affected their actions

during subsequent tornado warnings. About 10% (n = 28) did not provide usable responses. Forty-six percent (n = 139) indicated the exposure compelled more awareness and more cautionary actions during future warnings. Some examples of comments were *"I take shelter more often now," "I am less likely to stay outside once the sirens start,"* and *"I take warnings more seriously now after seeing the damage."* Alternatively, 44% (n = 132) reported the experience not affecting later actions. However, thirteen of these students whose subsequent actions were not affected reported taking shelter prior to ever having the experience. Since the proportion of those being compelled to shelter was not significantly higher than those for whom the experience made no difference, this data does not strongly support prior experience heavily influencing future perceptions or actions, similar to Nagele and Trainor (2012).

Determining consistency between reported actions and self-reported impact of having prior experience was of interest. The students who reported prior experience making them more cautious or aware were indeed more likely to initially take shelter during most warnings (41% took shelter, $p = 0.004$) compared with any other action, and sheltered during a higher proportion of warnings overall (59% average shelter rate, $p = 0.001$), than those who reported the experience not having any lasting effect on them (21% usually took shelter, with 42% average shelter rate). Insightful comments from people who were not affected are shown below:

"I still get scared but only take cover if really needed."

"I watch the clouds always and know what to look for."

"If it is going to hit us I will take shelter, otherwise I will go outside and watch for it until I know for a fact that it will hit my place."

"It really hasn't. I grew up in Nebraska, so I can tell when a tornado is actually coming, and when it's just a warning that my area might be hit."

These responses all showed a tendency to use personal knowledge to decide when there might 'truly' be danger, and show the need for personalization of the risk. These types of responses are concerning; how can they know for certain if they are genuinely in danger? None of these particular students could accurately identify the warning polygon when asked. They instead responded with answers such as: '*area for potential hazardous weather*,' or '*path of the storm*,' and a couple even felt '*relatively safe or neutral*' when shown the supercell image. This suggests this group of students may not understand as much as they think they do.

Safety Plans

In the second survey, a safety plan was further clarified to mean 'having a safe place to seek shelter, and knowing how to get there.' Students were asked if they had such a plan they could use immediately in case of a tornado (Item 13; Appendix B). As in the first survey, a student's home or current residence was the most popular location for having a safety plan. Compared with the first survey the portion of students reporting having a plan at home and school rose about 10% each, with 88% (n = 519) of students having plans at home, followed by school at 78% (n = 549). Student's work-places were the least popular locations for having safety plans (76%, n = 315). Yet, this was still higher than the percentage of nursing students reported by Schmidt et al. (2011), where

less than 43% of students had disaster plans. Some students reported home not applying to their situation, and it is unknown if they were referring to their original home location, or their place of residence in Lincoln. There were also a few students who indicated presence of a safety plan at school was not applicable to them. These results show the limitations of some of the survey questions not being interpreted the way intended by the author.

Certain student attributes were shown to affect the presence of safety plans. Students residing in Nebraska for less than 1 year ($p = 0.019$), those believing cities to be invulnerable ($p = 0.001$), and those who perceived neutral safety near a tornado-warned supercell ($p = 0.060$) were all statistically *less likely* to have safety plans in place while at work. There was also an association between pFARs and the presence of safety plans at work. Those who had a plan had an average pFAR of 42%, those without a plan had an average pFAR of 51% ($p = 0.011$). This association could reflect the fact that some businesses do not have strict emergency policies in place for severe weather, or it could show students with higher pFARs may not feel concerned enough to learn their company's safety policies, if any are present.

A few factors were associated with the presence of safety plans at home. International students ($p = 0.0002$), Non-Plains students ($p = 0.003$), and those lacking prior experience ($p = 0.0014$) were all statistically *less likely* to have safety plans in place at home. This implies students coming from regions where tornadoes are less prevalent may not know what a safety plan should be, or may simply not think about it very often. The only variable seen to positively influence having a safety plan at home was specific

knowledge sources. Those students learning from their parents were *more likely* to have a safety plan at home compared to those gaining their knowledge elsewhere ($p = 0.005$), as found in the first survey. This suggests if a student's home has an active learning and preparation environment supported by parents, the student will be more likely to have a safety plan. One student who reported her parents as a knowledge source also said:

> *"I learned from a young age [to] always know where your shoes are when the storm clears you won't be in danger of stepping on broken glass or other debris barefoot."*

As in the first surveys, few factors were predictive of students having plans at school. The only factor shown to affect having a plan at school was the education of international students. Those taught information about tornadoes before or shortly after arriving to the U.S. were *more likely* to have plans at school than those who were not taught ($p = 0.012$). This shows the value of educating those less familiar with tornado risks.

Intended Safety Actions

After determining safety plan prevalence, the next logical question is where students are choosing to shelter. An open-response item asked students where they should go to be safe in a tornado (Item 14; Appendix B). Many students generically replied with 'the basement' with little further detail. However, 42% (n = 251) specifically mentioned avoiding windows, and 12% (n = 71) elaborated by suggesting areas such as bathrooms, underneath staircases, and interior closets. Four percent (n = 24) reported less-safe options, e.g., in the lower central hallway or stairwell of an apartment complex, which may be the best option available to them depending on the building they live in. Five

percent (n = 30) of students provided unsafe responses or indicated not knowing where to go. International students were significantly less likely to know appropriate locations to shelter during a tornado. This group was much more likely to offer generic answers such as '*school*', '*dorm*', '*apartment*,' or explicitly state that they did not know where to go (p = 0.001). One international student even responded with:

> *"Nobody taught me, so how can I know? I've never learned about where to go from UNL."*

In all dormitories on campus, there are bulletins posted which indicate safe areas and information about tornadoes. This teaching strategy is passive, however, and requires international students to take a proactive role in their severe-weather education. Those in Nebraska for less than one year were more likely to provide incorrect places to shelter, and those residing in the state for 5 years or more were less likely to provide these erroneous responses (p = 0.001 for both). Those here for less than one year consisted of 59% international and 41% domestic students, and there were no significant differences in the proportion of these two groups who supplied safe versus unsafe locations to shelter.

In addition to an open-response item, students were given a more specific question regarding possible sheltering locations within a basement (Item 15; Appendix B). Fig. 6.5 shows a simple basement floor plan that students could choose rooms in which to shelter. One source of possible confusion during survey-testing was that the image represented a cross section of multiple floors instead of a plan-view of the single bottom floor. This was further clarified in the question when the survey was officially

distributed through email invitation. The question text presented to students specifically said the view was looking down from above. The floor plan was oriented so north was toward the top of the page. The regions available for selection were not visible until hovered over with the mouse. Students were instructed to choose between one and three locations where they would decide to shelter to be the safest during a tornado. The two most popular locations were underneath the stairs and the interior bathroom, as both options had just over 57% of students choosing them as one place they would shelter. These were followed by the interior closet and exterior bathroom, at 44% and 31%, respectively. The larger windowed rooms and four closets around the perimeter were less frequently chosen, although 47% of students chose at least one of these seven relatively unsafe locations. This shows although many students may choose safe locations, they may not be differentiating between relatively safe and unsafe rooms, since they would choose one of both. Approximately 43% (n = 237) of students chose only from the three correct interior locations, no matter how many they selected. There were 80 participants who chose at least one corner. The 'southwest corner' myth made prevalent by 1950's era newsreels held true in this study, as 56% (n = 45) chose that corner compared to 10% (n = 8) choosing the northeast corner. The northwest and southeast corners were chosen about 39% and 35% of the time, respectively. There were slight inconsistencies in students' responses; there were 21 students who specifically said '*away from windows*' but then at least one of their chosen locations had windows.

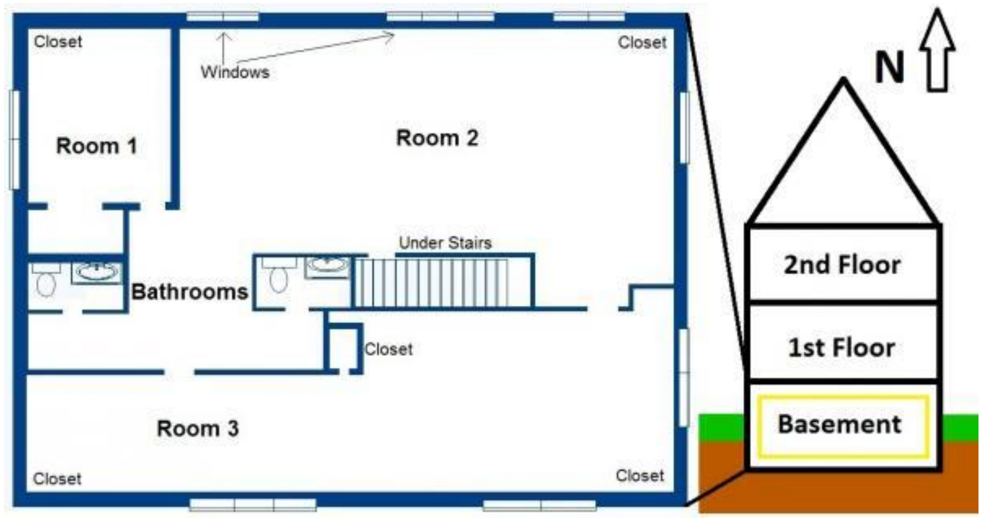


Fig. 6.5 Basement floor plan shown to students. Clickable regions were not visible unless hovered over with a cursor.

Safe locations were determined from NWS guidelines to be small, windowless, interior rooms (NWS 2015b). Thus, unsafe locations were defined to be the three large open rooms, the four corner closets, and the exterior bathroom. Accounting for knowledge sources and demographics, international students were 2.6 times more likely to choose ‘unsafe’ locations than domestic students ($p = 0.023$). This difference is shown by comparing the top and bottom panels of Fig. 6.6. The color scale on the right shows the number of students picking each room. In these figures, black with a color saturation of zero, represents zero students. The brightest and most saturated shade of red, represent the rooms chosen by the highest number of students. This was based on the number of clicks per room, and participants could pick between one and three locations, hence the sum for all rooms is greater than the number of students. Controlling for gender and residence length, international students who were not taught any information were 4.4 times more likely to choose an unsafe location compared to those who were taught

(p = 0.006). This reiterates the value of severe weather education for those new to tornado-prone areas. Controlling for other demographic variables, female students were found to be 1.6 times more likely to choose an unsafe location (p = 0.017). It is intuitive that domestic students would choose safer sheltering locations; their exposure to tornado-safety practices during childhood is most likely higher. However, the reasoning for females being more likely to choose unsafe locations is unclear.

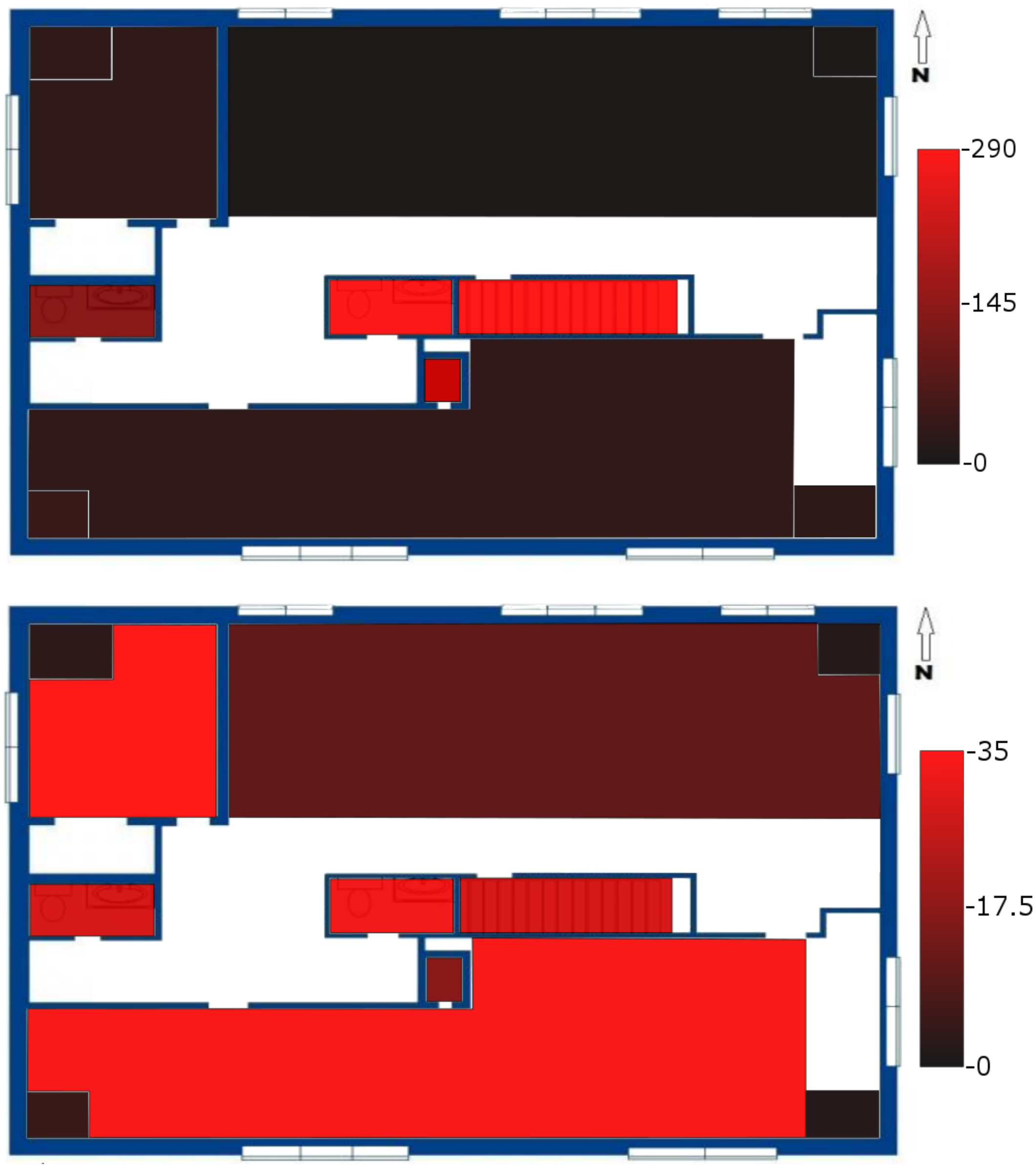


Fig. 6.6 Number of (Top) domestic students, and (Bottom) international students choosing each room. Scale on right represents the number of students choosing each room, with black indicating little to no students and fully saturated bright red indicating the largest number of students.

V. Perceptions of Tornadoes and Tornado Warnings

Perception of City Vulnerability

The second survey explicitly asked if tornadoes could hit cities, and 93% (n = 542) of students correctly believed tornadoes could affect cities (Item 16; Appendix B). Slightly less than seven percent (n = 39) believed cities to be safe. When asked why they believed tornadoes could hit cities, nearly 94% (n = 506) chose either the option of ‘tornadoes can occur anywhere’ or ‘the probability of the city getting hit is the same as any other area of the same size in the same region.’ Others cited prior experience with severe weather or knowledge of prior tornadoes occurring in cities nation-wide. The most popular reasoning for cities (in general) being immune to tornadoes was the belief that buildings would disrupt the wind (46%, n = 18), or that tornadoes usually move around cities (31%, n = 12). The options to explain why cities were vulnerable (or not vulnerable) were presented in a multiple choice fashion, and this may lead to very different responses than what would have been gained through free-response.

Respondents were also asked to judge the tornado vulnerability of Lincoln compared to nearby rural land of equal size (Item 17; Appendix B). Sixty-four percent (n = 370) of students correctly believed the city was equally vulnerable, and 34% (n = 198) responded with less vulnerable. Only two percent (n = 11) felt the city was more vulnerable than the surrounding land. Through a multiple choice question students were asked to clarify why they believed Lincoln to be equally, more, or less at risk than the surrounding area. The majority of the students who thought Lincoln is equally vulnerable chose the option of there being no difference in urban versus rural area

vulnerability. Twenty-three percent (n = 84) of the students used prior examples of other cities being affected by tornadoes. Out of students who presumed Lincoln to be less vulnerable, the 'bowl effect' myth was the most popular reasoning, as found by Van Den Broeke and Arthurs (2015). Another popular belief was that tornadoes and severe weather actively avoid cities due to heat or other types of emissions. Interestingly over 11% (n = 62) of the students who said cities in general were vulnerable to tornadoes also thought Lincoln was less vulnerable due to 'tornadoes usually occurring in rural areas instead of cities.' This shows inconsistency in responses, and again shows the power of local optimism bias. Some additional interesting answers used to explain why Lincoln is less vulnerable included:

> *"Besides the geographical features of the area, cities also maintain a 'weather shield' due to the heat-capturing structures found uniquely within a city which forces most large weather events to move around a city rather than through it."*

> *"There is research to suggest that the large electromagnetic emissions of larger cities deflect large storms. Ever notice how they head straight for us, then move around, split around, or dissipate before hitting town?"*

> *"We get tornadoes that pass near Lincoln once in a while, but for some reason it always seems to divert. I don't know what the scientific reason for this is, but they tend to avoid big cities. But I wouldn't say they have a smaller chance to hit them."*

This prevalent belief that cities are not affected by tornadoes for various reasons had been seen in prior work as well, for both university students (Van Den Broeke and Arthurs 2015) and the general population (Donner et al. 2012, Klockow et al. 2014). Some believed that cities, while not immune, are still less vulnerable than surrounding rural

land. Through free response items, Van Den Broeke and Arthurs (2015) showed an extensive list of factors cited by students as to why Lincoln specifically should be less affected. These reasons included Lincoln being at a locally lower elevation, having few tornadoes historically, too many tall buildings, or that tornadoes are more likely to affect rural areas, among other reasons. International students (p = 0.001), those who thought warnings were issued by non-meteorologists (p = 0.020), and those gaining their tornado related knowledge primarily from elementary classes (p = 0.027) were all more likely to perceive cities as *less vulnerable* to tornadoes. Accounting for home origin, gender, length of residence, and pFAR, those students lacking any prior experience were 1.5 times more likely to believe Lincoln was *less vulnerable* to tornadoes (p = 0.055).

Perceptions of Warning Polygons on Radar Images

Perceptions of tornado warning polygons were hypothesized to have an effect on actions taken by students during warnings. Students were presented the image shown in Fig. 6.7 and were asked to interpret the meaning of the 'red rectangle' which indicated the tornado warning polygon (Item 18; Appendix B). The largest group of students (41%, n = 222) had generic responses such as *'danger zone,' 'high impact area,'* or the *'width of the storm path'*. This group showed that they knew the polygon indicated something related to severe weather that would be cause for concern, but did not mention the word tornado in their explanation. The second most popular response (25%, n = 134) was comprised of ideas similar to *'Path of the tornado,'* or *'area that may be affected by a tornado,'* but did not mention the word warning. Slightly less than 17% (n = 91) specifically said 'tornado warning.' Finally, about 17% (n = 96) students either gave

completely incorrect answers, or did not know. Examples included: *'The region the storm is staying in,'* or even *'It might be the safe area, Safe distance from the tornado. I'm not sure.'* These responses seemed to indicate a dichotomous nature regarding safety at the threshold of the polygon, akin to what was found by Ash et al. (2014), representing danger inside the polygon, but safety outside it. Twelve students incorrectly identified the polygon as a tornado watch.

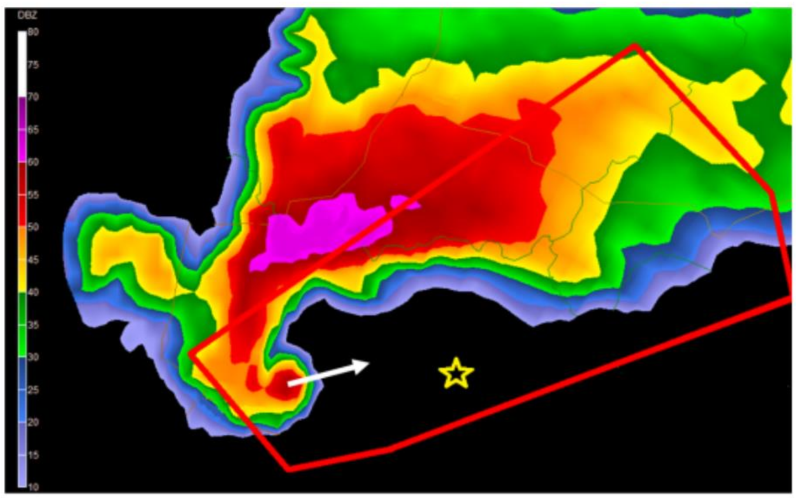


Fig. 6.7 Radar reflectivity image of generic supercell, with corresponding tornado warning polygon. The yellow star indicates location of interest, and white arrow indicates direction of motion.

A few responses indicated students might only be learning vague ideas regarding radar images from television, as shown:

> *"I really don't know. I never understand what that means on the weather channel, only that the red and pink areas are the most dangerous."*
>
> *"Red can mean heavy rain, thunderstorms, hail, and tornadoes."*

Some responses demonstrated students actively trying to recall information taught to them. Seven expressed concern related to the hook echo, with one student saying:

> *"A tornado has a potential to form there, it has something to do with the way that the storm shape is curling at the bottom left-hand side."*

Responses ranging from fairly accurate to completely incorrect illustrate the need for further education of radar image interpretation and the appearance of tornado-warned areas from a variety of sources.

For analysis purposes, responses were categorized into two broad groups. The first group was denoted 'relatively correct' and was comprised of students correctly saying 'tornado warning' or mentioning the word tornado. The second group encompassed inaccurate answers such as '*where the storm will hit*,' and '*dangerous zone*.' No factors which significantly influenced polygon interpretation in this broadest sense were found. However, international students (p = 0.001), those lacking prior experience (p = 0.010), and those who were in residence less than one year (p = 0.002) were all *less likely* to correctly identify the polygon as a 'tornado warning.'

Perceived Safety near a Supercell

To assess perceptions of risk associated with radar imagery, students were instructed to assume the yellow star in Fig. 6.7 was their location, with the white arrow showing the motion of this hypothetical 'strong storm.' A five-point Likert scale ranging from complete danger to complete safety was presented (Item 19; Appendix B). After being instructed to choose how safe they would feel at the star, 81% (n = 448) reported feeling some degree of danger, and 19% (n = 106) felt either safe to some degree, or felt

neutrally about their safety (Table 6.1). No options were given for the students to indicate they did not know how they felt, and one option needed to be selected to proceed with the survey. Therefore, it was assumed that some students who selected 'neutral' simply did not know, or did not feel strongly either way. By not having a strong opinion, if placed in a real situation, these students may put themselves at risk. This group was thus assigned to the same category as those who felt some degree of safety. Even though the arrow in the image may give the impression the hook echo may travel just to the north of the star, this location is still within the boundaries of the warning polygon. It was of interest to determine what factors influenced perceived safety level near the supercell.

Table 6.1 Perceived safety near a supercell located on a radar image.

Perceived Safety Near Tornado Warning Polygon in a Radar Image		
Category	**n**	**% of total**
In complete danger	161	29
Somewhat unsafe	287	52
Neutral	36	7
Somewhat safe	62	11
Completely safe	8	1

Chi-square analysis of individual variables shows international students ($p = 0.0058$), and those from Non-Plains states ($p = 0.025$) being less likely to perceive themselves as safe. This may show domestic non-Plains students still recognize the

danger with the supercell even if they grew up in a place without many of them. There was also a relationship between residence length and perceived safety. Those residing in Nebraska for 5 years or more were more likely to view themselves as safe ($p = 0.001$) than those who were not here as long. This suggests the more time one spends in tornado-prone regions, the more accustomed they grow to severe weather, and will possibly develop complacency during warnings as was shown by Paul et al. (2014).

The significant variables from chi-square analysis were used in a logistic regression to determine which variables influenced perceived safety the most, while removing any effects of possible confounding variables. Variables thought a priori to affect safety perception, such as gender, experience, knowledge source, and warning polygon interpretation were also included in the model. The only variable found to influence perceived safety was accuracy in warning polygon interpretation. Those students who did not associate the word ‘tornado’ with the warning polygon were nearly twice as likely to report feeling some degree of safety near the supercell ($p = 0.018$). This shows how incorrect knowledge of a hazard may lead to incorrect risk perception near that hazard. Students may be frequently exposed to warning polygons overlaid on a radar images on television or the internet, hence it is crucial to know how these images are being interpreted. One variable that was expected to influence perceived safety regarding radar images was prior experience, but this variable had the least influence ($p = 0.826$). This may simply indicate that during prior events students were not watching radar, or that prior experience does not equate to increased knowledge of radar images.

Perceived False Alarm Rate

Students were presented an interactive movable percentage scale ranging from 0 to 100, with instructions to slide the marker to represent the percent of tornado warnings they felt resulted in false alarms (Item 20; Appendix B). The pFAR was obtained from 581 students. As shown in Fig. 6.8, the average student pFAR was highly variable with an average of 45% and a standard deviation of 27%. This was similar to Ripberger et al. (2015) who found an average subjective pFAR of 51% with a standard deviation of 32%. Both studies show the subjective pFAR to be below the national mean of 73% (Ripberger et al. 2015). Approximately one-quarter (n = 137) of students reported values within 10 percentage points of the national value. Few students (six percent, n = 33) had a pFAR at or above 90%, indicating relatively few students will initially dismiss nearly every warning.

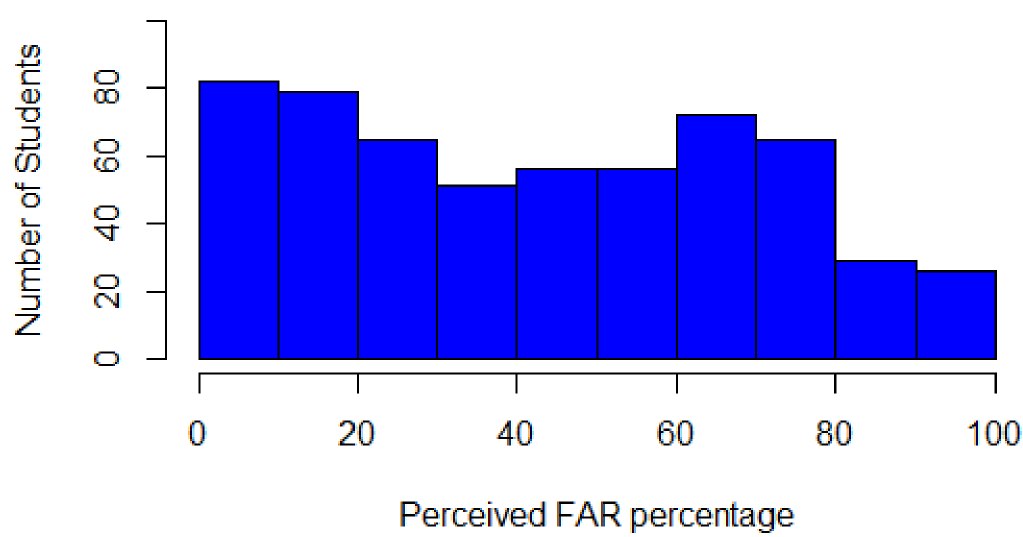


Fig. 6.8 Percentage of perceived false alarm rate among students.

Utilizing chi-square analysis, higher average pFARs were seen in those who believed cities ($p = 0.026$) and Lincoln itself ($p = 0.035$) were not equally vulnerable to tornadoes. Higher average pFARs were also seen in students residing in Nebraska less than one year ($p = 0.005$). It was investigated whether country of origin would be a confounding variable for students here less than one year. No significant differences in average pFAR between international students and domestic students were found between these groups.

The significant variables from the chi-squared analysis as well as other student demographics were next used in a linear regression model. International students living in Nebraska longer than one year were seen to have a decreased pFAR by over 22% ($p = 0.002$) compared to those here less than one year, possibly showing more exposure to severe weather and/or educational materials may reduce perceived false alarms. Those who obtained their tornado-related knowledge from Group D (friends, peers, common knowledge, or popular culture) had > 11% increase in pFAR when compared to formal education through school ($p = 0.036$). This may indicate students gaining incorrect perceptions from their classmates and friends. This is shown by a quote from a student who had prior experience with a tornado, then moved from a rural area to the city of Lincoln:

> *"It made me take them a lot [more] seriously when I lived out in the country, as the back half of our property took a lot of damage. However, living in Lincoln, I always hear that tornadoes 'never hit the city,' so I've begun to take it a lot less seriously."*

This student is a clear example of having a correct perception of risk changed to complacency as a result of learning local myths from others. Yet other students were seen to question this local myth, for example:

> *"I wonder if it is true that Lincoln is in a natural depression that makes tornado touch downs less likely."*

Statements such as these indicate local mythology having a significant impact on shaping and/or changing perceptions of tornadoes and tornado-risk as was found by Klockow et al. (2014) and Paul et al. (2014).

Perceptions of Who Issues Warnings and Controls Sirens

Students were asked who they thought issues tornado warnings and controls sirens (Free response, Items 21 and 22; Appendix B). To the author's knowledge, this has never before been investigated in the general population or in samples of university students. Five hundred forty-eight students provided a response for who issues warnings. Out of these, nearly half (48%, n = 264) correctly and explicitly stated '*National Weather Service*.' An additional 26% (n = 143) responded generically with '*meteorologists*,' '*official weather experts*,' or '*storm chasers*.' Sixteen percent (n = 90) of students responded with answers such as '*police*,' '*fire department*,' '*local city*,' or some form of governing official. Nine percent (n = 51) of students reported not knowing. Data regarding the entity responsible for sounding sirens was collected from 561 students. Nearly 52% (n = 291) reported local government, police, fire department, or some type of official local to the city. This is generally correct, as meteorologists issuing warnings have no direct control over the sounding of sirens. Twenty-six percent (n = 147) of

students presumed sirens were sounded by the National Weather Service or other meteorologists. Twenty-two percent (n = 123) responded with some generic person or agency, or did not know the answer.

Using the WMW test, mean pFARs and shelter rates were related to perceptions of who issues warnings and sounds sirens. Those correctly believing the NWS issues warnings perceived a lower average pFAR than those who believed otherwise (41% and 47%, respectively; p = 0.010). If the students view the source of warnings as credible (e.g., the NWS), or are more knowledgeable regarding warnings in general, they may have the perception of fewer false alarms. Those who correctly think some form of local government or the city is responsible for sounding sirens respond to fewer warnings (48% vs 55%) (p = 0.036). This may be due to students realizing the sirens are not being sounded by meteorologists, hence less cause for concern. Those who said 'some other generic source' was responsible for sounding the sirens responded to a higher proportion of warnings (67% vs 50%, p = 0.004). This group included a wide variety of responses. These included everything else besides meteorologists or local government (e.g., '*friends*', '*staff*', '*volunteers*', '*the guy on duty*', '*local news*', '*the school*', or an '*automated system*'). A similar trend was found with the group that simply said '*I don't know*' who sounds sirens. They responded to, on average, 59% of warnings compared to 50% for others (p = 0.054). Many of these relationships though may confounded by other variables, since these results were not evident in the regression analysis.

VI. Response during Warnings

Trigger to Motivate Response

Students were asked what would cause them to seek shelter once aware of a tornado warning. They were able to select from a multiple choice list, or supply their own typed response (Item 23; Appendix B). Students gave between one and nine triggers. The most popular trigger was 'Seeing or hearing the tornado' as 62% (n = 375) of the students chose this option. This was followed by hearing sirens and being responsible for other people's safety (55%, n = 334 and 52%, n = 319, respectively). The decision to shelter seemed to be dependent on the presence, behavior, and interactions with other people, with 74% (n = 452) of students selecting at least one triggering mechanism involving human interaction. There were 145 students who reported all three socially-dependent triggers available. This question was flawed because it did not ask what students' primary triggers would be. Those that listed more than one could not indicate which would be the most important.

Factors Influencing Actions Taken

Only inquiring about the last warning experienced in the first survey may have biased results for actions taken during warnings. It is reasonable to assume each tornado warning may be spatially, temporally, and socially unique. Only investigating one event may not have shown what students do overall, thus in the second survey participants were asked what they *usually did* when first aware of any tornado warning (Item 24; Appendix B). The most popular response was confirming the warning by numerous means, with

61% (n = 332) students initially taking action to confirm their risk. Specific actions taken to confirm the threat, as well as the number sheltering and ignoring the warnings are shown in Fig. 6.9. After confirmation, seeking shelter was the next most popular response with 30% (n = 167) choosing this option. Eight percent (n = 45) of students neither confirm their risk nor shelter, but report typically ignore warnings. Six people reported usually chasing the storms, and five others did not have useful answers. The proportion of students confirming risk was much higher and sheltering was much lower than in the first survey (Chapter 4). This may be a result of the second surveys asking about all warnings experienced, as opposed to only the most recent. It is assumed this is a more genuine representation of what students do during most warnings. As supported by studies of the general population and of students (Sherman-Morris 2009) most students feel the need to confirm their risk before sheltering.

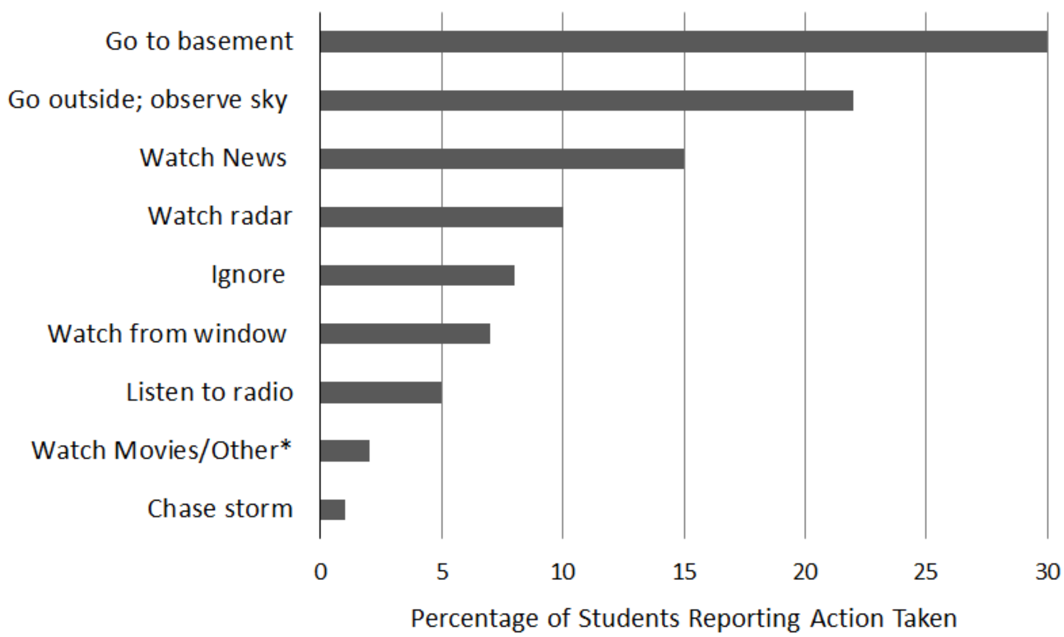


Fig. 6.9 Initial actions taken during warnings. *Any item not news-related.

Controlling for knowledge source, warning source, pFAR, perceived vulnerability, and other student demographics, it was found that international students were 5.5 times more likely to usually seek shelter than American students ($p = 0.001$). This indicates that American students, having experienced general severe weather or tornadoes more often than international students, may have developed more of a need to confirm the warning first rather than taking shelter. The fact that international students are more likely to shelter than American students does not necessarily imply that they are independently choosing safe places to shelter. They may simply follow other students to shelter without fully understanding the potential danger. Controlling for demographics, warning source, and perceived vulnerability, international students who were taught were 7 times more likely to take shelter ($p = 0.001$) than those who were not taught.

Females were twice as likely to shelter as males ($p = 0.003$), reiterating the consensus in the literature. The odds of sheltering was 59% lower for those gaining knowledge from Group D (e.g., friends, common knowledge, or popular culture) compared to all other knowledge sources ($p = 0.083$). Those students getting warnings primarily through traditional auditory means (e.g., sirens, radio, or NWR: Group A) were 2.3 times more likely to shelter than those receiving warnings through newer technology (e.g., internet or mobile technology: Group C) ($p = 0.002$). Finally, for every one percent increase in pFAR, the *odds* of students usually seeking shelter decreased by nearly one percent ($p = 0.042$). As students believe more warnings are simply false alarms, the odds

of them seeking sheltering slightly decrease, and they will be slightly more likely to need to confirm the warning.

Factors Influencing Sheltering Rate

The author's concept of a safe response may have differed from some students' interpretation of 'responding.' Responding to some may have simply meant seeking additional information by consulting multiple sources, or confirming the threat by going outside. To alleviate this ambiguity in the second survey students were asked during what percentage of tornado warnings they *ultimately choose to take shelter* in Item 25; Appendix B. The average 'shelter rate' was 51% with a standard deviation of 33%. Fig. 6.10 shows a clear bimodal distribution, which might indicate a tendency for students to develop habits of usually responding to warnings, or seldom responding to warnings, with little middle ground.

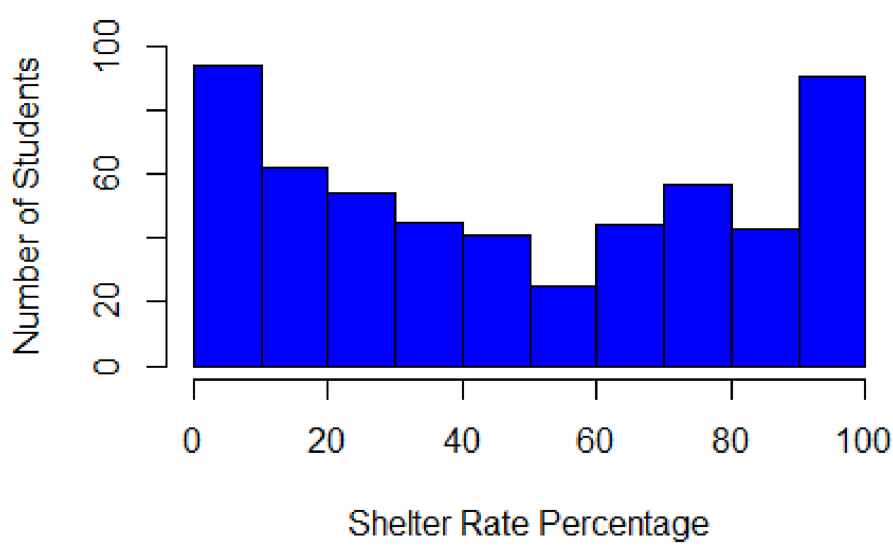


Fig. 6.10 Students' self-reported sheltering rate.

Linear regression was again used to determine effects of different variables on sheltering rate. Results shown here support those shown in the previous section, and show consistency in responses. Holding other variables constant, females sheltered nine percent more often than males ($p = 0.007$). International students sheltered 14% more often than domestic students ($p = 0.044$). This may support the habituation effect, as was shown in Paul et al. (2014) with people with longer residence times in tornado-prone areas succumbing to complacency. Students being warned through Group A (e.g., traditional auditory sources) took shelter 14% and nine percent more often than those using Group C (newer technology, $p = 0.001$) or television ($p = 0.025$). This may indicate warning sources such as mobile weather applications and television are being used more for confirmation than anything else, and that traditional warning sources such as sirens are still very much needed and used. Finally, for every one percent increase in pFAR, sheltering rate drops by 0.18%. This reiterates findings from LeClerc and Joslyn (2015) in which a higher pFAR was associated with lowered trust in warnings, and a reduced likelihood of taking shelter.

VII. Student Comments and Suggestions

Students were given the option at the end of the survey to provide any comments or suggestions they felt the researchers should know regarding tornadoes and tornado safety (Item 26; Appendix B). Thirty-one students indicated wanting or needing to be taught more knowledge of tornadoes. One student from Illinois, where tornado drills are mandated, wanted it to be known that they knew the difference between a watch and a warning, and proceeded to define the terms, only to get the definitions reversed. Some

domestic students expressed the desire to see more information being distributed on campus, as shown in the following quotes:

> *"Should probably suggest safe areas for non-basement floors, if possible."*
>
> *"Send more alerts with specific information of what we should know about and do."*
>
> *"More awareness around campus would be nice - like tornado shelters inside the buildings. I can see there being mass chaos due to not knowing shelter areas in places like the union, Hamilton. etc."*

These types of answers suggest students recognize a lack of information on campus regarding what safety practices to take during tornadoes. Due to UNL being designated a StormReady® campus by the local NWS WFO, there are signs posted in many buildings that inform students of preferred shelter locations. However, many students may not take notice of these signs, as one student specifically mentioned. Other quotes from students indicating the need for more tornado education on college campuses included answers such as:

> *"Could probably educate myself more, as I don't know much about where to go besides the stairway. I also don't know the public plans, i.e. in any given building at unl. If it happened I'd have to rely on people telling me what to do and where to go."*
>
> *"Haven't had any teaching on the subject since grade school fire drills, so my knowledge is lacking."*

This shows some students not knowing where to go, yet possibly being willing to learn more information about tornadoes. International students especially showed enthusiasm and willingness to learn more about tornadoes, or had creative suggestions:

> *"I suggest School put LED boards which show temperature, time, as well as warnings like tornado in every buildings and halls."*

> *"I heard a lot since I came here that I should run to the basement when hearing the alarm. But besides this I really don't know much about tornado. I think it would be a good idea to provide free bulletins to student to introduce tornado knowledge if the tornado is a serious problem in Lincoln."*

> *"I know there're signs of tornado shelters everywhere on campus but nobody actually pays attention to those unless something happens which will be too late. Maybe have instructors mention these locations at the beginning of each lecture (just those shelter locations of the building where class is in) or add them in our syllabus would be much more helpful."*

During severe weather, it is UNL policy to put additional signs on major entry/exit doors of dormitory buildings which notify residents of type and duration of the watch or warning. Each UNL dormitory has a weather radio located at the main desk, which is constantly monitored. If a tornado warning is issued, desk staff and Resident Assistants direct students to shelter areas. This is a good policy when students are in dorm buildings, but will not be applicable when in class or elsewhere on campus. Some professors do not know designated shelter locations for the buildings in which they teach or have offices. Others do not know the monthly testing schedule, and so may not be able to differentiate between a test and a real warning. The author observed one UNL instructor dismissing a lecture hall full of students due to 'not knowing what to do' and not knowing the warning was the monthly test until they walked outside and saw blue sky. The messages played on building intercoms do not contain the word 'test,' and are presented as though they are real. This would conceivably increase the pFAR in students' minds, leading to habituation and a possibly cavalier attitude in future warning events,

especially in those who do not know the monthly testing schedule. This is shown in one student's statement:

> *"Since I have been living in on campus dorms for 4 years, it is hard to notice which is practice alarm and which is the real one for tornadoes*."

It is therefore recommended that university instructors and administrators receive information regarding shelter locations and warning versus testing information, and relay this information to students.

Chapter 7. Summary and Conclusion

Using two large samples of undergraduates in Nebraska, the author determined significant relationships between student demographics, perceptions, and response actions. It has been shown that parents and school are the most popular sources of tornado-related knowledge for domestic students. However, parents may establish better habits regarding sheltering and preparedness. School may not be instilling a sense of urgency when students are under tornado warnings. Indeed, those who remember being taught primarily through elementary school classes were more likely to assume cities were safe from tornadoes. Students gaining knowledge from friends, common knowledge, or popular culture often shelter less and have a higher pFAR.

Even though university students in Nebraska do not seem to differ much from the general population regarding tornado knowledge, perception, and warning reception, there appears to be a shift away from direct forms of warnings such as visual cues and face-to-face communication to newer technology-based warnings, especially in the more recent survey. However, traditional warning sources such as sirens, television and radio remain the most popular. Many students could correctly identify relatively safe areas to shelter during tornadoes (e.g., in a ditch if outside, or lowest possible level if inside). Even though 80 to 90% of students did well on these types of questions, many myths remain common such as city immunity, sheltering under overpasses, and sheltering in southwest corners of basements. Many students also thought that land surface features affected tornado likelihood and/or formation.

Even though student perceptions of tornadoes and associated risk has occasionally been investigated, relating these perceptions to actions taken during warnings has seldom, if ever, been done. International student perceptions and knowledge regarding tornadoes also seems scarce prior to this research. International students in this study had a higher average pFAR, and assumed cities and Lincoln specifically were safe from tornadoes, but they were more likely to shelter than American students in the second surveys. They could not interpret a warning polygon very accurately, but were less likely to perceive themselves as safe near the supercell. Instead, they were much more likely to feel neutral or unsure. Tornado-related education seemed to impact international students. Those who were educated were more likely to have a plan at school, and were more likely to shelter during warnings, including choosing safer locations to shelter. International students who were in Nebraska greater than one year also had decreased pFARs, presumably due to more experience or exposure to educational material.

Many students did not initially take shelter once aware of a tornado warning, but instead sought more information to confirm the risk. The same has been shown for the general population. It has also been shown that some students do not take the threat of tornadoes very seriously, as between 8% and 13% of students report ignoring warnings. This is due to a prevalent optimism bias, habituation, the sense of perceived protections offered by cities, and the lack of recent tornadoes impacting many students' immediate areas. The personalization of risk will be situationally dependent, as every warning is spatially, temporally, and socially different.

In the second survey most students correctly knew cities are not immune to tornadoes, but this correct perception did not hold true for Lincoln specifically, as many of these same students believed Lincoln to be less vulnerable. This shows the power of local myths being able to change otherwise correct conceptions of tornado behavior. Those lacking prior experience also tended to perceive Lincoln as immune to tornadoes. In light of the results obtained, and student statements regarding what they would like to see changed, the following recommendations seem warranted:

1. In addition to standard participation in school drills, students should be taught correct perceptions of general tornado behavior, with special attention to any local myths.
2. Throughout the year, students who live on campus should be actively taught basic terminology regarding tornadoes, and sheltering locations available to them.
3. University instructors should receive information regarding shelter locations and warning test information.
4. Warning response researchers may benefit from focusing on how to make students *personalize* risk, in addition to heeding warnings.

Components of the warning-response process that are crucial, and still being explored, are the perceptions and decisions of those in warning situations. More and more institutions are becoming StormReady®, but preparing and educating students should not end with this campaign. There is still much to be learned regarding student perceptions of tornadoes, actual warnings, and situation-specific actions taken. Correct perceptions of tornado behavior generally leads to safer actions being taken, and incorrect perceptions

leads to students responding to a lower percentage of warnings. Thus, continued tornado education on university campuses is warranted, with an emphasis on personalization of risk. There is more we can do to prepare students, especially those from places where tornadoes are less common, to know how to correctly perceive and respond to tornadoes. Given that many students themselves recognize tornado knowledge and safety knowledge to be lacking on campus and seem to be willing to learn, we should give them the tools to do this.

REFERENCES

Accuweather.com: Important tornado safety tips to follow. (2012, December 25). Retrieved September 30, 2015. http://www.accuweather.com/en/weather-news/important-tornado-safety-tips-1/30770

Ash KD, Schumann III RL, Bowser GC (2014) Tornado warning trade-offs: Evaluating choices for visually communicating risk. Weather Clim Soc 6:104-118. doi: 10.1175/WCAS-D-13-00021.1

Baldwin TD (2008) Communicating with university students in an emergency: A survey of what they know and how to reach them. Master's Thesis, University of North Carolina

Balluz L, Schieve L, Holmes T, Kiezak S, Malilay J (2000) Predictors for people's response to a tornado warning: Arkansas, 1 March 1997. Disasters 24:71-77. doi: 10.1111/1467-7717.00132

Barnes LR, Gruntfest EC (2007) False alarms and close calls: A Conceptual model of warning accuracy. Weather and Forecast 22:1140-1454. Doi: 10.1175/WAF1031.1

Blanchard-Boehm RD, Cook MJ (2004) Risk communication and public education in Edmonton, Alberta, Canada on the 10th anniversary of the 'Black Friday' tornado. International research in geographical and environmental education 13(1):38-54. doi: 10.1080/10382040408668791

Brown S, Archer P, Kruger E, Mallonee S (2002) Tornado-related deaths and injuries in Oklahoma due to the 3 May 1999 tornadoes. Weather Forecast 17:343–353. doi: http://dx.doi.org/10.1175/1520 0434(2002)017<0343:TRDAII>2.0.CO;2

Chaney P, Weaver G (2008) The Super Tuesday tornado disaster at Lafayette, Tennessee: Preparedness, response, and previous experience. Quick Response Report #198, Natural Hazards Research Applications and Information Center, Boulder

Comstock RD, Mallonee S (2005) Comparing reactions to two severe tornadoes in one Oklahoma community. Disasters 29:277-87. doi: 10.1111/j.0361-3666.2005.00291.x

Demuth JL, Lazo JK, Morss RE (2011) Exploring variations in people's sources, uses, and perceptions of weather forecasts. Weather Clim Soc 3:177-191. Doi: 10.1175/2011WCAS1061.1

Dillman DA, Smyth JD, Christian LM (2000) Internet, mail, and mixed-mode surveys: The tailored design method. 3rd Edn. Wiley.

Donner WR, Rodriquez H, Diaz W (2007) Public Warning Response Following Tornadoes in New Orleans, LA, and Springfield, MO: A Sociological Analysis. Poster session presented at American meteorological society conference

Donner WR, Rodriquez H, Diaz W (2012) Tornado warnings in three southern states: A Qualitative analysis of public response patterns. J Homeland Secur Emerg Manag 9(2): 1547-7355 ISSN (online)

Dow K, Cutter S (1998) Crying wolf: Repeat responses to hurricane evacuation orders. Coastal Management 1998. 26(4):237—252. Doi: 10.1080/08920759809362356

Dudaite J (2003) The influence of item-stem format and item-answer format on the results for selected items in TIMSS 2003. The Second IEA International Research Conference: Proceedings of the IRC-2006 1:83-88

Grazulis TP (2001) The Tornado: Nature's ultimate windstorm. University of Oklahoma.

Hammer B, Schmidlin TW (2002) Responses to warnings during the 3 May 1999 Oklahoma City tornado: Reasons and relative injury rates. Weather Forecast 17:577-581 doi: http://dx.doi.org/10.1175/1520-0434(2002)017<0577:RTWDTM>2.0.CO;2

Harris Poll, 2007: November 28, 2007. The Harris Poll #118. Local television news is the place for weather forecasts for a plurality of Americans. [Available online at www.harrisinteractive.com/harris_poll/index.asp?PID=839.]

Klockow KE, Peppler RA, McPherson RA (2014) Tornado folk science in Alabama and Mississippi in the 27 April 2011 tornado outbreak. GeoJournal 79:791-804 doi: 10.1007/s10708-013-9518-6.

LeClerc J, Joslyn S (2015) The cry wolf effect and weather related decision making. Risk Analysis. 35(3):385 - 395 doi: 10.1111/risa.12336

Legates DR, Biddle MD (1999) Warning response and risk behavior in the Oak Grove-Birmingham, Alabama, tornado of 08 April 1998. Quick Response Report #116, Natural Hazards Research Applications and Information Center, Boulder

Lovekamp WE, McMahon SK (2011) I have a Snickers bar in the trunk of my car: Student narratives of disaster risk, fear, preparedness, and reflections on Union University. Int J Mass Emerg Disasters 29(2):132-148.

Mileti DD, Sorensen JH (1990) Communication for Emergency Public Warnings: A Social Science Perspective and State-of-the-Art assessment. Oak Ridge, TN: Oak Ridge National Laboratory Report ORNL-6609 for the Federal Management Agency.

Mitchem JD (2003) An analysis of the September 20, 2002 Indianapolis tornado: Public response to a tornado warning and damage assessment difficulties. Quick Response Report #161. Natural Hazards Research Applications and Information Center, Boulder

Nagele DE, Trainor JE (2012) Geographic specificity, tornadoes, and protective action. Weather Clim Soc 4:145 - 155. doi: 10.1175/WCAS-D-11-00047.1

National Oceanic and Atmospheric Administration (NOAA) (2015) NOAA Weather Radio All Hazards. National Oceanic and Atmospheric Administration, n.d. Web. 30 Nov. 2015.

National Weather Service (NWS) (2008) National Weather Service Weather Forecast Office, Memphis Tennessee. Preliminary storm reports from February 5 2008.

National Weather Service (NWS) (2009) Highway overpasses as tornado shelters: Fallout from the 3 May 1999 Oklahoma/Kansas violent tornado outbreak. http://www.srh.noaa.gov/oun/?n=safety-overpass. Accessed April 29, 2015.

National Weather Service (NWS) (2011) Central Regions Service Assessment: Joplin, Missouri, Tornado - May 22, 2011. National Oceanic and Atmospheric Administration, US Department of Commerce.

National Weather Service (NWS) (2015a) National Weather Service Storm Ready Universities. http://www.stormready.noaa.gov/universities.htm. Accessed November 29, 2015.

National Weather Service (NWS) (2015b) NWS tornado safety: During a tornado. http://www.nws.noaa.gov/om/severeweather/during.shtml. Accessed September 25, 2015.

Nichols (2012) How university administrators made decisions during National Weather Service tornado warnings in the Spring of 2011. Master's Thesis, University of Oklahoma

Paul BK, Brock VT, Csiki S, Emerson L, (2003) Public Response to Tornado Warnings: A Comparative study of the May 4, 2003, tornadoes in Kansas, Missouri, and Tennessee, Quick Response Report #165. Natural Hazards Research and Applications Information Center, Boulder

Paul BK, Stimers M, Caldas M, (2014) Predictors of compliance with tornado warnings issued in Joplin, Missouri in 2011. Disasters 39:108-124. doi: 10.1111/disa.12087

Reja U (2003) Open-ended vs. Close-ended questions in web questionnaires. Developments in applied statistics Anuška Ferligoj and Andrej Mrvar (Editors) Metodološki zvezki, 19, Ljubljana: FDV, 2003

Ripberger JT, Silva CL, Jenkins-Smith HC, Carlson DE, James M, Herron KG (2015) False alarms and missed events: the impact and origins of perceived inaccuracy in tornado warning systems. Risk Analysis. 35(1):44 – 56. doi: 10.1111/risa.112262

Schmidt CK, Davis JM, Sanders JL, Chapman LA, Cisco MC (2011) Exploring nursing students' level of preparedness for disaster response. Report for Nursing Education Perspectives.

Schultz DM, Gruntfest EC, Hayden MH, Benight CC, Drobot S, Barnes LR (2010) Decision making by Austin, Texas, residents in hypothetical tornado scenarios. Weather Clim Soc 2:249 - 254. doi: http://dx.doi.org/10.1175/2010WCAS1067.1

Senkbeil JC, Rockman MS, Mason JB (2012) Shelter seeking plans of Tuscaloosa residents for a future tornado event. Weather Clim Soc 4:159 - 171. doi: 10.1175WCAS-D-11-00048.1

Sharpe, D (2015) Your chi-square test is statistically significant: Now what? Practical assessment, research & evaluation 20(8). http://pareonline.net/getvn.asp?v=20&n=8

Sherman-Morris, K (2009) Tornado warning dissemination and response at a university campus. Nat. Hazards 52:623 - 638. doi: 10.1007/s11069-009-9405-0

Silver A, Andrey J (2014) The influence of previous disaster experience and sociodemographics on protective behaviors during two successive tornado events. Weather Clim Soc 6:91 - 103. Doi: 10.1175/WCAS-D-11-00026.1

Simmons KM, Sutter D (2009) False alarms, tornado warnings, and tornado casualties. Weather Clim Soc. 1:38 - 53. doi: 10.11752009WCAS1005.1

Suls J, Rose JP, Windschitl PD, Smith AR (2013) Optimism following a tornado disaster. Personality Soc Psychology Bull 39:691. doi:10.1177/0146167213477457

Tiefenbacher JP, Monfredo W, Shuey M, Cecora RJ (2001) Examining a ‘near-miss’ experience: Awareness, behavior, and post-disaster response among residents on the periphery of a tornado-damage path. Quick Response Report # 137. Natural Hazards Research and Applications Information Center, Boulder

UNL (2012) University of Nebraska-Lincoln Fact Book 2012 – 2013. Office of Institutional Research and Planning. University of Nebraska-Lincoln

U.S. Department of Education (2015) Institute of Education Sciences, National Center for Education Statistics. Projections of Education Statistics to 2021. http://nces.ed.gov/programs/projections/projections2021/tables/table_20.asp. Accessed January 20, 2015.

Van Den Broeke MS, Arthurs L (2015) Conceptions of tornado wind speed and land surface interactions among undergraduate students in Nebraska, J. Geosci Educ. in press.

Weinstein, ND (1980) Unrealistic optimism about future life events. J. of Personality and Soc Psychology 39:806 - 820.

Wilks, DS (2011) Statistical methods in the atmospheric sciences. International geophysics series, Vol. 100, Academic Press, 161 pp.

Wong TF, Yan YY (2002) Perceptions of severe weather warning in Hong Kong. Meteorol Appl 9:377 - 382. doi: 10.1017/S1350482702003110.

Youtube (2013) Tornado 1950’s Public Safety & Social Guidance / Educational Documentary Online video clip. Val73TV4.YouTube. 15 Jan. 2013. Web. 29 Nov 2015. [Available online at https://www.youtube.com/watch?v=SFrcn5ROl6c]

APPENDIX A
Questions and Scoring/Coding Rubrics for Each

- General Questions

1) What is your home state or home country?

____

2) How many years have you lived in Nebraska (please circle appropriate number, to the nearest year)?

< 1 1 2 3 4 5+

3) From what source did you learn the majority of what you know about tornadoes and tornado safety?

1 = TV, News
2 = School (Generic)
3 = Parents or guardian
4 = Internet
5 = Weather radio
6 = Other radio
7 = High school or college
8 = Government (NWS or other)
9 = Friends/Acquaintances
A = 'Common Knowledge'
B = Self-Educated
C = Movies/Pop Culture
M = no clear response

4) How do you receive tornado warnings? List as many sources as you want, *in order of your usage*.

1 = TV, News Stations
2 = Weather Radio
3 = Sirens
4 = Mobile application
5 = Phone call
6 = Internet
7 = Other radio
8 = Intercom System
9 = Visual Cues/Observations
A = Direct Communication with others
M = Missing or unclear response

- Tornado Knowledge Score

5) What does it mean if a *tornado watch* is in effect for your area?

1 = Correct explanation and explains that there are favorable conditions, but hasn't developed yet

0.75 =Tornadoes could occur; possible tornado

0.5 = Partially correct, stay inside, stay updated on weather

0 = Incorrect understanding (e.g. tornado ongoing)

6) What does it mean if a *tornado warning* is in effect for your area?

1 = Correct explanation; tornado spotted or inferred by radar

0.75 = Strong chance of tornado occurring, funnel clouds spotted

0.5 = Partially correct, 'take cover', tornado forming signs, a tornado has been spotted 'somewhere.'

0 = Incorrect understanding (no mention of active/ongoing tornado), or too low of urgency

7) What is a typical wind speed in a very strong tornado (please include units)?

1 = 225 – 350 mph; 195 – 306 kts; 101 – 156 m/s

.5 = 187 – 224 mph or 351 – 398 mph; 163 – 194 kts or 307 – 345 kts; 84 – 100 m/s or 157 – 178 m/s

0 = Value outside of these ranges

8) Why do tornadoes contain strong winds?

1 = Correctly mentions PGF or horizontally-varying pressure, tight circulation or rotation

0.5 = Local temperature gradients, 'Air pressure'

0 = Poor/incorrect explanation; air masses colliding

9) Briefly explain your understanding of how a tornado forms. Include a picture if it helps your explanation.

1 = Illustrates or explains a correct tornado formation mechanism (e.g. stretching of vorticity, low-level convergence)

0.5 = Partially-correct process or mechanism, details lacking

0 = Incorrect or poor logic/understanding

10) In which directions could a tornado move (circle all that apply)?

N NE E SE S SW W NW

1 = All 8 directions are circled

0.5 = 4 – 7 directions are circled

0 = 1 – 3 directions circled

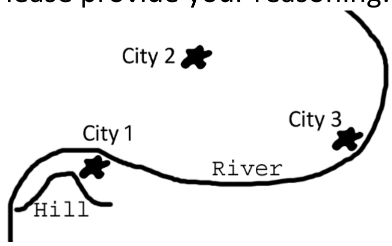
11) Compared to the rest of southeast Nebraska, how likely is [the local city] to be affected by a tornado? Briefly provide your reasoning:

1 = Equally likely; right conditions are required rather than location dependency

0.5 = Equally Likely without reasoning

0 = Can't happen or less/more likely than surroundings (for any reason)

12) Three cities of the same size are located within a small area, shown on the drawing below. Briefly discuss the relative risk of being affected by a tornado in each city. Please provide your reasoning:



1 = Discusses that all equally likely. Reasoning is fairly correct

0.5 = All equally likely due to proximity

0 = Different levels of risk for any of the three cities for any reason

13) Could a tornado occur when there was snow on the ground?

YES NO Briefly provide your reasoning:

1 = YES, right conditions are necessary, gets concept of above-surface factors

0.5 = YES, poor, incorrect, or partial explanation

0 = NO

14) Could a tornado cross a mountainous area?

YES NO Briefly provide your reasoning:

1 = YES, right conditions are necessary, gets concept of above-surface factors, shows previous example

0.5 = YES, poor, incorrect, or partial explanation

0 = NO

15) If a tornado does not appear to be reaching the ground, can it still be doing damage?

YES NO Briefly provide your reasoning:

1 = YES, explains the lack of dependence of damage on a visible condensation funnel

0.5 = YES, poor explanation lacking details

0 = NO

16) Briefly explain the relationship between tornado size and strength of the winds:
1 = No relationship exists
0 = A relationship exists

- Tornado Safety Score

17a) Do you have a substantial, well-thought-out tornado safety plan you could use if a tornado was approaching your location where you live?

	YES	NO
Code:	**1**	**0**

17b) Do you have a substantial, well-thought-out tornado safety plan you could use if a tornado was approaching your location at work/school?

	YES	NO
Code:	**1**	**0**

18) If you have a basement available, where in it should you go to be safest in a tornado?
1 = Under heavy furniture/stairs or in bathroom
0.5 = 'To the basement,' room without windows
0 = 'No basement', or unsafe locations (electric box, furnace, along outside wall)

19) If no safe indoor location is available (you're caught outside), what should you do if a tornado is approaching?
1 = Getting down low in a ditch or other appropriate area AND covering head
0.5 = Generic response, 'Find a ditch' with no other details
0 = Panic/Run/Unsafe actions (e.g. go under tree)

20) Is it safe to take shelter under a highway overpass during a tornado?

	YES	NO
Code:	**0**	**1**

21) Is it appropriate to open windows before a tornado arrives?

	YES	NO
Code:	**0**	**1**

22) How did you respond during the most recent tornado warning you experienced?
1 = Took shelter in a safe place and explained in more detail
0.5 = Took shelter, but didn't explain/generic
0 = No action or unsafe action taken

23) What would cause you to respond to a tornado warning (to *take action/seek safety)* when you learned of the warning, or afterward)?
1 = Got warning and acted as a result
0.5 = Watched Radar/News, but didn't explain where
0 = No action or unsafe action taken

24) In approximately what percentage of cases do you respond to a tornado warning?
100% = 1, 90% = 0.9, 80% = 0.8, …, 10% = 0.1

APPENDIX B
Questions and Scoring/Coding Rubrics for Each

1) What is your home country? *(Chosen from comprehensive list)*

2) What is your home state? *(Chosen from comprehensive list)*

3) How long have you lived in Nebraska? *(Chosen from following options)*
- Less than 1 year
- Between 1 and 5 years
- More than 5 years

4) What is your gender?
- Female
- Male
- Prefer not to Answer

5) What is the 1 major source from which you learned the most about tornadoes and tornado safety?
- Elementary school safety drills
- Elementary school classes
- High school science classes
- College earth and atmospheric science courses
- Parents/Guardians
- Friends/colleagues/ co-workers
- Local T.V. News station
- Self-educated (reading books/online sources)
- Personal experience of severe weather
- Popular culture (Twister, Storm chasing shows)
- Documentary/National Geographic/Science channel
- Other source __________________
- I have not learned about tornadoes, my home country or state does not have them

6) Are there any other sources that you have learned about tornadoes from?
(able to choose multiple options from same sources listed in … excluding the option chosen)

7) Before or shortly after you arrived in the United States, were you taught information about tornadoes? *(Only shown to international students; yes/no response)*

8) What is your 1 major (primary) source for tornado warnings?

- Weather Radio
- Public Radio
- Speaking face-to-face with others
- Building Intercoms
- Sirens
- T.V.
  -- Local News
  -- The Weather Channel
  -- Weather Nation
  -- Other______
- Phone call from another person
- Text Message
  -- From Parent or family
  -- From peer (someone your age)
  -- From National Weather Service
  -- Other______
- Mobile campus alert
  -- Email
  -- Text notification
  -- Other______
- Weather app on mobile device
  -- Weather Channel App
  -- Weather Bug
  -- Radar Scope
  -- Other app ________
- Internet
  -- National Weather Service (Weather.gov)
  -- Local news channel website
  -- The Weather Channel (Weather.com)
  -- Facebook
  -- Twitter
  -- Other______
- Visual Cues (looking outside)
- Other_________

9) Are there any other sources you get tornado warnings from?
(able to choose multiple options from same sources listed in … excluding the option chosen)

10) Have you ever been under a tornado warning?

- Yes
- No
- I don't know

11) How do you receive your weather information?
(shown to those who indicated they were never in a warning.)

- Public Radio
- Television
- Weather App: Mobile device
- Internet
- Other

12) Have you or anyone close to you (family or friends) ever been in a tornado or had part of their home damaged by a confirmed tornado?
(Those who said 'yes', were asked how the experience affected how they act during tornado warnings now)

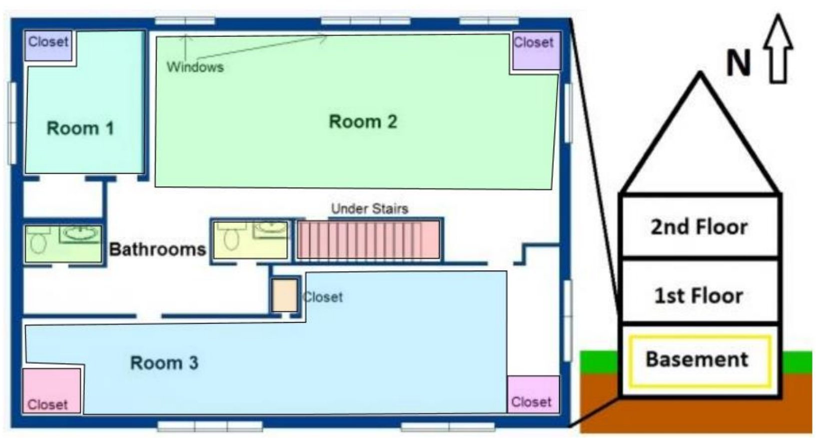
13) Do you have a safety plan you could use immediately in case of a tornado? Meaning do you have a safe place to go and know how to get there?

At home (current residence)?	YES	NO	DOES NOT APPLY
At work?	YES	NO	DOES NOT APPLY
At school?	YES	NO	DOES NOT APPLY

14) Where should you go to be safe during a tornado?
(Open written response)

15) This is an underground basement. The view is looking down on the floor from above. North is towards the top of the page. Where would be the safest places during a tornado?

(You may pick anywhere from 1 to 3 locations. Click a region to select it, click again to de-select it.) *Students could not see the highlighted areas until the cursor hovered over it.*



16) Tornadoes usually <u>cannot</u> hit cities. *(True or False)*

You said tornadoes usually **cannot** hit cites. Why did you say this?

- Tornadoes usually go around cities.
- The tall buildings may disrupt winds.
- The city produces too much heat.
- Other_______

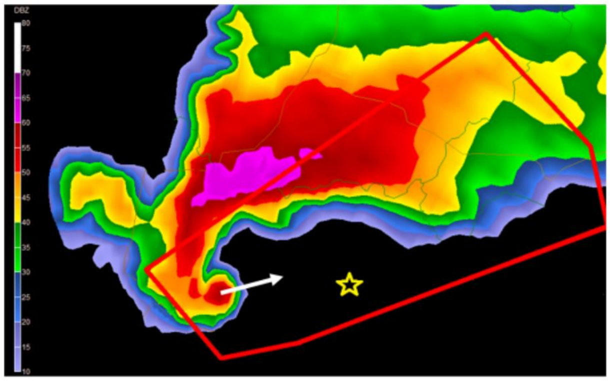
You said tornadoes **can** hit cities. Why did you say this?

- Tornadoes can occur anywhere.
- The probability of the city getting hit is the same as any other area of the same size in the same region.
- Other_______

17) How likely is the city of Lincoln to be affected by a tornado, compared to a rural area of equal size?

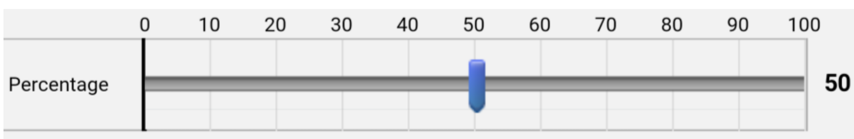
- Less Likely
  -Tornadoes usually hit rural areas instead of cities.
  -Lincoln has had few tornadoes historically.
  -Lincoln's bowl-shaped dip in the surrounding land makes it less vulnerable.
  -Other_________
- Equally Likely
  -Urban vs rural land does not matter, the entire region has the same risk.
  -I have seen or heard of this happening before.
  -Other_________
- More Likely
  -The land is flatter here than the surrounding region
  - Lincoln is closer to tornado alley than the rest of Southeastern Nebraska
  -Other_________

18) Shown below is a picture of a strong storm. The white arrow shows directions of motion, and the yellow star is your location. What does the red rectangle mean?
(Open written response)



19) Shown is a picture of a strong storm. The white arrow shows directions of motion, and the yellow star is your location.   How safe would you feel at the yellow star?
(Shown as 5 – point Likert scale)

20) What percentage of tornado warnings do you think have been false alarms?
(Slide the marker to the desired percentage)



21) Who do you think issues tornado warnings?
(Open written response)

22) Who do you think controls when tornado sirens sound?
(Open written response)

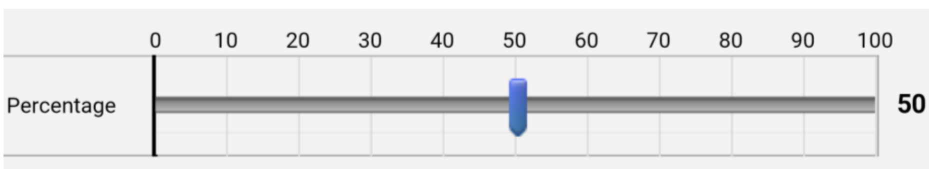
23) Which of these would convince you to take shelter once you were aware of a tornado warning?
(Able to select multiple options)

- If surrounding people took shelter themselves
- Hearing the warning once would be enough motivation for me to take shelter
- Hearing the sirens
- Getting warned from more than one source
- Meteorologist on TV says to take shelter
- Being able to see or hear the tornado itself
- Having more knowledge about the tornado
    - Where the tornado is relative to my location
    - Direction of tornado's movement
    - Damage already done by the tornado

- If I was responsible for other people's safety
- Other _______________

24) What do you usually do first during tornado warnings?
- Go to a basement or otherwise take shelter
- Continue current activity without worrying too much
- Watch out the window until storm gets worse
- Go outside to look at the sky conditions
- Get in a vehicle and chase storm
- Watch News on T.V.
- Watch things that are not News (movies, recordings, etc)
- Listen to radio for updates
- Watch radar
- Other____________

25) In what percentage of cases do you end up taking shelter during a warning?
(Slide the marker to the desired percentage)



26) Last Question! Any comments or suggestions, or anything else you would like us to know regarding tornadoes and tornado safety? *(Answering was not necessary to finish the survey.)* *(Open written response)*