1.3 AN EVALUATION OF CONVECTIVE WARNING UTILIZATION BY THE GENERAL PUBLIC

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1. INTRODUCTION

The National Weather Service routinely verifies the lead-time and accuracy of severe thunderstorm and tornado warnings to measure the success of the warning program in meeting the agency's primary mission to protect life and property from weather-related hazards. An important, but rarely studied, component that ultimately influences the role of convective warnings in protecting life and property is the proper utilization of warning information by the intended audience. Warning utilization by groups or individuals experiencing various types of weather events requires at least three key elements: receipt of the warning message, an understanding of its meaning and personal relevance, and appropriate action if necessary. Other studies report similar and more detailed cognitive and behavioral steps from warning reception to response (e.g., Doswell 2005; Lindell and Perry 2004, p. 64; Mileti 1995; Mileti and Sorensen 1990).

Warning reception rates reported in previous studies vary somewhat depending on the threat and research methods. Paul et al. (2003) determine through personal interviews following a regional tornado outbreak that nearly three-quarters of the population successfully received tornado warnings. In the same study, respondents reported sirens, followed by television, as the most common source of warning information. Other studies also find that television and sirens, when available, are the primary sources for warning information (e.g., Balluz et al. 2000; Hammer and Schmidlin 2002). Sherman-Morris (2010) reports that approximately two-thirds of respondents to an online survey of university students and employees following a tornado event indicate receiving a campus alert message warning of the tornado, mostly via cell phone, while many learned of the National Weather Service warning through local television, personal communication, an alert service, or the Internet. In the same set of interviews, only 3% of students and less than 6% of faculty and staff on a college campus report learning of the tornado warning via National Oceanic and Atmospheric Administration (NOAA) weather radio. In contrast to relatively high tornado warning reception rates, the reception rate for flood warnings reported in several studies lies close to 40% (Parker et al. 2009).

While warning reception plays a major role in the effort to protect life and property, studies show that interpretation of the warning by the recipient and a proper response remain critical (e.g., Schumacher et al. 2010). In an examination of the casualties resulting from the 1979 Wichita Falls tornado, Glass et al. (1980) write, "Since 96 percent of people claimed they had adequate warning, the problem was one of proper education and response." The fact that one survey shows that 90% of respondents who received a tornado warning immediately sought shelter (Paul et al. 2003) provides some encouragement. One factor that inhibits an appropriate response involves the miscommunication about what protective action or a safe location might look like. Sherman-Morris (2010) finds that recipients of a tornado warning wanted to find safe shelter as the warning message recommended, but did not completely understand where to do so. About three quarters of the sampled population took shelter in the Sherman-Morris (2010) study.

Cognitive and situational factors strongly influence the decision-making process of individuals who have received a warning about a potential threat (Legates and Biddle 1999). One such factor includes the influence of false alarms, which are widely regarded as problematic, but others argue that false alarms do no harm to the public perception of threats communicated in future warnings (e.g., Barnes et al. 2007; Schultz et al. 2010). Risk perception also influences warning response (Dash and Gladwin 2007). In the context of hurricane forecasts, Morss and Hayden (2010) find that including information on specific threats posed by a storm may enhance warning communication. The authors note the importance of research on how people interpret and use warning messages in order to convey risk and encourage protective action. The present work addresses aspects of this type of research using a large-scale online survey to assess individual experiences with convective warnings.

2. WARNING SUCCESS RATE

In an effort to assess the proper utilization of convective warnings by the general public, and hence the success of a warning in meeting the primary mission of the

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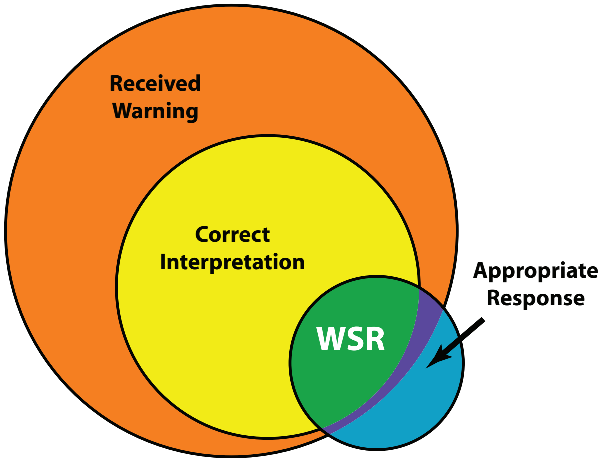

FIG. 1. The warning success rate (green) corresponds with the percentage of the warned population that receives the warning message (orange circle), correctly interprets the warning (yellow circle), and responds appropriately (blue circle). Not all appropriate responses to the warning follow from a correct interpretation (purple).

National Weather Service in protecting life and property, Wolf (2009) introduces the concept of warning success rate (WSR). The WSR, given by

$$\mathrm{WSR} = P_w \times P_i \times P_r \tag{1}$$

and expressed as a percentage, measures the percentage of the warned population that receives, correctly interprets, and appropriately responds to a given warning message. Here, P_w represents the proportion of the population that receives the warning message, P_i represents the proportion of recipients of the warning who interpret it correctly, and P_r represents the proportion of those who both receive the warning and make a correct interpretation who also take appropriate action. Unlike other verification measures that assess warning accuracy and timeliness, the WSR focuses on warning utilization by measuring the effectiveness of the threat communication.

Figure 1 graphically illustrates the WSR. Note that a correct response to a warning message (i.e., whether or not to take shelter) may not necessarily follow from either a correct interpretation of that message or receipt of the message at all. Proper utilization of a warning must generate an appropriate response and therefore requires a timely receipt and correct interpretation of the threat to each individual. Thus, the WSR measures only those individuals who actually receive the warning, correctly interpret that warning in terms of their location with respect to the warned area, and respond by taking appropriate action if necessary. The WSR therefore focuses on the value of convective warnings in protecting life and property and represents the percentage of the warned population that fully utilizes the warning information. Wolf (2009) suggests that the WSR remains low (i.e., approximately 10%), indicating that the vast majority of the warned population does not properly utilize the warning message, yet no studies to date specifically target the three elements of the WSR to quantify this measure of warning utilization. The present study represents the first large-scale effort to evaluate the WSR for the general population by determining how the general public receives, interprets, and responds to severe thunderstorm and tornado warnings.

3. SURVEY

The online survey gathers information on experiences with severe thunderstorm and tornado warnings from respondents during the period April–August 2010. This period covers the bulk of the spring storm season and spans enough time to include a variety of storm types and event scales, from isolated thunderstorms to tornado outbreaks, and a wide geographic coverage. The survey, open to respondents from the 39 states east of the Rocky Mountains (i.e., North Dakota, South Dakota, Nebraska, Colorado, New Mexico, and all states eastward), requests information regarding experiences with severe thunderstorm and tornado warnings. The study region focuses on the states receiving the majority of springtime and summertime convective warnings and neglects areas from the Rocky Mountains westward given the dramatic decrease in the number of overall convective warnings issued for this area.

An automated script obtains all of the severe thunderstorm and tornado warning text files in real time from the National Weather Service and parses the information in the warning text to determine the states and counties included in the warning, the warning time, and the warning type (i.e., severe thunderstorm or tornado). The script generates a dynamic list of states with recent and active warnings within the last three days. A 72-hour limit on the warnings provides sufficient time for respondents to complete the survey, prevents the accumulation of an overwhelming list of warnings, and lessens the possibility that respondents will forget essential elements of their experiences. The script automatically removes warnings older than 72 hours, but archives expired warnings for future reference. Respondents accessing the survey at www.warningstudy.org[1] trigger a unique survey tailored for each warning. Hidden fields containing information on the warning selected by each respondent, as well as a unique survey identification number, are paired with that individual's responses upon submission of the completed survey.

To spread awareness of the study and acquire survey participants, all broadcast meteorologists and newspaper organizations within the study region received a tailored letter explaining the study goals, along with a request to publicize the survey. While noble, this effort resulted in only a handful of positive responses and eventual survey participants. A substantial portion of the pool of respon-

[1] Please note that this Uniform Resource Locator (URL) is no longer active.

TABLE 1. Survey questions and selected responses. Percentages are out of the applicable total and may not sum to 100% due to rounding error, blank responses, or the option to choose multiple answers.

Survey Question	Response
1. Please select the year in which you were born	—
2. Did you receive word of the warning when it was issued?	
Yes	88%
No	12%
If you answered *yes*, how did you FIRST learn of the warning? (Choose one)	
While watching TV	29%
While listening to commercial radio	6%
Through NOAA weather radio	18%
Through the Internet (e.g., e-mail or Web pages)	16%
Through Internet-based social media (e.g., Twitter or Facebook)	6%
Through an alert service through my telephone, cell phone, or pager	15%
From community sirens	3%
Received warning, but unsure how	0%
Other	5%
3. Based on what you recall from the warning message, you believe your location was (choose one):	
Near the center of the warned area	28%
Inside the warned area, but not near the center	38%
Close to the warned area, but not within it	25%
Far away from the warned area	4%
Unsure	3%
Other	1%
4. Based on what you recall from the warning message, you believe your location was (choose one):	
Directly in the path of the storm	41%
Within the warned area, but not directly in the path of the storm	40%
Not within the warned area or in the path of the storm	13%
Unsure	3%
Other	2%
5. What weather conditions, if any, did the warning message mention? (Choose all the conditions that apply)	
Destructive hail (golfball-size or larger)	11%
Severe hail (quarter-size up to golfball-size)	35%
Destructive winds (in excess of 80 m.p.h.)	9%
Severe winds (in excess of 60 m.p.h.)	65%
Tornado	21%
Deadly lightning	33%
Flooding	16%
Unsure	9%
6. If you received the warning message, what did you do FIRST? (Choose one)	
Went to a safe location	7%
Turned on local TV station or checked the Internet for more information about the threat	43%
Looked outside to see if threatening weather was approaching my area	24%
Notified nearby friends, family, or neighbors about the warning	7%
Took no action	11%
Unsure	0%
Did not receive the warning	—
Other	7%

dents likely received word of the study via social media messages (e.g., Facebook and Twitter). Large spikes in participation correspond with the timing of individual messages posted by meteorologists affiliated with popular outlets for weather information (e.g., The Weather Channel). In this way, much of the participation in the study results from requests of personal contacts by the authors to post information about the survey via wide-reaching social media platforms.

Participants accessing the survey first see a welcome message that describes the goal of the study. To continue, each participant must check a box indicating his or her willingness to participate and attesting that he or she is over 18 years of age. The next page shows a list of the 39 states in the study region with links available only for those states with a convective warning in the last 72 hours. Clicking on a state name brings the participant to a list of recent convective warnings, sorted temporally from most recent to the oldest, showing the type of warning (i.e., severe thunderstorm or tornado), and the county. In cases where one individual warning mentions multiple counties, the page lists each county individually. Participants then complete two steps for the chosen county. In the first step, participants review the warning text by clicking on the available link. The warning text presented to the participant is an exact replica of the text available through the National Weather Service. In the second step, participants move forward and begin the

TABLE 1. (*Continued*)

Survey Question	Response
7. If you ultimately went to a safe location, answer PART A. Otherwise, answer PART B.	
PART A: What led to your decision to seek a safe location? (Choose the answer that best applies to your situation)	
Took cover immediately after receiving the warning that was issued for my area	26%
Other information source(s) (e.g., TV, radio, Internet, friends/family) confirmed that dangerous weather was approaching my area	41%
Seeing dangerous weather outside	24%
Unsure	1%
Other	7%
PART B: If you decided not to seek a safe location, what led to that decision? (Choose the answer that best applies to your sitation)	
Received no warning for my area	12%
No other information source(s) (e.g., TV, radio, Internet, friends/family) confirmed that I was in danger	15%
Did not see any dangerous weather outside	30%
Most of the warnings I've received have been wrong	4%
Unsure	4%
Other	35%
8. For a given severe weather warning issued for your area, what do you think is the likely range of probability that your location would actually be struck by life-threatening weather (i.e., tornadoes, extreme winds, and/or destructive hail)? (Choose one)	
Less than 5%	27%
5 to 25% range	43%
25 to 50% range	29%
50 to 75% range	1%
75 to 100% range	0%
Unsure	0%
9. Enter your city, state, and zip code for your location (do not enter your street address)	—
10. What is your highest level of education? (Choose one)	
Less than high school	1%
High school degree or equivalent (GED)	13%
Some college, no degree	34%
College undergraduate (Bachelor's)	34%
College graduate (Master's and/or Ph.D.)	18%
11. Have you taken part in any of the following? (Check all that apply)	
Meteorology training	15%
Storm spotter training	24%
Emergency preparedness or response training	23%
None of the above	58%
Unsure	1%
12. From your viewpoint, how often are severe weather warnings issued for your area? (Choose one)	
My county is frequently under a severe weather warning.	32%
My county is occasionally under a severe weather warning.	64%
My county is rarely under a severe weather warning.	3%
My county is never under a severe weather warning.	0%
Unsure	1%
13. Which of the following is most applicable to you over the past 10 years? (Choose one)	
I have experienced 3 or more thunderstorm or tornado events resulting in property damage or personal injury.	27%
I have experienced 1 or 2 thunderstorm or tornado events resulting in property damage or personal injury.	43%
I have experienced no thunderstorm or tornado events that led to property damage or personal injury.	29%
Unsure	1%

survey.

At the top of the page that displays all of the survey questions, a statement emphasizes to the participant that the questions do not constitute a quiz and then requests the participant's initials to indicate his or her understanding that participation is voluntary. The survey requests demographic information and asks questions specific to the convective warning and the participant's prior experience with severe weather. Table 1 details the specific questions in the survey.

For each survey response, details regarding wording in the warning, meteorological conditions, and available forecast products enhance the overall picture of an individual's experience with each warning and, when paired with the location of the respondent, allow an evaluation of the WSR score. Additional information determined from various external resources includes 1) whether or not the respondent was in the warning polygon or within the path of the warned storm, 2) whether the storm occurred during the day or night (determined from sunrise and sunset times), 3) the convective mode of the storm, 4) whether or not officials received severe weather reports

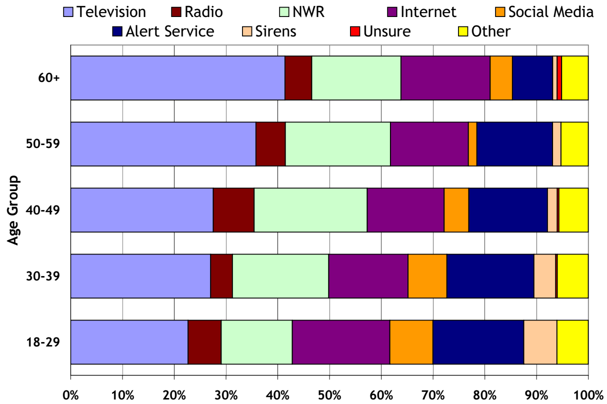

FIG. 2. Methods for receiving the warning message for different age groups shown by percentage of those receiving the warning in that age group. Recipients received warnings while watching television, listening to commercial radio (Radio) or NOAA Weather Radio (NWR), or through the Internet, social media, an alert service, or community sirens.

from the storm, 5) the NOAA/Storm Prediction Center Day 1 risk category and type of watch (if any) in effect in advance of the warning, 6) whether or not the storm or storm complex has a history of producing severe weather prior to the warning, 7) whether or not officials received tornado reports or multiple severe weather reports in the respondent's state or adjacent states on the previous day, and 8) whether or not the storm is part of a tornado outbreak. Recognizing that all tornado outbreak definitions require some degree of subjectivity (Verbout et al. 2006), five or more separate tornadoes from the same weather system on a given day shall constitute an outbreak for this purpose.

4. RESULTS

The survey garnered a total of 1658 responses during the study period. In order to facilitate data analysis and lessen potential bias in the results, several objective criteria help filter duplicate or enigmatic responses. If multiple responses with the same initials originate from the same IP address within 14 days, a filter removes all but the first response. This approach removes the influence of enthusiastic respondents who submit multiple sets of responses for one or more warnings (one individual completed the survey 10 times). However, an individual may have a very different response to a severe thunderstorm warning compared with a tornado warning. In cases where the same IP address and initials correspond with both a tornado warning and a severe thunderstorm warning, the filter keeps the first response for each type of warning. To address the bias introduced by receiving multiple responses from different individuals at the same physical location, and presumably with similar reactions, the filter removes all but the first response from the same IP address and different initials if the two individuals responded to either the same event or different events on the same UTC calendar day. If two of the responses correspond with different types of warnings, then the first severe thunderstorm and the first tornado warning remain. Exceptions to this rule apply for certain IP addresses that the authors could identify as corresponding with network address translation (NAT) firewalls (e.g., America Online proxy servers and traffic from the National Weather Center), where multiple responses appear to originate from the same IP address. The filter also removes all responses that do not indicate a location. Finally, a handful of responses required manual removal. For example, one respondent completed the survey three times within a few minutes, but only included a valid location with the last response. After filtering, 1555 responses remain available for analysis.

4.1 *Reception*

Table 1 shows the breakdown of the remaining valid responses for each question in the survey. A large proportion of the survey respondents indicate that they received the warning, making $P_w = 88\%$. Of the recipients of the warning, the majority of respondents initially received the warning via television, followed by NOAA weather radio, the Internet, and an alert service. Many of the respondents answering "Other" write that they received the warning via word of mouth. Social media, though less popular overall as a means for receiving warnings, plays a larger role in alerting the younger generation. Compared with younger people, a larger percentage of older individuals receives warnings via television (Figure 2). The large proportion of the sampled population who received the warning via any method, combined with the unexpectedly large percentage who learned of the warning from NOAA weather radio (18%), indicates a possible bias toward a general awareness of the weather within the pool of respondents. Indeed, only

TABLE 2. Weather conditions either mentioned or not mentioned in the warning message and corresponding responses to survey question #5, which asks what weather conditions the warning message mentioned.

Hazards	Mentioned in the warning		Not mentioned in the warning	
	Correct	Incorrect	Correct	Incorrect
Hail (destructive or severe)	60%	40%	77%	23%
Wind (destructive or severe)	78%	22%	56%	44%
Tornado	90%	10%	92%	8%
Deadly lightning	60%	40%	71%	29%
Flooding	46%	54%	85%	15%

TABLE 3. Interpretation of location with respect to both the warning polygon and the path of the storm. Values show the percentage of all respondents (All) and of those under severe thunderstorm (Sev) and tornado (Tor) warnings who believe that they were in (Response: In) or out of (Response: Out) either the warning polygon or the direct path of the storm. Highlighting indicates correct (green) and incorrect (red) responses.

	Polygon			Path		
Response: In	**All**	**Sev**	**Tor**	**All**	**Sev**	**Tor**
Actually in	74%	77%	53%	87%	88%	76%
Actually out	26%	23%	47%	13%	12%	24%
Response: Out	**All**	**Sev**	**Tor**	**All**	**Sev**	**Tor**
Actually in	35%	37%	26%	64%	70%	42%
Actually out	65%	63%	74%	36%	30%	58%

58% of the survey population indicates neither meteorology, storm spotter, nor emergency preparedness training, with 5% of the respondents indicating experience with all three types of training.

4.2 *Interpretation*

Most warnings mention specific hazards (e.g., tornado, hail, wind, lightning, or flooding), though respondents may not necessarily understand which of those hazards to expect with the passage of a warned storm after reading the warning message. Table 2 shows the percentage of respondents who either correctly or incorrectly identified a specific threat mentioned in the warning message. For the most part, respondents recall that a warning either does or does not mention a tornado. However, if the warning mentions flooding, 54% do not recall flooding as a potential hazard. Similarly, 40% of respondents do not recall either hail or deadly lightning as a threat listed in warnings that do in fact mention these hazards. Alternatively, 44% of respondents incorrectly recall wind as a threat in those warnings that do not mention severe or destructive winds. It appears that people take from the warning what they expect to read, not necessarily what the warning actually tries to convey.

Archived radar observations and warning polygon information, combined with the city, state, and zip code provided by the survey respondents, allows a determination of each respondent's location with respect to both the warning polygon and the path of the storm. A comparison between each respondent's *understanding* of his or her location after reading the warning message and his or her *actual* location yields insight into the interpretation component of the WSR (Table 3). Surprisingly, 64% of those who believed that they were not in the direct path of the storm actually were in the path of the storm, with 42% of these individuals unknowingly in the path of a possible tornado. Separately considering severe thunderstorm warnings, tornado warnings, and all warnings combined, the majority of respondents in each case correctly determined their locations with respect to the warning polygon.

Since the location data from the survey may not provide sufficient detail to determine whether or not a respondent's location lies directly within the path of the storm, a correct interpretation of the threat in the present study relies strictly on the location of the respondent with respect to the warning polygon. A correct interpretation therefore corresponds with a correct answer to survey question #3, determined by comparing the location information provided by each respondent with the location of the warning polygon. Applying this criterion, the percentage of those who received the warning message who also correctly interpreted that message is $P_i = 68\%$.

Again, given the difficulties with precisely determining a respondent's location on the storm scale, a correct interpretation defined here considers only the extent of the warning polygon. Studies that interview individuals face-to-face and can more precisely determine the person's location with respect to a particular storm may be able to extend this analysis to account for the actual threat experienced by that individual. However, using a best guess at the respondent's location with respect to the path of the storm, a second method for determining a correct interpretation might correspond with a response in which either a) the respondent correctly indicates that he or she is within the warning polygon or b) the respondent correctly indicates that he or she is within the path of the storm. A respondent's location may lie directly in the path of the storm, but he or she may reside far enough ahead of the storm to remain out of the warning polygon. In such cases, a correct response following from a correct interpretation of the warning message may eventually entail seeking shelter. Using the alternative criterion that a correct interpretation of the threat comprises unique responses with either criterion a) or b) results in $P_i = 41\%$. However, P_r using this criterion increases such that the overall WSR changes from the result shown below by only $+1.2\%$.

4.3 *Response*

Following receipt of a warning message and a correct interpretation of that message, individuals will choose whether or not to take protective action. Here, we define an appropriate response as one in which either a) the warning polygon encloses a respondent's location and he or she takes protective action or b) the warning polygon does not enclose a respondent's location and he or she does not take protective action. Using this definition, the percentage of those who received the warning message and interpreted it correctly who also responded appropriately is $P_r = 28\%$.

Of the recipients of the warning message, 43% searched for confirmation of the threat via television or Internet sources and 24% looked outside. This represents a total of 67% of the respondents who confirmed the threat through a second information source. Answers to survey question #7 further indicate some measure of threat confirmation. Of those seeking shelter, 41% indicate that some secondary information source led to the decision and another 24% saw dangerous weather.

TABLE 4. Warning success rate for respondents indicating varying levels of experience with thunderstorm or tornado events resulting in property damage or personal injury over the past 10 years, shown in aggregate (All) and for severe thunderstorm (Sev) and tornado (Tor) warnings only.

Experience	All	Sev	Tor
Three or more events	20%	19%	27%
One or two events	17%	14%	28%
No events	14%	12%	27%

Of those choosing not to seek shelter, 15% cite another information source in making the decision and another 30% came to the decision after looking outside. This finding supports previous studies that show that individuals seek to confirm warning information prior to taking action (e.g., Hammer and Schmidlin 2002; Mileti and Darlington 1997; Sherman-Morris 2010). However, the survey questions do not appropriately capture the response by those who were already online or watching television. For this reason, it remains difficult to ascertain which respondents truly confirmed the threat of severe weather, but results hint at the fact that the confirmation process plays an important role in threat personalization.

There exists no appreciable difference in initial response between those with and without meteorological, emergency preparedness, or storm spotter training. However, and as one might expect, 11% of those with emergency preparedness training notified others, compared with 6% of those with no formal training.

4.4 *Warning Success Rate*

Multiplying the three elements of the WSR (i.e., P_w, P_i, and P_r), the overall percentage of the warned population that properly utilizes convective warnings through receipt, a correct interpretation, and an appropriate response is

$$\mathrm{WSR} = (0.88)\,(0.68)\,(0.28) = 17\%. \qquad (2)$$

When separated by warning type, $\mathrm{WSR} = 28\%$ for tornado warnings, compared with $\mathrm{WSR} = 15\%$ for severe thunderstorm warnings alone, suggesting that individuals understand the urgency of a tornado warning compared with that for a severe thunderstorm and therefore take appropriate action if necessary. Still, this result shows that a tornado warning does not get properly utilized in 72% of the warned population and, overall, convective warnings remain unsuccessful for 83% of the warned population.

The value of the analysis of these data lies in pairing individual responses with storm information, demographics, and the warning text to gain a more complete picture of the three elements of warning utilization. While practical considerations preclude an exhaustive analysis here, some selected highlights reveal some interesting characteristics of the respondent pool. Separating the study region into eight subregions, two distinct groups emerge (Figure 3). Four regions have a WSR in the 10–12% range and the other four have a WSR in the 18–20% range. One might expect that regions prone to severe weather would have a more weather-savvy population and would thus boast a higher WSR. This may in fact explain the lower WSR in New England and the Mid-Atlantic. Indeed, Table 4 indicates that a larger percentage of those with prior experience with damaging severe thunderstorm events properly utilize the warning information compared with those with less experience with such events. This experience, however, does not affect the WSR for tornado warnings, likely due to the perceived urgency of tornado warnings. By analyzing the spatial distribution of the respondents and further separating them according to formal training level,

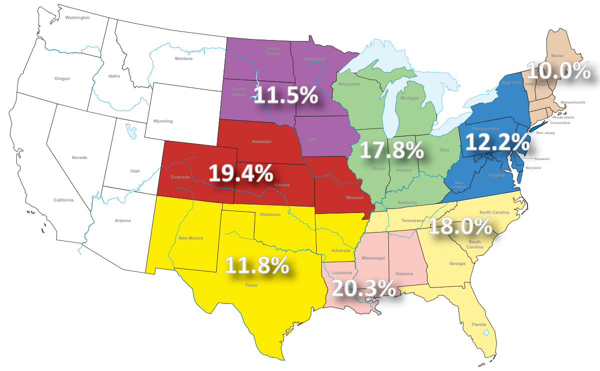

FIG. 3. Warning success rate for eight subregions within the primary study region.

TABLE 5. Warning success rate for respondents with differing levels of formal training, shown in aggregate (All) and for severe thunderstorm (Sev) and tornado (Tor) warnings only. Asterisks indicate subsets with fewer than 10 responses.

Training level	All	Sev	Tor
Meteorology	17%	14%	26%
Storm spotter	20%	17%	34%
Emergency preparedness/response	16%	13%	34%
None	17%	15%	27%
At least one form	18%	15%	28%
All forms	17%	*	*

TABLE 6. Warning success rate separated by the medium through which respondents first received the warning message, shown in aggregate (All) and for severe thunderstorm (Sev) and tornado (Tor) warnings only. Asterisks indicate subsets with fewer than 10 responses.

Reception medium	All	Sev	Tor
Television	17%	16%	24%
Commerical radio	16%	17%	*
NOAA weather radio	21%	19%	36%
Internet	20%	19%	*
Social media	17%	15%	*
Alert service	17%	13%	52%
Sirens	24%	*	*
Other	22%	23%	*

it becomes apparent that many of the responses originating from the Southern Great Plains and Northern Great Plains come from respondents with meteorological training. After reviewing some of the comments received on the survey, it appears that several of these respondents either observed or actively searched for the severe weather rather than take cover. Hence, an artificially low WSR results in regions that frequently receive severe weather, likely as a result of the bias toward weather awareness and general interest in the sampled population. On the other hand, the sample size becomes quite small (e.g., less than 10 is several groupings) when broken down by region, training, and the components of the WSR, so this conclusion deserves some degree of skepticism. In fact, the overall WSR for those with meteorological training does not differ substantially from those with no training at all (Table 5). In addition to many other possible factors, complacency within the general population in regions that receive frequent severe weather warnings may also contribute to low WSR values.

The WSR for respondents receiving the warning via various forms of media ranges from 16–24% (Table 6). The highest values of WSR correspond with respondents who received the warning via sirens, NOAA weather radio, or the Internet. A high WSR value for those receiving the warning via some other means, mostly personal communication, indicates the impact of personal communication regarding a potential threat. The lowest values of WSR correspond with those receiving the warning via commercial radio, television, or an alert service.

5. DISCUSSION

This survey serves as a springboard for more focused future studies that can incorporate important lessons learned here. In particular, several of the survey questions could benefit from more multiple choice options. For example, 35% of those who decided not to seek a safe location (survey question #7B) selected "Other," with many of those using the comments box to indicate that they were already in a safe location. A similar question on a future survey should include "I was already in a safe location" as an option. The list of ways to receive the warning (survey question #2) must also include "personal communication," which several respondents indicated in the "Other" field for this question.

As noted above, an essential aspect of warning communication is threat confirmation. It therefore remains particularly important to determine whether or not the warning recipient confirmed the threat from a second source of information before deciding on a course of action. This survey asks what the respondent did first upon learning of the warning message (survey question #6), so it becomes possible to guess at whether or not he or she confirmed the threat based on how he or she received the warning, but it is difficult to say with confidence whether or not the respondent did in fact confirm the threat. The survey would benefit from a question that explicitly asks the participant whether or not, and in what way, he or she took steps to confirm the threat. Lastly, open-ended questions may provide richer and more useful answers, but this format significantly complicates the data analysis.

The survey results suffer from a strong bias toward participation by those trained in meteorology, storm spotting, and emergency management. The methods by which the authors publicized the survey, and hence the media platforms through which the public learned of the study, likely contribute to this bias. Through posts via social media outlets and Web sites tailored for those interested in the weather, including storm spotter blogs, Facebook pages, and the National Weather Association home page, the publicity effort largely missed its target population of those in the general public. More participation by newspaper outlets and television broadcasts could mitigate bias in future studies.

TABLE 7. Selected reasons offered for not taking protective action in response to the open-ended portion of survey question #7B. All reasons shown here are from respondents who received the warning, interpreted it correctly, and were actually in the *path* of the storm. The text shown here has not been altered.

Warning type	**Reason for not taking protective action**
Severe thunderstorm	At work
Severe thunderstorm	warnings come early enough to wait until it is closer
Severe thunderstorm	If I had heard the siren I would have gone to the basement
Severe thunderstorm	experience with past storm warnings
Severe thunderstorm	I didn't hear sirens and I still had power.
Severe thunderstorm	We receive too many warnings to pay attention to them.
Severe thunderstorm	Storm warning, not a Tornado warning
Severe thunderstorm	Usually only do so when there is a Tornado warning.
Severe thunderstorm	did not hear any sirens
Severe thunderstorm	Storm warning, not a Tornado warning
Severe thunderstorm	There was no need to take shelter for a thunderstorm
Tornado	wanted to get home to get safe
Tornado	I would rather watch the sky than cower in a basement.
Tornado	sent children to safe place and watched weather untill storm arrived
Tornado	didnt seem that bad yet
Tornado	funnel cloud already went over house

Despite this apparent bias, the overall WSR of 17% indicates that the vast majority of the warned population does not properly utilize severe thunderstorm and tornado warnings. Several factors complicate the communication process from the National Weather Service to the user of the warning information. Ultimately, the decision to take appropriate action must rest with the recipient of the warning message. Of the survey participants who received the warning, interpreted it correctly, and were actually in the *path* of the storm, but chose not to take protective action, many offer unsettling reasons for their decisions (Table 7). Results of these and further analyses on the data collected during the present study may shed some light on how the National Weather Service can provide a more effective warning product and improve the communication process to enhance convective warning utilization among the general public.

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