The Influence of Demographic and Place Variables on Personalized Tornado Risk Area

KATHLEEN SHERMAN-MORRIS,[a] COLE VAUGHN,[a] JASON C. SENKBEIL,[b] AND STEPHEN WOOTEN[a]

[a] *Mississippi State University, Mississippi State, Mississippi*
[b] *University of Alabama, Tuscaloosa, Alabama*

(Manuscript received 24 June 2022, in final form 13 September 2022)

ABSTRACT: Although there is clear evidence that proximity to a tornado or forecast tornado increases an individual's risk perception, the specific relationships between risk personalization and spatial variables are unclear. It has also been established that one's own evaluation of distance does not always match objective measurement. This study sought to explain the differences in the distance at which an individual would personalize the risk from a tornado across personally relevant geospatial factors such as the distance between places frequented (e.g., home and work), urban/rural classification of the area, and the length of residence in the county. A survey of 1023 respondents across eight states (Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee) was used to obtain risk personalization distances, which were distinguished as "worry distances" (the distances at which one would worry about their house or loved ones, or take protective action) and "confirmation distances" (the distances at which one would expect to see, hear, or feel the effects of a tornado). We found that individuals who traveled greater distances and traveled more frequently to the grocery store and another location, those who self-defined their area as urban, and those with advanced degrees had increased risk personalization distances. Lengthier residency in the county influenced these distances as well. Future research is required to better comprehend the relationship of place, risk perception, and geographic mobility on protective action when a tornado occurs.

SIGNIFICANCE STATEMENT: Greater tornado risk personalization distances were associated with self-defining as urban, having an advanced degree, and driving farther and more frequently to the grocery store and to another location. Longer length of residence was associated with shorter risk personalization distances. With rural participants expressing shorter tornado risk personalization distances, warning communicators with the ability to tailor messages to multiple communities may wish to adjust messages no the basis of whether they are targeted to rural communities or to urban communities.

KEYWORDS: Social science; Tornadoes; Decision-making

1. Introduction

Despite advances in tornado forecasting and warning messaging, lives continue to be lost during tornadoes and most fatalities occur in permanent or mobile homes (Fricker and Friesenhahn 2022). A survey of mobile home residents in Mississippi and Alabama found that about one-half of respondents would feel safe in their home during a tornado, making them less likely to seek sturdier shelter elsewhere (Ash et al. 2020). Similar relationships are common in hurricane evacuation studies where the belief that one's home or home location is unsafe is related to evacuation (Baker 1991; Sherman-Morris et al. 2020). The home is often believed to be a place of refuge (Klockow et al. 2014), which makes it important to understand how perceptions of home and what is considered nearby relate to tornado risk perception and response to a warning.

After receiving a warning, individuals often seek to confirm the warning as well as perceive they are personally at risk before they take any protective actions (Mileti and O'Brien 1992; Wood et al. 2018). Personalization occurs when a person develops a feeling that they are at risk in a dangerous situation and that they may be personally affected (Wood et al. 2018). People also "almost constantly infer information about their environment, and how it evolves over time" (Egenhofer and Mark 1995, p. 8). This is especially true in an uncertain and rapidly evolving environment such as during a tornado warning. Place-based knowledge, emotions, or actions can influence the personalization of threat (Klockow et al. 2014). A case study on tornadoes in 2011 showed that when a tornado had entered a person's familiar environment, it became a more realistic and imminent threat to them (Klockow 2013).

Proximity to a tornado also often influences perceived risk or the decision to take protective action, although the relationship can be complicated. Proximity to a tornado's path increased likelihood of protective action (Miran et al. 2018), and proximity to a warning polygon increased the false perception one was under a tornado warning following Oklahoma tornado events (Krocak et al. 2020). Experimental tornado scenarios have also revealed a positive influence of proximity on perceived risk (Jon et al. 2019; Klockow-McClain et al. 2019; Lindell 2020) and protective decision-making (Klockow-McClain et al. 2019). However, in the real world, objective distance is not always as important as some other perceived distance.

Corresponding author: Kathleen Sherman-Morris, kms5@msstate.edu

DOI: 10.1175/WCAS-D-22-0073.1

A combination of factors interacted with previous tornado proximity to lead to different perceptions of tornado vulnerability among Oklahoma residents (Johnson et al. 2021). In that study, intense, recent, close events led to a heightened perception of risk while weak, recent, close events led to lower perceived risk. How people conceive of distance, space, and their place in it can be related to various factors such as their experiences moving around that space, known geographic biases, perceived barriers among places or similarities to locations with which they are familiar, or even momentarily relevant information (Mark et al. 1999; Tversky 2003). The knowledge people have about their geographic environment or their mental understanding of space is not always consistent with an objective assessment (Egenhofer and Mark 1995; Tversky 2003). The subjectivity of distance in the mental map can be influenced by a number of factors, many of which have emotional and psychological ties (Greer et al. 2020).

More study is needed to better understand how conceptions of geographic space influence risk perception. When faced with a proximate hazard—tornadoes in this study—how close is too close? In this paper we examine the distances at which individuals begin to worry about and take action during a tornado warning. Specifically, we focus on the contributors to the variation in these distances among different people, and especially examine the roles place and spatial movement can play in risk perception. We begin by discussing these potential influences.

2. Literature

The central focus of this paper is an investigation of how distance and other geospatial variables can factor into risk perception. Location of a person relative to the hazard has been shown to influence risk perception (Tobin and Montz 1997; O'Neill et al. 2016). In general, when a person is physically closer to a hazard, they will feel more at risk (Zhang et al. 2010; O'Neill et al. 2016; Lindell and Hwang 2008; Lindell and Perry 2012; Klockow-McClain et al. 2019). Proximity has been shown to influence likelihood of taking protective action during an actual tornado (Miran et al. 2018) and risk judgments in hypothetical tornado scenarios (Lindell 2020).

Place attachment, or the feelings of connectedness one has with a geographic location, can help explain the complexity of beliefs about risk in one's local environment (Klockow et al. 2014). When faced with a threat from industrial development, individuals with greater attachments to place saw the development as a personal threat to the safety of their homes, which were seen as a refuge or safe place (Masuda and Garvin 2006). However, because home is often experienced as a place of refuge, acknowledging it as vulnerable could be incompatible with perceptions of its safety (Klockow et al. 2014), and high levels of place attachment have been associated with lower likelihood of adopting protective measures (Greer et al. 2020). For example, rural individuals in Iceland who had a greater level of place attachment were found to be less accepting of evacuation plans in the event of a volcanic eruption (Bird et al. 2011).

Place attachment can be influenced by the length of time an individual has lived in a location (Anton and Lawrence 2014; Brown et al. 2015; Lewicka 2010), and length of residence has also been both positively (Lechowska 2018; Ruin et al. 2007) and negatively (O'Neill et al. 2016) associated with risk perception in flood research. There does not appear to be a clear relationship between length of residence and tornado risk perception. With higher place attachment and the potential for more knowledge about the surrounding area, it is possible that longer length of residency could lead to either a greater or lesser distance at which a person would feel threatened from a tornado. Homeowners typically live at an address longer than renters, which could translate into higher levels of attachment. Home ownership has been shown to increase mitigation practices and may have an influence on an individual's risk perception and more specifically how far away from a threat a person would feel threatened (Grothmann and Reusswig 2006; Qasim et al. 2015; Thistlethwaite et al. 2018).

Dependence on a place to fulfill certain needs is a common component of place attachment (e.g., Anton and Lawrence 2014; Greer et al. 2020). The concept of functional place dependence was described by Brown et al. (2015) as the spatial extent of the area that has what a person needs. This aspect of place attachment can be compared with what biologists call a home range, which is the "area traversed by the individual in its normal activities of food gathering, mating, and caring for young" (Burt 1943 in Brown et al. 2015). Those who live in rural areas are often more rooted in their area and have a greater attachment to it (Anton and Lawrence 2014; McKnight et al. 2017). While living in a rural community is often associated with higher levels of place attachment, the lack of opportunities to become involved in rural areas may also have the opposite effect on attachment (McKnight et al. 2017). Rural individuals may have farther to travel to get to work, school, and stores and traveling longer distances on a regular basis may increase what feels close. Most place attachment studies have focused on the neighborhood scale, but the scale may influence the attitude toward the place (Lewicka 2010). The highest levels of place attachment in Lewicka's (2010) study of four cites were found at the neighborhood level. The purpose or nature of travel among locations may be important in understanding whether place attachment is likely (Gustafson 2014). The association of mobility with place attachment can be more complex than initially conceived where individuals may become attached to multiple places, or even make themselves "at home" in their cars, becoming a "contemporary place of dwellingness" (Gustafson 2014, p. 42).

3. Hypotheses and research question

The primary goal of the study was to explain differences in the distance at which an individual would personalize the risk from a tornado. We expected there to be some differences based on demographics but were most interested in differences that could be related to spatial factors. Based on the concept of functional place dependence, one component of place attachment, we expected people who routinely travel farther distances to personalize tornado risk at greater distances due to the larger area they are dependent upon. We anticipated urban dwellers to name smaller risk personalization distances based on what we expected to be smaller distances they routinely travel. Because length of time in a location is also associated with greater attachment to place, we also expected length of residence to place a role. Thus, we proposed the following hypotheses:

H1: People who routinely travel farther distances will express greater risk personalization distances.
H2: Personalized risk distances will be influenced by classification of the area as urban or rural where (H2a) people living in urban areas name risk personalization distances that are smaller than people in rural areas.
H3: Personalized risk distances will be influenced by length of residence.
H4: People living in urban areas will identify routine travel areas that are smaller than people in rural areas, and
H5: (H5a) People living in rural areas will express a greater perceived knowledge of their surrounding counties than people in urban areas (H5b) because of the greater functional dependence on the county expressed through farther travel distances and (H5c) because people living in rural areas will have longer lengths of residence.

To account for other factors, we raised the research question, How do other factors such as education, gender, use of weather information, and previous exposure to a tornado explain differences in risk personalization distances?

4. Methods

a. Measures

The study used an online survey administered by Qualtrics. The full survey consisted of multiple parts, some of which will not be discussed in this paper. [See Sherman-Morris et al. (2022) and Senkbeil et al. (2022) for additional information.] Relevant to the purpose of this paper, the survey included questions about geographic place and functional place dependence, characteristics of a participant's home location including how long they lived there and their perceived knowledge of the area, weather forecast behaviors, demographic information, and preferred distances related to risk personalization.

The key dependent variables in the study were risk personalization distances, a set of six questions that we refer to as worry distances and expected confirmation distances. Both were related to the concept of risk personalization and were based on past work by Demuth (2018) who included statements about worry for one's house in a tornado, fear for loved ones, and whether one had heard a storm firsthand or saw scenes from it. Because our survey's focus was on a hypothetical tornado, it was necessary to modify the questions slightly. The first three statements measure what we refer to as worry distance.

- I would worry about my loved ones if a tornado was within (x) miles.
- I would worry about my house if a tornado was within (x) miles.
- I would act to protect myself or my loved ones if a tornado was within (x) miles.

The following three statements measured expected confirmation distance.

- I think I would be able to see a tornado if it was within (x) miles.
- I think I could hear a tornado if it was within (x) miles.
- I think I would be able to feel the effects of the tornado firsthand if it was within (x) miles.

All participants responded to these statements using a slider bar format in which they could drag the bar to values ranging from 0 to 25 mi (1 mi ≈ 1.61 km). We chose 0–25 mi to exceed the width of a large tornado polygon. Values were labeled at 5-mi increments.

A set of place-based questions was informed by the concept of functional place dependence (Brown et al. 2015), a component of place attachment. In our survey, we chose to include questions about travel to work, travel to the grocery store, and travel to one other place of the participant's choosing to capture their home range or the area upon which they were functionally dependent. Questions included the following:

- About how far away from your home (in miles) is your workplace/grocery store where you shop most often/any one of the other places you visit regularly?
- About how long does or would it take you to travel there (in minutes)?
- How frequently do you currently commute to your workplace/usually travel to this location?
- Do you consider this close to home?

Questions asking how far and how long were open ended, whereas the other two provided answer choices. Because we administered this survey during the COVID-19 pandemic, we included questions to account for participants who were currently working from home such as asking them how frequently they would normally commute. For the question about the workplace, participants were also asked how long they have or had been making their normal commute.

Other place-based questions included county name, how a participant would rate their knowledge of their home county, how long they have lived in their current county, as well as at their current address, and whether they own or rent. Participants were also asked to provide their zip code. For sampling, zip code determined whether a participant was urban or rural based on the 2010 Rural-Urban Commuting Area (RUCA) Codes from the USDA Economic Research Service. This dataset stratifies land areas based on zip codes and assigns them a number on a scale from 1 to 10 ranging from highly urbanized metropolitan areas (choice 1) to highly rural areas (choice 10). RUCA considers numbers 1–3 metropolitan, 4–6 micropolitan, 7–9 small town, and 10 rural. For the purpose of our sample in the Southeast, numbers 1–3 were easily classified as urban and 7–10 were classified rural. Zip codes that were assigned numbers 4–6 were further examined.

TABLE 1. Sample characteristics.

Characteristic	Category	Percentage
Whether zip code was classified as urban or rural	Rural	34.5%
	Urban	65.5%
Highest level of education completed	Some high school	3.5%
	High school diploma or GED	23.8%
	Some college, technical school, or associate	29.8%
	Bachelor's degree	19.4%
	Advanced degree	22.7%
	Prefer not to answer	0.9%
Gender	Female	51.1%
	Male	47.9%
	Other responses	1%
Age (yr)	Min 18, max 92, and avg 44.5 (std dev 16.8)	

Based on coding of small towns in the parts of the sample area where the research team was most familiar, 4 was labeled urban while zip codes outside these towns, numbered 5–6, were designated as rural. In addition to screening participants based on their zip code, we believed perceptions of the area as urban or rural would be meaningful and perhaps not the same as their RUCA designation (Onega et al. 2020). Therefore, participants were also asked to describe where they live as urban, suburban, rural small town, or rural outside a town.

Last, participants were asked about their past experiences with tornadoes, weather forecast behaviors and demographic information. Questions included where they had seen or heard a forecast in the last 24 h, whether they use any weather applications, what sources they use for tornado warning information and other questions about the information they seek to confirm a tornado warning. Questions about past experiences queried how much experience participants had with being under a tornado warning, hearing tornado sirens, and seeing news coverage about the aftermath of a tornado, as well as approximately how close they had come to a tornado. Demographic questions gathered information about gender, race or ethnicity, type of housing, age, and education level.

b. Sample

A Qualtrics Panel provided 1023 responses to the survey. Participants were screened at the beginning of the survey to provide an adequate distribution as described below based on age, zip code, education, and gender. The sample area was chosen to represent states in the southeastern United States that regularly experienced tornadoes. As described in Sherman-Morris et al. (2022), zip codes were used to recruit participants from portions of eight states (Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee), and also to recruit at least 30%–40% of participants from rural areas. For reasons discussed above, we considered zip codes 1–4 to be urban and 5–10 rural. We also requested from Qualtrics an approximately equal ratio of male to female (among those identifying as either male or female), at least 50% of participants who had an education level of some college or less, and a sample with participants' ages fairly evenly distributed among age groups 18–34, 35–55, and older than 55. See Table 1 for actual sample characteristics.

5. Descriptive results

a. Risk personalization distances

The two sets of dependent variables measuring risk personalization distance were worry distances and expected confirmation distances. The average distance at which a participant would worry about their house in a tornado was 12.3 mi (std dev 7.7 mi). They would worry about their house or take action to protect themselves or loved ones if a tornado were closer to 11 mi [11.0 mi (std dev 7.7 mi) and 11.1 mi (std dev 7.6 mi) respectively]. The distances at which participants expected to be able to confirm a tornado were closer to 8 mi, or 7.8 mi (std dev 6.9 mi) to see a tornado and 7.7 mi (std dev 7.0 mi) to hear one as well as feel the effects of one. These distances are discussed in greater detail in Sherman-Morris et al. (2022).

b. Place-based responses

Participants rated their knowledge of their home county very well; the most frequent response was excellent (43%) followed by good (40.6%). They have also lived in their current county for a lengthy time, with 41.6% living there 20 years or longer (see Table 2). Participants were well mixed with regard to how long they have lived at their current address. The most frequent response was between 5 and 10 years (19.4%), but the lowest response category (less than one year) had 12.7%. In addition to the demographic information presented in Table 1, participants were also asked about their type of housing, whether they owned or rented, and how they would characterize their location. Most (68.6%) owned their home. Participants were mixed in how they described their location with the greatest percentage describing it as suburban (27.5%) and the smallest percentage describing it as rural outside a town (19.6%).

We based functional place dependence on the distances in miles regularly traveled to work, the grocery store and one other location regularly visited and compared the distances among urban and rural locations. Values that were too large to seem realistic (e.g., 1000 or 300 mi) were removed. The most frequently reported distances for each location were 5 mi or less, which accounted for almost one-half of the reported distances to the grocery store (47.5%) and other

TABLE 2. Place-based sample characteristics.

Question	Response category	Percentage
Length of time in current county (current address)	Less than 1 year	6.6 (12.7)
	At least 1 year but less than 3	11.2 (17.4)
	At least 3 years but less than 5	10 (14.6)
	At least 5 years but less than 10	13.9 (19.4)
	At least 10 years but less than 20	16.7 (18.5)
	20 years or longer	41.6 (17.5)
How would you describe where you live?	Urban	26.5
	Suburban	27.5
	Rural small town	26.4
	Rural outside a town	19.6
How would you describe your home?	Mobile or manufactured	16.1
	Single-family home primarily brick	37.1
	Single-family home primarily wood	30.5
	Multifamily/apartment	13.4
	Some other type	2.9
Do you own or rent your home?	Own	68.6
	Rent	31.4

location (40.6%) but only 29.2% of distances traveled to work. The average distances traveled to these locations were 12.8 mi (std dev 15.4 mi) to work, 7.7 mi (std dev 9.8 mi) to the grocery store, and 9.9 mi (std dev 13.2 mi) to the other location (Fig. 1). Because we expected people to worry about a tornado and personalize the risk only when they believed it was close, we filtered responses to the distances traveled by whether a participant believed that location (work, grocery or other) was close. The majority of participants (83.2%) considered their work location close to home. The average distances that were considered close were 10.4 mi (std dev 14.2 mi) for work, 7 mi (std dev 9.2 mi) for the grocery, and 8 mi (std dev 9.7 mi) for the other location. Approximately 70% reported traveling to work at least 5 times per week, and if not for the pandemic, the number would have been approximately 74%. Once per week or less was the most common frequency of travel to the grocery store or the other location (43.8% and 47.7%), although over 20% reported traveling to these locations 5 times per week or more.

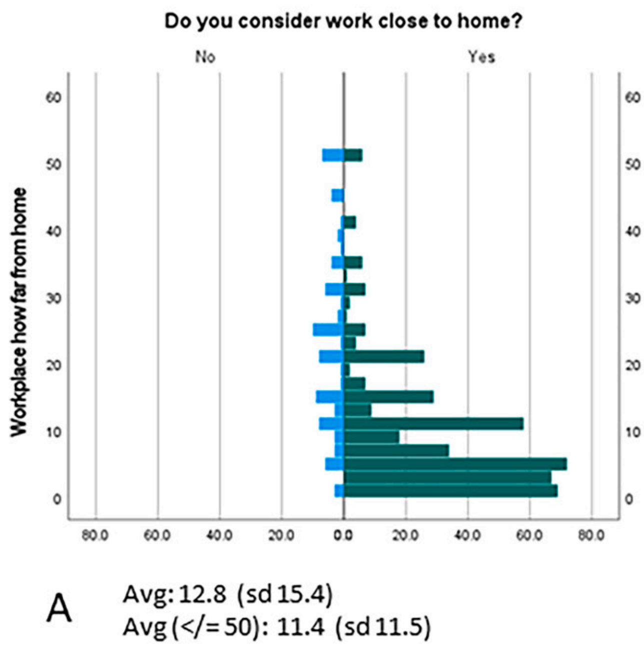
c. *Weather information use*

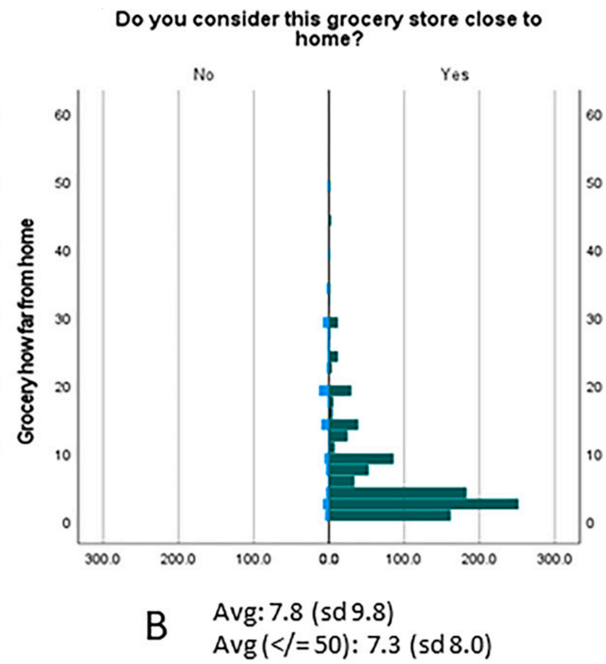
The top five sources of weather information used most frequently by participants in the 24 h prior to taking the survey were a mobile device weather application, local television news, National Weather Service products (either through a website or social media), radio, and the Weather Channel on television (Fig. 2). Three-quarters of respondents had used at least one source of weather information in the last 24 h. A new variable was created to sum the number of sources participants reported using in the last 24 h. The most frequent response was only one source (28.8%) followed by no sources (25.1%). An additional 28.9% reported using two or three sources.

The top five sources for tornado warning information were mobile device weather applications, local television broadcasts, mobile device emergency weather alert notifications, sirens, and National Weather Service products (Fig. 2). When asked where they typically first find out they are under tornado warning, the most frequent responses were local television (19.1%), a mobile device emergency weather alert notification (18.4%), and mobile device weather applications (16.1%). If under a tornado warning, 40.8% would seek out more information "all of the time" before taking shelter. The additional information sought could include watching a meteorologist describe the severe weather threat, checking the way the storm looks on radar, and/or looking at their location in relation to the tornado polygon, which 35.9%, 35.6%, and 37.4% of participants reported doing all of the time.

6. Statistical analysis

In the first hypothesis, we proposed that people who routinely travel farther distances will express greater risk personalization distances. When exploring the relationship between routine distances traveled and risk personalization distances using Spearman correlation, we found no relationship between the distance traveled to work and worry distances or expected confirmation distances. There were significant relationships between travel time to work and the distance at which one expected to hear ($r_s = 0.110$; $p = 0.011$) and feel the effects of a tornado ($r_s = 0.108$; $p = 0.012$). None of the other times traveled to locations were significantly related with risk personalization distances. Significant relationships were found between distance to the grocery store and worry about loved ones ($r_s = 0.074$; $p = 0.018$) and also distance to the other location and worry about loved ones ($r_s = 0.086$; $p = 0.007$), worry about one's house ($r_s = 0.063$; $p = 0.05$), and distance at which one expected to see a tornado ($r_s = 0.069$; $p = 0.032$). All of the relationships were positive, but fairly weak. To further explore the notion that it is the regularity of the travel and not just the distance that may be influential on risk personalization distances, new variables were created that reflected both distance and frequency of travel (frequency weighted distances). These new variables were created by multiplying the distance traveled to work, grocery or the other





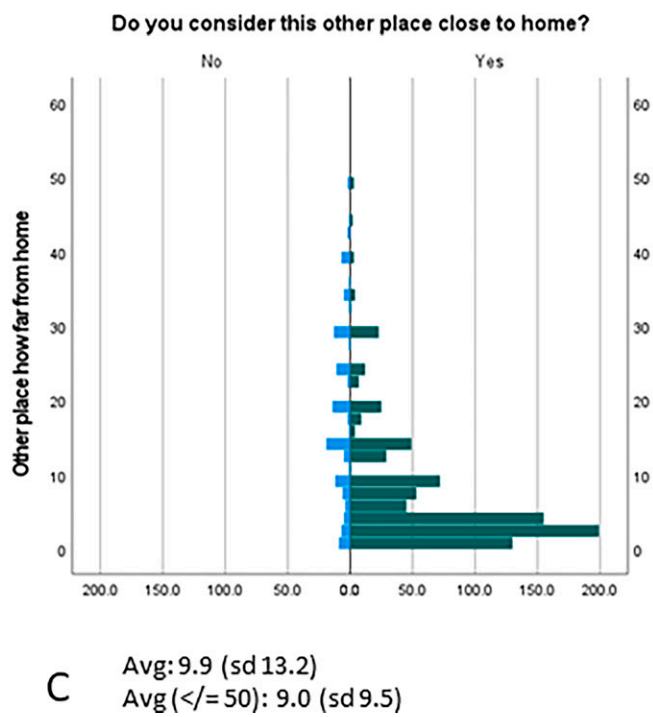


FIG. 1. Distances traveled to (a) work, (b) the grocery store, and (c) some other location, with distances greater than 50 mi removed. Horizontal bars show the number of participants who believed that distance was (right side) or was not (left side) close to home.

5 times = 2, 5 times = 3, and more than 5 times = 4). When frequency weighted distances were compared with the risk personalization distances, positive, significant relationships were found between frequency weighted travel to the grocery store as well as the other location with all worry and confirmation distances. The correlations ranged from the lowest significant value for frequency weighted distance to the grocery store and the distance at which one would protect oneself (r_s = 0.071; which one expected to feel the effects of a tornado (r_s = 0.173; $p < 0.001$). While the correlation is still somewhat weak, there appears to be a relationship between the regularity of travel within a certain distance and what is considered close enough to personalize risk from a tornado.

Hypothesis 2 proposed that personalized risk distances will be influenced by classification of the area as urban or rural where people living in urban areas name risk personalization

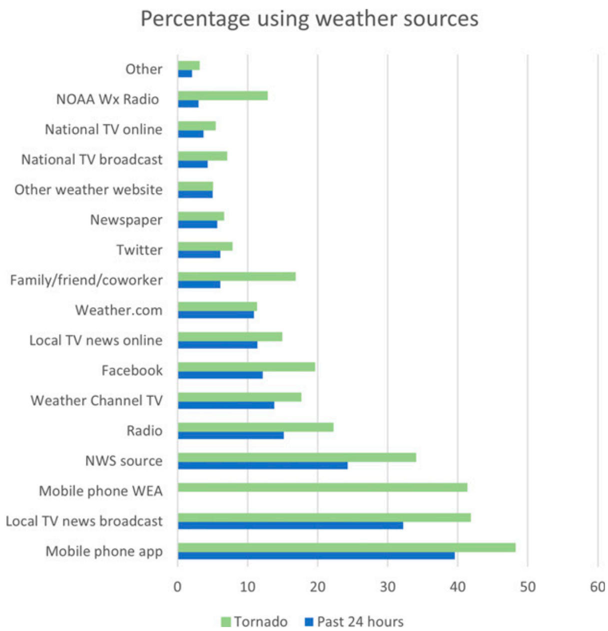


FIG. 2. Percentage of participants using sources of weather information in the last 24 h and for tornado warning information.

distances that are smaller than people in rural areas. To test this hypothesis, we first used an independent samples Mann–Whitney U test for nonparametric data. This test was chosen because the distances were not normally distributed. When examining differences in the three worry distances and three expected confirmation distances based on zip code classification, we found no significant differences between urban and rural zip codes with respect to worry distances ($p > 0.05$). However, each of the expected confirmation distances was significantly different based on urban versus rural zip code. Mean ranks were higher in the urban category for each item, indicating higher distances but only significant for the distance at which a participant thought they could see ($p < 0.001$), hear ($p = 0.007$), or feel the effects of a tornado ($p = 0.007$). The distance at which someone would take action approached significance ($p = 0.056$). When using the participants' self-described location classification, a Kruskal–Wallis test for multiple independent samples found significant differences in all of the risk personalization distances (Table 3). Pairwise comparisons indicated that those who described their home location as urban expressed greater risk personalization distances than those self-describing as suburban, rural small town and rural outside a town for each of the three worry distances and each of the three expected confirmation distances. Once again, urban risk personalization distances were higher than the other locations.

To explore the influence of the urban/rural distinction as well as the influence routine travel distance may have on risk personalization distances, we examined differences in travel behavior among the location classifications (Table 4). In hypothesis 4, we proposed that people living in urban areas will identify routine travel areas that are smaller than people in rural areas. Those participants who lived in zip codes classified as urban expressed longer travel times to work, but shorter travel times to the other location, and shorter travel times and shorter travel distances to the grocery store. These differences were significant in a Mann–Whitney U test. When using self-defined location classifications, a Kruskal–Wallis test indicated significant differences among the location categories for time and distance traveled to each location. However, because of the number of pairwise comparisons, some of the pairwise differences between location categories lost significance when adjusted. All pairs were significantly different for distance traveled to the grocery store except for urban versus suburban, with distance values increasing the more rural the location is described. Similar results were found for distance to the other location. All pairs of locations had significantly different distances to the other location except urban versus suburban and urban versus rural small town, which approached significance ($p = 0.07$).

There were other factors that may help to explain differences in risk personalization distances based on location classification. The length of time living in one's county influenced worry distances and expected confirmation distances as suggested in hypothesis 3. A Kruskal–Wallis test found significant differences across all risk personalization distances overall ($p < 0.001$ for each of the distances but worry about loved ones, for which $p = 0.024$). A number of pairwise comparisons were also significant. There were no significant pairwise differences for worry about loved ones, but for each of the other worry distances and expected confirmation distances,

TABLE 3. Results of Mann–Whitney *U* (rows 1–2) or Kruskal–Wallis (rows 3–8) tests for significant differences in risk personalization distances among locations. The table displays the significance level of the difference, with the location of significantly greater distance in boldface type.

	Loved ones	House	Protect self/others	See	Hear	Feel effects
Urban vs rural (zip code)	0.441	0.124	0.056	<0.001	0.007	0.007
Self-described location (overall)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Urban vs suburban[a]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Urban vs rural small town[a]	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Urban vs rural outside a town[a]	0.007	<0.001	<0.001	<0.001	<0.001	<0.001
Suburban vs rural small town[a]	0.178	1	1	1	1	1
Suburban vs rural outside a town[a]	0.142	1	1	0.61	0.937	1
Rural small town vs rural outside a town[a]	0.821	1	1	1	1	1

[a] Significance adjusted because of the large number of comparisons.

TABLE 4. Results of Mann–Whitney U (rows 1–2) or Kruskal–Wallis (rows 3–8) tests for significant differences in routine travel distances and time among locations. The table displays the significance level of the difference, with the location of significantly greater distance in boldface type.

	Work distance	Work time	Grocery distance	Grocery time	Other distance	Other time
Urban vs **rural (zip code)**	0.355	0.001	<0.001	0.001	<0.001	0.52
Self-described location (overall)	0.024	0.037	<0.001	<0.001	<0.001	<0.001
Urban vs suburban[a]	1	0.109	1	0.133	1	0.404
Urban vs **rural small town**[a]	0.083	0.084	<0.001	1	0.07	0.542
Urban vs **rural outside a town**[a]	0.196	1	<0.001	<0.001	<0.001	0.111
Suburban vs **rural small town**[a]	0.216	1	<0.001	0.628	0.019	1
Suburban vs **rural outside a town**[a]	0.389	1	<0.001	<0.001	<0.001	<0.001
Rural small town vs **rural outside a town**[a]	1	1	<0.001	<0.001	<0.001	0.001

[a] Adjusted because of the large number of comparisons.

significant differences existed between those who had lived in their county 20 years or more and those who had only lived there 1–3 years or 3–5 years. Additional pairs were significantly different for confirmation distances, including the distance at which one expected to hear or feel the effects of a tornado when comparing 10–20 years with the three groups indicating less than 5 years. Chi-squared analyses indicated significant associations between length of residence (at current address and county) and both classifications of location (zip code and self-defined) where rural residents, especially those who described their location as rural outside a town, were more likely to live in their current address or county for 20 years or longer.

Risk personalization distances were also significantly different based on a participant's professed knowledge of their county. Differences were significant based on a Kruskal–Wallis test overall ($p < 0.001$). Distances were also significantly different for all worry and expected confirmation distances between those who perceived their county knowledge as excellent and those who perceived their knowledge as good ($p < 0.001$). Differences for all expected confirmation distances were also significant ($p < 0.001$) between those who perceived their county knowledge as excellent and those who perceived their knowledge as fair. The overall significance appeared to be the result of lower distances among those who perceived their knowledge to be good or fair. Hypothesis 5 proposed that people living in rural areas will express a greater perceived knowledge of their surrounding counties than people in urban areas. A chi-squared test indicated a significant level of association between self-defined location type and professed knowledge [$\chi^2 = 52.048$, with degrees of freedom (df) = 9; $p < 0.001$]. Professed knowledge was higher among those self-describing as urban. The same held true when comparing urban and rural on the basis of zip code ($\chi^2 = 119.869$, with df = 3; $p < 0.001$). Perceived knowledge was not related to travel distances to work or the grocery store and weakly related to travel to the other location ($r_s = 0.075$; $p = 0.019$).

Greater risk personalization distances were also associated with having an advanced degree and being male. When comparing only those identifying as male or female in a Mann–Whitney test, males expressed higher confirmation distances for seeing, hearing, and feeling the effects of a tornado ($p < 0.001$, $p = 0.004$, and $p = 0.22$, respectively). Males also would take action to protect themselves or loved ones at a greater distance ($p = 0.048$). Education led to a significant difference in a Kruskal–Wallis test for all risk personalization distances overall but there were very few significant differences among pairs of education categories. Those with advanced degrees had higher distances than those with some college for all worry and confirmation distances, those with a high school diploma for all but worry about loved ones, and those with a bachelor's degree for each of the confirmation distances and worry about one's house (adjusted p values ranged from <0.001 to 0.012). Those with no high school diploma/General Educational Development (GED) also tended to also have higher distances, but this class was not significantly different from any of the other classes. There was some interaction among these factors. For example, individuals classified as urban tended to be more educated. This was true whether comparing across self-defined location types ($\chi^2 = 242.44$, with df = 15; $p < 0.001$) or by zip code classification ($\chi^2 = 74.30$, with df = 5; $p < 0.001$). Urban residents (as discussed above) as well as homeowners (χ^2 11.999, with df = 3; $p = 0.007$) professed a higher level of knowledge of their county. In a Kruskal–Wallis test, urban residents also used a greater number of weather sources than did those who described their location as rural outside a town ($p = 0.001$) or rural small town ($p = 0.025$).

Separately published results from the same sample (Sherman-Morris et al. 2022) indicated that participants who believed they had been closer to a tornado in the past expressed shorter worry and confirmation distances. To explore this relationship further, we summed the three types of experiences with tornadoes (being under a warning, hearing sirens, and seeing news coverage) and tested for any relationships with worry distance and confirmation distance. The sum of tornado experiences was only significantly related to the distance at which participants expected to be able to see a tornado ($r_s = -0.63$; $p = 0.045$). As might be expected, participants who thought they had been closer to a tornado had a greater level of experiences with warnings, sirens, and news coverage. Participants who described their location as rural small town or rural outside a town reported being closer to a tornado than would be expected statistically while the opposite was true for urban or suburban participants. This association was significant in a chi-squared test ($\chi^2 = 33.77$;

TABLE 5. Hypotheses and summary of results. The tests on which the results are based are listed in parentheses. For example, (χ^2) indicates a chi-squared test, (KW) indicates Kruskal–Wallis, (MW) indicates Mann–Whitney, and (SC) indicates Spearman correlation.

Hypothesis	Summary of results
H1: People who routinely travel farther distances will express greater risk personalization distances	H1: Generally not supported for travel to work; supported for travel to grocery and other location (SC)
H2: Personalized risk distances will be influenced by classification of the area as urban or rural where H2a: people living in urban areas name risk personalization distances that are smaller than people in rural areas	H2: Mixed, generally supported— Not supported for worry distances comparing urban vs rural zip codes (MW) Supported for confirmation distances urban vs rural zip codes (MW) Supported when comparing across self-defined location type (KW) Supported when comparing self-defined urban location with each other location (KW; pairwise) H2a: Not supported; distances were greater in urban zip codes (when significant) across tests
H3: Personalized risk distances will be influenced by length of residence	H3: Supported— Supported when comparing across length of time in county overall (KW) Supported across multiple pairs with residents in the current county for 20 yr or more expressing shorter distances where significant (KW; pairwise)
H4: People living in urban areas will identify routine travel areas that are smaller than will people in rural areas	H4: Mixed— Supported for comparing distance to grocery store urban vs rural zip codes (MW) Not supported when comparing distance to work urban vs rural zip codes (MW); urban zip codes were longer Supported when comparing self-defined urban location with both rural locations for distance to grocery and other (KW, pairwise); in general, these distances became greater the less self-described urban was the location
H5a: People living in rural areas will express a greater perceived knowledge of their surrounding counties than people in urban areas (H5b: because of the greater functional dependence on the county expressed through farther travel distances and H5c: because people living in rural areas will have longer lengths of residence)	H5a: Not supported; an association existed but those in urban areas professed greater knowledge (χ^2) H5b: Not supported; perceived knowledge was not related to travel distances to work or the grocery store and weakly related to travel to the other location (SC) H5c: Supported; longest lengths of residence were associated with individuals living in rural areas (χ^2)

$p = 0.004$). There was also a significant association between perceived distance of exposure to a tornado and education ($\chi^2 = 63.38$; $p < 0.001$). There was not a clear pattern among the education groups; however, individuals with an advanced degree were less likely than expected statistically to have experienced a tornado in less than 1 mi.

7. Discussion and conclusions

We expected people who travel farther distances to express greater risk personalization distances due to a sense that the larger area represented their home range, an area upon which they are functionally dependent, which is a component of place attachment. (A summary of the research hypotheses and results is provided in Table 5.) Positive relationships were identified between travel to the grocery store or travel to the other location and some of the worry and confirmation distances. The positive relationships became much more consistent when incorporating a frequency of travel value, especially for travel to the grocery and other location. This may indicate positive influence of one's voluntary travel behavior on risk personalization area. However, if someone has a lower perception of what is close, they may preferentially go to closer places. This could explain why travel distance and travel time to work was not related to any of the worry distances.

We also anticipated that rural dwellers would be the ones to have a larger area upon which they were functionally dependent. This was true to some extent. Participants in urban zip codes traveled farther for work, but generally distances to the other two locations tended to be greater the more rural the home location was described. Even though we found positive relationships between functional travel area and risk personalization distances, when we found significant differences based on self-described location, risk personalization distances were greater in urban zip codes. This suggests other factors such as those we discuss below are likely responsible for greater urban risk personalization distance other than the area regularly traveled.

Our results may suggest that the rootedness often felt in rural locations is likely more important in explaining shorter risk personalization distances than functional place attachment. Pew Research Center results support that rural residents are less mobile (more rooted) by choice (Parker et al. 2018). In our sample, rural-outside-a-town residents have lived at their address and in their county longer. Despite being exposed to a greater area via routine travel distance, rural residents may conceive of their home location as smaller due to less lifetime mobility. Future studies should attempt to capture the feeling of rootedness with respect to risk personalization distance to determine whether it can explain some of these place-based differences.

There may be other, demographic variables that can also explain urban versus rural differences in risk personalization distance. Generally, people who were urban had higher levels of education, lived in their county a shorter period of time, had higher professed county knowledge, and used a greater number of weather sources. Urban residents also did not report being as close to a tornado in the past as was expected statistically while the opposite was true for rural residents. Direct relationships between education level and tornado risk perception or action are inconsistent. For example, education did not predict taking protective action during an Oklahoma tornado (Miran et al. 2018), but having less than a high school education was related to a fatalistic response in multiple 2000–01 tornadoes (Schmidlin et al. 2009). Education may be important in its association with other factors such as safety of housing (Miran et al. 2018). The relationship (if any) between length of residence and tornado risk perception or action is not clear. Future research should consider the influence of geographic mobility and migration into tornado-prone areas on risk perception. Research should also examine the relationships between number of weather information sources, risk perception and protective action. Using a greater number of weather information sources was associated with taking protective action during the 2011 Joplin, Missouri, tornado (Luo et al. 2015) and the 2018 Oklahoma City, Oklahoma, tornado (Miran et al. 2018) but not the 2011 Tuscaloosa, Alabama, tornado (Luo et al. 2015). The number of information sources used prior to Hurricane Irma was positively related with risk perception, but not evacuation, which may indicate higher perceived risk was responsible for the greater number of sources used (Sherman-Morris et al. 2020). Future research should also incorporate risk propensity in understanding differences between urban and rural residents. Additional research into weather-related behaviors should also consider concepts such as weather salience (Stewart et al. 2012) or personal motivations for weather information use (Demuth et al. 2011), which may help explain how weather information relates to risk perception.

There were some limitations associated with our research. We did not measure place identity, which is a measure of the emotional attachment to the home due to limitations of the survey. In addition to our desire to minimize response fatigue, the variety of locations that participants live in would each require specific survey questions, making personalized questions about identity with the home location more challenging. Thus, we were not able to fully capture the role place attachment might play in risk personalization. Future work should incorporate other measures of place dependence and place identity from literature on place attachment. The sample also had limitations. The sample used quotas to reach targeted values for several important variables but was not fully representative of the population of the eight states or the U.S. population as a whole.

To summarize, our results suggest that greater risk personalization distances were associated with self-defining as urban, having an advanced degree, driving farther and more frequently to the grocery store and another location, and, to some extent, being male. One of the worry distance measures asked about likelihood of taking shelter, so the results suggest that these characteristics could be related to both risk perception and protective action. Because one possible explanation for rural participants expressing shorter risk personalization is that they conceive of their home area as being smaller through length of residence, homeownership, and a sense of rootedness, warning communicators may be more effective if they adjust messages targeted to rural communities in a way that counters the perception of home as a place of safety (Masuda and Garvin 2006; Klockow et al. 2014). It may also be possible for warning communicators to relate the average distances considered to be close with respect to grocery stores and other locations to the location of a tornado. These voluntarily traveled distances as well as all of the average confirmation distances were approximately 7–8 mi, whereas the average worry distances were 11–12 mi. It seems reasonable to expect that one would only expect to see, hear, or feel the effects of a tornado if it were close by, so the similarities of these results may help demonstrate what the average individual considers truly close and not just close enough to start worrying about. Further research is needed to more fully understand the idea of what is perceived as close with respect to tornadoes as well as the influences of place, geographic mobility, and risk perception on protective action during a tornado.

Acknowledgments. This material is based upon work supported by the Vortex SE Program within the NOAA/OAR Office of Weather and Air Quality under Grant NA19OAR459029.

Data availability statement. Deidentified data will be made available upon request upon completion of the project.

REFERENCES

Anton, C. E., and C. Lawrence, 2014: Home is where the heart is: The effect of place of residence on place attachment and community participation. *J. Environ. Psychol.*, **40**, 451–461, https://doi.org/10.1016/j.jenvp.2014.10.007.

Ash, K. D., M. J. Egnoto, S. M. Strader, W. S. Ashley, D. B. Roueche, K. E. Klockow-McClain, D. Caplen, and M. Dickerson, 2020: Structural forces: Perception and vulnerability factors for tornado sheltering within mobile and manufactured housing in Alabama and Mississippi. *Wea. Climate Soc.*, **12**, 453–472, https://doi.org/10.1175/WCAS-D-19-0088.1.

Baker, E. J., 1991: Hurricane evacuation behavior. *Int. J. Mass Emerg. Disasters*, **9**, 287–310.

Bird, D. K., G. Gísladóttir, and D. Dominey-Howes, 2011: Different communities, different perspectives: Issues affecting residents' response to a volcanic eruption in southern Iceland. *Bull. Volcanol.*, **73**, 1209–1227, https://doi.org/10.1007/s00445-011-0464-1.

Brown, G., C. M. Raymond, and J. Corcoran, 2015: Mapping and measuring place attachment. *Appl. Geogr.*, **57**, 42–53, https://doi.org/10.1016/j.apgeog.2014.12.011.

Demuth, J. L., 2018: Explicating experience: Development of a valid scale of past hazard experience for tornadoes. *Risk Anal.*, **38**, 1921–1943, https://doi.org/10.1111/risa.12983.

——, J. K. Lazo, and R. E. Morss, 2011: Exploring variations in people's sources, uses, and perceptions of weather forecasts. *Wea. Climate Soc.*, **3**, 177–192, https://doi.org/10.1175/2011WCAS1061.1.

Egenhofer, M. J., and D. M. Mark, 1995: Naïve geography. *Spatial Information Theory: A Theoretical Basis for GIS*, A. U. Frank and W. Kuhn, Eds., Lecture Notes in Computer Science, Vol. 988, Springer, 1–15.

Fricker, T., and C. Friesenhahn, 2022: Tornado fatalities in context: 1995–2018. *Wea. Climate Soc.*, **14**, 81–93, https://doi.org/10.1175/WCAS-D-21-0028.1.

Greer, A., S. B. Binder, A. Thiel, M. Jamali, and A. Nejat, 2020: Place attachment in disaster studies: Measurement and the case of the 2013 Moore tornado. *Popul. Environ.*, **41**, 306–329, https://doi.org/10.1007/s11111-019-00332-7.

Grothmann, T., and F. Reusswig, 2006: People at risk of flooding: Why some residents take precautionary action while others do not. *Nat. Hazards*, **38**, 101–120, https://doi.org/10.1007/s11069-005-8604-6.

Gustafson, P., 2014: Place attachment in an age of mobility. *Place Attachment: Advances in Theory, Methods and Applications*, L. Manzo, and P. Devine-Wright, Eds., 1st ed. Routledge, 37–48, https://doi.org/10.4324/9780203757765.

Johnson, V. A., K. E. Klockow-McClain, R. A. Peppler, and A. M. Person, 2021: Tornado climatology and risk perception in central Oklahoma. *Wea. Climate Soc.*, **13**, 743–751, https://doi.org/10.1175/WCAS-D-20-0137.1.

Jon, I., S. K. Huang, and M. K. Lindell, 2019: Perceptions and expected immediate reactions to severe storm displays. *Risk Anal.*, **39**, 274–290, https://doi.org/10.1111/risa.12896.

Klockow, K. E., 2013: *Spatializing Tornado Warning Lead-time: Risk Perception and Response in a Spatio-temporal Framework*. University of Oklahoma, 284 pp.

——, R. A. Peppler, and R. A. McPherson, 2014: Tornado folk science in Alabama and Mississippi in the 27 April 2011 tornado outbreak. *GeoJournal*, **79**, 791–804, https://doi.org/10.1007/s10708-013-9518-6.

Klockow-McClain, K. E., R. A. McPherson, and R. P. Thomas, 2019: Cartographic design for improved decision making: Trade-offs in uncertainty visualization for tornado threats. *Ann. Amer. Assoc. Geogr.*, **110**, 314–333, https://doi.org/10.1080/24694452.2019.1602467.

Krocak, M. J., S. Ernst, J. N. Allan, W. Wehde, J. T. Ripberger, C. L. Silva, and H. C. Jenkins-Smith, 2020: Thinking outside the polygon: A study of tornado warning perception outside of warning polygon bounds. *Nat. Hazards*, **102**, 1351–1368, https://doi.org/10.1007/s11069-020-03970-5.

Lechowska, E., 2018: What determines flood risk perception? A review of factors of flood risk perception and relations between its basic elements. *Nat. Hazards*, **94**, 1341–1366, https://doi.org/10.1007/s11069-018-3480-z.

Lewicka, M., 2010: What makes neighborhood different from home and city? Effects of place scale on place attachment. *J. Environ. Psychol.*, **30**, 35–51, https://doi.org/10.1016/j.jenvp.2009.05.004.

Lindell, M. K., 2020: Improving hazard map comprehension for protective action decision making. *Front. Comput. Sci.*, **2**, 27, https://doi.org/10.3389/fcomp.2020.00027.

——, and S. N. Hwang, 2008: Households' perceived personal risk and responses in a multihazard environment. *Risk Anal.*, **28**, 539–556, https://doi.org/10.1111/j.1539-6924.2008.01032.x.

——, and R. W. Perry, 2012: The protective action decision model: Theoretical modifications and additional evidence. *Risk Anal.*, **32**, 616–632, https://doi.org/10.1111/j.1539-6924.2011.01647.x.

Luo, J., Z. Cong, and D. Liang, 2015: Number of warning information sources and decision making during tornadoes. *Amer. J. Prev. Med.*, **48**, 334–337, https://doi.org/10.1016/j.amepre.2014.09.007.

Mark, D. M., C. Freksa, S. C. Hirtle, R. Lloyd, and B. Tversky, 1999: Cognitive models of geographical space. *Int. J. Geogr. Inf. Sci.*, **13**, 747–774, https://doi.org/10.1080/136588199241003.

Masuda, J. R., and T. Garvin, 2006: Place, culture, and the social amplification of risk. *Risk Anal.*, **26**, 437–454, https://doi.org/10.1111/j.1539-6924.2006.00749.x.

McKnight, M. L., S. R. Sanders, B. G. Gibbs, and R. B. Brown, 2017: Communities of place? New evidence for the role of distance and population size in community attachment. *Rural Sociol.*, **82**, 291–317, https://doi.org/10.1111/ruso.12123.

Mileti, D. S., and P. W. O'Brien, 1992: Warnings during disaster: Normalizing communicated risk. *Soc. Probl.*, **39**, 40–57, https://doi.org/10.2307/3096912.

Miran, S. M., C. Ling, and L. Rothfusz, 2018: Factors influencing people's decision making during three consecutive tornado events. *Int. J. Disaster Risk Reduct.*, **28**, 150–157, https://doi.org/10.1016/j.ijdrr.2018.02.034.

Onega, T., J. E. Weiss, J. Alford-Teaster, M. Goodrich, M. S. Eliassen, and S. J. Kim, 2020: Concordance of rural-urban self-identity and zip code-derived rural-urban commuting area (RUCA) designation. *J. Rural Health*, **36**, 274–280, https://doi.org/10.1111/jrh.12364.

O'Neill, E., F. Brereton, H. Shahumyan, and J. P. Clinch, 2016: The impact of perceived flood exposure on flood-risk perception: The role of distance. *Risk Anal.*, **36**, 2158–2186, https://doi.org/10.1111/risa.12597.

Parker, K., J. Horowitz, A. Brown, R. Fry, D. V. Cohn, and R. Igielnik, 2018: What unites and divides urban, suburban and rural communities. Pew Research Center, https://www.pewresearch.org/social-trends/2018/05/22/what-unites-and-divides-urban-suburban-and-rural-communities/.

Qasim, S., A. N. Khan, R. P. Shrestha, and M. Qasim, 2015: Risk perception of the people in the flood prone Khyber Pukhthunkhwa province of Pakistan. *Int. J. Disaster Risk Reduct.*, **14**, 373–378, https://doi.org/10.1016/j.ijdrr.2015.09.001.

Ruin, I., J. C. Gaillard, and C. Lutoff, 2007: How to get there? Assessing motorists' flash flood risk perception on daily itineraries. *Environ. Hazards*, **7**, 235–244, https://doi.org/10.1016/j.envhaz.2007.07.005.

Schmidlin, T. W., B. O. Hammer, Y. Ono, and P. S. King, 2009: Tornado shelter-seeking behavior and tornado shelter options among mobile home residents in the United States. *Nat. Hazards*, **48**, 191–201, https://doi.org/10.1007/s11069-008-9257-z.

Senkbeil, J. C., K. Sherman-Morris, W. Skeeter, and C. Vaughn, 2022: Tornado radar images and path directions: An assessment of public knowledge in the southeastern United States.

Bull. Amer. Meteor. Soc., https://doi.org/10.1175/BAMS-D-21-0204, in press.

Sherman-Morris, K., P. S. Poe, C. Nunley, and J. A. Morris, 2020: Perceived risk, protective actions and the parasocial relationship with the local weathercaster: A case study of Hurricane Irma. *Southeast. Geogr.*, **60**, 23–47, https://doi.org/10.1353/sgo.2020.0003.

——, J. C. Senkbeil, and C. Vaughn, 2022: How close is close enough? A discussion of the distances relevant to personalizing tornado risk. *Bull. Amer. Meteor. Soc.*, **103**, E1573–E1586, https://doi.org/10.1175/BAMS-D-21-0142.1.

Stewart, A. E., J. K. Lazo, R. E. Morss, and J. L. Demuth, 2012: The relationship of weather salience with the perceptions and uses of weather information in a nationwide sample of the United States. *Wea. Climate Soc.*, **4**, 172–189, https://doi.org/10.1175/WCAS-D-11-00033.1.

Thistlethwaite, J., D. Henstra, C. Brown, and D. Scott, 2018: How flood experience and risk perception influences protective actions and behaviours among Canadian homeowners. *Environ. Manage.*, **61**, 197–208, https://doi.org/10.1007/s00267-017-0969-2.

Tobin, G. A., and B. Montz, 1997: *Natural Hazards: Explanation and Integration*. Guilford Press, 388 pp.

Tversky, B., 2003: Structures of mental spaces: How people think about space. *Environ. Behav.*, **35**, 66–80, https://doi.org/10.1177/0013916502238865.

Wood, M. M., D. S. Mileti, H. Bean, B. F. Liu, J. Sutton, and S. Madden, 2018: Milling and public warnings. *Environ. Behav.*, **50**, 535–566, https://doi.org/10.1177/0013916517709561.

Zhang, Y., S. N. Hwang, and M. K. Lindell, 2010: Hazard proximity or risk perception? Evaluating effects of natural and technological hazards on housing values. *Environ. Behav.*, **42**, 597–624, https://doi.org/10.1177/0013916509334564.