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How Close is Close Enough? A Discussion of the Distances Relevant to Personalizing Tornado Risk

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ABSTRACT: Risk perception and the desire to personalize and confirm warning information have been associated with protective action. Risk perception typically increases with close proximity to a threat, but research involving time, space, and tornado risk perception has stopped short of attempting to define a distance at which an individual would believe they are personally at risk from a tornado. In this study, we surveyed 1,023 individuals across the southeastern United States at risk from tornadoes. The goal was to add to our understanding of the role of distance in tornado risk perception by quantifying an individual's "worry distance." The study examined an individual's worry distance in multiple ways, including three map-based warning scenarios. Our results indicated that participants would worry about their house or loved ones or take shelter in a tornado if it was on average within 11–12 mi. These distances were greater than the 7–8 mi at which they believed they could see, hear, or feel the effects of a tornado. There was a considerable amount of variation in the self-reported distances, some of which can be explained by past exposure. When provided tornado warning maps with varying scales or county borders, neither map scale nor the presence of a border had an influence. The lack of any influence of map scale raises the question of how individuals consider objective geospatial distance when using a map-based warning for familiar or novel locations.

Keywords: Social Science; Tornadoes; Decision making

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Distance from an environmental threat often influences risk perception (O'Neill et al. 2016; Klockow-McClain et al. 2020). Research on a number of different hazards has found a positive relationship between perceived personal risk and proximity, and this may be the result of interrelated factors, including the often-correct belief that risk from a hazard decreases with distance from it and other factors such as cues from information sources or observations that confirm a threat (Lindell and Hwang 2008). For example, proximity to risk of a greater concentration of a water quality hazard led to greater risk perception, especially among those for whom the risk was personally relevant (Severtson and Vatovec 2012). Being in geographical proximity to the disaster/hazard has also increased the likelihood of a person responding to a warning message; for example, proximity to the coast increased the decision to evacuate in Hurricane Lili (Lindell et al. 2005).

Spatial factors play a role in how individuals interpret forecasted threats. Lindell (2020) described four spatial heuristics that influence tornado as well as other hazard risk perception—the centroid effect, the transect effect, the proximity effect, and the absence of an edge effect. Providing evidence of a centroid effect, experimental research has shown that individuals rate the likelihood probability of a hurricane or tornado to be the greatest closest to the center of the forecasted area—in a polygon for a tornado (Sherman-Morris and Brown 2012; Ash et al. 2014; Lindell et al. 2016; Jon et al. 2019) or the forecast track and cone for a hurricane (Broad et al. 2007; Radford et al. 2013; Wu et al. 2014; Saunders and Senkbeil 2017; Sherman Morris and Antonelli 2018). Similar to the centroid effect, studies also show continuously decreasing judgements of probability the farther one moves from the longitudinal axis of a polygon—the transect effect (Lindell et al. 2016; Jon et al. 2019). The proximity effect, which relates perceived risk to the location of the threat, was present in an experimental study where risk perceptions were high near the location of the storm cell when that information was provided along with the polygon (Jon et al. 2019). Displaying the location of the tornado in a forecast or hypothetical scenario is necessary for proximity to outweigh the centroid effect (Lindell 2020). In an actual event, close proximity to the path of an Oklahoma tornado increased the likelihood of taking protective action (Miran et al. 2018). Research using an experimental tornado scenario with a radar image, warning polygon, and four location points at progressively farther distances (described as 15 min of lead time apart) from a hypothetical tornado showed that protective decision-making decreased along with distance from the tornado (Klockow-McClain et al. 2020). Interestingly, in that study, there was a steeper decline in the proportion of respondents who would make protective decisions from the second to the third location point than from point one to point two or point three to point four. No geographic scale was provided to indicate the hypothetical distance of the locations, but the authors proposed that participants separated the four locations into "close to" and "far from" locations; this distinction could also have been encouraged by the conditions of the experiment which instructed participants to use 50% as a threshold between a high chance and a low chance (Klockow-McClain et al. 2020, p. 325). Last, a tornado polygon is intended to produce a strong edge effect—that probability judgements should drop to near zero outside the boundary (Lindell 2020). However, research indicates the decrease is not as large as would be predicted based on presence of an edge effect (Lindell et al. 2016; Jon et al. 2019; Klockow-McClain et al. 2020). In a real-world test of the influence of the tornado polygon, Nagele and Trainor (2012) did not find a relationship between being inside a polygon and taking protective action. However, the authors noted that their study did not determine if users actually saw or used the polygon information.

In addition to the spatial heuristics that can influence perception of risk in a tornado forecast, other subjective factors may play a role in risk perception. Distance from a threat may be objectively measured; however, the distance in the mind of the individual at risk from some hazard can be subjective and may vary from person to person (Liberman and Trope 2008; Spence et al. 2012). For example, if a tornado is in a familiar town 10 mi from an individual's home, they may feel threatened. However, if a tornado is 10 mi away from an individual's home but is not near a particular town, they may feel less threatened since there is no town to identify with. The risk perception here would be based less on physical distance and more on the identification with the town as a nearby, familiar place. This type of influence was found among hurricane evacuees who perceived hurricane tracks to be closer to their home locations than they were forecasted and closer than they actually occurred (Senkbeil et al. 2020).

Furthermore, two points of relatively close proximity may be considered separate in the mental map of an individual because of a barrier that exists between them (Hirtle and Jonides 1985). For example, would an individual feel more threatened by a tornado that is 10 mi away but within their local county than a tornado that is the same distance away but outside their county? Individuals may also consider distance from point A to point B according to the route that they take to get there instead of the straight Euclidean distance between the two points (McNamara et al. 1984). Typically, following roads will increase the distance and time traveled to get to a location since the roads are not straight lines between the starting point and the destination. These examples show how distance can become subjective. Even when maps include scales to provide an objective standard for distance, the map user may not accurately assess distance (Raghubir and Krishna 1996). Differences in risk perception have been shown with differing map scales where a person's lived area and mobility within the mapped area determined the scale at which they were aware of actual flood hazards (Klonner et al. 2018). More research is needed to better understand how map scale is used and interpreted, especially in the area of risk perception.

Similarly, the way individuals think about the risk in their environments can alter a simple relationship between objective distance to a threat, risk perception, and protective behaviors. For example, perceived risk had a greater effect on adoption of earthquake insurance than location in an objectively defined special hazard zone (Palm and Hodgson 1992). Locally held beliefs about a place such as the protective powers of water or hills can also influence tornado risk perception (Klockow et al. 2014). The relationship between distance of exposure to previous events and risk perception is not straightforward. Following the 2011 tornado outbreak in Alabama, participants thought the risk of their own town experiencing a tornado was higher than it had been previously; however, direct experience (having property or being personally in the tornado's path) did not play a significant role (Wallace et al. 2015). Having prior experience led Tennessee participants to correctly estimate or overestimate their tornado risk (Ellis et al. 2018). The nature of the hazard experience may partially mediate the relationship between proximity and perceived personal risk (Lindell and Hwang 2008). Recent research indicated that proximity in time and space to an intense tornado had a positive effect on risk perception but recent exposure to a weak tornado had the opposite "inoculating" effect (Johnson et al. 2021).

Last, scale may influence perceived risk or protective action. Results regarding the influence of the geographic scale of information on tornado risk perception and protective action are mixed. The results of an experimental study using hypothetical severe weather forecasts similar to SPC convective outlooks suggested that people were more willing to take preparatory action when the geographic scale of the information was broader, such as impacting a multiregion area rather than a city, even if they were asked to imagine they lived in that city (Shivers-Williams and Klockow-McClain 2021). When using location information from actual tornado warning polygons, Nagele and Trainor (2012) found that larger polygons led to people being *less* likely to take shelter; when polygons covered more than 50% of the county, people were marginally less likely to seek additional information. Scale can also play a role when a graphic encourages too much attention to a single path as opposed to a broader area. For example, individuals in a 2008 tornado misunderstand their actual level of risk because the actual tornado track and the anticipated track differed (Montz 2012).

Further study is needed to more fully understand the influence of distance to hazardous events on risk perception (Trumbo et al. 2011). In many of the previous studies discussed, the distance to the threat was controlled, either experimentally, or through proximity to an actual event. Forecasters could benefit from a better understanding of how individuals express the distance at which they would perceive risk. Thus, a goal of the study described here is to better quantify what we refer to as an individual's worry distance associated with a forecasted tornado—the distance at which they would expect to experience certain beliefs, actions, or sensations. To add to our understanding of the role of distance in risk perception, this study examined an individual's worry distance in several ways, including several scenarios that examine worry distance with respect to scale and proximity effect.

Methods

Measures. We use the phrase worry distance as a convenient way to talk about the distance at which an individual would personalize the threat from a tornado. The ability to see and hear a tornado also addresses an individual's desire to confirm a threat through the senses. Physical cues provide evidence that a threat exists and that it warrants taking protective action (Lindell and Perry 2003). Our measures are based on Demuth (2018), whose questions aimed at quantifying the extent to which a respondent had personalized the risk from a previous tornadic event. For example, Demuth (2018, p. 1940) included statements such as "I worried about my house," "I feared for my loved ones," "I heard sounds of the storm firsthand," and "I saw scenes of the storm firsthand." The questions were modified to consider the hypothetical nature of the survey. Participants in our study were asked:

- 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.
- 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.

They were presented a slider bar with values that ranged from 0 to 25 mi, with tick marks and labels at 5-mi increments. The maximum value was intended to more than capture the width of a large tornado polygon. The question of scale was posed to two National Weather Service (NWS) meteorologists as well as reviewed by project team members with meteorology expertise prior to administering the survey to help ensure the distance scale was appropriate.

Following this general question about worry distance, participants were shown several scenarios that manipulated geographic features on a map related to scale or borders. Respondents were first shown the map in Fig. 1 on which there is no depiction of scale. For the purpose of this discussion, the map provides a test for the proximity effect without reference to the specific distance from the tornado threat. The image is of fictional Colby County with a tornado moving toward points A and B at 30 mi h^{-1}. The second scenario presented participants with one of the two images in Fig. 2. The distinction between these two images was whether the tornado moving toward the two locations was presently located within the target county, or just on the other side of the county border. The distances were carefully measured to be the same in both maps and participants were informed that the tornado would be near at the first location in 10 min and at the second location in 20 min. The purpose of this map was to determine if the presence of a border interferes with the effect of proximity. Based on the suggestions of Hirtle and Jonides (1985) and the actual influence of landscape features reported in Klockow et al. (2014), we believed that there could be an effect, but the potential for an effect was not well supported in the literature either way. Last, participants were provided another fictional county map similar to the first one. The county name (Drake) and shape were different than in the first scenario, but the direction and forward speed were the same so that results could be compared. The map in Fig. 3 included a scale bar with either a 1- or 5-mi scale. The purpose of the last scenario was to determine whether the scale of the map played a role in participants' worry distances. Based on the proximity effect, we expected

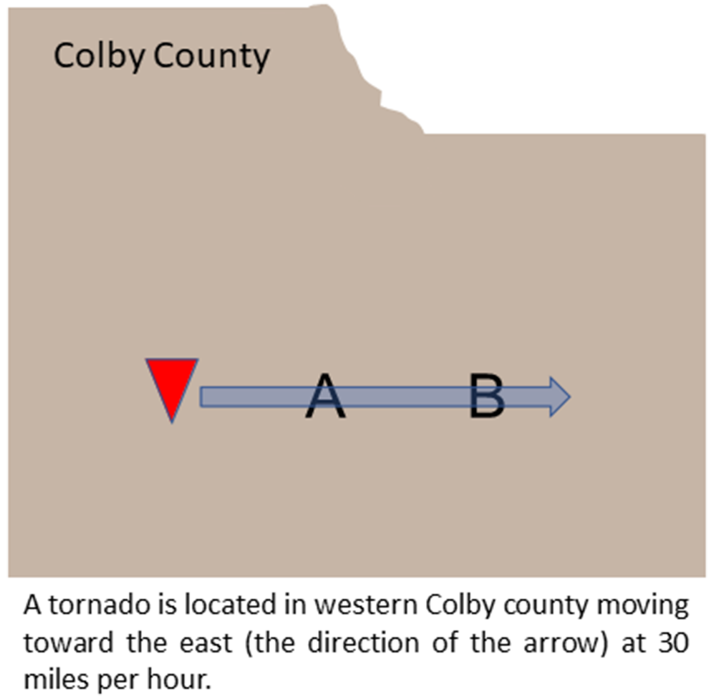

Fig. 1. Image depicting fictional Colby County with a tornado moving toward points A and B at 30 mi h^{-1}.

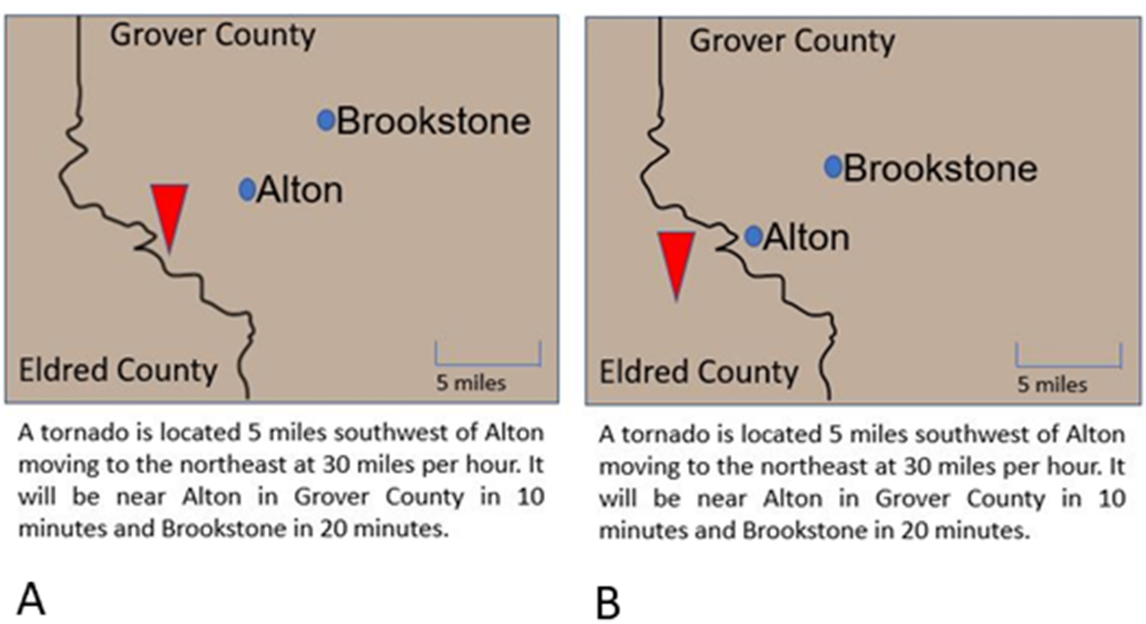

Fig. 2. Fictional scenario showing a tornado moving toward two locations either located within the target county, or just on the other side of the county border.

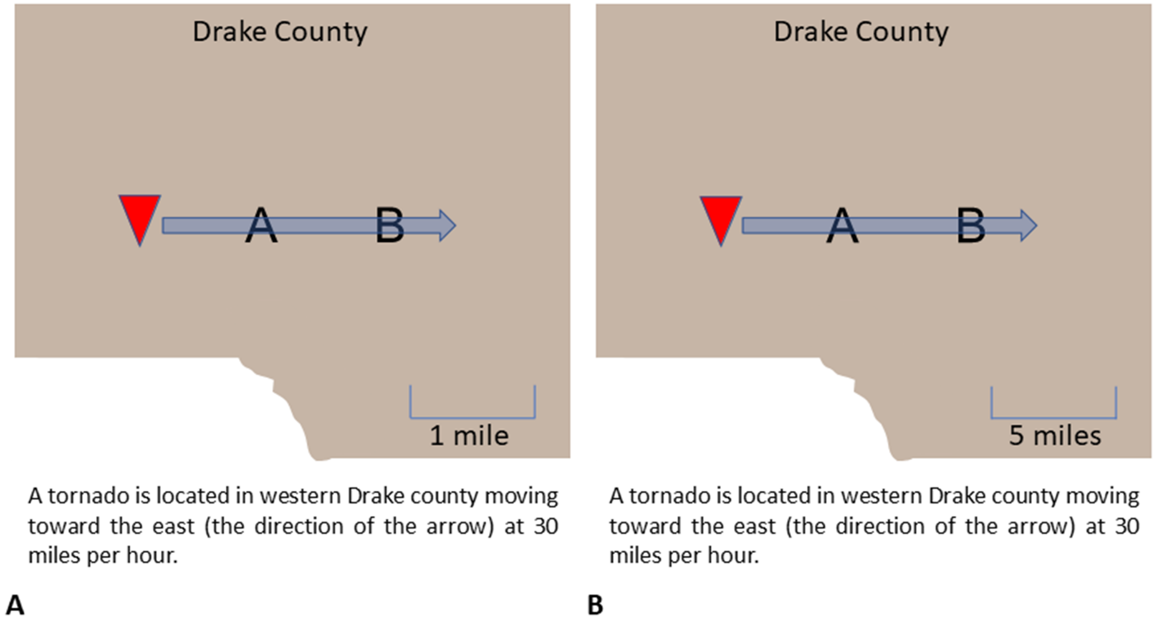

Fig. 3. Image depicting fictional Drake County with a tornado moving toward points A and B. The image included a scale bar with either a 1- or 5-mi scale.

that point A would be rated a higher level of risk than point B. However, we expected the effect to diminish when point B was farther from the tornado, as in the map with 5-mi scale.

Each scenario asked an image-appropriate version of the following questions to measure differences:

- To what extent would you worry about loved ones if they were located at (point A, point B, Alton)?
- To what extent would you worry about your house if it were located at (point A, point B, Alton)?
- How likely would you be to take action to protect yourself or your loved ones if you lived at (point A, point B, Alton)?
- How likely do you think it would be for the tornado to affect (point A, point B, Alton)?

The order of the images was the same for each participant. The map without a scale was presented first so that participants would not assume a scale from a previous image. The county border scenario was provided next to offer a buffer between the first and third scenarios, which were intentionally similar. Participants saw one map for each scenario. Because of this, comparisons can be made within subjects for locations of points (i.e., A versus B) or responses to like questions, but between subjects for the different scales and the county border effect.

In addition to the questions about risk perception, participants were asked approximately what was the closest they had ever been to a tornado. They were given the choices less than 1, 1–5, 6–10, 11–25, and over 25 mi. They were also given a not applicable choice and two choices for unsure—unsure but likely within 25 mi and unsure but likely more than 25 mi. Based on the mixed role of experience in past studies, we wanted to test whether people with more direct past tornado experience (closer distances) would express worry distances that were shorter than participants with less direct experiences. Information about their demographics including zip code, gender, education, age, and race/ethnicity was requested. Participants also provided information about their home location, including the type of structure in which they lived, whether they owned or rented their home, and their county and state. The survey included additional questions that are beyond the scope of this paper.

Participants. Following Institutional Review Board (IRB) review and an exemption determination (IRB-19-337), a sample of 1,023 participants was recruited using a Qualtrics panel. Participants were screened according to age, zip code, education, and gender. Zip codes limited the sample to residents of portions of eight states (Alabama, Arkansas, Georgia, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee). Zip codes were also used to ensure at least 30%–40% of participants were from rural areas (to meet a project goal outside the scope of this paper). The rural/urban distinction was based on the 2010 Rural–Urban Commuting Area (RUCA) Codes from the USDA Economic Research Service where zip codes 1–4 were classified as urban. Other quotas were set to provide an approximately 50:50 ratio of male to female (among those identifying as either male or female), at least 50% with an education level of some college or less, and an age distribution fairly evenly split among ages 18–34, 35–55, and older than 55. The actual sample characteristics are provided in Table 1.

Results

Tornado worry distance. The distance at which someone would worry about loved ones was the greatest of the estimated distances at 12.3 mi (7.7 s.d.; s.d. = standard deviation). This was followed by 11.1 mi (7.6 s.d.) at which participants would take action to protect themselves or loved ones and 11.0 mi (7.7 s.d.) at which participants would worry about their house. A Wilcoxon signed rank test for non-normally distributed related samples showed that the difference between the distance at which one would worry about loved ones was significantly different (greater) than the distances associated with worrying about one's house ($p < 0.001$) or taking protective action ($p < 0.001$) (see Table 2).

The distances at which participants thought they could see, hear, or feel the effects of a tornado were all significantly less than the above distances ($p < 0.001$) but similar to each other. Participants believed they could see a tornado within 7.8 mi (6.9 s.d.) and hear or feel the effects from a tornado within 7.7 mi (7.0 s.d.).

Table 1. Sample characteristics.

State in which participants live (N = 1,019)	Alabama	15.7%
	Arkansas	7.8%
	Georgia	35.3%
	Kentucky	3.7%
	Louisiana	2.9%
	Mississippi	7.9%
	Missouri	4.7%
	Tennessee	22.0%
Whether zip code was classified as urban or rural (N = 1,019)	Rural	34.5%
	Urban	65.5%
Highest level of education completed (N = 1,023)	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 (N = 1,023)	Female	51.1%
	Male	47.9%
	Other responses	1%
Age (N = 1,023)	Min 18, max 92, average 44.5 (16.8 s.d.)	

Table 2. Significance of pairwise comparisons among worry distances reported by participants. Bonferroni adjusted significance level is $p = 0.003$.

	1	2	3	4	5
1) Worry about loved ones	—				
2) Worry about house	<0.001	—			
3) Take action to protect self	<0.001	0.447	—		
4) See tornado	<0.001	<0.001	<0.001	—	
5) Hear tornado	<0.001	<0.001	<0.001	0.331	—
6) Feel effects from tornado	<0.001	<0.001	<0.001	0.158	0.359

The distance at which one would worry about loved ones was the most evenly distributed throughout the range of choices between 0 and 25 mi (Figs. 4a–f). Responses were more prevalent at the lower end of the slider scale for the other questions, but especially for the distances at which participants thought they could see, hear, or feel the effects from a tornado. All items showed some influence from the question design in that responses were higher at the tick marks (5, 10, 15, 20, and 25) than surrounding values. However, the distributions did not show a preference for the midpoint of the slider bar scale. Even though some of the average values were close to the midpoint, responses were not clustered around it.

Prior distance to a tornado. Previous research found that people with past tornado experiences were more likely to either accurately estimate or overestimate their actual tornado risk in Tennessee (Ellis et al. 2018). Our research tested whether people with more direct past tornado experience (closer distances) would express worry distances that were shorter than participants with less direct experiences. The majority of participants in our research reported having had a nearby experience with a tornado, with 27% responding that they had been within 1 mi of a tornado and another 24% from 1 to 5 mi. Approximately 25% reported being between 6 and 25 mi. A small percentage (13.5%) reported being unsure.

To explore whether previous nearby exposure to a tornado influenced worry distance, a Kruskal–Wallis test with post-hoc comparisons was performed comparing the responses to the three worry distance items and the three see/hear/feel items by the five categories indicating previous exposure to a tornado (not applicable and unsure responses were omitted from the comparison.) The Kruskal–Wallis tests indicated a significant difference among the categories for each of the six distance items. Post-hoc tests revealed that the largest differences in distances existed between people who think they experienced a tornado nearby versus those who experienced one farther away. Significant differences in the three worry distances by exposure categories existed where past exposure had been less than a mile compared to greater than 10 mi (Table 3). For seeing, hearing, or feeling effects of a tornado, significant differences in distance by exposure category existed where exposures were less than 1 mi compared to exposures greater than 5 mi. As anticipated, the differences indicated that participants who thought they had closer experiences with tornadoes tended to express shorter worry distances.

The results reported here are dependent on self-reported tornado distance of past experiences and cannot be verified. Other research suggests that individuals were not always able to accurately estimate how close they had been to a tornado. In one study, 18% of participants indicated that they had been within 1 mi of a past tornado; however, comparing the details they provided against tornado records in Storm Data revealed many questionable direct experiences for these participants (Senkbeil et al. 2019). While collecting enough data to accurately verify a participant's past tornado exposure was beyond the scope of this project, we did ask participants for their address and the name, distance, and time to travel

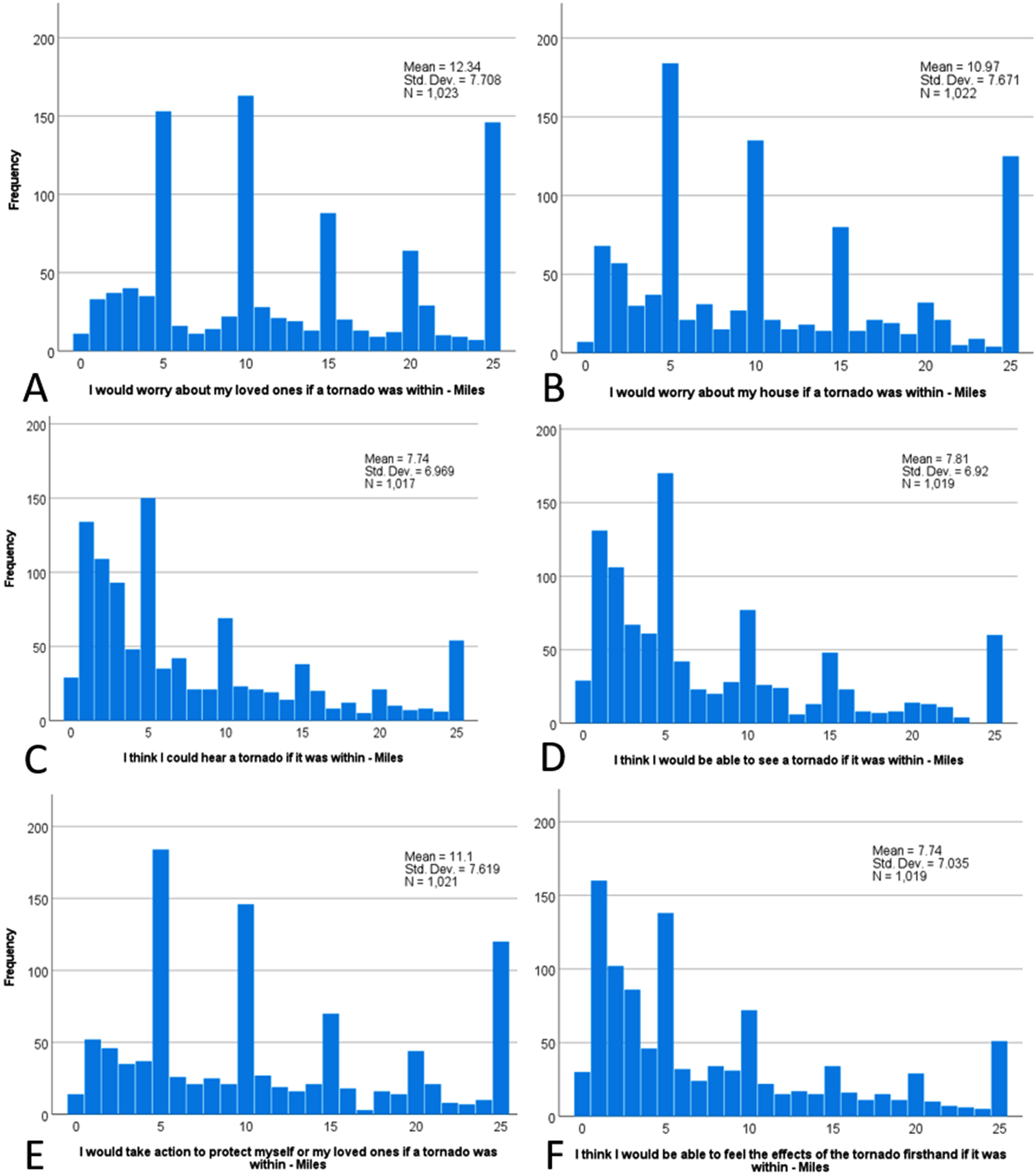

Fig. 4. The distance at which participants would (a) worry about loved ones, (b) worry about their house, (c) hear a tornado, (d) see a tornado, (e) take action to protect themselves, and (f) feel the effects of a tornado.

to the grocery store they shop most often as part of a separate research question. A random sample of 98 responses were geocoded, mapped, and evaluated for the differences in actual/estimated distance and travel time. A Wilcoxon signed rank test for related samples (a test for differences between responses given by the same participant) revealed that participants

Table 3. **Significance (Bonferroni adjusted significance values) of pairwise comparisons among worry distances reported by participants based on reported nearest exposure to a tornado.**

	1	2	3	4	5
Worry about loved ones					
1. Less than 1 mi	—				
2. 1 to 5 mi	1.000	—			
3. 6 to 10 mi	1.000	0.663	—		
4. 11 to 25 mi	0.010	0.006	1.000	—	
5. Over 25 mi	<0.001	<0.001	0.024	1.000	—
Worry about house					
1. Less than 1 mi	—				
2. 1 to 5 mi	1.000	—			
3. 6 to 10 mi	0.063	0.710	—		
4. 11 to 25 mi	0.023	0.226	1.000	—	
5. Over 25 mi	<0.001	<0.001	0.001	0.022	—
Take action to protect self					
1. Less than 1 mi	—				
2. 1 to 5 mi	0.772	—			
3. 6 to 10 mi	0.083	1.000	—		
4. 11 to 25 mi	0.007	0.591	1.000	—	
5. Over 25 mi	<0.001	<0.001	0.003	0.206	—
Able to see tornado					
1. Less than 1 mi	—				
2. 1 to 5 mi	0.206	—			
3. 6 to 10 mi	<0.001	0.011	—		
4. 11 to 25 mi	<0.001	0.005	1.000	—	
5. Over 25 mi	<0.001	<0.001	0.183	1.000	—
Able to hear tornado					
1. Less than 1 mi	—				
2. 1 to 5 mi	0.080	—			
3. 6 to 10 mi	<0.001	0.003	—		
4. 11 to 25 mi	<0.001	0.027	1.000	—	
5. Over 25 mi	<0.001	<0.001	1.000	1.000	—
Feel effects from tornado					
1. Less than 1 mi	—				
2. 1 to 5 mi	0.003	—			
3. 6 to 10 mi	<0.001	0.008	—		
4. 11 to 25 mi	<0.001	0.020	1.000	—	
5. Over 25 mi	<0.001	0.001	1.000	1.000	—

tended to overestimate the distance to their grocery store by about 2.3 mi but that the time estimate was very close—0.8 min. Only distance (estimated versus mapped) was significantly different ($p < 0.001$).

Map-based tornado scenarios. In the first scenario without a scale (Fig. 1), participants responded with higher levels of risk perception for point A than point B in each question. This is reflected in statistically different scores between point A and point B for the extent to which they would worry about loved ones, worry about their house, how likely they would be to take action to protect themselves, and how likely they believed the tornado would affect points A and B.

In the third scenario (Fig. 3), which was very similar to the first except for the scale bar, the results were the same. Responses indicated higher risk perception or greater intent to take action at point A over point B. A Wilcoxon signed rank test indicated significant differences between points A and B for each of the questions ($p < 0.001$). Interestingly, this pattern was true when the scale of the map as well as the distance between point A and point B was only 1 mi. One mile is well within the distances participants said they would worry about loved ones and their house, take action, and also the distances at which they believed they could see, hear, or feel the effects from a tornado. A Mann–Whitney test for independent samples confirmed that there was no difference based on the scale of the map. Regardless of whether participants received the map with 1- or 5-mi scale, they rated each of the responses the same when comparing similar items (e.g., worry about loved ones at point A on the 1-mi map versus worry about loved ones at point A on the 5-mi map). The intention to take action was the closest item to approach a significant difference ($p = 0.13$), but with the size of the sample and the number of comparisons, there is no reason to entertain a higher probability value threshold.

Last, the second scenario (Fig. 2) indicated that county borders did not influence risk perception or intent to take action. This scenario did not ask participants to compare risk at two points. Rather, responses to similar items were compared with a Mann–Whitney test to determine if differences existed between those who saw a tornado in the same county as the location of interest compared to those who saw the tornado located in the county adjacent to the location of interest. The greatest difference between the two maps was for worry about loved ones (1.69 versus 1.75 on a 5-point scale); however, this difference was not significant ($p = 0.55$). There were no differences in responses to any of the map scenarios that could be explained by past nearby exposure to tornadoes.

Discussion and conclusions

The participants in our study reported worry distances that suggest they would personalize risk from a tornado on average around 11 or 12 mi. The standard deviations associated with the average values were large (7–8 mi), however, indicating that there was a wide level of variation among participants. The values for distances at which participants thought they could see, hear, or feel the effects of a tornado were lower, ranging from 7 to 8 mi. The variation among responses to these items was also large, but the responses were more concentrated at the lower end of the range. The degree of variation in the responses to this type of question was not unique to this study. In semistructured interviews with 45 participants, Walters et al. (2020, p. 75) noted that one participant would take shelter if a tornado was within "a couple of miles" while others gave responses of 10 and 50 mi. Given the fact that participants tended to slightly overestimate the distance they travel to a grocery store, these distances may be somewhat overestimated compared to the worry distance one could visualize on a map. However, these distances should still be relevant for warnings which give numeric estimates of tornado distances (e.g., a tornado is located 5 mi from…).

Attempts to confirm a warning is a typical response to a threat. Studies have reported the percentage of individuals who attempt to confirm a tornado visually at 10% to over 20% (Sherman-Morris 2013). Experimental research also indicated that participants' decision criteria and their ability to detect tornadic weather visually were independent; people used appropriate heuristics, but this may have led to inaccurate assessment of the actual risk from tornadoes based on some cloud types or degree of darkness (Dewitt et al. 2015). The difference between distances at which participants would feel worried or take protective action from a tornado and the distances at which they believe they could see or hear a tornado suggests that many participants understand that visual or aural confirmation may not be possible given their personal risk area. This is somewhat counter to reported NWS perceptions that many want to see or hear a tornado, or else they would doubt the warning, and that people do not want to be "bothered with reports" if the tornado would not be affecting their home or neighborhood (Walters et al. 2020, p. 75). Based on decades of research, confirmation is likely still necessary, but perhaps the need for confirmation is met most frequently by other means such as weather graphics. At the average distance participants expected to see, hear, or feel the effects of a tornado, they would not likely be able to confirm visually, or see the features described in Dewitt et al.'s (2015) study effectively. Future research should explore specific needs for confirmatory information further.

Our findings suggest that participants either did not consult the scale of the map when responding to the question items or that the scale was not sufficient to produce a result. There were no differences in worry distance or intention to take action whether a hypothetical tornado was 2 or 10 mi away as indicated by a map scale bar. This raises the question of whether individuals would actually consider scale if the event were real. Results from a pair of studies suggests that scale may be more relevant when the event is real and personal to the participant. For example, a study focusing on real-world tornado warnings found that larger polygons led to people being *less* likely to take shelter (Nagele and Trainor 2012) while a study with hypothetical severe weather forecast scenarios found people were *more* willing to take preparatory action when the warning was impacting a multiregion area rather than a city (Shivers-Williams and Klockow-McClain 2021). The two studies are not directly comparable, but the differences suggest a need for future studies involving scale and local places with which participants are likely to be familiar. Also, when examining a map that is personally relevant, individuals process the information in a way driven by that personal relevance as opposed to prominent map features (Severtson and Vatovec 2012). The results also raise a question as to how well individuals can approximate distances in general. Previous research on risk perception and hazard mapping suggested that participants did not consciously estimate their distance to hazards but that their processing of map distance occurred at a pre-attentive level (Severtson and Vatovec 2012). Further research is planned to examine the influence of the distances associated with the participants' lived experiences and any influences they might have on personalized risk area. Additional research planned by the authors will also examine to what extent individuals have an accurate understanding of the scale of warnings as well as how they personalize risk spatially in their own counties. Now that we have a better idea of the average distances at which individuals may worry about a tornado, map experiments should test scales that should lead to differences in risk perception or intended action.

The possibility exists that the scale on the maps was not different enough to capture this wide range in worry distances. Ten miles is still within the range at which the average participant would worry about their house and loved ones and the distance at which they stated they would take shelter. The comparison of worry distances with the distances at which participants had experienced tornadoes in the past seemed to indicate the distinction between nearer exposure and farther exposure being <10 mi and >10 mi, respectively, while the distinction for the experiential items was shorter. These results seem in line with research by Johnson et al. (2021), who identified effects on risk perception from intense tornadoes that were within 10 mi or weaker tornadoes that were within 5 mi. Our study did not ask participants any questions about the intensity of the tornadoes they had experienced so the results cannot be compared directly. There is also evidence from an early study (Sullivan 1977, cited in Lindell and Perry 2000) that 5 mi was within the area in which an individual would worry about a threat. That research reported that the majority of people surveyed about seismic risks knew there was an active fault within a mile of their home, but most would not feel any safer if they were 5 mi (or more) from it.

Lasty, we found no influence for county borders on risk perception or intent to take action. As with other null results, this could be influenced by the fictional nature of the county and the lack of any personal relevance of the border to the participant. In a real-world scenario, the participant may feel more connected to the area within their county. Thus, a tornado crossing the county border would be viewed as entering a more personal space. We were not able to account for this in the study. Past research has shown that even telling participants that they live in a particular location may not be sufficient (Shivers-Williams and Klockow-McClain 2021). Research currently being conducted by the authors is examining whether county borders are relevant to descriptions of personalized risk areas. Future research should examine the conditions in which borders may influence risk perception.

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