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Executive Summary

NOAA's National Weather Service (NWS) forecasters and the broadcast media commonly use maps to communicate tornado risk to the U.S. public; however, little research has been conducted to explore the effects of tornado warning map content and design on risk perceptions and decision-making. The NOAA-funded study NA12OAR4590118 is an important contribution to knowledge in this area, examining the ways modern-day tornado warning maps are interpreted and then comparing those interpretations to those evoked by potential future technologies. In particular, this research examined the decision-shaping properties of longer lead-times as depicted on a map (i.e., larger risk spaces), inquired about what happens when people find themselves inside or outside of tornado warning polygons of various lengths, and explored the effects of rendering explicit on a map the probability that a given thunderstorm will produce a tornado at points downstream.

Our work has generated several key findings of relevance to NOAA. First, the research supports a growing body of literature that suggests that providing estimates of forecast uncertainty may provide significant benefits to end-users. The work also demonstrates that it's beneficial for forecasters to communicate times when they are more certain that a tornado exists through simple verbal statements; this practice could be implemented now, without waiting for programs like Warn-on-Forecast to render those estimates explicit at longer lead-times. Additionally, the project demonstrates that the way forecasters depict spaces of risk influences

decision-making. There are complex trade-offs involved in lengthening the lead-time of deterministic warnings. Finally, the research finds that the use of cool colors in risk depictions may lead people to underestimate tornado threat, and we therefore recommend that cool colors not be used in tornado threat graphics.

This research used an experimental approach to systematically study the effects of warning content within a series of maps. While this approach allowed for a straightforward comparative analysis, the ecology of warning communication and decision-making in the real world is much more complex. We recommend several avenues of research to follow from this study, including deeper and more place-based examinations of response and self efficacy in situations of tornado threat, more systematic experimental work related to communicating forecast uncertainty, and more real-world case studies of warning comprehension.

1. Background

Presently, little is known about how people interpret and use tornado risk maps to make protective action decisions. Several studies have established that most people consult television to receive warning information and, thus, are no doubt heavily exposed to risk maps (NOAA 2008, NOAA 2011). The tornado warnings people receive today are deterministic — essentially yes/no forecasts for location of tornado occurrence — and tornado warnings are visually depicted as regions, or polygons, where forecasters believe a tornado is imminent. However, NWS forecasters have more certainty about the existence of a tornado in some storm environments and for some locations than others; the deterministic system constrains their ability to express differing degrees of certainty (both within and between events). Forecasters currently attempt to express this increased likelihood through verbal enhancements to warnings, such as tornado emergencies and tiered tornado threat tags. To date, few studies have demonstrated the impact of these measures on warning interpretation or response tendency (Ripberger et al. 2015).

In addition, new technologies are currently in development by the NOAA's National Severe Storms Laboratory and partners that, if successful, would change geospatial representations of tornado potential in two ways: (1) by increasing lead-time (longer alerts/larger warning spaces) and (2) by providing explicit probabilities of the existence of a hazard throughout the warned area. This change would offer forecasters many new ways of presenting uncertainty information, including considerations for numeric format and visual design of the mapped warnings. **This research explores the impacts of longer lead-times, explicit probabilities, and various warning map design options on risk perception and response** to better understand how forecasters affect the way people understand tornado risk today, and how that might change with future technologies.

While a dearth of literature exists to describe how lead-time affects warning response, aggregate outcomes of tornadoes with varying lead-times suggest that increasing lead-time can be beneficial. Tornado-related fatalities decreased significantly from the 1920s to today (with the notable exception of 2011), a fact attributed in part to increases in tornado detection and warning technologies and increases in warning lead-time (Brooks and Doswell 2002). One study indirectly linking lead-time to mortality and morbidity found that both quantities tended to decrease until about 15 minutes, past which mortality increased again (Simmons and Sutter 2008). Many people reported a preference for longer lead-times than are currently provided, on average (Hoekstra et al. 2011); however, increasing lead-times for tornadoes within the modern deterministic system may not, on its own, lead to beneficial collective responses (NOAA 2013, Klockow 2015). Therefore, in real-world settings, there is a suggestion that increasing lead-time may be beneficial to a point.

In addition to the temporal dimension of future warning message content, there is also evidence to suggest that explicit estimates of uncertainty may improve decision-making by the U.S. public (Morss et al. 2009, Joslyn et al. 2009). For some forecast contexts, people have expressed a preference for explicit estimates of uncertainty rather than deterministic forecasts alone (Demuth et al. 2008). A comparative analysis that compares the effects of deterministic information and probabilistic information on warning decisions would help the meteorological community understand if these positive signals could extend to the tornado warning context, motivating the present study.

2. Study Design

To better understand how these various considerations – changes in lead-time, deterministic vs. probabilistic information, and map design – influenced perceptions of threat, we implemented a controlled decision experiment that varied tornado message characteristics, tornado risk map designs, and distances from fictitious, mapped thunderstorms. To compare performance between the experimental conditions, we measured *response tendencies over space* (an indication of subjective risk perception in a geospatial context) and *response errors* (over or under-responding to potential tornado threats) using a web-based experimental platform.

To complete the study, eight project objectives were as follows: (1) the construction of the web-based experimental platform, (2) a pilot study with undergraduates to test the experimental design, (3) a nationally implemented study drawing from a representative sample of the U.S. population, (4) analysis of experimental results, (5) the creation of a training module for National Weather Service forecasters highlighting the value and implications of using uncertainty information, (6) publications preparation, (7) presentations of the work at conferences, and (8) outreach.

The web-based platform development began immediately in September 2012 and was completed in November 2012 for the pilot study. Using PI McPherson and Thomas' classes (and others), 135 undergraduates were recruited from introductory courses in physical geography and psychology at the University of Oklahoma to participate in the experimental pilot study. In part, the pilot was to help determine how quickly participants could answer questions and if there were problems in the study design. These data were collected during the first week of December 2012.

Data from the pilot study were analyzed from December 2012 through early February 2013. Improvements were identified for the national study, including the addition of a few questions that measured certain severe weather-related attitudes, the addition of a probabilistic graphic with no color scheme (as an experimental control), and a change in logic for how the "biased forecast" condition was designed. Programming activities included working through logic issues, quality controlling database functions, improving graphics, and conducting informal tests of the experiments. An example of the web-based survey is in the Appendices.

The Institutional Review Board approved the modifications to the protocol in March 2013. The approved IRB forms are in the Appendices. [Please note that according to the protocol, elements of the dataset (e.g., names of individuals) cannot be disclosed to NOAA.] De-identified results that are available include decisions made over all 96 experimental trials for each participant, the experimental condition of each participant (e.g., graphic type, verbal information, bias type) and trial (e.g., objective probability 85%, etc.), and answers to the follow-up questions at the end.

Data collection for the full implementation of the experiment commenced during the first week of April 2013. Approximately 5900 participants from a census-balanced panel, furnished by a national survey sampling company, completed the experiment; however, a number of experiments were incomplete and others were completed too quickly for the results to be reliable. Hence, study data were drawn from 5564 participants from across the U.S., and approximately 100 people from each state completed the experiment. Participants were paid about $6 for their participation, and they accessed the maps via a web link to our online experimental platform.

For each map and its associated verbal guidance (if applicable), the participant was presented with the following decision scenario: they were the managers of a series of airports for which severe weather was forecasted to occur. They could protect their airport and risk losing revenue, or they could continue operations and risk a loss that was twice as large as the lost revenue. A rational operator would choose to protect their assets when they were at least 50% sure a storm would affect their airport. Each participant was presented with this decision scenario 96 times.

We used a 6x2 between-subjects experimental design: people were assigned evenly to one of two verbal conditions (i.e., they either received verbal guidance or they did not) and one of six graphics. The map graphics were two deterministic graphics (one long and one short) and four probabilistic graphics (one without color and three with distinct and commonly used color schemes, displayed in Figure 1). Therefore, approximately 460 participants (1/12 of our total sample) received each of the 12 conditions. Participants who received verbal guidance were told that there was a "high chance" that a tornado would strike if the probability exceeded the decision threshold (described below) and a "low chance" for probabilities under the decision threshold. This verbal guidance was designed to mimic the emphasis that NWS forecasters currently place on certain warnings using a verbal, tiered structure to communicate increased certainty.

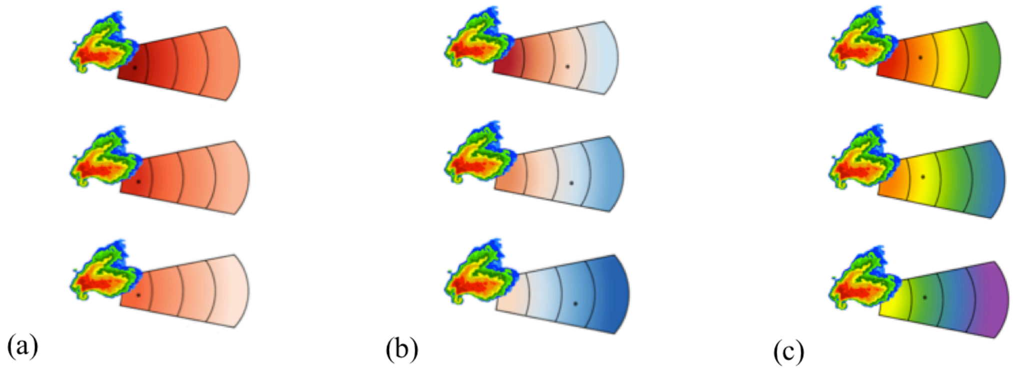


Figure 1: Three different color schemes used in the study, representing three different color schemes NWS forecasters could use to probabilistically depict tornado threat. The color schemes used were (a) continuous, (b) divergent, and (c) qualitative. The dots represent example airport locations in each graphic for comparison within color schemes (hereafter referred to as locations A, B, C and D, in order from left to right); from top to bottom, each graphic represents an event that is increasingly less likely to produce a tornado (between-event differences in probability).In other words, for graphic (a), deeper shades of red were associated with higher probabilities. Thus, at a given point (A, B, C or D), a participant would expect to see one of three different probabilities (associated with one of the three graphics in the series). Probabilities are assumed to fall off with increasing distance from a storm (from point A to D), from left to right (within-event differences in probability).

3. Research Questions and Key Findings

Our study involved the following research questions:

Research Question #1: How do individuals make decisions in a geospatial context based on deterministic warning guidance (i.e., present technology)? Specifically,

(a) what are the effects on decision-making of being included or excluded from a warning?,

(b) do people infer uncertainty over distance within deterministic warnings?, and

(c) does the addition of a verbal, tiered system for communicating different levels of existence-of-tornado uncertainty alter responses over distance?

Research Question #2: How do probabilistic tornado guidance products (i.e., future technology) affect decision-making in a geospatial context? Specifically,

(a) how does existence-of-tornado uncertainty, expressed geospatially (e.g., on a map), influence decision-making?, and

(b) do different symbolic representations influence the way uncertainty is understood and weighted in decision-making?

PI Klockow documented the analyses of the results of this study in her dissertation, which was completed on July 26, 2013, and successfully defended on August 9, 2013. The key results of the analyses are discussed below.

4. Key Results

4.1 Subjective risk estimates with deterministic information

4.1.1 Effect of being included in warning guidance

To investigate the influence of a mapped tornado warning boundary on response decisions, we plotted the average proportion of response decisions made per point. Figure 2 displays such a plot for our experimental comparison of short vs. long deterministic forecasts, with the location of the participants airport at either point A, B, C, or D (*x*-axis) plotted against the average proportion of decisions to protect the airport (*y*-axis). We found that the average proportion of the protection decisions differed at several places based on the presence of a warning. The differences were greatest at points A, B, and D. Analyzing these differences together, **long deterministic guidance significantly ($p < 0.05$) reduced protective decisions closest to the storm (point A), but then increased the rate of protection significantly ($p < 0.05$) at points farthest away (point D), as compared to short deterministic guidance.**

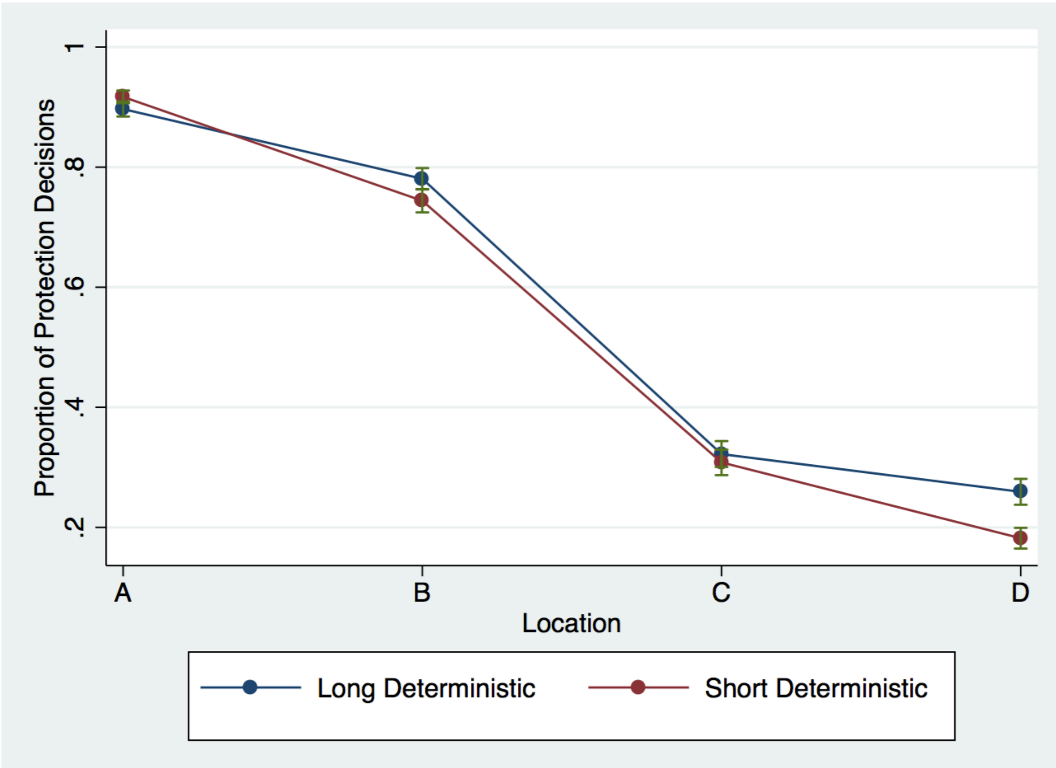


Figure 2: The proportion of response decisions made by people who received long deterministic and short deterministic warning information, respectively, by location.

These results indicated that being included in a mapped warning area had a significant effect on subjective estimates of risk. Being included within the shorter guidance product seemed to emphasize the risk close to the storm more than the longer guidance did, but this relationship reversed at point B - the farthest point included within the short deterministic warning. Being excluded from the warning appeared to have no effect at the point lying closest to the warning (point C), but it had a strong effect for the point that was farthest from the warning boundary (point D).

4.1.2 Effect of distance on response tendency for the deterministic warning

Subjective estimates of risk clearly decreased with distance for deterministic information, based on Figure 2. The effect of distance was highly significant ($p < 0.001$), with responsiveness reducing by 25% with each increase in distance from the storm (intercept = 0.17, *SD* = 0.002). Thus, people appeared to infer uncertainty into ostensibly certain, deterministic forecasts based on distance.

While this trend was observed for deterministic information generally, the rate of decrease in protective actions over distance differed significantly between the two forms of deterministic guidance. Longer guidance had an apparent leveling effect on spatial risk perception over distance, reducing the average proportion of protective decisions closest to the storm (as compared to shorter guidance) and increasing this proportion at farther distances. The overall rates of decline in protection decisions with distance differed significantly between the two forms of guidance ($ß_{long} = –0.24$, *SD* = 0.004; $ß_{short} = –0.26$, *SD* = 0.004).

While average response tendencies over distance differed between the two map graphics, they shared a statistically indistinguishable rate of decline in average protection decisions between points B and C – a rate that exceeded those between locations A and B and between locations C and D for both graphics (Fig. 2). Our participants, therefore, saw less distinction between locations A and B and between locations C and D than they saw between locations B and C in either graphic – in other words, **our participants appeared to group points "close to the storm" and points "far from the storm" and responded very differently to those two groups of points**. *Absolute* distance from a storm seems to matter, but people are also cueing in on another way of thinking about their risk that is *relative* – their relative position to the storm, compared with other places, in a specified geographic area.

4.1.3 Effect of verbal information on response tendency

To examine the influence of verbal information on decision-making, we plotted response tendencies for people who were placed at airport locations A, B, C, and D by the objective probability of the trial (e.g., Figs. 3 and 4). (Recall that, for each location, a person could experience one of three objective probabilities that were dependent on the displayed graphic). We found that participants using deterministic information but no verbal support were *unable to distinguish between underlying objective probabilities* (Fig. 3). Given only distance as a cue, this was the expected baseline state against which the influence of verbal guidance could be compared.

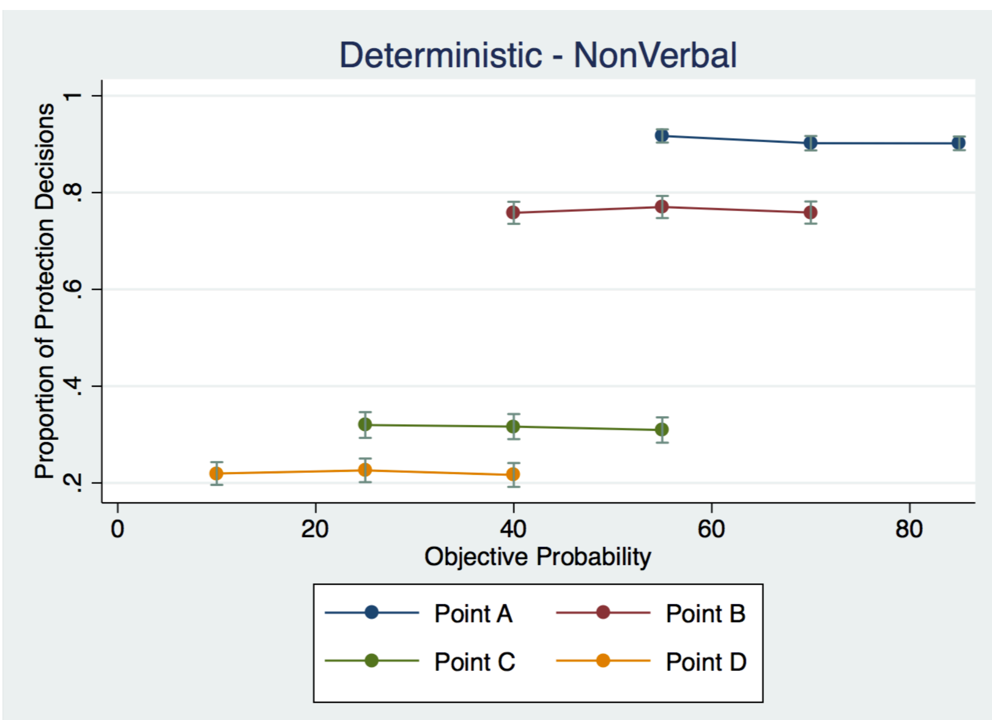


Figure 3: Response tendencies for participants with deterministic information and no verbal guidance, by point and underlying objective probability.

When verbal information was added (Fig. 4), response tendencies changed significantly across the 50% decision threshold. That is, for people who made decisions for airport location C with an objective probability of 55% (above the decision threshold), the verbal guidance made them protect the airport 25% more often than when the objective probability fell beneath the decision threshold ($M_{\text{above}} = 0.52$, $SD_{\text{above}} = 0.32$; $M_{\text{below}} = 0.24$, $SD_{\text{below}} = 0.27$, $p < 0.001$). When the objective probability was 40% (under the decision threshold), participants who made decisions for location B protected 25% less often than when the objective probability was above the decision threshold ($M_{\text{above}} = 0.84$, $SD_{\text{above}} = 0.19$; $M_{\text{below}} = 0.59$, $SD_{\text{below}} = 0.30$, $p < 0.001$).

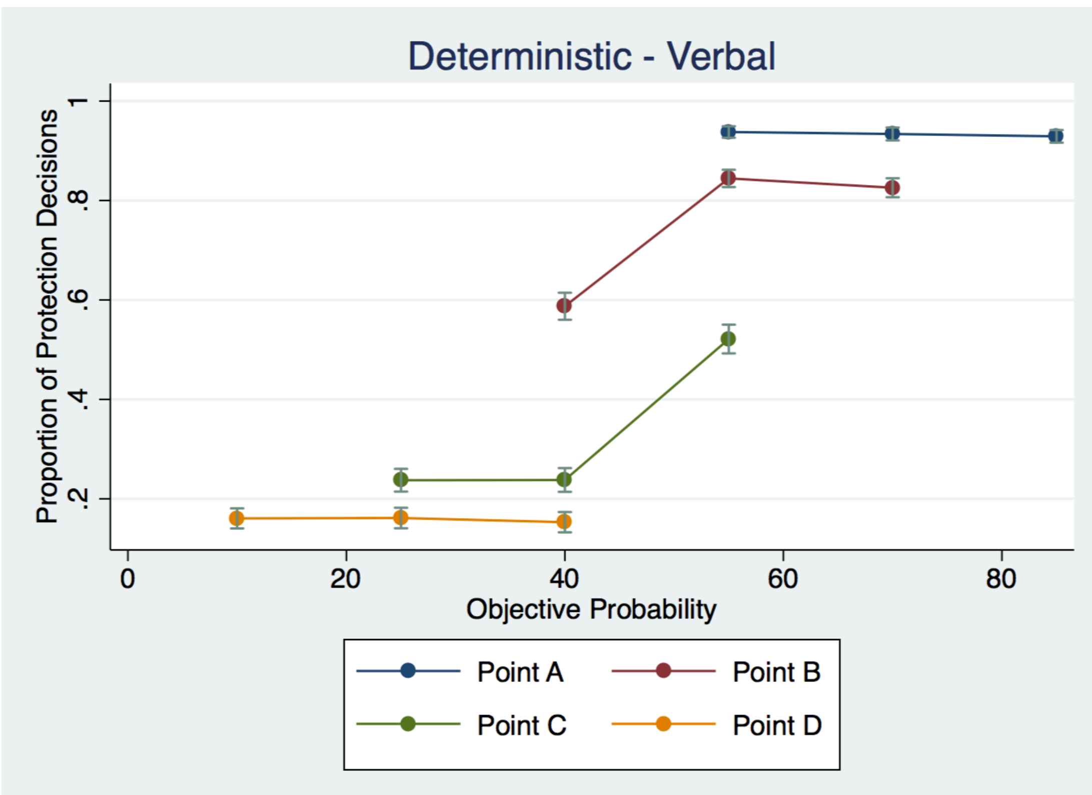


Figure 4: Response tendencies for participants with deterministic information and verbal guidance, by point and underlying objective probability.

Stated another way, the negative verbal information (i.e., "low chance" of a tornado occurring) reduced the subjective estimates of threat for participants who made decisions at location B by about as much as if they were deciding for location C; positive verbal information (i.e., "high chance" of a tornado occurring) increased subjective risk estimates for people at point C about as much as moving them to point B. Thus, while distance clearly had an impact on response decisions, verbal information modified this relationship to provide a distinction between high and low certainty situations. **Including positive verbal information had the apparent effect of increasing response tendencies at a closerpoint; negative verbal information had the opposite effect. Receiving verbal guidance had the additional benefit of increasing trust in the forecast**, rated by participants on a 1-10 scale, for those who received deterministic information ($M_{\text{nonverbal}} = 5.98$, $SD_{\text{nonverbal}} = 2.60$; $M_{\text{verbal}} = 6.34$, $SD_{\text{verbal}} = 2.64$, $p < 0.001$).

4.2 Subjective risk estimates with probabilistic information

4.2.1 Response tendency with probabilistic information

Plotting response tendencies by objective probability for participants who used probabilistic information, we found a different response pattern than we saw with deterministic information (Fig. 5). **Generally, responses appeared to be governed by probability rather than distance**, since response tendencies for many objective probability/location pairs were the same. For example, people who received a forecast of 75% chance of tornado occurrence responded with statistically indistinguishable proportions of protection decisions when placed at locations A and B. However, there were very significant differences between locations B and C for probabilities both above and below the decision threshold (e.g., 40% and 55%).

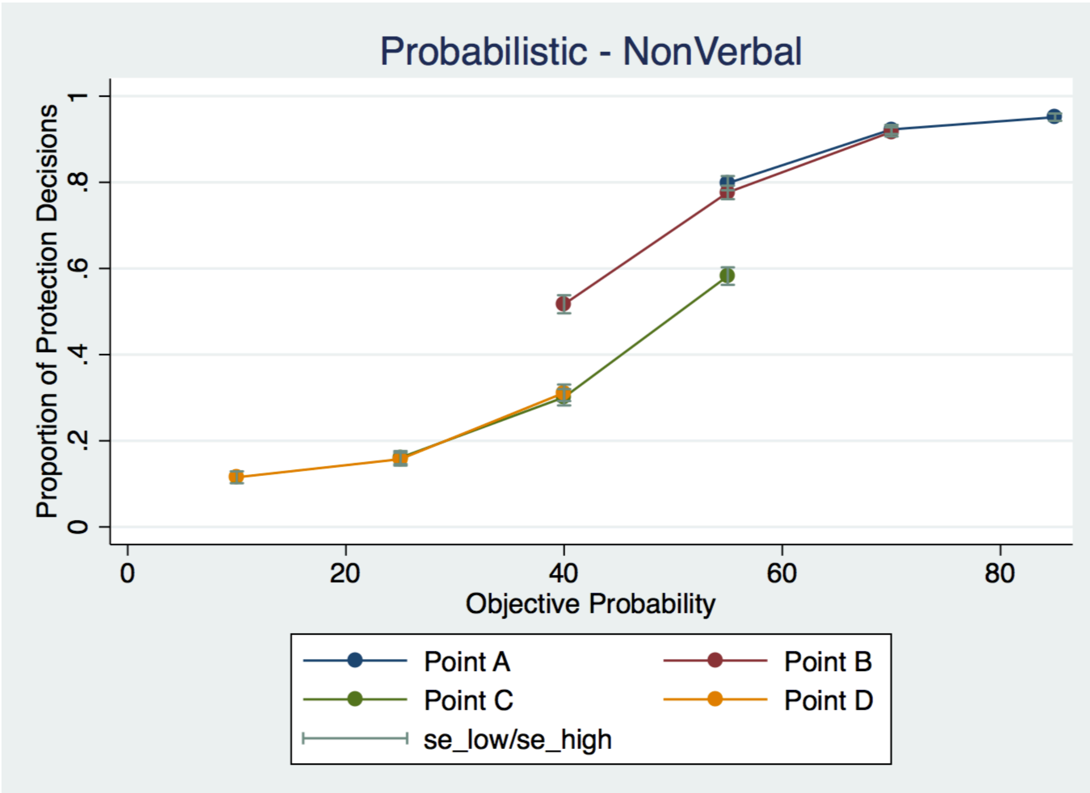


Figure 5: Response tendencies for participants with probabilistic information and verbal guidance, by point and objective probability.

When given a forecast of 40%, participants at locations C and D chose to protect 19% less often than people who were placed at location B ($M_{CD} = 0.26$, $SD_{CD} = 0.28$; $M_B = 0.45$, $SD_B = 0.32$, $p < 0.001$). At a 55% objective probability level, people placed at airport locations A and B chose to protect 21% more often than those at location C ($M_{AB} = 0.82$, $SD_{AB} = 0.22$; $M_C = 0.66$, $SD_C = 0.31$, $p < 0.001$). This result indicated that relative position within a specific geographic area could bias objective estimates of threat. **In effect, people did not interpret 40% always as 40% in a geospatial context - its meaning depended on how far that 40% probability was from the storm.**

Notably, this effect was not consistent: it only happened in the transition between the points that were "near the storm" and those that were "far from the storm." Recall that we saw this response tendency with deterministic information too for both long and short deterministic guidance (noted earlier). Thus, this effect might exist independent of warning size and type, and could instead depend on the extent of an area that was included on a map. **We note that this distinction in relative nearness and farness may be yet another geospatial framing effect.**

4.2.2 Response tendency for different cartographic designs

Several patterns were evident in Figure 6, which displays the average proportion of protection decisions by objective probability for all six map types. First, the mean proportion of protection decisions generally differed between probabilistic and deterministic conditions when objective probabilities were above the decision threshold (i.e., greater than 50%). **Participants who received probabilistic information protected more frequently at higher probabilities than people with deterministic information, and less frequently at lower probabilities.** Given the scenario, the people who were provided with probabilistic information did better than those without it.

To examine the significance of these patterns, we conducted Tukey's post-hoc pairwise comparison tests (Jaccard et al. 1984) between the graphic types at each objective probability level. Table 1 displays the results, including the mean and standard deviation for the difference in response decisions between each pair of graphics.

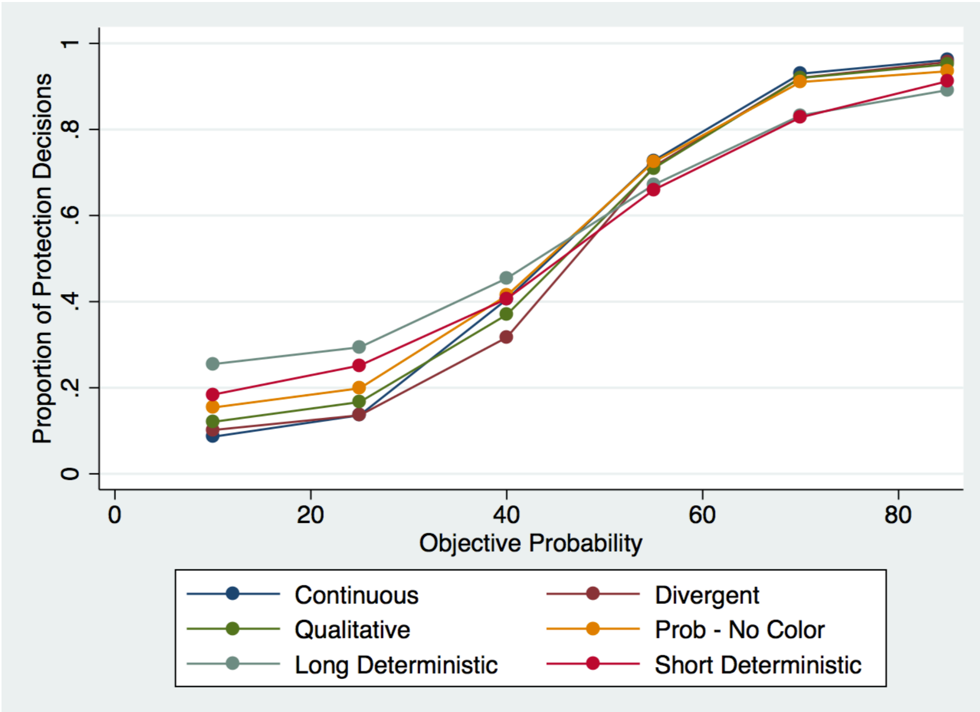


Figure 6: Response tendencies for all participants, by map type and underlying objective probability.

Pairwise Differences in Mean Proportions of Protection Decisions

(Significance determined using Tukey's HSD)

Graphic Type	Probability Level	Continuous	Divergent	Qualitative	Prob/No Color	Long Det.
Divergent	10					
	25					
	40	(-.088) (.021)***				
	55					
	70					
	85					
Qualitative	10					
	25					
	40					
	55					
	70					
	85					
Prob/No Color	10	.067 (.021)*				
	25	.063 (.020)*	.062 (.020)*			
	40		.097 (.021)***			
	55					
	70					
	85					
Long Det.	10	.169 (.021)***	.153 (.021)***	.134 (.021)***	.101 (.021)***	
	25	.158 (.020)***	.158 (.020)***	.127 (.020)***	.095 (.0204)***	
	40		.137 (.021)***	.084 (.021)**		
	55	(-.056) (.017)*			(-.053) (0.17)*	
	70	(-.097) (.014)***	(-.087) (.014)***	(-.087) (.014)***	(-.078) (.014)***	
	85	(-.070) (.012)***	(-.065) (.012)***	(-.600) (.013)***	(-.044) (.013)**	
Short Det.	10	.098 (.021)***	.082 (.021)**	.063 (.021)*		(-.071) (.021)*
	25	.115 (.020)***	.115 (.020)***	.085 (.020)**		
	40		.090 (.021)***			
	55	(-.068) (.174)**	(-.054) (.017)*	(-.050) (.017)*	(-.065) (.017)**	
	70	(-.101) (.014)***	(-.920) (.014)***	(-.091) (.014)***	(-.082) (.014)***	
	85	(-.050) (.012)**	(-.044) (.012)**	(-.039) (.013)*		
		* for p < .05	** for p < .01	*** for p < .001		

Table 1: Pairwise comparisons of response decisions among all graphics, broken down by objective probability level.

A key result of this study was that average protection rates for the long and short deterministic graphics differed significantly at almost every point as compared to the rates of protection for people who had uncertainty information. Generally, at all points above the decision threshold, people with deterministic information protected significantly less often. The opposite relationship held for all points below the decision threshold, where people with deterministic information protected significantly more often.

Notably, **probabilistic graphics with color generally did not differ significantly from each other at any probability level with one exception: at 40%, just beneath the decision threshold, participants who received the divergent color scheme protected significantly less than people who had the continuous color scheme**. Referencing the data series for these schemes (Fig. 6), it appeared that protections declined more rapidly beneath the decision threshold for people with the divergent color scheme. At the 40% probability level, the divergent and continuous color schemes began to differ in hue for the first time; *the divergent color scheme started to incorporate blue*, while the continuous color scheme was a less saturated red color. By the 25% probability level, response decisions to both color schemes were statistically indistinguishable.

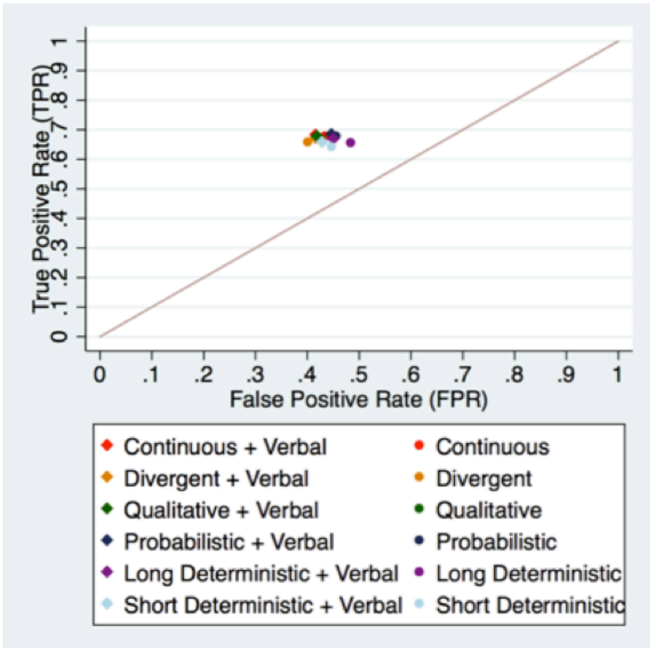
While proportions of protection decisions did not appear to differ significantly between color scheme groups, there were several significant points of difference between the probabilistic graphic without color and some of the graphics with color. At the two lowest probabilities (10% and 25%), participants who received the colorless graphic protected significantly more than those participants who received the continuous color scheme. The same pattern was observed between the colorless probabilistic graphic and the divergent color scheme at 25% and 40%. **Both the divergent and continuous color schemes significantly reduced**

protective actions at low probabilities as compared to the control, and thus, emphasized the low value extremes in ways that reduced subjective estimates of threat.

4.2.3 Examining decision error rates for graphics, verbal guidance

In the previous section, we established several relationships between response tendency and graphic type. However, understanding the implications of these response patterns required a separate analysis. Ideally, a good warning system will help people to discriminate truly threatening situations from those that are non-threatening and not simply make people more or less responsive (i.e., biasing the response criterion, but not enhancing discriminability; Swets et al. 2000). To investigate this issue, we constructed a receiver operating characteristic (ROC) diagram (Fig. 7). The perfectly discriminating person would be represented in the upper left corner of Fig. 7. **In our study, for all graphics, the true positive rate (i.e., the proportion of times that participants protected out of all the times a tornado occurred) was relatively constant among all the graphics. The short deterministic graphic group recorded the lowest true positive rate.**

(a)



(b)

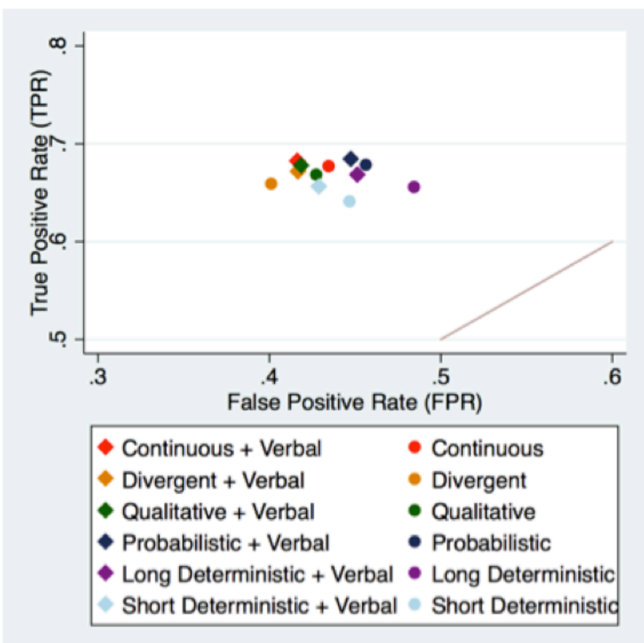


Figure 7: ROC diagrams for all of the graphic and verbal conditions; (b) magnifies the pertinent region of (a) to more clearly demonstrate differences among data points. Conditions that received verbal support are indicated with the use of diamond symbols, and conditions without verbal support are indicated with the use of circles.

What varied most among the graphic types was the false positive rate, or the number of times the participants protected out of all the times a tornado did not occur (i.e., the type 1 error rate). **People receiving deterministic information, and specifically the long deterministic graphic, had the highest false positive rate.** Notably, people receiving the probabilistic graphic without color clustered with those who received the deterministic graphics; they also had higher false positive rates than those with color-emphasized probabilistic information. **Generally, having verbal information (the diamonds in the graphic) helped people to reduce their false positive rate.**

Using an ordinary least squares regression, we explored the potential relationships between error rates and information type (e.g., probabilistic vs. deterministic, verbal vs. nonverbal), accounting for other factors such as gender, numeracy, membership in an ethnic minority group, education, and living below the poverty line. To determine numeracy, we used the subjective numeracy scale of Zikmund-Fisher et al. (2007). Probabilistic and verbal information helped to reduce errors significantly, holding all other factors constant ($p < 0.001$ for both). Participants who were more highly numerate and female participants both made significantly fewer errors also ($p < 0.001$ for both), and with higher educational achievement, error rates fell somewhat ($p = 0.072$). Minorities, including both black and Hispanic participants, and people living below the poverty line were more likely to incur errors than both non-black, non-Hispanic participants ($p < 0.001$) and all people living above the poverty line ($p < 0.001$). An ordinary least squares analysis of these same regressors on protection decisions revealed that our minority participants and participants living in poverty tended to have significantly higher average proportions of protection decisions overall ($p < 0.001$). This effect could reflect greater risk aversion within these groups and, thus, more willingness to accept Type 1 errors in situations of tornado threat. These groups tend to be the most vulnerable in tornado events, exhibiting relatively high rates of mortality and morbidity (Donner 2007).

5. Implications of this Study for Practitioners

This study had several key findings pertinent to NOAA NWS tornado warning operations. First, we found evidence that uncertainty was inferred into ostensibly deterministic, or certain, tornado forecasts based on distance from a storm. Second, we found evidence for the existence of a boundary effect on subjective estimates of risk, but it was more complex than we had predicted. It appeared that lengthening the tornado warning polygon not only increased subjective estimates of threat for points farther away from the storm, but it also decreased these subjective perceptions for people who were close to the storm. Thus, a trade-off may exist between alerting people downstream earlier and maintaining a sense of urgency for those who are closest to the storm. Additionally, longer deterministic warnings caused the *highest incidence of false alarms* of any condition in our study. Without knowing more about the tolerance for type 1 errors within the population, and without improvements to tornado prediction technologies, **we currently do not advise that forecasters increase lead-times by extending deterministic warning information through use of larger polygons in warning maps.**

As an alternative course of action, **forecasters could offer verbal information that indicates their increased confidence that a storm will produce a tornado**. In our study, people made fewer response errors with verbal information and trusted their forecast guidance more than they did without it. Information with positive directionality had the apparent effect of increasing the lead-space of alarm; that is, people at farther distances from the storm protected much more often.

With probabilistic information displayed visually on a map, study participants protected more frequently at high probabilities and less frequently at low probabilities, and thus, they had fewer false protections than the deterministic information group. **This supports the growing body of literature that suggests that providing probabilistic forecast information, including in tornado warning forecasts, may promote better decision-making.** Color-coding probability information had effects in certain situations. The protection decisions made by participants with divergent and continuous color schemes differed significantly at low probabilities from the control graphic (probabilistic information with no color). The former two color schemes emphasized low probabilities in ways that reduced subjective estimates of threat. We demonstrated in this study that cool colors, or a decline from warm colors toward an absence of color, could decrease subjective estimates of risk. **Thus, in the interests of promoting precaution, we advise weather forecasters to avoid using cool colors in risk depictions.**

6. Limitations of the Study and Future Research Directions

Our study reveals that geospatial risk depictions using maps can influence subjective estimates of threat in numerous ways. We found evidence for each of our proposed geospatial framing effects — namely, that distance, risk boundaries, and color-coding represented in maps can all influence the perception of risk over space. However, this work was conducted in a simulated, experimental setting. In the real world, the decisions people have to make are much more complex, and go far beyond the probability of an event times its occurrence. People must receive the warning information, understand it and evaluate their options for safety, and they must feel efficacious in pursuing those response activities (Lindell and Perry 2012). Importantly, changes in lead-time will change the horizon of potential response activities, including to enable actions such as fleeing (Hoekstra et al. 2011). Real-world events with extended lead-time demonstrate that lead-time alone may not garner improved collective responses, though the reasons these poor collective responses are as yet unclear (NOAA 2013). Therefore, we recommend that the following avenues of research be explored:

(1) Examinations of perceptions of safety from tornadoes, especially for those who live in vulnerable places or situations (such as apartments, mobile homes, or in places with lower information saturation/access). This research would help the weather community understand how safe people feel in different structures, including their home, or for different response options (including fleeing in an urban area). These responses could be compared to objective estimates, thereby revealing gaps in understanding that may drive ineffective protective response. This research should be conducted across different places to examine the intersection of local hazards climatology and place-based, culturally-situated notions of optimal response actions.

(2) Research into response efficacy for tornado protection. This research would reveal how empowered people feel in taking various response actions, which is an important consideration for improving risk communication strategies.

(3) More experimental work should be conducted to explore the many ways forecasters could consider communicating forecast uncertainty, and how those representations would be understood and used in decision-making. It would be helpful, for example, for human-oriented researchers to have a rigorous, detailed accounting of the ways ensemble forecasts work, and the kinds of parameters that are available to communicate. They could then assemble a body of research to understand how those parameters (such as the most likely case, the median case, range of options, etc.) work within/are accessible through various communication channels, and are understood and acted upon by the publics.

(4) More real-world case studies should be conducted to examine the ways people receive warning information, and how uncertainty information may (or may not) be communicated through those channels. Some channels, such as sirens, are not designed to offer anything but binary forecast information. It is unclear how these technologies would be used in a probabilistic forecasting regime.

7. Transitioning research to operations: Training for NWS forecasters

Klockow visited Warning Decision Training Branch (WDTB) – now Warning Decision Training Division (WDTD) – on August 28-29, 2014, and the assembled team outlined a draft of content for a module on risk communication principles and warning response processes to fit into the Advanced Warning Operations Course core track. As of June 1, 2015, these training modules will be live within the WDTD Warning Operations Course (WOC). Klockow worked with the team to combine this risk communication and response background with an NWS initiative on social media, and a course of four modules was designed to help forecasters empower appropriate responses by the U.S. publics:

(1) Risk assessment – Module documents the decision processes people go through in high-risk situations (warning response models, social influences).
(2) Risk communication – Module provides guidance on how the weather service can encourage people to consider what actions they will take during severe weather (preparedness), and serve as an influential risk communicator.
(3) Social media – Module provides best practices guidance for the use of social media.
(4) Social media – How it can be used before, during, and after severe weather events to communicate impacts.

WDTD staff spent 5.3 months of staff time to generate the series of modules, most of which were funded through this grant.

8. Outreach and Publications

PI Klockow presented preliminary findings from the pilot study at the Society for Risk Analysis Annual meeting in December 2012 and the American Meteorological Society Annual Meeting in January 2013. She also presented preliminary findings from the national study at the Association of American Geographers Annual Meeting in April 2013, and a summary of key findings from the national quantitative study at the 2014 American Meteorological Society Annual Meeting. Klockow provided an overview of findings from her entire dissertation to the National Weather Center community in Norman at a departmental colloquium on August 23, 2013. Consistent with this grant but beyond the funded project period, Klockow presented this work in a variety of forums, including at NOAA Headquarters, the University of Ohio, and at a specialty group meeting of the American Association for the Advancement of Science in Washington, D.C. in March 2014. She highlighted key findings of this work on the WeatherBrains radio show, with a national audience of over 10,000 weekly listeners, in April 2014.

9. Budget Summary

9.1 Original Budget

The following are the original budget, budgeted expenses, and balance by category.

	Budget	Expenses	Balance
Grad Research	$24,286	$17,979.59	$6,306.41
Staff Salaries	$3,000	$7,356.02	$(4,356.02)
Fringe Benefits	$2,722	$3,686.65	$(964.65)
Supplies	$-	$-	$-
Equipment	$-	$-	$-
Travel	$-	$757.20	$(757.20)
Communications	$-	$-	$-
Computing & Related	$-	$-	$-
Contractual & Related	$26,520	$27,247.48	$(727.48)
Tuition	$3,886	$2,876.77	$1,009.23
Overhead (26%)	$14,696	$14,827.05	$(131.05)
Total Costs	**$75,110**	**$74,730.76**	**$379.24**

9.2 Revised Budget

As a result of sequestration and the defunding of one of their key courses by National Weather Service Headquarters, the Warning Decision Training Branch (WDTB) had staff reductions that forced them to narrow the scope of their activities. Although we had funding in this grant to cover a portion of one of their developers to work with Klockow on content for a learning module, WDTB was no longer able to collaborate on this project. That is, as of March 17, 2014, there was no developer available to work with us, even with the funding. On March 18, Ms. Liz Quoetone, WDTB's lead instructor and our SSWR collaborator, lost her battle to cancer. At that time, we intended to close this grant and return the remaining funding. By May, however, NWS HQ changed their decision and we have added a new WDTB collaborator, Ms. Jami Boettcher. We will submit a no-cost extension to this grant and work on completing the uncompleted training module objectives. The budget was revised at that time, using most but not all of the remaining funds. The following are the revised budget, budgeted expenses, and balance by category.

	Budget	Expenses	Balance
Staff Salaries	$7,000.00	$7,356.02	$(356.02)
Fringe Benefits	$2,926.00	$2,574.16	$351.84
Travel	$1,010.00	$1,004.68	$5.32
Contractual & Related	$1,000.00	$1,000.00	$-
Overhead (26%)	$3,103.36	$3,103.07	$0.29
Total Costs	**$15,039.36**	$15,037.93	**$1.43**

10. Acknowledgements

The National Oceanic and Atmospheric Administration funded the quantitative portion of this work (NOAA Grant #NA12OAR4590118) and The University of Colorado's National Hazards Center Grant Program funded the qualitative work (NSF CMMI1030670). The Oklahoma Climatological Survey provided funding for both portions of the study. Harold Brooks, Scott Greene, Darren Purcell, and Aondover Tarhule provided valuable guidance to PI Klockow as part of her Ph.D. committee. We thank Ryan Sobash for programming the web-based experiment, Angelyn Hobson for transcribing interview recordings, and Survey Sampling International (SSI) for their assistance with subject recruitment. Use of SSI does not constitute an endorsement by the University of Oklahoma or NOAA.

Appendices

1. **University of Oklahoma Institutional Review Board: Information Sheet to Participate in a Research Study**
2. **University of Oklahoma Institutional Review Board: Approved Description of Study Protocol**
3. **Example of Tornado Warning Experiment Questions**

University of Oklahoma
Institutional Review Board
Information Sheet to Participate in a Research Study

Project Title: The impact of uncertainty information on tornado warning response
Principal Investigator: Renee McPherson
Department: Geography

You are being asked to volunteer for this research study. This study is being conducted where you are able to access the Internet. You were selected as a possible participant by Survey Sampling Incorporated (SSI), and volunteered to participate in this experiment for payment by SSI.

Please read this form and ask any questions that you may have before agreeing to take part in this study.

Purpose of the Research Study

The purpose of this study is to understand how people use forecast guidance information, specifically tornado warnings, to make protection choices.

Number of Participants

About 5500 people will take part in this study.

Procedures

If you agree to be in this study, you will be asked to make protection choices for a set of fictitious theme parks in the face of potential severe weather. You will complete 96 decision scenarios. Next, you will answer a few questions about your confidence in and interpretation of this information.

Length of Participation

This procedure should take about 15 minutes to complete.

Risks and Benefits

There are no known risks of participation. You will receive payment from SSI for participating.

Compensation

You will be paid for your time and participation in this study by SSI.

Confidentiality

In published reports, there will be no information included that will make it possible to identify you. SSI will retain your contact information for payment, but they will only be notified when you have completed the task (they have no access to your responses) and the researchers will never have access to your contact information.

Voluntary Nature of the Study

Participation in this study is voluntary. If you withdraw or decline participation, you will not be penalized or lose benefits or services unrelated to the study. If you decide to participate, you may decline to answer any question and may choose to withdraw at any time.

Contacts and Questions

If you have concerns or complaints about the research, the researcher(s) conducting this study can be contacted at: Renee McPherson, 405-325-2541, renee@ou.edu.

Contact the researcher(s) if you have questions or if you have experienced a research-related injury.

If you have any questions about your rights as a research participant, concerns, or complaints about the research and wish to talk to someone other than individuals on the research team or if you cannot reach the research team, you may contact the University of Oklahoma – Norman Campus Institutional Review Board (OU-NC IRB) at 405-325-8110 or irb@ou.edu.

Please keep this information sheet for your records. By providing information to the researcher(s), I am agreeing to participate in this study.

University of Oklahoma – Norman Campus
Institutional Review Board
Description of Study Protocol

1. **What** is your research design? (**Examples**: A pre-test – post test 2 x 2 experiment, with a control group and an experimental group that will receive one intervention. A grounded theory exploration of a topic. A pre-test post-test evaluation of a new classroom teaching method. An online cross-sectional survey of students related to curriculum topic. An 8-week walking study with a control and 2 comparison groups receiving either a diet or exercise message intervention). Guidance: This description should be short and written for a lay reader not for someone in your field. Also, your response should be understandable without the reader having to refer to another study document. Do not cut and paste your thesis/dissertation research abstract.

The study is a 5x2x2 between-subjects experiment. Each participant will receive one of twenty potential combinations of forecast information: one of five forecast graphics, one of two forecast error types, and text guidance or no text guidance. In each of 96 trials, participants will be asked to look at the forecast information and make a choice about whether or not they want to protect a fictional recreation park from the potential of severe weather (there will be four fictional parks spread over an area. They will have a starting budget of $500,000 and a cost/loss scenario as follows:

	Tornado occurs	No tornado occurs
Protect	$3,000	$3,000
Do not protect	$5,000	$0

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The control group will receive modern-day forecasting guidance (30-minute, deterministic tornado warning with no text guidance), and other groups will receive experimental warning information (one of three probabilistic designs, or a 60-minute deterministic tornado warning). The dependent variables in the study will be the final budget remaining after successful completion of 96 trials, and rating of trust given to the forecast system at the conclusion of the trials.

The independent variables in the experiment are graphic type, forecast error type, and verbal guidance (yes or no).

Following these choice experiments, participants will be asked to rate their level of trust in the forecast information, and to provide some basic interpretations of the information they were presented.~~[Type your response here]~~

2. **Describe** your participants (examples: 10 day care directors in Tulsa, 50 employees of ABC Company in Norman, 5 people between 18 and 45 who do weight resistance exercise at least two times a week). **Include** information for each type of participant. Guidance: Many studies gather data from different types of participants such as teachers and their students, employees and their supervisors, kids and their parents. Be sure to provide a description of all types of potential participants.

~~[Type your response here]~~Participants will be members of the US public selected for participation by the survey company Survey Sampling, Inc (SSI). There will be between 5300 and 5500 participants, ranging in age from 18 through 85, and of a variety of social, ethnic, and economic backgrounds.

3. **Provide** the inclusion and exclusion criteria for selection for each type of participant. **Where** will you obtain the contact information for potential participants? Guidance: If the information is public, describe the source of the contact information. You may not ask an organization or other entity to provide contact information for potential participants without their (potential participants) consent to release this information. You may ask that institution to distribute recruiting material that includes the researcher's contact information so that potential participants can contact the researcher directly if interested in participating. If you involve an institution or other entity in recruitment activities, upload a signed, site- support letter, on the organization's letterhead, that confirms that the signor has reviewed your research design and is willing to assist you in participant recruitment. Please note that access to contact information as a component of your job function DOES NOT automatically mean that you have access to this information for research purposes. This permission must be provided by your employing organization.

4. The participants will be selected from a pool of survey-takers who have registered with the survey company Survey Sampling, International (SSI). They will be approached by SSI with a link to the survey, and they can choose to participate or not of their own free will. I will not have access to individual contact information; only de-identified socio-demographics will be retained.~~{Type your response here}~~

~~4.~~5. **Recruitment: Who** will approach potential participants? What information are potential participants given about the study? What safeguards are in place to minimize coercion? **If** the researcher(s) is also the participants' supervisor/instructor, how will you assure that the identity of the research participants remains unknown to the researchers until after (1) the data have been gathered and are de-identified or (2) the class grades have been assigned? Guidance: If the participants are under the direct supervision of the researcher(s) (such as employees or students of the researcher(s)), someone other than the researcher must conduct all recruitment and identifiable data collection activities. Upload recruitment materials, such as verbal or written scripts, email messages, postings to websites, flyers, and/or letters. If you recruit participants who are not at OU, include this language: The University of Oklahoma is an Equal Opportunity Institution. For OU mass email – you must have the proper permission to use the email list and must include this language in your email message: The OU-IRB has approved the content of this message, but has not authorized the distribution method.

Potential participants are volunteers enlisted with the survey company SSI. No coercion is involved, participants volunteer for the experiments for the opportunity to earn money for participation. They may exit the study at any time. The identity of the participants will be protected by SSI; no connection will remain between participants and their responses except for de-identified socio-demographic information.~~{Type your response here}~~

~~5.~~6. **What identifying information will you collect? How** long will you retain participant contact/identifying information? **How** will you store this information during the study? **How** will you dispose of contact information when the study is completed or when you no longer need this information? Guidance: If you do not have permission to report the names of your participants, then it is advisable to assign pseudonyms or study numbers to each participant as soon as the data are collected to reduce the risk to participants if research files are accidentally released. Participants can give you permission to release their identities or to store identifiable research records in the Waiver of Elements of Confidentiality section of the informed consent documents.

Participants will each be assigned a unique ID number, but this is only done to assure that individual records are stored in our experiment's database. These IDs are not linked to their real identities in any way.~~{Type your response here}~~

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~~6.~~7. **Provide** a step-by-step description of each of the tasks that participants will be asked to perform during the study. Guidance: Tasks include: the consent process, completion of data collection instruments and any intervention or de-briefing activities.

For each study task, list each task sequentially in the order participants will complete it; indicate the approximate time it will take to complete each task and the setting (such as, in a classroom, in the participants' workplace, in a public place, at home). Guidance: If you have multiple kinds of participants (i.e., students and teachers, employees and executives, etc.), include separate entries for each kind of participant and each task.

For each data collection instrument, indicate the frequency of administration and the method of administration (i.e., face-to-face, telephone, mail, or via a website). Guidance: Upload a copy of each data collection instrument, including surveys, questionnaires, interview protocols, questions for focus groups, observation recording forms, etc.

For face-to-face interviews and focus groups/group interviews, describe other persons who are not participants who will be present and the activities of each of these persons. **What** steps will you take to ensure that the discussion is held confidential by all the participants after the focus group? Guidance: All non-participant attendees are considered key study personnel since they have access to identifiable data. If someone other than the researcher will transcribe interviews, a confidentiality agreement should be completed and submitted with your application. A copy of the OU-NC approved confidentiality agreement form should be modified for your study and uploaded with other study documents.

Task	Time	Setting	Method of Administration
Introduction and consent	3 min.	Wherever the participant has Internet access	Web link
Example trial	1 min.	"	Computer
96 decision trials	11 min.	"	Computer

~~{Type your response here}~~

~~7.~~8. **What** steps will you take to protect the identity of your participants? If interviews or focus groups are audio recorded and will be transcribed, who will transcribe the audio, and how will participants' identities be protected in the transcipts? Guidance: for audio-recorded data, you can mask the identity of the participants by using software programs such as Audacity (a free download). Also, participants should be addressed by a pseudonym or code during interviews to avoid inclusion of names that make interviewees identifiable or a procedure for de-identifying transcripts must be proposed. Photographs of classrooms should not include any identifiable images of the students under 18 who are in the classroom. If you intend to publicly release audio, video or photography, then you will need to have participants sign the OU Talent Release document.

Their experimental performance will be coded following the assignment noted above.~~{Type your response here}~~

~~8.~~9. **How** will you store, secure, and dispose of each kind of data in your research records, including paper documents, electronic files, audio/video recorded data, photography and/or research records? **How** will you store and dispose of signed consent documents and master lists that link identifying information to ID code numbers? **For** what length of time will you retain your research records? Guidance: To retain research records that contain identifiable information about the participants (or that contain sufficient information for deductive re-identification) after the close of the study, you will need to provide a justification for this request. In addition, you will need to include the Waiver of Elements of Confidentiality section on the consent documents. For de-identified data sets with no potential for deductive re-identification of participants, research records can be kept indefinitely.

Data type	Storage	Security	Disposal Method	Retention Time

Data comes de-identified; there will never be a link to participants.~~{Type your response here}~~

Tornado Warning Experiment

Welcome to the Tornado Warning experiment!

University of Oklahoma
Institutional Review Board
Information Sheet to Participate in a Research Study

You are being asked to volunteer for a research study. This study is being conducted where you are able to access the Internet. You were selected as a possible participant by Survey Sampling Incorporated (SSI), and volunteered to participate in this experiment for payment by SSI.

Please read this form and ask any questions that you may have before agreeing to take part in this study.

Purpose of the Research Study
The purpose of this study is to understand how people use forecast guidance information, specifically tornado warnings, to make protection choices.

Number of Participants
About 5500 people will take part in this study.

Procedures
If you agree to be in this study, you will be asked to make protection choices for a set of fictitious airport hangars in the face of potential severe weather. You will complete 96 decision scenarios. Next, you will answer a few questions about your confidence in and interpretation of this information.

Length of Participation
This procedure should take about 20-25 minutes to complete.

Risks and Benefits
There are no known risks of participation. You will receive payment from SSI for participating.

Compensation
You will be paid for your time and participation in this study by SSI

Confidentiality
In published reports, there will be no information included that will make it possible to identify you. SSI will retain your contact information for payment, but they will only be notified when you have completed the task (they have no access to your responses) and the researchers will never have access to your contact information.

Voluntary Nature of the Study
Participation in this study is voluntary. If you withdraw or decline participation, you will not be penalized or lose benefits or services unrelated to the study. If you decide to participate, you may decline to answer any question and may choose to withdraw at any time.

Contacts and Questions
If you have concerns or complaints about the research, the researcher(s) conducting this study can be contacted at: Renee McPherson, 405-325-2541, renee@ou.edu.

Contact the researcher(s) if you have questions or if you have experienced a research related injury.

If you have any questions about your rights as a research participant, concerns, or complaints about the research and wish to talk to someone other than individuals on the research team or if you cannot reach the research team, you may contact the University of Oklahoma - Norman Campus Institutional Review Board (OU-NC IRB) at 405-325-8110 or irb@ou.edu.

Clicking "Continue" below indicates your consent to participate and acknowledges that you are over the age of 18.

To decline this survey, click "Decline" to return to SSI.

You must complete the entire experiment to receive compensation by SSI.

Continue

Decline

Page 2:

Tornado Warning Experiment

Welcome to the Tornado Warning Experiment!

In today's experiment, you will be given a scenario, and asked to make choices about protecting yourself from potential tornado strikes.

Continue

Page 3:

Tornado Warning Experiment

Scenario: You are the manager for four airports. Your task is to decide whether or not to order the planes to hangars for safety (protect the airplanes).

Your choices have consequences:

To protect , you must spend **$3,000**. You are protected against a tornado if it occurs.

If you choose not to protect and a tornado occurs, you'll lose **$6,000**.

If you choose not to protect and a tornado doesn't occur , you lose **nothing**.

Your starting budget is **$500,000**. You will go through 96 decision scenarios.

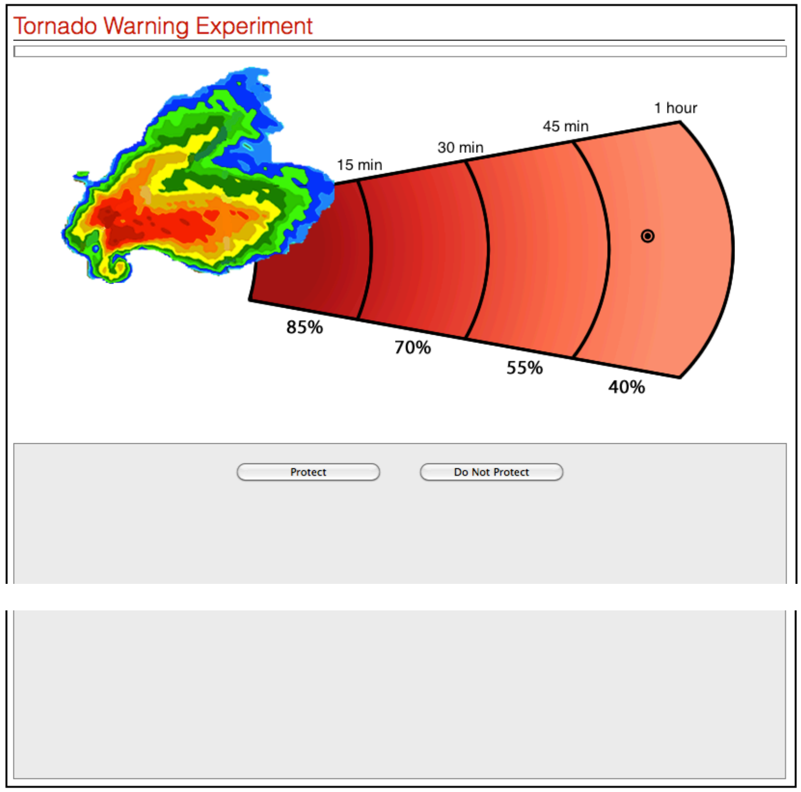
Continue

Page 4:

Tornado Warning Experiment

To help you decide whether or not to protect, you will receive warning information, similar to the graphic below. Each warning lasts 1 hour and is broken into four 15-minute segments.

The average probability that a tornado will occur in a given segment is provided under the warning. In the graphic below, from 45-60 minutes, there is a 40% chance that a tornado will occur in that region.



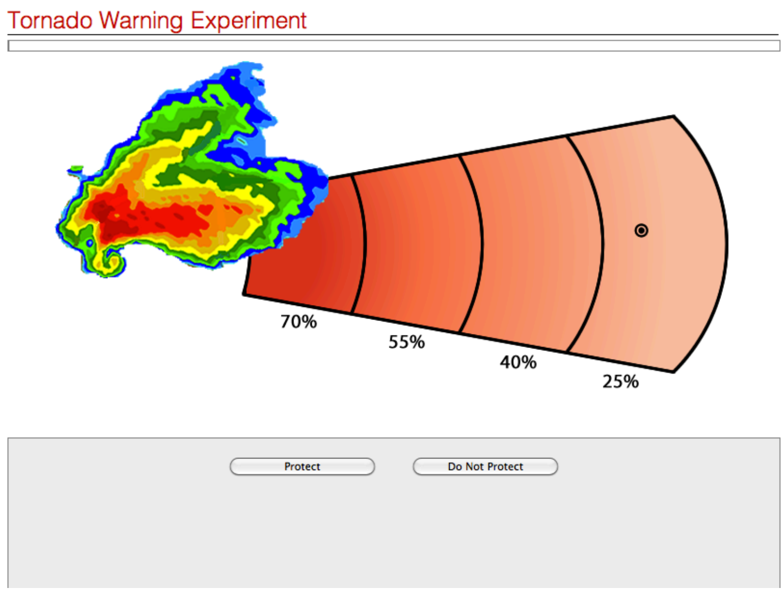
The location of the airport of concern will be labeled on the map. You will be shown a warning graphic at the time when a decision must be made for that airport. For example, airports appearing further away from the storm require more time to protect than others.

To protect, click the button that says "Protect". To maintain operations as-is, click "Do Not Protect".

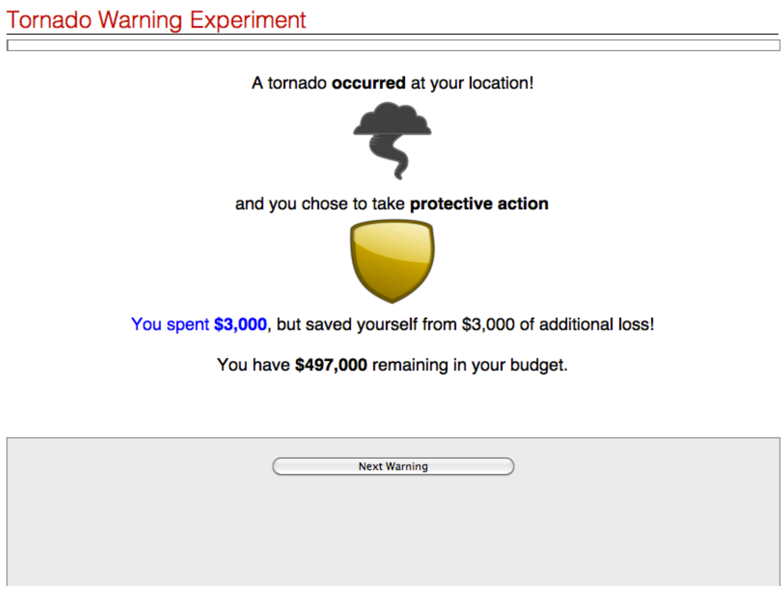
Click "Begin" to start the warning experiment!

BEGIN

Page 5 (experimental trial #1):



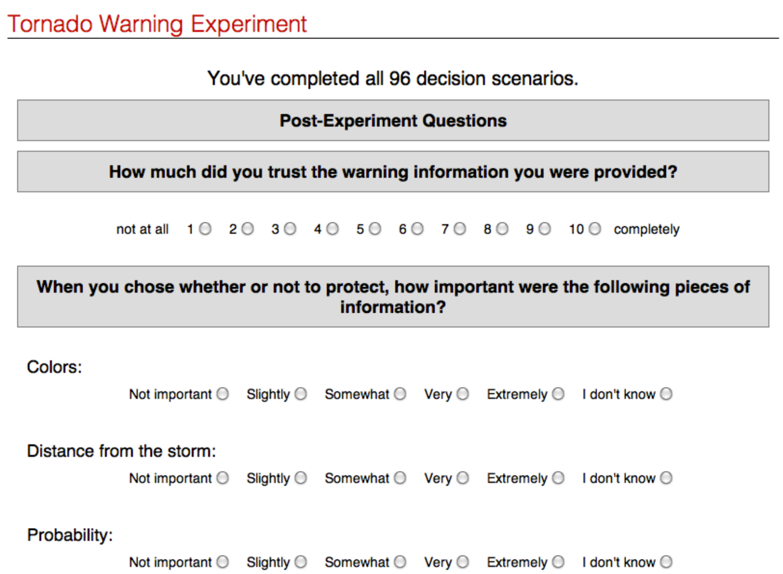
The choice made influences the feedback individuals receive. If, for example, they choose "Protect", and a tornado is chosen for that trial by the program, they see the following feedback:



Feedback is in the same format when a tornado does not occur or when individuals do not protect. The icons shown change as appropriate for those outcomes.

Participants repeat this procedure for 96 trials.

Page 1 of questions, after completion of the experimental trials:



Did you like the color scheme used in your warnings?

Yes ○ No ○ No preference ○

To what degree did the colors confuse you?

Not at all ○ Slightly ○ Somewhat ○ Moderately ○ Extremely ○ I don't know ○

To what degree did the probabilities confuse you?

Not at all ○ Slightly ○ Somewhat ○ Moderately ○ Extremely ○ I don't know ○

Imagine it's storm season where you live. Your home has been under four tornado warnings this year, but no tornadoes happened with those storms. These false alarms would make you would think the chances of getting a tornado next time would be:

Higher ○ Lower ○ Unchanged ○ I don't know ○ None of these ○

Now imagine that a storm produces a tornado near your home. You would think the chances of getting a tornado next time would be:

Higher ○ Lower ○ Unchanged ○ I don't know ○ None of these ○

Submit

Page 2 of questions:

Tornado Warning Experiment

For each of the following questions, please check the box that best reflects how good you are at doing the following things:

How good are you at working with fractions?

not at all good 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ extremely good

How good are you at working with percentages?

not at all good 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ extremely good

How good are you at calculating a 15% tip?

not at all good 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ extremely good

How good are you at figuring out how much a shirt will cost if it is 25% off?

not at all good 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ extremely good

For each of the following questions, please check the box that best reflects your answer:

When reading the newspaper, how **helpful** do you find tables and graphs that are parts of the story?

Not at all helpful 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ Extremely helpful

When people tell you the chance of something happening, do you prefer that they use **words** ("it rarely happens") or **numbers** ("there's a 1% chance")?

Always prefer words 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ Always prefer numbers

When you hear a weather forecast, do you prefer predictions using **percentages** (e.g., "there will be a 20% chance of rain today") or predictions using only **words** (e.g. "there is a small chance of rain today")?

Always prefer percentages 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ Always prefer words

How **often** do you find numerical information to be useful?

Never 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ Very often

Submit

Page 3 of questions:

Tornado Warning Experiment

Thank you for your participation in this experiment.

To receive credit for survey completion, please click the button below to return to SSI.

Complete Experiment

Debrief information

In this study we were interested in how you made protection choices when provided a particular combination of forecast information. To discover what combination of forecast information lead to the most well-calibrated choices, we varied the graphic type (making probabilities explicit for some participants), the verbal guidance information, and the accuracy of forecast information. Previous work suggests that using probabilistic weather information for decision-making can improve decisions. Additionally, the format of probabilistic information can change the way it's interpreted and used in decision-making, and since certain cartographic designs are used to highlight particular features on a map, this difference in graphical format could have similar effects depending on the way different ranges of probability were highlighted.

Due to the sensitive nature the research process, please DO NOT DISCUSS this procedure with other people that may later participate in this experiment.

If you noticed any technical problems, or have feedback about the experiment, please contact Kim Klockow at kklockow@ou.edu.