IDENTIFIFICATION OF TORNADO PROTECTIVE ACTIONS OF OKLAHOMA STATE UNIVERSITY STUDENTS – A PILOT STUDY

By

DILLON J. HARNESS

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Thesis Approved:

Dr. Haley C. Murphy (PhD)

Thesis Adviser

Dr. Tristan (Hao-Che) Wu (PhD)

Dr. Tony McAleavy (PhD)

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"The greatest gift you ever give is your honest self" – Fred Rogers

Name: DILLON J. HARNESS

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Title of Study: IDENTIFIFICATION OF TORNADO PROTECTIVE ACTIONS OF OKLAHOMA STATE UNIVERSITY STUDENTS – A PILOT STUDY

Major Field: FIRE AND EMERGENCY MANAGEMENT ADMINISTRATION

Abstract: Tornadoes account for the most violent of all-natural atmospheric hazards known to mankind (National Weather Service 2008). On average, the United States experiences approximately 1,200 tornadoes annually (NWS 2008). They are categorized by the Enhanced Fujita Scale (Fujita 2007) developed in 2007 as an update to the 1971 Fujita Scale (Fujita 1971) to rate tornadoes not solely on wind speeds anymore but more on the damage caused by the tornado. The aim of this study is threefold; one, chronologically identify the earliest literature on tornado warning preparedness to the latest study as of 2020, two, determine the process in tornado risk perception, and three, analyze the principles of Lindell and Perry's (2012) Protective Action Decision Model (PADM) as it ascertains to tornado preparedness as it relates to Oklahoma State University students. As a theoretical foundation, the PADM guides the ebbs and flows to finding a research question and deductively testing the research hypothesis. The intended outcomes of this study necessitated the use of external data sources for quantitative purposes. The data was collected via DynaSearch using computer simulations to perceive the risk of tornadoes through a series of stages. These stages grew from a severe thunderstorm watch to a complete tornado warning. A pilot study that coincides with this project had 119 participants from Oklahoma State University. The participants examined DynaSearch visual (images) and written (text) sources of information within the survey. The demographics of participants were noted at the end of the survey for collective purposes and will be noted in this subsequent study. Much of this study will analyze the literature from 2004 to 2019, using works from various disciplines ranging from disaster science to sociology. Some findings in this project may pave the way for future tornado research that may be deemed significant. Ultimately this project has a diverse data corpus to increase its validity and reliability. The experiment involving the OSU students was under control of the research team to manage any issues that arose during the research process.

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CHAPTER 1

INTRODUCTION

1.1. Overview of Watches and Warnings

Imagine it is bright and sunny day and there are no predictions for severe weather. That is until these sunny conditions rapidly to ingredients for severe thunderstorms. As conditions change, the National Weather Service issues a precautionary severe thunderstorm watch for your location. At this point, severe weather seems possible, but you are not fully confident. The National Weather Service continues monitoring the changing weather with each passing minute and then… a new watch comes out. This time, the National Weather Service issues a 'Tornado Watch'. Now the situation is quickly unravelling from that bright and sunny day earlier. Still under the 'watch' condition, severe weather becomes a little more certain. Soon, the weather radio goes off transmitting a new message from the National Weather Service… it is now a warning. Paying careful attention to this warning, the National Weather Service declares 'Severe Thunderstorm Warning' now in effect. At this moment, you begin to contemplate taking shelter. You grab your pets, loved ones and your priceless items and head into your safe zone in your house, and just in time too. For now, moments after you get into the storm

shelter, the National Weather Service issues the *granddaddy* of all severe weather warnings. They issue a 'Tornado Warning', though you are in a safe place with your pets to ride out the impending storm, and you survive a significant tornado that ravaged much of your community.

1.2. Significance of the Study

This was merely a hyperbolic scenario, but it highlights several key issues related to tornadoes. How individuals including those with pets, perceive risk and how they take protective actions to safeguard those they love. Researchers like E.L. Quarantelli (1977, 1995) and Slovic (1987, 2002) studied risk perceptions and tornado warnings, and much has been learned. Prior to 2012, there was not a widely used model for identifying all underlying factors affiliated with protective actions for emergencies and disasters, leading to the creation of the "Protective Action Decision Model (PADM)" (Lindell and Perry 2012, Lindell 2018). Much of this research, including Mileti and Sorensen (1990), Drabek (1986), and others have worked to identify the social cues that trigger a response when a tornado warning is issued, notably with Mileti and Sorensen's (1992) focus on communication. Accordingly, this study aims to

- *Distinguish the importance of risk perceptions based on a hypothetical advisory message.*
- *Break down the statistical significance of OSU student risk perceptions based on SPSS-generated results.*

Data analysis for this project requires the use the SPSS computer-based statistical analysis software to effectively determine the research outcomes. The research outcomes are: *What is the preferred protective action for each of the six advisory messages?, Are there any statistically significant relationships between risk perception and protective actions?,* and *Do protective actions increase as the advisories become more severe?.* The resultant SPSS-based quantitative data will demonstrate correlations and relationships among variables from the experiment. Once all the data has been analyzed, the results will be clearly outlined within the 'Findings' section to illustrate the results.

In the 'Conclusions' section, this project will highlight the limitations associated within the project. These will retrospectively assess all aspects of the project, from the literature review through the methodology and findings. When all the limitations are emphasized in the conclusion section, a summary of all the information that was presented will be drawn. By that time, no new information will be presented, and the project will end with a reference list showcasing all references that were necessary to complete the project to its fullest extent.

CHAPTER II

REVIEW OF LITERATURE

2.1. PROTECTIVE ACTION DECISION MODEL ELEMENTS

The Protective Action Decision Making Model was developed to help explain how people decide when and how to take protective action in an emergency situation. Firstly, the *environmental cues* involve the natural environment, which according to Lindell (2018) can consist of meteorological conditions that generate tornadoes. Secondly, social cues, deals more with observation of other people's behavior (family, friends, community, etc.) in order to make an individual decision. Thirdly, Information sources are the method(s) an individual chooses to receive their warning message (television, radio, etc.). Fourthly, channel access and preference explain individual's access to a warning message, and their preferred method of receiving warning messages. Fifthly, warning message is the actual message itself, which for the experiment that was conducted for this study is each of the advisories (severe thunderstorm watch, severe thunderstorm warning, tornado watch and tornado warning). Sixthly and finally, receiver characteristics, by definition, is certain behaviors and beliefs held by the individual receiving the warning message.

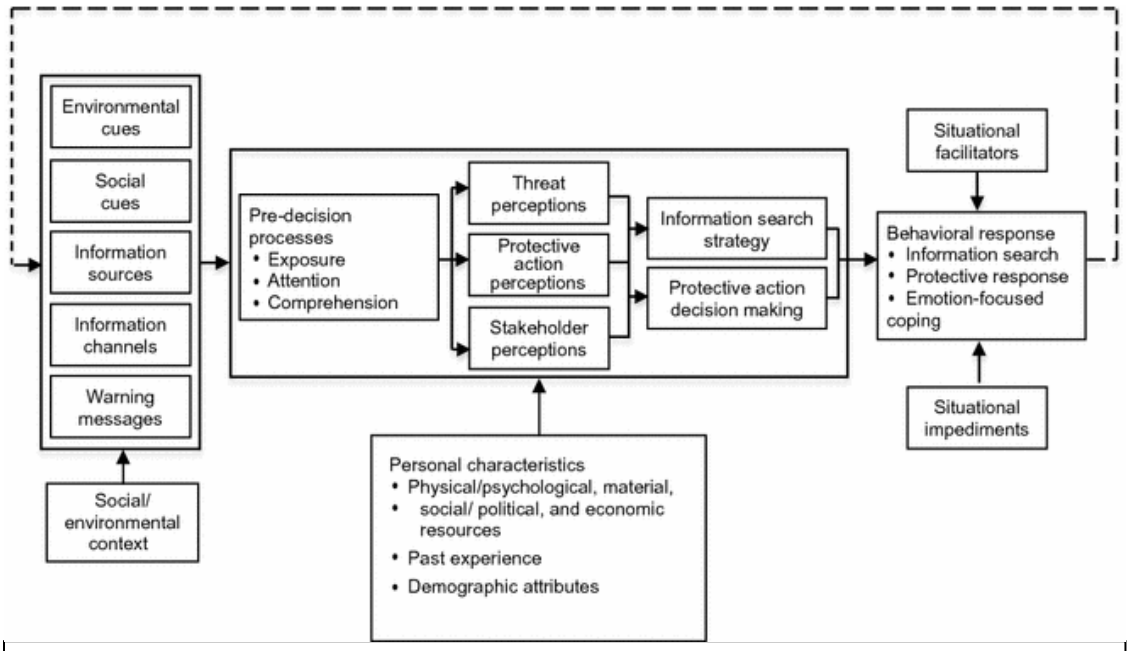

Figure 1-1: Lindell (2018) Protective Action Decision Model

This feeds into the second set of components to the PADM, which includes predecision processes, threat/risk perceptions, protective action perception, stakeholder perceptions and ultimately protective action decision making, which is core of the model. By definition, Lindell (2018) identifies predecision processes, in addition to exposure, attention and comprehension as core psychological responses. Exposure intends to make certain that a warning message is received, on the other hand, attention begs the question of whether the warning message is heeded. Comprehension, suggested by Lindell (2018), ideally means does the person receiving the warning message understand the message? Differences exist when talking about threat perceptions because threat perceptions require a sharper cognitive thought process. Threat perceptions are distinctive because they are seldom uniform from person to person. As an example, one person's perception of a

tornado threat to a community may be higher than their neighbor's. Protective action perceptions work in a similar fashion, a person may see the need for protective action, based on inexperience, at an earlier stage of a tornado situation than an individual who has more experience with tornadic situations. Stakeholder perceptions, the final aspect of the model preceding Protective Action Decision Making, is the blend of family unit threat perceptions, but also includes those in higher education, and others.

Protective Action Decision Making, the fundamental principle of this entire project and model, is the relationship between all elements that aides in modeling individual decision making. Lindell (2018) has dubbed this as essentially intermingling of all previous components into determining the best course of action during preparedness and planning. There are a handful of subcategories of Protective Action Decision Making identified by Lindell (2018) including risk identification, risk assessment, protective action search, protective action implementation, information needs assessment, communication action assessment, and finally communication action implementation. Broken down individually, risk identification is the cognitive process of identifying conditions of normalcy and striving to attain such conditions. Risk assessment seeks to understand the consequences of an event, in this case, tornadic activity. Protective action search is the mental process of identifying a means of protecting oneself based on real life experience, such as going to the basement for a tornado. Using simulated radar imagery and descriptions of an ersatz tornado warned storm, individuals can make improvised protective action decisions such as going to an interior room or going to a

storm shelter. Following identification of a protective action, the next phase is to choose whether to perform the protective action using critical thinking and decision making. Protective action implementation simply put says that an individual decides to take appropriate actions. Information needs assessment is distinct in which a person at this stage tests whether their risk reduction was satisfactory or not. Communication Action Assessment seeks to understand how an individual can receive information in the future about a particular threat or risk. Finally, Communication Action Implementation questions the urgency of a message, and whether it is needed at the moment. Each of these subsections of Protective Action Decision Making outlines the characteristics that are involved with making better decisions based on critical analysis of varying factors. Based on all these factors, there have been a few practical applications of Lindell and Perry's PADM in related research, which will now be discussed in brief.

2.2. OTHER USES OF THE PADM

Lindell (2018) suggests that the PADM has many uses but has only been applied to three key research areas… risk communication, evacuation modeling, and hazard adjustment. One of those uses, evacuation modeling, will be outlined in this section due to its relevancy to the overall topic at hand and subsequent research questions/hypothesis to follow later. Studies such as Dash and Gladwin (2007) and Sorensen et al. (2004) are example studies that utilize the barebones concept of protective action decision making and adapt it to evacuation behavior. Similar studies like Hasan et al. (2011), Huang et al. (2012), Lindell et al. (2007) and Lazo et al. (2010) use the same conceptual framework

but apply protective action decision making specifically to hurricanes. Tornado research using the PADM such as Durage and Wirasinghe (2016), Nagele and Trainor (2012), and Schultz et al. (2010) are just a few examples of this research. Ash (2017) also performed a tornado study using protective actions, but the study is qualitative in nature, meaning it does not utilize statistics. Yet, the studies like Nagele and Trainor (2012), Schultz et al. (2010), Durage and Wirasinghe (2016), Sorensen et al. (2004), and of course Lindell (2018) are five important studies. Each of these studies uses one or more aspects of the PADM to explain evacuation behavior or protective action and why individuals may or may not evacuate to protect themselves adequately.

2.3. RESEARCH HYPOTHESIS/QUESTIONS

Before moving into the Methodology section, this study must identify its key research hypothesis and key research questions in order to help guide the Methodology and eventually Findings. These are the **six** research questions and **one** research hypothesis.

Research Questions:

- **RQ-1:** What is the preferred protective action for advisory 1?
- **RQ-2:** What is the preferred protective action for advisory 2?
- **RQ-3:** What is the preferred protective action for advisory 3?
- **RQ-4:** What is the preferred protective action for advisory 4?
- **RQ-5:** What is the preferred protective action for advisory 5?
- **RQ-6:** What is the preferred protective action for advisory 6?

Research Hypothesis:

- **RH-1:** Participants' risk perceptions are higher when receiving tornado warning advisories.

Each question and lone hypothesis are important to the overall study because statistical findings from the data corpus and use of the statistical analysis computer-based software SPSS will determine the most appropriate protective action as the advisories in the survey change. Bearing this in mind, this paper will now shift away from the literature review into the methodology section.

CHAPTER III

METHODOLOGY

3.1. RESEARCH OBJECTIVE

This project examines key demographics in the sample, such as age, level of education and cognitive risk perception among students at OSU-Stillwater. Ultimately the research attempted to be equitable to all facets of the university community and include all demographics as test subjects. Some of the participants had a companion animal, see Al-Zaher (2019). A number of participants noted they had companion animals, but this did not place them in exclusive categories. Rather, the following research sought to measure Oklahoma State University students' risk perception and preparedness activities for natural hazards, such as tornadoes.

3.2. SAMPLE FRAME

Oklahoma is one of seven states, Texas, Oklahoma, Kansas, Nebraska, Missouri, Iowa, and South Dakota as being in Tornado Alley, a meteorological term "for being a high risk tornado area" (Fawbush and Miller 1952). Stillwater, located in Oklahoma, is no exception. Due to its geography, the city fits within that frame of high tornado strike probabilities (National Weather Service – Norman 2018).Thus, college students are considered a socially vulnerable population, according to Cutter (2003) and Sherman-Morris (2010), therefore it is important to understand how they make protective action

decisions in a tornado scenario. For that reason, the sample for this study will be Oklahoma State University students. The best way to accomplish this mission is by using a random sample. Ultimately the research attempted to be equitable to all facets of the university community and include all demographics as test subjects.

3.3. RESEARCH DESIGN AND MEASUREMENTS

To accurately reflect the relationship between the variables of warnings and protective actions, the researcher utilized both DynaSearch and SPSS. DynaSearch, as described by Lindell and others (2018), is computer-based software aimed at using surveys in a questionnaire format. SPSS is a computer-assisted quantitative analysis software that was used to analyze the data. 3000 blindly carbon-copied emails were sent out to students at Oklahoma State University with a link to the DynaSearch questionnaire. The base criteria for inclusion was simply being enrolled as a student at Oklahoma State University – Stillwater. Of the 3000 emails sent out, only 119 students chose to openly participate in the study. It was suggested in a letter of invitation that participants used a reliable web browser such as Google Chrome or Mozilla Firefox, otherwise the survey would not have loaded in the intended format. The response rate was just over two percent, which will be assessed in the limitations section.

Each participant faced a series of questions relating to various advisories. For the first question they were provided an advisory that showcased a custom-created weather radar image and supplementary information that read out “Severe Thunderstorm Watch for Payne County.” Once the student had the opportunity to review the information,

he/she was to answer a series of questions based on the radar image and supplementary information provided. A full questionnaire can be found in *Appendix A* with the various screens that participants were exposed to from the least severe to the most severe. *Appendix B* will demonstrate the Questionnaire that was followed by each participant that were under condition 1, which included all six survey questions.

3.3.1. ***Individual Demographics*** **–** The majority of those who participated stated that they graduated from a high school within the United States; in fact, more students graduated from Oklahoma high schools than any other state (66.4%). Of this sample, there were more female respondents than male respondents. The largest age bracket was the 19-20 year old group which accounted for 43.7% of all respondents. Individuals older than 31 years old made up less than 1% of respondents (0.32%, Mode = 9, $s^2 = 4.5$). There were more senior class respondents than any other group of OSU students (30.3%, Mode = 4, $s^2 = 1.2$). Also, it was noted that more students live off campus than on campus (55.2%, Mode = 3, $s^2 = 0.49$).

Of the 119 students who chose to participate, only 53 out of the 119 were used as the sample frame. These 53 students were exposed to all six questions in the questionnaire. After each scenario, while the other 66 students only received the questionnaire one-time after viewing all scenarios. It is impossible to know how the protective actions of those 66 students would have changed between each scenario, and therefore, they were excluded from this study. The students were placed into random groups intentionally in order to curb biases. Participants of the study received an

incentive for their participation, one of four $100 Amazon Gift Cards would be awarded to four randomly selected survey participants (Bell et al 2019). On 29 April 2019, after all the data had been collected, the four winners were randomly selected. In order to be eligible, a student had to adhere to a nonbinding agreement at the end of their survey in order to protect privacy and be assured their personal information would not be compromised. Participation in the study was not mandatory, though for those that did participate, the study took roughly one hour. The Institutional Review Board [IRB] required that issues arising from the distribution of the gift cards to raise red-flags and report them immediately. This would have been brought to the attention of the faculty in charge of oversight, Dr. Tristan Wu of Fire and Emergency and Emergency Management Administration – College of Engineering, Architecture and Technology at Oklahoma State University – Stillwater.

3.4. DATA ANALYSIS PROCEDURES

Why Oklahoma and OSU Students?

For purposes of this project, Oklahoma and OSU students were chosen at random for this experiment due to Stillwater, located in Oklahoma being identified by the National Weather Service as a high tornado risk community. It is also a college town with a diverse student population. Most students, based on demographics, come from the state of Oklahoma, though there is a plentiful international student presence and students may also attend from other states, like Iowa or Illinois for example. The students seemed like

the appropriate subjects because they may have experienced, or know someone who, has experienced tornadoes in the past.

Survey Design and Implementation

For this experiment, all units of analysis were Oklahoma State University students, which required IRB approval first. IRB approval was granted to the project and the project began on 7 January 2019. Graduate students conducted a dry test run of the survey to determine if any changes were necessary. A few tweaks were made before the product went live on 7 February 2019. These tweaks included rewording of questions, clarification of concepts to aid answering the research questions previously presented. These changes were not wholesale changes that would have drastically altered the outcomes of the study.

Breakdown of Experiment Variables

In the experiment, there were six different advisories that each student in Group 1 faced, and this is a breakdown of each advisory. In *Appendix A*, there is a screenshot representation of each of these different advisories to help better understand them visually, plus this helps the results of the experiment make more sense if there is a description of each variable prior to the release of the findings.

- Advisory #1 – Severe Thunderstorm Watch, meaning the meteorological conditions are favorable for the development of severe weather, but there are no severe thunderstorms, yet, protective actions suggested, not recommended.

- Advisory #2 – Severe Thunderstorm Warning, meaning meteorological conditions have expanded and now conditions are prime for severe thunderstorms, but not tornadoes, protective actions encouraged.
- Advisory #3 – Tornado Watch, meteorological conditions are favorable for the development of tornadoes, protective actions highly recommended, not encouraged. Encouraged because the storm is not happening in a watch, whereas in a warning the storm is occurring.
- Advisory #4 – Tornado Watch, meteorological conditions are favorable for the development of tornadoes, protective actions highly recommended, not encouraged. Encouraged because the storm is not happening in a watch, whereas in a warning the storm is occurring.
- Advisory #5 – Tornado Warning, meteorological conditions are consistent with tornado development, protective actions highly encouraged.
- Advisory #6 – Tornado Warning, meteorological conditions are consistent with tornado development, protective actions highly encouraged.

The next section will showcase the findings from the experiment using data corpus and analysis of SPSS-generated data based on each of the six advisories as an answer to each of the six research questions and one research hypothesis.

CHAPTER IV

CHAPTER IV

FINDINGS

Repeated Measure ANOVA was used to answer Research Questions 1-6, because the researcher was trying to determine which protective action respondents were more likely to take. Results of the repeated measure ANOVA are discussed below.

4.1. Risk Perception and Protective Actions

RQ-1: What is the preferred protective action for advisory 1 (thunderstorm watch)?

Repeated Measure ANOVA (Girden 1992) is used to test and answer this research question. The findings suggest respondents' likelihood of adopting tornado protective actions is significantly different across different protective action choices (*Wilks' Lambda* = .13; $F_{(5,47)} = 53.49$, $p < .01$). Table 1 shows respondents' have higher ratings to *continue what I am doing* (m=4.23) and *protect private property* (m=4.21) under advisory 1 (thunderstorm watch). They are less likely to choose sheltering or evacuation options.

Table 1. Respondents' likelihood of adopting protective actions under tornado advisory 1 (n=51)

Protective Actions	**Mean**	**S.D.**
Continue what I am doing	4.23	1.04
Protect private property. Have your doors, windows, and garage doors closed.	4.21	.99
Monitor TV or radio	3.42	1.30
Stay home and move to an interior room in the home (e.g. a closet), in a bathtub, or a tornado shelter.	2.00	1.32
Leave my home and take shelter in either an above or below ground tornado shelter at a nearby neighbor, friend, or families' house	1.62	1.10

Leave my home and take shelter at a public tornado shelter	1.46	.94
Leave my home with no destination in mind, simply to get out of the path of the storm	1.38	.87
Wilks' Lambda = .13; $F_{(5,47)}$ = 53.49, p <.01		

RQ-2: What is the preferred protection action for advisory 2 (thunderstorm warning)?

Repeated Measure ANOVA is used to test and answer this research question. The findings suggest respondents' likelihood of adopting tornado protective actions is significantly different across different protective action choices (*Wilks' Lambda* = .132; $F_{(5,47)}$ = 66.45, p < .01). Table 2 shows respondents' have higher ratings to *protect private property* (m=4.62) and *monitor tv or radio* (m=3.87) under advisory 2 (thunderstorm warning). They are less likely to choose sheltering or evacuation options.

Table 2. Respondents' likelihood of adopting protective actions under tornado advisory 2 (n=52)

Protective Actions	**Mean**	**S.D.**
Continue what I am doing	3.33	1.28
Protect private property. Have your doors, windows, and garage doors closed.	4.62	.77
Monitor TV or radio	3.87	1.16
Stay home and move to an interior room in the home (e.g. a closet), in a bathtub, or a tornado shelter.	2.94	1.29
Leave my home and take shelter in either an above or below ground tornado shelter at a nearby neighbor, friend, or families' house	1.73	1.16
Leave my home and take shelter at a public tornado shelter	1.65	1.22
Leave my home with no destination in mind, simply to get out of the path of the storm	1.52	1.04
Wilks' Lambda = .132; $F_{(5,47)}$ = 66.45, p <.01		

RQ-3: What is the preferred protection action for advisory 3 (tornado watch)?

Repeated Measure ANOVA is used to test and answer this research question. The findings suggest respondents' likelihood of adopting tornado protective actions is significantly different across different protective action choices (*Wilks' Lambda* = .095; $F_{(5,47)}$ = 71.07 , p < .01). Table 3 shows respondents' have higher ratings to protect

private property (m=4.69) and *monitor tv or radio* (m=4.37) under advisory 3 (tornado watch). They are less likely to choose sheltering or evacuation options.

Table 3. Respondents' likelihood of adopting protective actions under tornado advisory 3 (n=51)		
Protective Actions	**Mean**	**S.D.**
Continue what I am doing	2.88	1.37
Protect private property. Have your doors, windows, and garage doors closed.	4.69	.79
Monitor TV or radio	4.37	.92
Stay home and move to an interior room in the home (e.g. a closet), in a bathtub, or a tornado shelter.	3.55	1.29
Leave my home and take shelter in either an above or below ground tornado shelter at a nearby neighbor, friend, or families' house	2.25	1.26
Leave my home and take shelter at a public tornado shelter	2.18	1.29
Leave my home with no destination in mind, simply to get out of the path of the storm	1.45	.86
Wilks' Lambda = .095; $F_{(5,47)} = 71.07$, $p < .01$		

RQ-4: What is the preferred protection action for advisory 4 (tornado watch 2)?

Repeated Measure ANOVA is used to test and answer this research question. The findings suggest respondents' likelihood of adopting tornado protective actions is significantly different across different protective action choices (*Wilks' Lambda* = .19; $F_{(5,47)} = 32.90$, $p < .01$). Table 4 shows respondents' have higher ratings to *protect private property* (m=4.52) and *monitor tv or radio* (m=4.54) under advisory 4 (tornado watch). They are less likely to choose sheltering or evacuation options.

Table 4. Respondents' likelihood of adopting protective actions under tornado advisory 4 (n=52)		
Protective Actions	**Mean**	**S.D.**
Continue what I am doing	2.46	1.41
Protect private property. Have your doors, windows, and garage doors closed.	4.52	1.09
Monitor TV or radio	4.54	1.30
Stay home and move to an interior room in the home (e.g. a closet), in a bathtub, or a tornado shelter.	3.44	.90
Leave my home and take shelter in either an above or below ground tornado shelter at a nearby neighbor, friend, or families' house	2.33	1.42

Leave my home and take shelter at a public tornado shelter	2.25	1.53
Leave my home with no destination in mind, simply to get out of the path of the storm	1.62	1.27
Wilks' Lambda = .19; $F_{(5,47)}$ = 32.90, p <.01		

RQ-5: What is the preferred protection action for advisory 5 (tornado warning 1)?

Repeated Measure ANOVA is used to test and answer this research question. The findings suggest respondents' likelihood of adopting tornado protective actions is significantly different across different protective action choices (*Wilks' Lambda* = .128; $F_{(5,47)}$ = 52.42, p < .01). Table 5 shows respondents' have higher ratings to *protect private property* (m=4.63) and *monitor tv or radio* (m=4.73) under advisory 5 (tornado warning). They are less likely to choose sheltering or evacuation options.

Table 5. Respondents' likelihood of adopting protective actions under tornado advisory 5 (n=52)

Protective Actions	**Mean**	**S.D.**
Continue what I am doing	1.87	1.17
Protect private property. Have your doors, windows, and garage doors closed.	4.63	.97
Monitor TV or radio	4.73	.77
Stay home and move to an interior room in the home (e.g. a closet), in a bathtub, or a tornado shelter.	3.75	1.41
Leave my home and take shelter in either an above or below ground tornado shelter at a nearby neighbor, friend, or families' house	2.73	1.66
Leave my home and take shelter at a public tornado shelter	2.54	1.54
Leave my home with no destination in mind, simply to get out of the path of the storm	1.60	1.30
Wilks' Lambda = .13; $F_{(5,47)}$ = 52.42, p <.01		

RQ-6: What is the preferred protection action for advisory 6 (tornado warning 2)?

Repeated Measure ANOVA is used to test and answer this research question. The findings suggest respondents' likelihood of adopting tornado protective actions is significantly different across different protective action choices (*Wilks' Lambda* = .16; $F_{(5,47)}$ = 40.84, p < .01). Table 6 shows respondents' have higher ratings to *protective*

private property (m=4.69), *monitor tv or radio* (m=4.71), and *move to an interior room in their home* (m=4.21) under advisory 6 (tornado warning). They are less likely to continue what they are doing or evacuation options.

Table 6. Respondents' likelihood of adopting protective actions under tornado advisory 6 (n=52)

Protective Actions	**Mean**	**S.D.**
Continue what I am doing	1.65	1.30
Protect private property. Have your doors, windows, and garage doors closed.	4.69	.81
Monitor TV or radio	4.71	.80
Stay home and move to an interior room in the home (e.g. a closet), in a bathtub, or a tornado shelter.	4.21	1.18
Leave my home and take shelter in either an above or below ground tornado shelter at a nearby neighbor, friend, or families' house	3.12	1.78
Leave my home and take shelter at a public tornado shelter	2.60	1.66
Leave my home with no destination in mind, simply to get out of the path of the storm	1.67	1.26
Wilks' Lambda = .16; $F_{(5,47)} = 40.84$, $p < .01$		

3.5.1 TESTING RESEARCH HYPOTHESIS

RH-1: Participants' risk perceptions are higher when receiving tornado warning advisories.

Repeat measure ANOVA tests were used to test this research hypothesis. The findings suggest that as each advisory changes from severe thunderstorm watch to tornado warning, the risk perceptions are higher at the tornado warning level. Table 7 shows the higher mean risk perception for tornado warnings (RPA6Q1) than the average severe thunderstorm watches (RPA1Q1).

Table 7. Respondents' mean risk perceptions as the advisory message changes (n=52)

Protective Actions	**Mean**	**S.D.**
Severe Thunderstorm Watch (Advisory 1)	.30	.22
Severe Thunderstorm Warning (Advisory 2)	.40	.22
Tornado Watch 1 (Advisory 3)	.57	.22

Tornado Watch 2 (Advisory 4)	.65	.26
Tornado Warning 1 (Advisory 5)	.77	.22
Tornado Warning 2 (Advisory 6)	.85	.22
Wilks' Lambda = .22; $F_{(5,47)}$ = 34.03, p <.01		

Each of the seven Repeat Measure ANOVA tests demonstrates a statistical significance between the warnings (severe thunderstorm warning or tornado warning) and protective actions. Perhaps it is appropriate that when the scenario shifts from a thunderstorm to a tornado, it is more likely that more drastic protective actions ensue. Alternatively, it could suggest that thunderstorms do not cause protective actions, but individuals start to think about protective actions just in case the situation escalates from the thunderstorm to a tornadic situation. Based on this proposition and supported by statistical analysis, these findings support the research of Lindell (2018), and adequately answers the research questions as well as the research hypothesis.

CHAPTER V

CONCLUSIONS

The Protective Action Decision Model as described by Lindell (2018) has many individual facets. From the environmental cues onward, each step along the way is important in determining the best means of protecting oneself from a hazard. Given the uniqueness of the PADM, applying the principles to tornado research is something that, going forward, should be expanded. When using the PADM for direct practice, the model is used to better understand how people make decisions, then it informs emergency management professionals of the findings so that they have a better understanding of why people do or do not evacuate and can adjust their messaging/decision making appropriately. The model has been applied in other research areas, like evacuation modeling, and those applications may suggest future research in the area. Likewise, a similar procedure for use in theory may require expansion of the model and add additional information that does not already exist on the current paradigm. One should appreciate the findings of this project. Even though the sample was only 53 participants, attempting to garner a larger sample of university students is challenging. For most college students, college life can be stressful, speaking from experience, and finding the time to take a questionnaire does not always fit in. Perhaps the response rate could have

been higher but that remains to be seen. Future studies may gather a larger response rate and will allow for more fluid statistical analysis and data corpus.

As noted by all the findings, there is statistical significance between the advisory screen and gradually increased protective actions. When the advisory was merely a severe thunderstorm watch, participants did not choose evacuating or sheltering options, they were more likely to continue what they were doing. It was not until watch was replaced by the keyword 'warning' that appropriate protective actions such as taking shelter began to increase, and the statistics prove this. Higher means for taking shelter among participants increased at warning stages compared to watch stages.

5.1. RECOMMENDATIONS

- Recommendation 1:

For the Oklahoma State University campus, the future remains murky the landscape of the university changes, aging infrastructure, new generations of college students, and more. Although some buildings on the OSU Stillwater campus are designated as "Fallout Shelters", there are no explicit public tornado shelters available to the public or students. This study, as well as studies by Sherman-Morris (2010), Jauernic and Van Den Broeke (2016), and Al-Zaher (2019) suggest that university administrators should inform students about sheltering options on campus. It is also recommended that Oklahoma State University make it a priority to enact tornado shelters and remind everyone where they are. It is made publicly aware of where to go during a tornadic situation, but it is the responsibility of the students to take the proactive approach to

protect themselves. No one can force students to take shelter, though warning messages are the best line of defense to give lead time and the opportunity to prepare and plan for impending storms. It is written in OSU policy that when severe weather strikes or is imminent, parking garages cannot be used as storm shelters. This recommendation involves rebuking that policy because it does not make clear sense. This one involves students who drive, which with a campus as big as OSU, may or may not happen. Exempting the policy that parking garages cannot be used as storm shelters; policy that is in place, means that students' cars run the risk of being damaged by hail. The problem is that many students will not come to campus to shelter where it is safe, because they are worried their car will be damaged if they cannot park it in a shelter. So, they will not take appropriate protective actions. Results from the experiment show that students are willing to protect their private property which can include personal cars, especially for a tornado warning. So perhaps offering some leniency on allowing students to protect their cars, regardless of whether they have a permit for a parking garage or not.

This experiment has demonstrated the importance of risk perceptions, protective actions measures OSU college students will take to save their lives or the ones of those they know and cherish. It could also be utilized by emergency managers who live in Tornado Alley to encourage protective actions among citizens. University emergency management may also choose to use this as means of comparison from Oklahoma State University to their own university. Of particular note, start with Oklahoma State

University, then as the influence expands, apply the same core principles outlined throughout this project to fit the needs of other universities nationwide.

5.2. LIMITATIONS

There were at least two notable limitations that directly affected this project, the first of which was the university sample. Because there was such as small response rate to the invitation to participate, the findings are not generalizable to the larger university population. Secondly, the overall design of this project is unique in which it does not use real-world threats, rather it uses makeshift scenarios. This in turn does not allow the research to conclude fully what would happen if real-world emergency scenarios were used instead of hypothetical ones. Had real emergencies been used, there would have been significant differences in the outcomes and statistical findings would be different than presented herein for makeshift scenarios.

A special thanks on this project goes out to Dr. Tristan Wu and Dr. Haley Murphy for their oversight and guidance throughout the entire process. Props also to Dr. Tony McAleavy, who was brought in as the supreme editor-in-chief despite the short notice, and a final thank you to all who have supported the efforts of this project from start to finish. May the odds be forever in your favor and the force be with you to live long and prosper, and maybe also to protect yourself from a tornado or other hazards.

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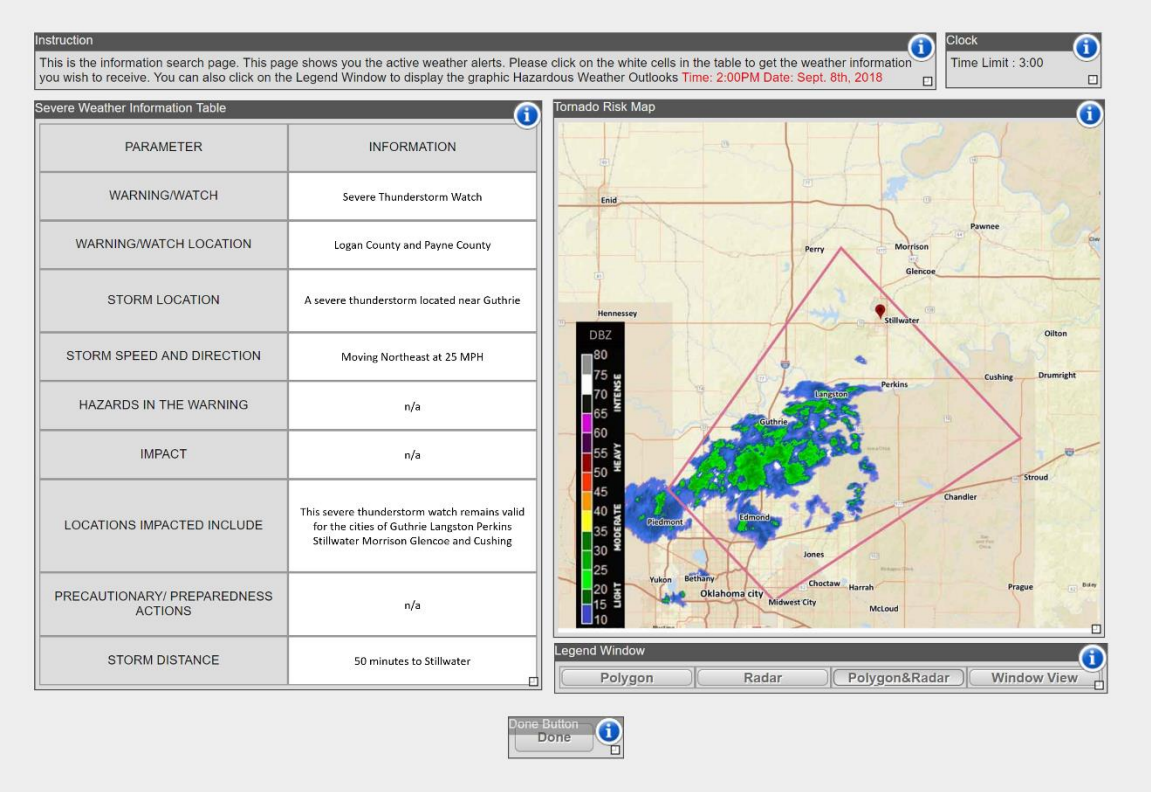
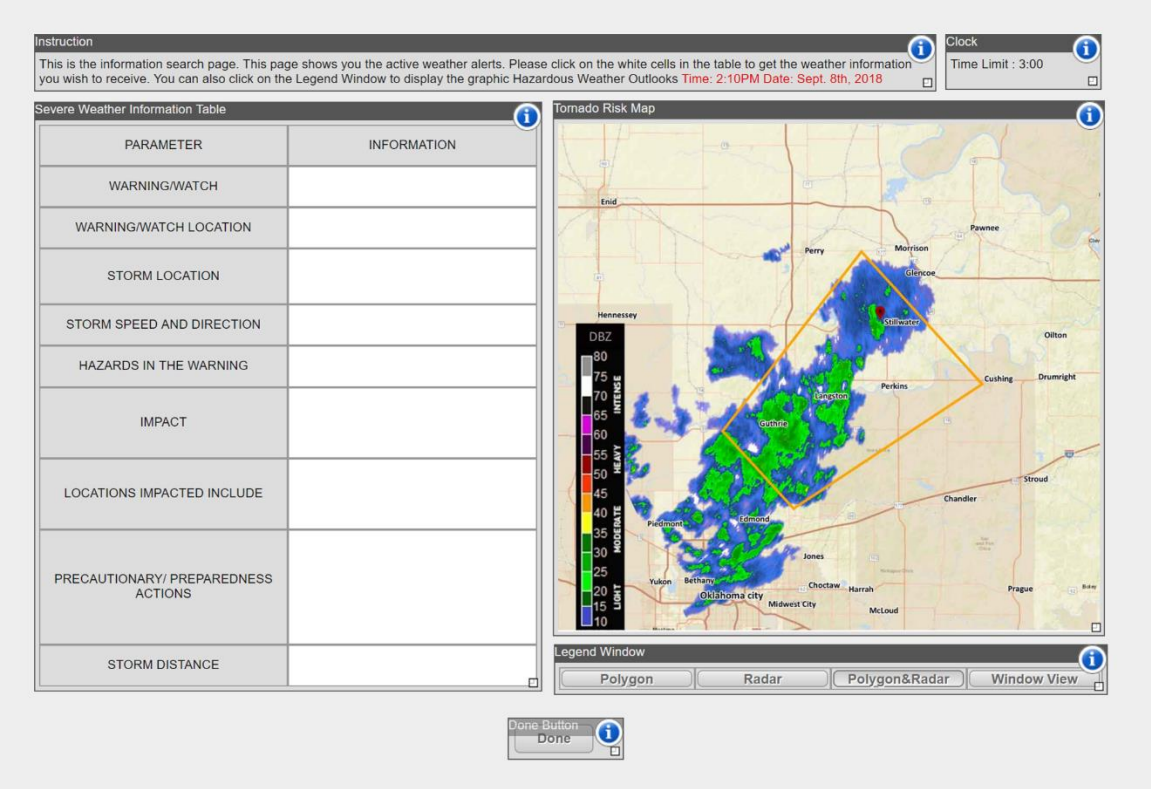
APPENDICES

APPENDIX A: *DynaSearch* – Screenshot of Each Advisory

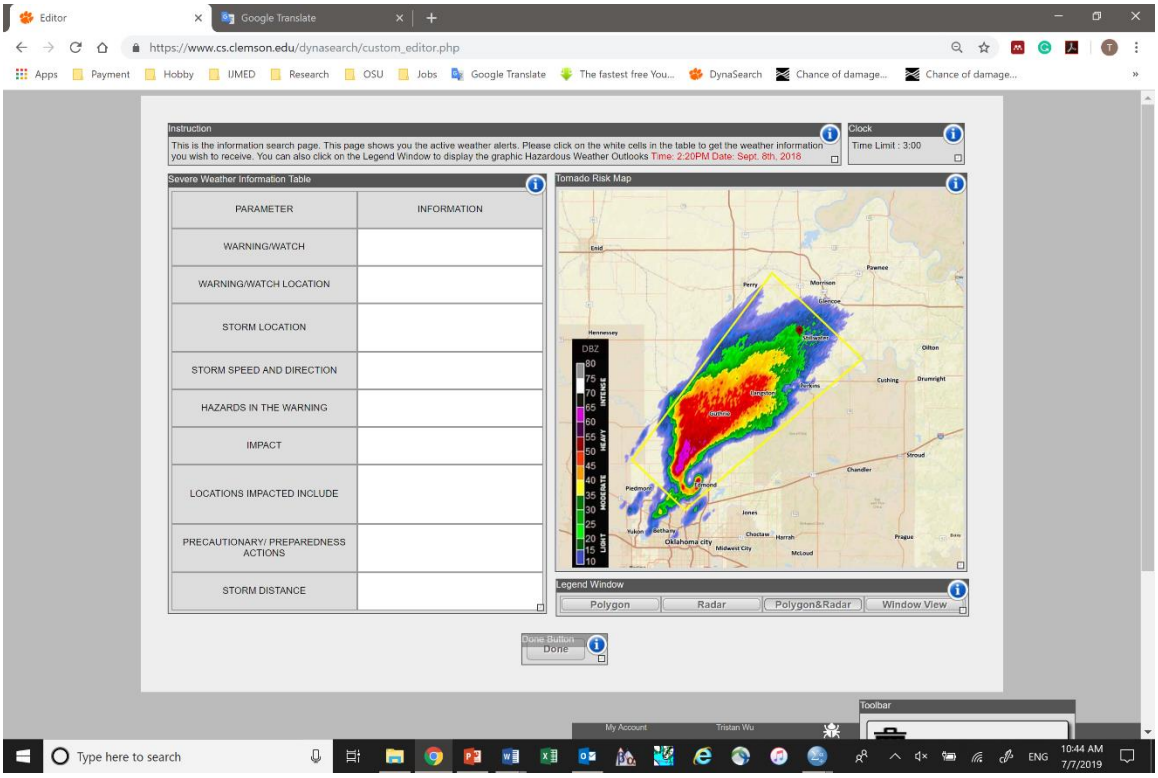
Advisory 1: Severe Thunderstorm Watch



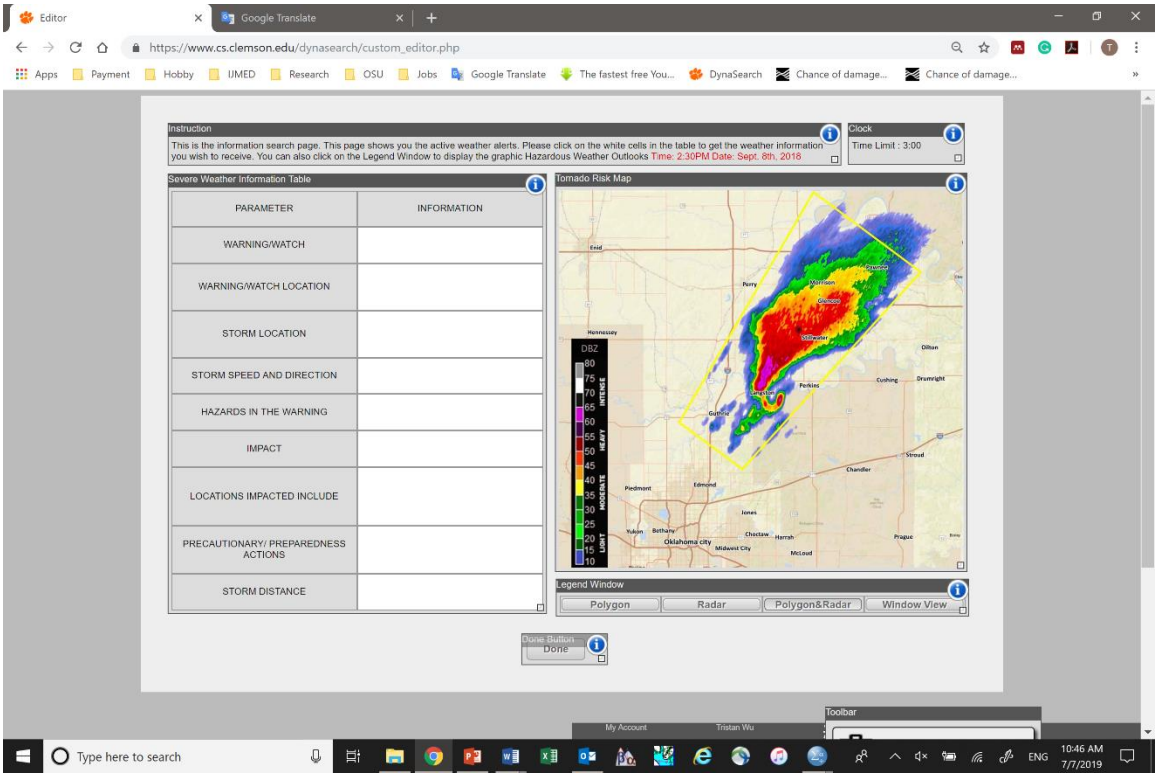
Advisory 2: Severe Thunderstorm Warning



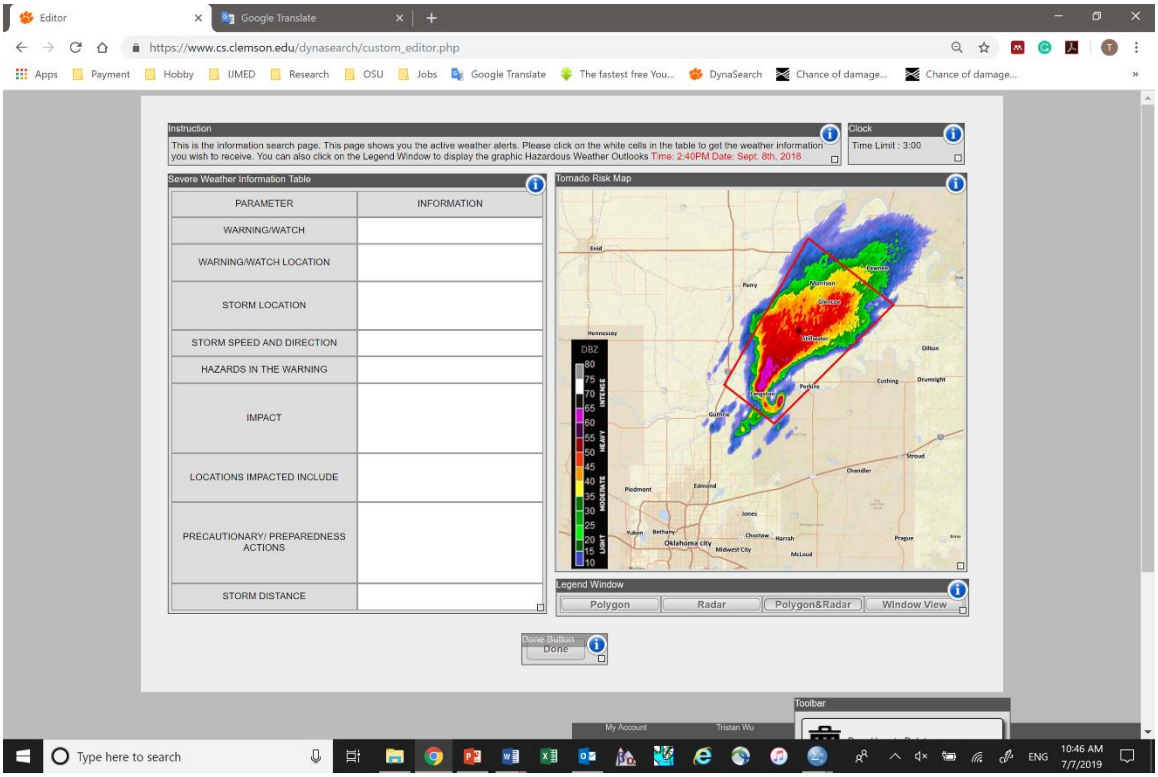
Advisory 3: Tornado Watch 1



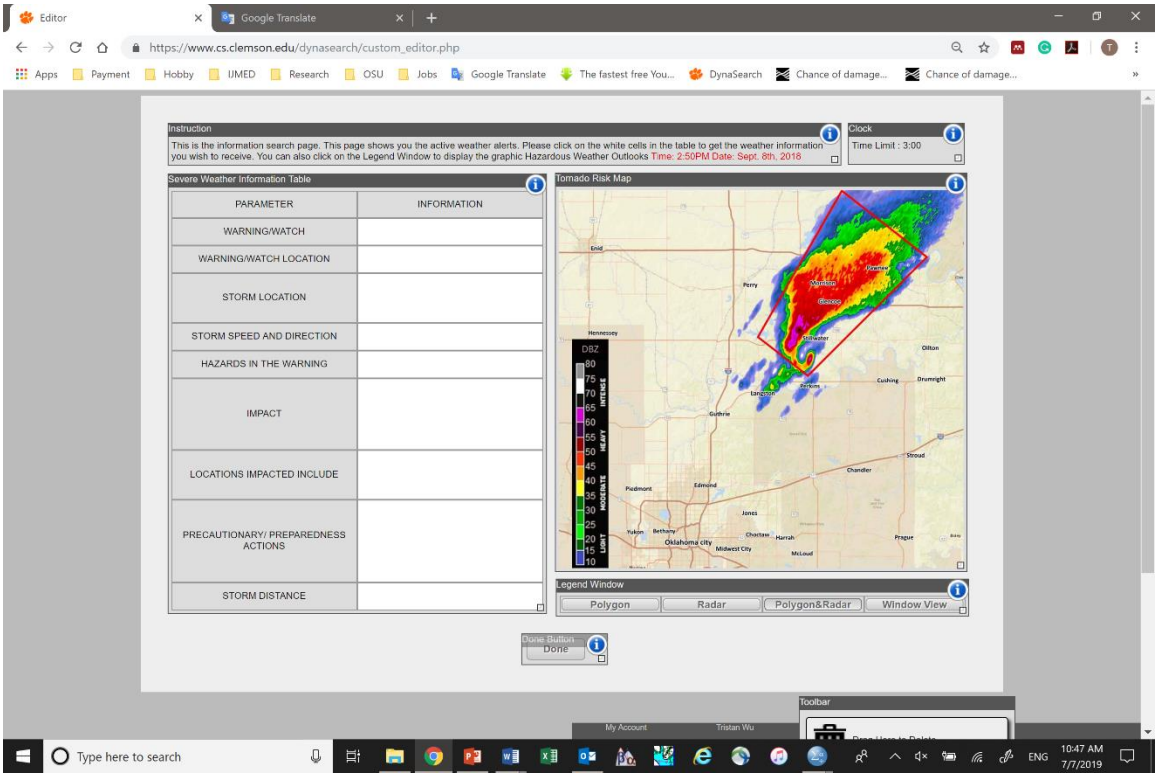
Advisory 4: Tornado Watch 2



Advisory 5: Tornado Warning 1



Advisory 6: Tornado Warning 2



APPENDIX B – SURVEY QUESTIONS

You are a resident of Stillwater, Oklahoma. This section asks you questions about you tornado risk perception and household response actions based on the information in the previous weather advisory. Please click on the section title to show the questions.

A. Risk Perception Question

(Q1) Please enter a tornado strike probability for Stillwater, Oklahoma. Remember that a strike probability is a number that ranges from 0% to 100%, where 0% indicates that an event is impossible, 50% indicates the likelihood is neutral, and 100% indicates that it will definitely happen. Numbers between 0% and 100% indicate varying degrees of belief that the event could occur. If you do not wish to answer this question, please type "I do not wish to answer."

B. Household Response Action Questions

Based on the previous weather advisory, please decide the likelihood of you taking the following response actions.

B-1. Continue what I am doing.

1	Extremely unlikely
2	Somewhat unlikely
3	Neutral
4	Somewhat likely
5	Extremely likely
6	I do not wish to answer

B-2.Protect private property. Have your doors, windows, and garage doors closed.

□	Extremely unlikely

□	Somewhat unlikely
□	Neutral
□	Somewhat likely
□	Extremely likely
□	I do not wish to answer

B-3.Monitor TV or radio

□	Extremely unlikely
□	Somewhat unlikely
□	Neutral
□	Somewhat likely
□	Extremely likely
□	I do not wish to answer

B-4.Stay home and move to an interior room in the home (e.g. a closet), in a bathtub, or a tornado shelter.

□	Extremely unlikely
□	Somewhat unlikely
□	Neutral
□	Somewhat likely
□	Extremely likely
□	I do not wish to answer

B-5.Leave my home and take shelter in either an above or below ground tornado shelter at a nearby neighbor, friend, or families' house

□	Extremely unlikely
□	Somewhat unlikely
□	Neutral
□	Somewhat likely
□	Extremely likely
□	I do not wish to answer

B-6.Leave my home and take shelter at a public tornado shelter

□	Extremely unlikely
□	Somewhat unlikely
□	Neutral
□	Somewhat likely
□	Extremely likely
□	I do not wish to answer

B-7.Leave my home with no destination in mind, simply to get out of the path of the storm

□	Extremely unlikely
□	Somewhat unlikely
□	Neutral
□	Somewhat likely

☐	Extremely likely
☐	I do not wish to answer

(Q9)B-8. Leash your pets or place them in airline-approved plastic carriers (Please select "I do not have pets" if you do not have one)

☐	I do not have pets
☐	Extremely unlikely
☐	Somewhat unlikely
☐	Neutral
☐	Somewhat likely
☐	Extremely likely
☐	I do not wish to answer

(Q10)B-9. Move your pets to an interior room in the home (e.g. a closet), in a bathtub, or a tornado shelter (Please select "I do not have pets" if you do not have one)

☐	I do not have pets
☐	Extremely unlikely
☐	Somewhat unlikely
☐	Neutral
☐	Somewhat likely
☐	Extremely likely
☐	I do not wish to answer

(Q11)B-10. Leave your home and take shelter somewhere else with your pets (Please select "I do not have pets" if you do not have one)

☐	I do not have pets
☐	Extremely unlikely
☐	Somewhat unlikely
☐	Neutral
☐	Somewhat likely
☐	Extremely likely
☐	I do not wish to answer

The following three sections asks you questions about your experience on this experiment, your tornado experience, Preparedness for pet and your demographic characteristics. Please make sure you scroll down your screen to answer all the questions before you click on the SUBMIT button; and do not hit ENTER on your keyboard while you are answering the questions. Thank you!

A. Your experience on the experiment

A-1. To what extent did you use the Polygon Image?

☐	Not at all
☐	Small extent
☐	Moderate extent
☐	Great extent
☐	Very great extent
☐	I do not wish to answer

A-2. To what extent did you use the Radar Image?

□	Not at all
□	Small extent
□	Moderate extent
□	Great extent
□	Very great extent
□	I do not wish to answer

A-3. To what extent did you use the Polygon plus Radar Image?

□	Not at all
□	Small extent
□	Moderate extent
□	Great extent
□	Very great extent
□	I do not wish to answer

A-4. To what extent did you use the Window View Image?

□	Not at all
□	Small extent
□	Moderate extent
□	Great extent
□	Very great extent

☐	I do not wish to answer

A-5. To what extent did you use the Warning/Watch Status information in the table?

☐	Not at all
☐	Small extent
☐	Moderate extent
☐	Great extent
☐	Very great extent
☐	I do not wish to answer

A-6. To what extent did you use the Warning/Watch Location information in the table?

☐	Not at all
☐	Small extent
☐	Moderate extent
☐	Great extent
☐	Very great extent
☐	I do not wish to answer

A-7. To what extent did you use the Storm Location information in the table?

☐	Not at all
☐	Small extent
☐	Moderate extent

□	Great extent
□	Very great extent
□	I do not wish to answer

A-8. To what extent did you use the Storm Moving Speed and Direction information in the table?

□	Not at all
□	Small extent
□	Moderate extent
□	Great extent
□	Very great extent
□	I do not wish to answer

A-9. To what extent did you use the Hazards in the Warning information in the table?

□	Not at all
□	Small extent
□	Moderate extent
□	Great extent
□	Very great extent
□	I do not wish to answer

A-10. To what extent did you use the Impact information in the table?

□	Not at all
□	Small extent
□	Moderate extent
□	Great extent
□	Very great extent
□	I do not wish to answer

A-11. To what extent did you use the Locations Impacted information in the table?

□	Not at all
□	Small extent
□	Moderate extent
□	Great extent
□	Very great extent
□	I do not wish to answer

A-12. To what extent did you use the Precautionary/Preparedness actions information in the table?

□	Not at all
□	Small extent
□	Moderate extent
□	Great extent
□	Very great extent

□	I do not wish to answer

A-13. To what extent did you use the Storm Distance information in the table?

□	Not at all
□	Small extent
□	Moderate extent
□	Great extent
□	Very great extent
□	I do not wish to answer

The following three sections asks you questions about your experience on this experiment, your tornado experience, Preparedness for pet and your demographic characteristics. Please make sure you scroll down your screen to answer all the questions before you click on the SUBMIT button; and do not hit ENTER on your keyboard while you are answering the questions. Thank you!

B. Your tornado experience

Have you ever...

B-1. seen a warning polygon on TV?

□	No
□	Yes
□	I do not wish to answer

B-2. received a tornado warning and took protective action?

□	No
□	Yes
□	I do not wish to answer

B-3. received a tornado warning but did not take protective action?

□	No
□	Yes
□	I do not wish to answer

Have you ever experienced a tornado that caused

B-4. damage to property in your city

□	No
□	Yes
□	I do not wish to answer

B-5. damage to your home

□	No
□	Yes
□	I do not wish to answer

B-6. damage to the home of a friend, relative, neighbor, or coworker you know personally

□	No

□	Yes
□	I do not wish to answer

B-7. injury to you or members of your immediate family

□	No
□	Yes
□	I do not wish to answer

B-8. injury to a friend, relative, neighbor, or coworker you know personally

□	No
□	Yes
□	I do not wish to answer

B-9. disruption to your school that prevented you from attending

□	No
□	Yes
□	I do not wish to answer

B-10. disruption to your shopping and other daily activities

□	No
□	Yes
□	I do not wish to answer

This section asks you to consider possible items or activities that pet owners prepare their pets for disasters. We would like to know if you have done any of the following activities. If you do not have any pet, please simply select "I do not have a Pet"

C. Have you done any of the following for your pet?

C-1. Prepare at least a three day supply in an airtight, waterproof container.

1	I do not have any pet
2	No
3	Yes
4	I do not wish to answer

C-2. Prepare at least three days of water specifically for your pet(s).

□	I do not have any pet
□	No
□	Yes
□	I do not wish to answer

C-3. Keep an extra supply of medicines your pet takes on a regular basis in a waterproof container.

□	I do not have any pet
□	No
□	Yes
□	I do not wish to answer

C-4. Keep your pets' medical records in a waterproof container.

☐	I do not have any pet
☐	No
☐	Yes
☐	I do not wish to answer

C-5. My pet(s) wears a collar with a ID tag or have a microchip with identification information

☐	I do not have any pet
☐	No
☐	Yes
☐	I do not wish to answer

C-6. Prepare pet(s) carriers for transporting all of your pet(s).

☐	I do not have any pet
☐	No
☐	Yes
☐	I do not wish to answer

C-7. Prepare pet(s) litter and litter box if appropriate, newspapers, paper towels, plastic trash bags and household chlorine bleach to provide for your pets' sanitation needs.

☐	I do not have any pet
☐	No

□	Yes
□	I do not wish to answer

C-8. Prepare a picture of you and your pet(s) together.

□	I do not have any pet
□	No
□	Yes
□	I do not wish to answer

C-9. Prepare your pets' favorite toys, treats or bedding in your pet emergency supply kit.

□	I do not have any pet
□	No
□	Yes
□	I do not wish to answer

C-10. Please list the number and type of pet(s) you own (i.e. 2-dogs) (please type "no pet" if you do not have pet)

D. Your demographic characteristics (If you do not wish to answer, please simply pick "I do not wish to answer" or type "I do not wish to answer")

D-1. What is your age?

D-2.What is your sex

□	Male
□	Female
□	I do not wish to answer

D-3.To which of the following ethnic groups do you belong and identify?

□	African American
□	Asian/Pacific Islander
□	Caucasian
□	Hispanic
□	Native American
□	Mixed
□	Other
□	I do not wish to answer

D-4.What is your current education level

□	freshmen
□	sophomore
□	junior
□	senior
□	graduate student

☐	I do not wish to answer

D-5. In which country is your high school located?

D-6. In which state is your high school located?

D-7. Are you paying your rent to Oklahoma State University?

☐	No
☐	Yes
☐	I do not wish to answer

E. Shelter Related Questions (If you do not wish to answer, please simply type "I do not wish to answer"; If you do not know the answer, please simply type “I do not know”)

E-1. Please let us know how far it is to the nearest peer's shelter (mile)

E-2. Please let us know how long it would take to get nearest peer's shelter (minutes)

E-3. Please let us know how far it is to the nearest public shelter (mile)

E-4. Please let us know how long it would take to get to the nearest public shelter (minutes)

The followings are questions that can help us identify your cognitive reflection process. If you do not wish to answer these questions, please simply type "I do not wish to answer"

F. Cognitive Reflection Questions

F-1. A bet and a ball cost $1.10 in total. The bet costs $1.00 more than the ball. How many cents does the ball cost?

F-2. If it takes 5 machines 5 minutes to make 5 widgets, how many minutes would it take 100 machines to make 100 widgets?

F-3. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how many days would it take for the patch to cover half of the lake?

How likely do you think you will take the same protective actions if the severe weather scenario in this experiment was real.

□	Extremely unlikely
□	Unlikely

□	Neutral
□	Likely
□	Extremely likely
□	I do not wish to answer

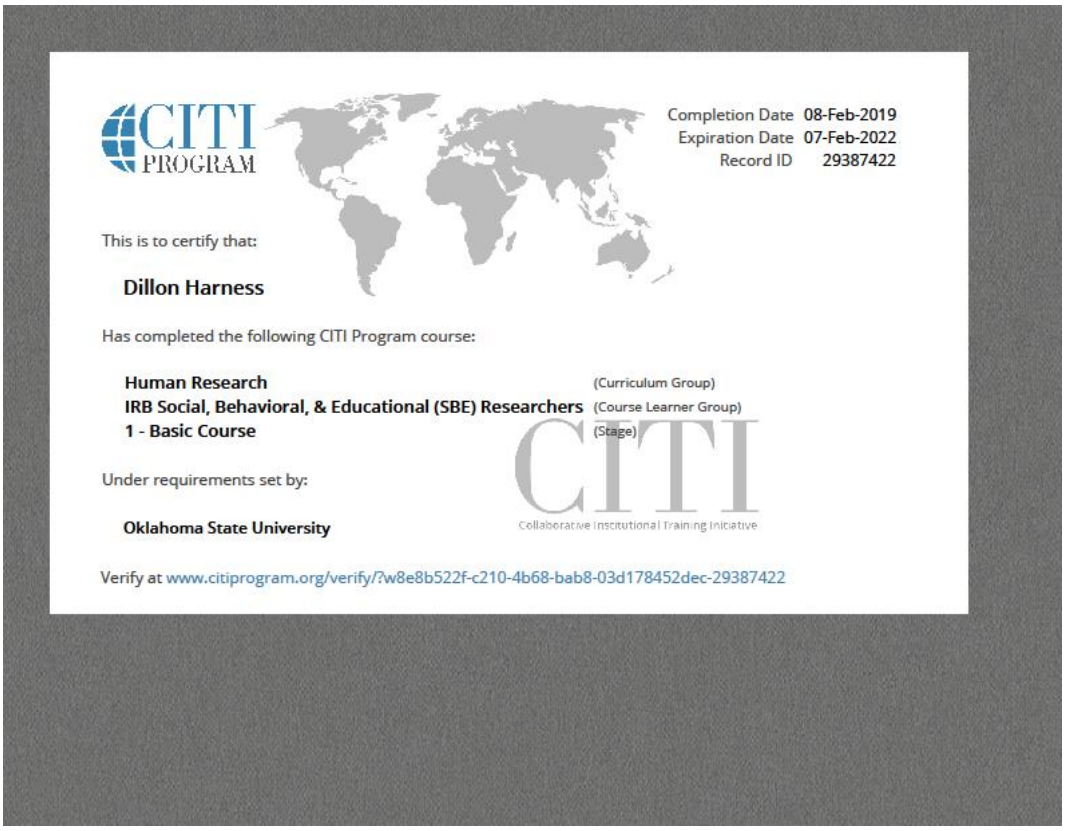
If you wish to win the 100 dollar Amazon gift card, please give us your OSU email address. We will contact you if you are one of the winners (If you don't want join the draw, please type "I do not wish to participate").

Do you have any suggestions or comments on this experiment (if you do not, please just type no)?

End of survey sample

APPENDIX B – CITI Certificate

CERT #1 – IRB Social, Behavioral, and Educational (SBE) Researchers



APPENDIX C – Invitation Letter to Participate in the Survey

From:

Email subject: 2019 Stillwater Tornado Study (Participate in our study and win a $100 Amazon Gift Card)

Dear Students,

You are receiving this email because you are currently enrolled in OSU undergraduate programs. As you might know, residents in Stillwater experience severe thunderstorm or receive tornado warning/watch during tornado seasons. Drs. Murphy and Wu are interested in understanding people's tornado information search preference and their decisions on protecting themselves and their pets. We are inviting you to participate in our online survey about thunderstorm and tornado hazards. The survey will show you different types of severe weather information and ask you some questions that have been designed to help us learn how you respond to severe weather events in Stillwater. We also would like to understand how you prepare your pets for possible tornado threats. This survey is anonymous. No one, including the researcher, will be able to associate your responses with your identity.

Of course, you may decline to participate in this study or decline to answer any question that you feel invades your privacy, but please remember that withholding information from us necessarily limits the study's scientific validity and our ability to present an accurate result. You may withdraw participation at any time without penalty. Refusing to participate will not affect your relationship with the researchers or Oklahoma State University.

However, if you participate and finish the survey, you will have a chance to win a $100 Amazon Gift Card. We only need 200 study participants. Therefore, only the first 200 participants will be able to participate in the drawing. We will randomly select four winners and contact them through their OSU email.

If you wish to participate in this study, please click on the following survey link to take this survey: Click Here, or copy and paste the following link in your browser to take the survey: https://goo.gl/FXmZRg

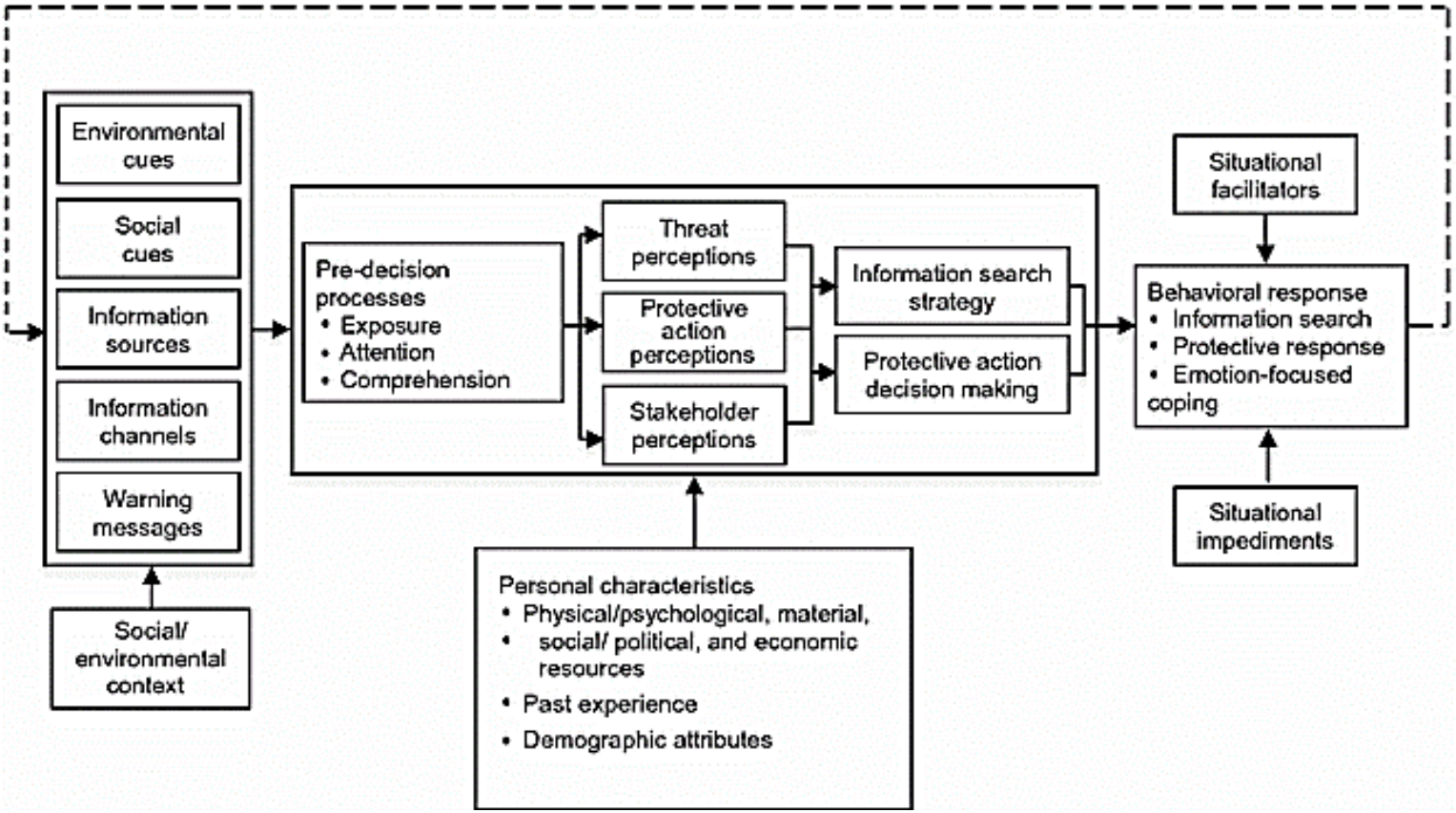
We want to thank you in advance for your cooperation and invite you to contact us at the email addresses below if you have any questions.

Sincerely,

Tristan Wu
Tristan.wu@okstate.edu
Assistant Professor
Fire and Emergency Management Program

Haley Murphy
Haley.C.Murphy@okstate.edu
Assistant Professor
Fire and Emergency Management Program

APPENDIX D – Protective Action Decision Making Model (Lindell 2018)



VITA

Dillon J. Harness

Candidate for the Degree of

Master of Science

Thesis: IDENTIFICATION OF TORNADO PROTECTIVE ACTIONS OF OKLAHOMA STATE UNIVERSITY STUDENTS – A PILOT STUDY

Major Field: FIRE AND EMERGENCY MANAGEMENT ADMINISTRATION

Biographical:

Education:

Completed the requirements for the Master of Science in Fire and Emergency Management Administration at Oklahoma State University, Stillwater, Oklahoma in May, 2020

Completed the requirements for the Bachelor of Science in Emergency Management at Western Illinois University, Macomb, Illinois, in July, 2018

Completed the requirements for the Associate of Arts in General Transfer Studies at St. Louis Community College, Wildwood, Missouri, in May, 2016

Experience:

Graduate Research Assistant (GRA) in the Division of Engineering, Fire and Emergency Management Program at Oklahoma State University, 2018-2020
Emergency Management Intern at St. Louis County Police Department, Office of Emergency Management, St. Louis, Missouri, May 2018-August 2018

Professional Memberships:

International Association of Emergency Managers (IAEM), 2019-Present