

THE INFLUENCE OF TORNADIC EXPERIENCES ON SEVERE WEATHER PREPAREDNESS: A COMPARATIVE STUDY OF ABILENE, TEXAS AND HUNTSVILLE, ALABAMA

Andrew Pennell

University College
London, England

Abstract

Through surveys conducted for the cities of Abilene, Texas and Huntsville, Alabama, the influence of previous tornadic experiences on residents' preparedness levels was assessed. Abilene was chosen for this study due to its lack of tornado strikes in recent history compared to Huntsville, where strong tornadoes struck in 1974 and violent tornadoes occurred in 1989. Local warning systems are equally sufficient in both cities; however, educational drives such as Severe Weather Awareness Week are proving to be more effective in Huntsville, where residents are more interested in and receptive to preparedness efforts. Indeed, risk perception, preparedness, awareness and response were all found to be at higher levels in Huntsville compared to Abilene. In large part, the differences between the two cities can be attributed to Huntsville's tornado legacy. Moreover, the impact of previous tornadic experiences upon the residents of Huntsville and the persistent coverage provided by the local media, recalling past tornado events, helps to impede Huntsville residents from becoming complacent towards preparedness efforts.

Corresponding Author: Andrew Pennell
55 Raleigh Court, Clarence Mews, Rotherhithe,
London, SE16 5GB, United Kingdom.
E-mail: andrew.pennell@yahoo.com

1. Introduction

As American cities expand, the risk of tornadoes passing through heavily populated areas is increasing. While tornado alley (commonly defined as parts of Texas, Oklahoma, Kansas and Nebraska) is well noted by the media as the region in the US most prone to the stronger tornadoes, there are other tornado prone areas, albeit smaller in scale, where significant tornadoes are also a risk. In the past decade, a number of cities over diverse regions of the US have encountered significant tornadoes - Oklahoma City, Miami, Salt Lake City, Nashville and Dallas-Fort Worth just to name a few.

Despite the increasing vulnerability to tornadoes, there are still communities, even those in and near tornado alley that have been fortunate enough to have never been hit or have gone for relatively long periods without a tornadic event. It is in these communities, where residents may have become complacent to severe weather preparedness; and therefore are less than well prepared (Grazulis 2003). There may also be a tendency for people to become desensitized to risk. Moreover, counties in tornado prone states are often included in tornado watches and/or warnings, while specific sites are in general rarely affected by significant tornadoes. Therefore as residents begin to associate tornado watches and warnings with an absence of tornadic activity, they may become indifferent and ignore the warnings, not taking the appropriate action (Bomar 1995).

Previous studies show that it is common to equate prior disaster experience with higher levels of preparedness, due to a greater awareness of the consequences of disasters (Tierney 2001). This study's principal objective is to determine if there is such a link between preparedness levels for tornadoes and experiencing prior disastrous tornadic events, not only on the part of individual residents, but also with respect to the larger community as a whole. More specifically, this research seeks to determine if personal experiences with tornadoes and/or an awareness of a city's tornadic history affect the following: i) degree of personal risk perceived from tornadoes, ii) an individual's level of severe weather awareness and preparedness, and iii) resident's responses to tornado watches and warnings. Furthermore, this study assesses the various contributions made by local emergency management, the National Weather Service and the local media in tornado preparedness and the tornado warning process, as well as how aware residents are of these and other local resources available to them.

2. Methodology

a. General overview

Four essential factors were utilized as a means to address the study's principal objectives:

- Two cities with similar characteristic were identified, one with a previous history of strong and violent tornadoes, and one without.
- Perception of current risk to tornadoes and previous tornadic experiences were assessed from a sample of individuals residing in both cities.
- The residents' responses to tornado watches and warnings and whether they were affected by previous personal experiences with tornadoes or by the city's tornadic history were evaluated using surveys.
- The residents' levels of preparedness and knowledge of severe weather preparedness were also evaluated.
- The role of local emergency management, the National Weather Service and local television media in preparedness and the warning process were assessed through structured interviews.

The legacy Fujita or F Scale was used to classify tornadic intensity. For the purposes of this research, F0-F1 is classified as weak tornadoes, F2-F3 as strong, F4-F5 as violent tornadoes, and significant tornadoes are those classified as F2 or greater.

a. City selection & tornado histories

The two cities were selected by analyzing records of tornadoes dating back to 1950. The cities had to fit the criteria of containing similar population sizes, being at similar risk to tornadoes, but with one city having little prior tornadic history and the other with a history of deadly tornadoes within the city limits. Abilene in Taylor County, Texas was selected as the city with little prior experience, despite its location at the southern end of tornado alley; and Huntsville in Madison County, Alabama represented the city with a history of tornadic activity.

1) Abilene, Texas

The city of Abilene has a population of approximately 116,000, and is situated in Taylor County in north-central Texas. Abilene has never been struck by a violent (F4 or greater) tornado in the city's brief 120 year history and has recorded only one tornado strike, when an F2 (strong) tornado injured 5 people and destroyed 7 homes there in 1949. (Grazulis 1990b).

2) Huntsville, Alabama

The city of Huntsville has a population of 158,000. It is located in Madison County in north Alabama. Huntsville has had two powerful tornadoes strike the city limits within the past 31 years. On April 3rd, 1974, an F3 (strong) tornado passed through the southern part of Huntsville, destroying homes, trailers, businesses and a school. Fortunately there were no deaths, but there were 50 injuries. On November 15th, 1989, an F4 (violent) tornado touched down also in the southern part of Huntsville. It tore through a main highway at rush hour, killing 21 people, injuring 463 others while also destroying 260 homes, 80 businesses, schools, churches and shopping centres. This tornado resulted in \$1,900,000 worth of public utility damage. (NWS Birmingham 1990). The majority of the fatalities and injuries occurred within a small area of Huntsville where traffic was heavy due to the rush hour (Grazulis 1990b).

b. Additional tornado details

It is noteworthy that Texas has been struck many more times by tornadoes than Alabama. This is largely due to the vast size of Texas. When comparing strikes against state area, the two states have a similar amount (4.7 annual average number of tornadoes, per 10,000 square miles for Texas and 4 for Alabama (National Climatic Data Centre 2005b)). When comparing the states on square mileage, frequency of death, injury, number of tornadoes and damage costs, Alabama is ranked the 7th highest state in the U.S.A. in that category, whilst Texas is ranked 17th (Disaster Centre 2005).

Table 1 shows the number of tornadoes, intensity, and the associated fatalities and injuries that occurred in Abilene, Taylor County; and Huntsville, Madison County from 1880 - 2004. Although Madison County Alabama has only had seven more tornadoes than Taylor County Tex-

as, there have been many more fatalities and injuries in Madison County. The majority of these fatalities occurred in the F4 and F5 tornadoes, which Taylor County has not experienced since 1914.

The risk from tornadoes in any given area is hard to fully quantify from a small data set spanning only 125 years, which is most likely incomplete and contains inconsistencies before the 1950's. However, the data suggests that the risk appears higher in Huntsville than in Abilene. However, Abilene may have just been fortunate over the past 125 years, unlike some of the other major Texan cities. (i.e., Lubbock).

c. Survey questionnaires

For the two cities, questionnaires of residents were developed and conducted through door to door surveys, focus groups, and Internet surveys, totalling 50 completed questionnaires in Abilene and 63 in Huntsville during May 2005. Residents in middle-income neighbourhoods in both cities were used for the surveys to ensure similar population groups were targeted. The questionnaires were designed to determine how much experience with tornadoes the resident's had, their tornado risk perception, awareness and preparation, all assessing the various sections of an integrated tornado warning system. The role of local emergency management, the National Weather Service and local television media were assessed through structured interviews with Abilene and Huntsville emergency managers, the National Weather Service in Huntsville and local television meteorologists in Abilene and Huntsville.

The qualitative data from the questionnaires and interview data from the city officials were extracted thematically for use in the results. The quantitative data from the questionnaires was entered into the statistical computer programme, Statistical Package for Social Sciences (SPSS), to produce frequencies, percentages and correlative statistics using Spearman's rank correlation

	Total Recorded Tornadoes 1880-2004	F1	F2	F3	F4	F5	Fatalities	Injuries
Abilene, Tx	1	0	1	0	0	0	0	5
Taylor, Tx	31	12	14	4	1	0	4	58
Huntsville, Al	7	0	2	4	1	0	24	595
Madison, Al	38	10	18	5	4	1	148	1783

Table 1. Number of tornadoes, fatalities and injuries in Abilene City, Taylor County, Huntsville City and Madison County. The legacy Fujita or F Scale was used to classify tornadoic intensity. Data from Grazulis, 1990b & National Climatic Data Centre, 2005a.

(Statistical Consulting Services 2005). SPSS is used for assimilating data that can then be applied to a number of statistical equations. Due to the nature of the data not fitting the assumptions required for parametric tests, Spearman's rank was chosen for producing correlative statistics between the variables (Foster 1998). See Appendix for further details. SPSS produces Spearman's rank correlations as a value between 1 and -1, with 1 indicating a perfect positive correlation, 0 indicating no correlation, and -1 indicating a perfect negative correlation. Positive correlations indicate that both variables increase or decrease together, while negative correlations indicate that as one variable increases, the other decreases (Puri 2002).

Significance values are also produced by SPSS, identifying which correlations are significant at either the 0.05 / 5% level (the possibility of the relationship being a chance event is 5%) or the 0.01 / 1% level (the possibility of the relationship being a chance event is 1%) (Foster 1998). Those correlations that were significant at the 1% or 5% levels are included in section 4 and will be described in accordance with the Table 2.

Spearman's rank correlation	Correlation basic interpretation
+/- 0 to 0.24	No to weak relationship
+/- 0.24 to 0.49	Fair degree of relationship
+/- 0.50 to 0.74	Moderate to good relationship
+/- 0.75 to 1	Good to strong relationship

Table 2. Spearman's rank correlations and basic interpretations. Adapted from Statistical Consulting Services, (2005).

3. Results

a. Tornado experiences

The degree of personal tornado experiences shows great variance between the two cities. In Abilene, 74% of the respondents had no previous experience of tornadoes, while in Huntsville this figure was vastly reduced at 22%. Only one respondent in Abilene reported to have had direct experience of a tornado involving structural damage to their property, while 24% either witnessed a tornado in action, or saw the aftermath of a tornado.

In Huntsville, the majority of respondents had experiences of tornadoes with 25% having had direct experience involving personal injury or structural damage to their property; and a further 52% witnessing a tornado or its destructive aftermath. 57% of the respondents lived in Huntsville in 1989 and over 90% of them were exposed

to the 1989 tornado's devastation and consequences. For family and friends of the respondents in both cities, tornadic experience was largely similar to the previous results, except the percentage of those with no experience rises to 84% for Abilene and 35% for Huntsville.

Of the respondents in Abilene, the personal direct tornadic experiences occurred in Nebraska, Oklahoma, and the nearby towns of Clyde, Lawn and Sweetwater. One respondent had witnessed the devastation after the F5 1970 Lubbock tornado, and others had seen funnel clouds pass over Abilene which fortunately dissipated before having the chance to touchdown on the ground.

Many of the respondents in Huntsville with tornadic experiences cited the 1974 and 1989 Huntsville tornadoes as their main or sole experience of tornadoes. Experiences ranged from structural damage of personal property to friends and family being injured in the tornadoes. Many witnessed the destruction left by the tornadoes and some helped with the clean up of the debris and assistance of the injured in the 1989 event.

b. Tornado risk perception

Respondent's perception of the risk they face from tornadoes in their cities is also significantly different between the two cities. In Abilene the categories with the highest percentages were moderate, low to moderate and low risk. The perception in Huntsville is generally of a higher risk with the highest percentages falling in the moderate to high and high risk bands. At the extremes of the scale there are also notable differences with 16% of the respondents in Huntsville perceiving themselves to be at a very high risk from tornadoes, compared to 0% in Abilene. Over a quarter of respondents in Abilene perceived themselves to be at low risk, compared with just 3% in Huntsville.

Nearly 70% of respondents in Huntsville perceived themselves to be at a moderate to high, high or very high risk, while in Abilene, 92% of respondents perceived themselves to be at risk in the opposite range of the scale at moderate, low to moderate and low risk. This displays a tendency for the respondents in Abilene to perceive themselves to be at a low to moderate risk, while in Huntsville the general perception is of a moderate to high risk from tornadoes.

The respondent's perceptions of the damage they would expect from a direct tornado strike on their properties shows some variance between the two cities. In Huntsville, 83% of the respondents felt the impacts would be either total destruction or high damage, compared with Abilene where 86% of responses fell in the moderate and high damage categories. The respondents in Huntsville therefore expect the impacts of a tornado strike to be

more severe compared to the respondents in Abilene.

One common myth concerning tornadoes is that tornadoes do not strike cities (Grazulis 2003). The respondents were asked if they felt at less risk to tornadoes in cities. In Abilene, 64% replied no or gave a valid reason for feeling safer in cities such as “better spotter networks”, “better constructed buildings to seek shelter in” and “more sirens and greater coverage”. In Huntsville, this figure is larger at 88.9%. The other 11.1% in Huntsville and 36% in Abilene comprises people who do feel safer but could not give a reason for this and people who believe reasons that have been discredited as myths. These myths included “there are no mobile homes near where I live in the city, tornadoes are attracted to mobile homes”, “tornadoes are likely to fall apart in cities due to building structures”, “tornadoes only strike rural areas” and “high buildings keep tornadoes away”.

In Abilene, a further question was asked to ascertain whether the respondents believed there was any reason as to why Abilene had never been struck by a severe tornado. 74% of the respondents believed there was no reason and that Abilene had just been lucky, while 26% believed there was a reason. These reasons included “severe weather splits around Abilene”, “as we have never been hit before; “I don’t believe we will be hit in the future”; “Abilene is in a valley so tornadoes lift off the ground here”; “Abilene is not in tornado alley”; and “the hills south of town may play a role in protecting Abilene from severe weather”. It is generally understood that such factors do not have a significant impact on tornado climatology. (Grazulis 2003).

c. Tornado risk preparedness

To gain an understanding of tornado preparedness in the cities, a wide range of questions were asked on general preparedness measures. First, the respondents were asked if they had sought information on severe weather to gain a better understanding of the threat posed and therefore be more able to take the appropriate preparedness actions. In Abilene, 8% of the respondents had sought information, compared to over 50% in Huntsville who had sought information or were trained storm spotters. In Abilene, the information was sought through local television programs and the Internet, with one respondent commenting that “if severe weather was more predictable then I would be more interested”. In Huntsville, information was also primarily sought through the Internet and local television. The older residents of Huntsville commented on having “plenty of first hand experience” and therefore they felt they did not need to seek further information. One respondent remarked that “public awareness and interest is high enough in this area that information is

readily available”.

The respondents were asked if they had informed their children of what to do during a tornado warning. In Abilene, 76% of the respondents had children and 22% (eleven respondents) of them had not discussed tornadoes with their children. In Huntsville, 65% of the respondents had children and only 1.6% (one respondent) had not discussed the matter with their children. In general those who had discussed tornadoes with their children had reviewed suitable shelter locations around the house, reinforced the seriousness of tornadoes, and taught them basic tornado safety such as staying away from windows.

The availability of storm shelters was assessed by asking respondents if they knew the location of their nearest shelter. In Abilene, only two respondents knew the location of their nearest shelter, one being privately owned and the other being a public shelter. In Huntsville, eighteen respondents knew the location of their nearest shelter with a further seven owning basements.

The only respondent in Abilene who possessed his own storm shelter stated that “personal storm shelters are very rare in Abilene”, and that “basements and shelters are much more common in Lubbock and Wichita Falls”, which are two Texan cities to the northwest and northeast of Abilene that have had tornado strikes in the past. Many respondents said they would support community shelters but had no desire to purchase or build their own shelters. In Huntsville, the tornado of 1974 prompted some residents to purchase or build their own storm shelters; but there have been problems maintaining them as they have deteriorated rapidly. This rapid deterioration, the costs of building and maintenance, and the chance of a violent tornado strike completely destroying their houses are the main reasons most people have decided against making the investment into shelters. In Huntsville, seven respondents have basements or “crawl spaces” to take shelter in, further negating the need for them to purchase shelters.

During minor tornadoes and on the periphery of a tornado’s track, small physical adjustments to a property can reduce the amount of injury or damage caused by the high winds. Such physical adjustments include securing outdoor furniture and objects that could potentially become deadly missiles, attaching hurricane straps on mobile homes, and installing window shutters. In Abilene, none of the respondents had taken any such actions; and in Huntsville 32% of people had made physical adjustments.

Severe weather plans are necessary to ensure that the correct action is taken during a tornado warning, when time can be lacking to find shelter. In Abilene, 54% of the respondents had discussed or thought of a severe weather plan for their families or households; while in Huntsville this figure rises to 89%. The overall majority of plans

consisted of seeking shelter in storm shelters, basements, windowless rooms, closets, bathtubs or hallways, or in the case of mobile homes to get out and find shelter outside in ditches.

In towns without warning sirens, NOAA Weather Radio can be the only way of receiving tornado warnings when most residents are asleep at night. The respondents were asked if they owned a Weather Radio and if they did, then when do they use it. Ownership of the radios is higher in Huntsville at 41%, in comparison with 8% in Abilene. Respondents in Abilene with a weather radio only use it when tornado watches are issued, or during power outages. This compares with 58% of respondents leaving their radios on standby all the time, so they can be alerted to watches and warnings at any time. The second biggest category in Huntsville is after tornado watches have been issued with 27%. The majority of people without Weather Radios depend on local television and in Huntsville also the sirens to alert them to watches and warnings. Some respondents in Huntsville stated that there were surges in sales of weather radios after tornadic events, but that people slowly become complacent with time, not using the radios very often.

d. Tornado risk awareness

The awareness of respondents to watches and warnings and how many sources they rely on to obtain these alerts were assessed in each city. Typically, the majority of tornadoes occur between April and June, but Huntsville has a second prone season from October to December (Grazulis 2003).

The respondents were asked if they had a heightened awareness to the tornadic threat in the prone months. Only 24% of respondents in Abilene stated that they had a raised awareness, compared to 67% in Huntsville. A further 28% stated they have a year round high awareness in Abilene, compared to a further 8% in Huntsville. The majority of respondents who stated they have a heightened awareness do so by being more alert to weather conditions outside, keeping local television or radio stations on more and thinking more about the actions to take in the event of a tornado. Also other common procedures included checking forecasts, discussions and radar images on the Internet, discussing tornado warning procedures with the family and keeping their safe area stocked with provisions.

Tornado watches and warnings can cause some confusion over their meanings, so the understanding of these phrases was assessed. In Huntsville, there were no problems with all respondents understanding the meanings. In Abilene, the majority of respondents understood the phrases but 12% of people were confused

by which phrase was more severe but could still understand the basic concepts. 14% of respondents had no idea of the meaning of a tornado watch and a further 12% did not understand the concept of a tornado warning.

The respondents were asked if they actively check to see if their area is under a tornado watch, and if they did, how often did they check. Huntsville has a higher proportion of respondents with 70% checking in comparison with 50% in Abilene. Of those that do check, 88% of respondents in Abilene only check during severe weather, compared with 55% of respondents in Huntsville who check on a daily basis.

The number of sources used to obtain tornado watches and warnings, as well as the sources residents used to obtain these alerts was assessed. The results contrast between the two cities, with the majority of respondents in Abilene using one or two sources for tornado watches and warnings. In Huntsville, the majority of respondents use two or three sources for tornado watches and warnings. The largest contrast is in the sources used for tornado warnings, where using none or one source accounts for 36% of the responses in Abilene compared to 0% in Huntsville. The main sources used for obtaining tornado watches and warnings in Abilene are local television and local radio. In Huntsville, local television is again the dominant source, followed by sirens, NOAA Weather Radio and local radio. In Abilene, some of the respondents commented that sirens used to be in operation in the town, but they malfunctioned so often that they were ignored by residents and eventually dismantled. Local television is widely perceived to provide the most accurate and current information as well as being the most accessible source, accounting for its dominance as a used and trusted source.

e. Tornado risk response

During a tornado watch it is advised that residents be more alert to the weather and if possible, make sure they have a source for receiving tornado warnings should one arise (Grazulis 2003). The respondents were asked if they modified their actions during tornado watches, and in Abilene 32% did, compared to 88% in Huntsville. The actions taken commonly included: keeping the television, radio, or NOAA Weather Radio on, staying indoors and limiting outdoor activities and travel, alerting friends and family, and being prepared to enter the safe place in the house or leave the mobile home.

Tornado warnings could be perceived as false alarms when rotation is indicated on Doppler radar or funnel clouds are spotted, but no actual tornado touches down. Until recently, warnings were county-based, so even if a tornado is on the ground and a warning is in effect for

your county, there was a good chance that the tornado would be miles away. These factors may lead people to become complacent about tornado warnings. Thus the respondents were asked if they had 'false' warnings in the past and whether these had affected their trust in tornado warnings. Nearly 50% of all respondents in Abilene and 64% in Huntsville had experienced what they would classify as a false alarm tornado warning. However, in each case only a very small minority reported that these false alarms had affected their trust in warnings. As a result of these false alarms, respondents report they will get outside to look for the tornado and confirm its presence before seeking shelter or respond slower to warnings. The majority of respondents reported that they accept the prediction of severe weather is not always 100% accurate and would rather be informed of a tornado a few miles away, than not at all.

f. Severe weather education

Raising levels of preparedness amongst residents can be achieved by providing regular information and education on severe weather and the threat of tornadoes. Before the tornado prone months, Alabama and Texas both hold severe weather awareness weeks to remind residents of the actions necessary in the event of severe weather. Awareness of these weeks was assessed with 46% of respondents in Abilene being conscious of their most recent severe weather awareness week and 84% in Huntsville. Respondents who were aware of the week reported daily shows on local television and radio and educational talks in their cities. Students in the local universities commented that they were made aware of the week at the university but received no specific information. Siren tests throughout Huntsville were reported and families also took the event as a reminder to review their plans and procedures in the event of severe weather. General severe weather safety classes were also commonly reported, and in Huntsville one respondent reported of a severe weather seminar in their high school on tornado safety, organized by the local National Weather Service office.

The awareness of respondents to severe weather talks and educational projects, such as storm spotter training, was assessed in both cities. The percentages are very similar between the cities, but in Huntsville a small number of respondents recounted there being many talks after previous tornado strikes in the city. In Abilene, respondents reported storm spotter training and talks during severe weather awareness week as the main informational sources in their city. For Huntsville, a wider variety of sources were reported including storm spotter classes, local television stations and emergency

management running severe weather safety exhibits in local schools, and an increase in general talks during the tornado season. After the 1989 tornado in Huntsville, some respondents reported an increase in talks on severe weather preparedness.

Lastly, respondents were asked if they had been presented information or seen television programs on severe weather safety. 40% of respondents in Abilene reported that they had received information, compared to 68% in Huntsville. Respondents in Abilene reported television shows on local stations and the nationally broadcasted Weather Channel, as well as some features in the local newspaper. In Huntsville, the respondents largely stated the same sources as in Abilene, with the addition of receiving leaflets on severe weather safety as part of severe weather awareness week.

4. Discussion

a. Previous tornado experience

It is clear from the data accumulated on previous tornado experience that of the respondents interviewed in Abilene, the majority do not have any personal experiences of tornadoes or their aftermath. This compares with the respondents in Huntsville, where the majority have been exposed to tornadoes and the destruction they can cause. Previous research has suggested that prior disaster experience leads to higher levels of preparedness and more effective performance during the response period, due to raised awareness of the consequences of the hazard and the demands it may generate (Tierney 2001). Experience can also increase eagerness to prepare for future events and increase the speed at which warnings are acted on and believed (Tierney 2001).

b. Risk perception

The respondents' perception of the risk they face from tornadoes reveals that the majority of Huntsville respondents perceive the tornadic risk in their city as moderate to very high. In Abilene the majority of respondents perceive the tornadic risk to be low to moderate. Statistically, tornado experience correlates highly with risk perception. These correlations have arisen due to low levels of tornadic experience in Abilene correlating with low levels of risk perception, and high levels of experience correlating with a high risk perception in Huntsville. Previous hazard experience is important for influencing risk perception, as people with experience of hazardous events tend to have more accurate views of the probability of future events (Smith 2004). With direct knowledge that tornadoes can pose a risk in the

area and experience of the consequences of tornadoes, people are more likely to perceive themselves to be at higher risk, as in Huntsville. Experience levels of family and friends also correlated well with risk perception, as did living in Huntsville during the 1989 F4 tornado, further suggesting that experiences of tornadoes will lead to higher perceptions of risk.

Similarly to previous tornado experience, perception of risk has been shown to produce increased responsiveness to warnings, safer response behaviour, and higher levels of preparedness (Tiefenbacher et al 2001). This may account for the weak to moderate statistical correlations between risk perception and levels of awareness and preparedness variables such as checking for tornado watches and having a severe weather plan. Significant correlations are detailed below in Tables 3(a-b).

Perception of the damage expected from a tornado strike on their property is lower for the respondents from Abilene than for those in Huntsville. Half of respondents in Huntsville expect total destruction or high damage compared with Abilene where the majority expect high or moderate damage. The lower damage levels expected in Abilene may represent that less destructive tornadoes are anticipated there, compared with Huntsville where respondents anticipate violent tornadoes in their area, influenced by Huntsville's past tornadoes. Perception of the magnitude of hazardous events has previously been understood to influence hazard awareness and preparedness. Therefore, the respondent's perception of the impacts they would face from a tornado may have wider influences on the respondent's attitude toward severe weather safety (Tiefenbacher et al 2001). Statistically there are significant correlations for Huntsville respondents of the impacts expected with previous tornado experience, risk perception and living through the 1989 F4 tornado, supplementing the previous assumptions of how the impacts expected from a tornado

strike may be influenced. These are detailed in Tables 4(a-b) and 5.

The prevalence of tornado safety myths shows almost equal low levels in both cities, as illustrated in the question of whether the respondents feel safer from tornadoes in cities than they do in rural areas. Although a slightly higher percentage in Abilene believed mythical reasons (such as 'buildings prevent tornado formation'), the majority of respondents in both cities do not believe they are any more or less at risk in cities, or felt that better warning systems in their cities increased their safety. This result demonstrates the effectiveness of the local warning systems in discrediting many myths that have become common knowledge. As the myths are refuted, it can take many years for them to be forgotten.

Abilene Risk Perception Correlations	Spearman's Rank Value	Statistical Significance Level
Tornado experience	.650	0.01
Define tornado warning	.648	0.01
Modify actions in watches	.477	0.01
Family & friends tornado experience	.418	0.01
Check for tornado watches	.369	0.01
Have severe weather plan	.358	0.05
Sought information	.353	0.05
Aware of severe weather awareness week	.306	0.05

Table 3a. Significant statistical correlations associated with the respondent's perception of tornado risk in Abilene.

Huntsville Risk Perception Correlations	Spearman's Rank Value	Statistical Significance Level
Tornado experience	.816	0.01
Family & friends tornado experience	.674	0.01
Lived in Huntsville in 1989	.558	0.01
Impacts expected	.474	0.01
Check for tornado watches	.454	0.01
Talked to children	.345	0.01
Made physical adjustments to home	.315	0.05
Have severe weather plan	.289	0.05
Own NOAA radio	.273	0.05

Table 3b. Significant statistical correlations associated with the respondent's perception of tornado risk in Huntsville.

Even though three quarters of respondents in Abilene believed their city had been lucky to avoid a serious tornado strike in the past, the majority still perceived themselves to be at a low to moderate risk for tornadoes. Similar research has established that even if a low frequency hazard is expected to occur at sometime in the future, perception and preparedness for the hazard can still remain low (Mileti 1999). This again demonstrates the necessity for previous experience to provide a shift in people’s attitudes towards adopting severe weather safety. There may also be an issue that is common in hazard perception - being aware of the hazard, but failing to personalize the risk (Tierney et al 2001). Although the majority of respondents may believe that a risk is posed, they may perceive this risk as minimal and that the chances of being personally affected are negligible, therefore believing themselves to be at low risk.

The respondents in Abilene appear to be displaying signs of apathy and indifference, which on the margins of

tornado alley can lead to disaster (Doswell et al. 1999). Residents are unaware of the possibility of significant and violent tornadoes in spite of historical records showing that over two thirds of the U.S.A. has been subject to such tornadoes since records began (Doswell et al. 1999). The false perception of “it can not happen here” seems prevalent among the respondents in Abilene, which is increasing complacency and the risk residents will face should a violent tornado cross through Abilene.

c. Tornado preparation

The purpose of preparing for hazards is essentially to enhance the response of an individual and ensure they understand exactly what the hazard entails and the best course of action (Tierney et al 2001). Hazard preparedness also aims to ensure the resources necessary for a sufficient response are already in place before the disaster occurs (Tierney et al 2001). Therefore, the risk of being injured or killed can be less for a prepared person as they know the appropriate course of action to take and in the case of tornadoes; they may only have seconds or minutes to take shelter. Research has shown that tornado preparedness levels increase significantly following tornadoes (Mulilis et al 2003). This finding with regard to Abilene and Huntsville is assessed in following text.

Over half of the respondents from Huntsville have sought information on tornado formation and safety compared to fewer than 10% in Abilene. Statistically, seeking information correlates well with tornado experience in Abilene, suggesting that the few respondents with tornado experience were more likely to have sought information. In Huntsville the only statistically significant correlations arose with other preparedness measures, such as having a severe weather plan and owning a NOAA Weather Radio. Accordingly, the respondents in Huntsville that have sought information may have been more inclined to take further preparedness measures.

Abilene Impacts Expected Correlations	Spearman’s Rank Value	Statistical Significance Level
Modify actions in watches	.285	0.05

Table 4a. Significant statistical correlations associated with the respondent’s perception of impacts expected from a tornado in Abilene.

Huntsville Impacts Expected Correlations	Spearman’s Rank Value	Statistical Significance Level
Risk perception	.474	0.01
Tornado experience	.379	0.01
Check for tornado watches	.344	0.01
Lived in Huntsville in 1989	.319	0.05

Table 4b. Significant statistical correlations associated with the respondent’s perception of impacts expected from a tornado in Huntsville.

Lived in Huntsville in 1989 Correlations	Spearman’s Rank Value	Statistical Significance Level
Tornado experience	.647	0.01
Risk perception	.558	0.01
Family & friends tornado experience	.442	0.01
Check for tornado watches	.344	0.01
Impacts expected	.319	0.05
Made physical adjustments to home	.255	0.05

Table 5. Significant statistical correlations associated with whether the respondent lived in Huntsville in 1989

The commemoration of previous tornado events in the media such as the 1989 F4 in Huntsville serves to arouse interest in tornado formation and safety, thereby accounting for the increased percentage of respondents in Huntsville who had sought information compared with Abilene. The respondents in Huntsville with experience of tornadoes would often state that having lived through a tornado event and taking the appropriate action during the event has meant that they do not feel it necessary to seek any further information. Statistical correlations are detailed in Tables 6(a-b).

In a similar context to seeking information, the passing of information by respondents to their children on shelter locations and tornado safety also shows a higher level in Huntsville. Those that have implemented a severe weather plan in their household are more likely to have discussed tornadoes with their children and even given their children a role to play when the plan is activated. An example of this came from one respondent in Abilene, who stated that each of his family members had their own small role to play during the activation of their severe weather plan while en-route to their storm shelter. Statistical correlations are detailed in Tables 7(a-b).

The availability of storm shelters also shows a higher level amongst the respondents from Huntsville. Even so, over 60% of respondents in Huntsville do not have access to a storm shelter or basement; this is still a significant improvement over the 96% in Abilene. As stated by many respondents, the availability of storm shelters can be traced back to past experience of the 1974 and 1989 tornadoes. These events served to prompt some residents to invest in their own shelters or discover where the nearest public

shelter is located. In Abilene the opposite is true, where the vast majority of respondents did not know where the nearest shelter was and basements are very rare. This may prove to be very costly for Abilene in the future as a lack of storm shelters has repeatedly contributed to high death tolls in tornadoes, as demonstrated in the moderate F2 and F3 tornadoes that occurred in Florida on the 22nd February 1998 (Schmidlin et al. 1998). As one respondent in Abilene noted, the other major cities in north Texas with previous tornado strikes all have larger amounts of storm

Abilene Sought Information Correlations	Spearman's Rank Value	Statistical Significance Level
Know location storm shelter	.586	0.01
Tornado experience	.504	0.01
Family & friends tornado experience	.352	0.05

Table 6a. Significant statistical correlations associated with whether the respondent sought information on the severe weather in Abilene.

Huntsville Sought Information Correlations	Spearman's Rank Value	Statistical Significance Level
Modify actions in watches	.317	0.05
Check for tornado watches	.306	0.05
Have severe weather plan	.282	0.05
Own NOAA radio	.272	0.05
Information presented	.260	0.05

Table 6b. Significant statistical correlations associated with whether the respondent sought information on the severe weather in Huntsville.

Abilene Talked To Children Correlations	Spearman's Rank Value	Statistical Significance Level
Modify actions in watches	.528	0.01
Have severe weather plan	.355	0.05

Table 7a. Significant statistical correlations associated with whether the respondent talked to their children about severe weather safety in Abilene.

Huntsville Talked To Children Correlations	Spearman's Rank Value	Statistical Significance Level
Have severe weather plan	.408	0.01
Risk perception	.345	0.01
Tornado experience	.320	0.05
Family & friends tornado experience	.305	0.05
Information presented	.259	0.05

Table 7b. Significant statistical correlations associated with whether the respondent talked to their children about severe weather safety in Huntsville.

shelters due to residents' experiences with tornadoes. The perceived proneness of an area to tornadoes has been ascertained to increase storm shelter availability, which also may account for the increased availability in Huntsville and lack thereof in Abilene (Ono 2002).

For reducing the damage and injuries caused particularly by weak tornadoes or on the peripheries of moderate tornadoes, measures such as securing outdoor furniture or installing window shutters can be effective. Just under a third of respondents in Huntsville had performed some physical adjustments to their home, compared to none in Abilene. This may be related to better awareness of the effectiveness of such measures, but some weak significant correlations for Huntsville were exhibited that may also play a role. These correlations include other general preparedness measures that indicate that some respondents who undertake preparedness measures will usually encompass all aspects of preparedness rather than just one or two random measures. Risk perception also shows a weak correlation with preparedness, possibly prompting residents to secure their outdoor objects, which they believe may become deadly missiles. Statistical correlations are detailed in Table 8.

Huntsville Physical Actions To House Correlations	Spearman's Rank Value	Statistical Significance Level
Risk perception	.315	0.05
Modify actions in watches	.279	0.05
Talked to children	.268	0.05
Lived in Huntsville in 1989	.255	0.05
Check for tornado watches	.253	0.05
Own or rent house	.249	0.05

Table 8. Significant statistical correlations associated with whether the respondent made physical adjustments to their house to minimise wind damage in Huntsville.

Household severe weather plans are critical for ensuring a rapid response during times of tornado warnings, when there may be only minutes or seconds to locate adequate shelter. Levels of implementation of plans again varied between the cities with nearly 90% of respondents in Huntsville and just over 50% in Abilene having devised a plan. As the vast majority of respondents in Abilene have no tornado experience yet the uptake of plans is high in comparison with other variables this implies that education efforts by the media and severe weather awareness weeks are prompting residents to devise severe weather plans. In Huntsville, the much higher level of adoption could also be accounted for by the severe weather education drive; but with the addition

of the city's history of tornadoes also influencing new and old residents. With the media reminding residents in Huntsville of the past tornadoes, this may provide an added incentive to new residents with no experience and prompt older residents to review or establish plans if they have become complacent since the last tornadoic event.

In towns such as Abilene where there are no siren warning systems, it is essential to own a NOAA Weather Radio in the event of a tornado warning being issued during the night or at times when the television or radio is not on. Night time tornadoes in communities without sirens can contribute to high death tolls as in the case of one on the 22 February 1998 Florida tornadoes. Warnings were issued up to 24 minutes in advance but since the tornado occurred at midnight and there was no siren system, many residents were unaware of the tornado until it struck (Schmidlin 1998). Even in cities with siren systems such as Huntsville, it is still highly recommended to own a NOAA Weather Radio due to the unreliability of sirens. Power outages can disable sirens and high winds can muffle the siren's sound or cause the actual siren to be damaged (Grazulis 2003). Any siren system is better than none and they have repeatedly proved to be an effective warning

source when maintained correctly (Liu et al. 1996). Over 40% of respondents in Huntsville own a NOAA Weather Radio compared to less than 10% in Abilene. This implies that 90% of respondents in Abilene have no method of receiving tornado warnings during the night. Statistically there are moderate significant correlations in both cities with risk perception, likely indicating that the higher perception of risk in Huntsville has prompted more residents to purchase the radios than in Abilene. Of the

four respondents in Abilene who owned NOAA Weather Radios, three perceived themselves to be at moderate risk and one at high risk, which is towards the higher end of the scale in terms of the risk perception results from Abilene. Statistical correlations are detailed in Tables 9(a-b).

d. Tornado risk awareness

During tornado prone months, approximately three quarters of respondents from Huntsville state they have a heightened awareness or continual year round awareness, compared with half of the respondents from Abilene. The more common concerns of daily life may overshadow the considerations of low probability events, no matter how

devastating the outcomes could potentially be (Legates et al. 1999). The respondent's personal circumstances may effect whether they consider severe weather during their day to day activities. The higher level in Huntsville may have arisen due to a Huntsville's tornadic history being kept fresh in the old resident's minds and also being instilled in new residents with no tornadic experience. These past events may prompt a variety of residents with differing experiences and circumstances to incorporate a heightened awareness during the tornado prone months.

A quarter of respondents in Abilene were confused by or had no idea about the meanings of tornado watches and warnings compared to none in Huntsville. Two of the respondents in Abilene who could not define the meaning of those terms had just moved into the country recently from abroad and had therefore not been subjected to the education and media attention on severe weather that locals are more likely to receive. Statistically, weak to moderate significant correlations were exhibited with general preparedness measures, suggesting that the more informed residents who are educated in tornado watch and warning meanings are more likely to undertake preparedness measures. This link has been exhibited in other studies such as in Tiefenbacher et al (2001), where understanding of tornado watches and warnings lead to higher levels of awareness and preparedness. Statistical correlations are detailed in Table 10.

Half of the respondents in Abilene and nearly three quarters in Huntsville stated they check for tornado watches. The majority in Abilene only check when the weather looks severe compared with Huntsville where the majority check regularly, on a daily basis or a few times a week. This indicates a difference in attitudes between the two cities with fewer respondents in Abilene checking for watches and

only checking when a storm is close, which if it contained a tornado then may not leave sufficient warning time. In Huntsville the attitude appears to be more proactive with more respondents checking, and those that checked doing so on regular basis no matter the weather conditions outside. Statistically, both cities exhibited correlations with risk perception indicating that those that perceive themselves to be at a higher risk are more likely to check for watches. In a previous study of tornado survivors after the Birmingham, Alabama tornado of 1998, it was discovered that awareness of tornado watches directly

Abilene Own NOAA Weather Radio Correlations	Spearman's Rank Value	Statistical Significance Level
Risk perception	.370	0.01
Tornado experience	.315	0.05
Modify actions in watches	.304	0.05
Family & friends tornado experience	.296	0.05

Table 9a. Significant statistical correlations associated with whether the respondent owns a NOAA Weather Radio in Abilene.

Huntsville Own NOAA Weather Radio Correlations	Spearman's Rank Value	Statistical Significance Level
Talked to children	.292	0.05
Modify actions in watches	.280	0.05
Risk perception	.273	0.05
Sought information	.272	0.05

Table 9b. Significant statistical correlations associated with whether the respondent owns a NOAA Weather Radio in Huntsville.

Abilene Define Tornado Watch Correlations	Spearman's Rank Value	Statistical Significance Level
Check for tornado watches	.479	0.01
Have severe weather plan	.481	0.01
Received severe weather education in school	.339	0.05
Modify actions in watches	.331	0.05
Information presented	.316	0.05

Table 10. Significant statistical correlations associated with whether the respondent can define the meaning of a tornado watch in Abilene.

increased the likelihood of becoming aware of the tornado warning, and decreased the likelihood of injury and death (Legates et al. 1999).

The amount of sources relied upon by residents for being informed of tornado watches and warnings is higher in Huntsville than in Abilene. In Huntsville, tornado experience and years lived in Huntsville correlate with the number of sources used. This indicates that previous tornadoic experience may play a role in prompting residents to rely on multiple sources so that accurate warnings can be received, even in times of possible power outages or lack of information from some sources. The availability of sirens and higher ownership of NOAA Weather Radios also partly explains the higher rates found in Huntsville. Statistical correlations are detailed in Tables 11(a-b).

e. Tornado response

A vast percentage more of respondents from Huntsville (87%) stated they modify their actions once they become aware of a tornado watch compared with Abilene (32%). Statistical correlations are detailed in Tables 12(a-b).

Previous disaster experience and high risk perception have been commonly correlated with more effective responses to hazards (Tierney et al. 2001). Balluz et al (2002) have attributed lower levels of compliance and response to frequent tornado watches with no tornadoic outcome, which can cause desensitising of people to the danger they may face. A combination of these factors may explain the differences in response between the two cities. Statistically, those that check for watches in both cities are more likely to modify their actions upon discovering their

Abilene Tornado Warning Sources Correlations	Spearman's Rank Value	Statistical Significance Level
Level of education	.373	0.01

Table 11a. Significant statistical correlations for the number of sources the respondent uses to receive tornado warnings in Abilene.

Huntsville Tornado Warning Sources Correlations	Spearman's Rank Value	Statistical Significance Level
Tornado experience	.429	0.01
Years Lived in Huntsville	.270	0.05

Table 11b. Significant statistical correlations for the number of sources the respondent uses to receive tornado warnings in Huntsville.

Abilene Modify Actions in Watches Correlations	Spearman's Rank Value	Statistical Significance Level
Risk perception	.477	0.01
Information presented	.443	0.01
Check for tornado watches	.408	0.01

Table 12a. Significant statistical correlations associated with whether the respondent modifies their actions during tornado watches in Abilene.

Huntsville Modify Actions in Watches Correlations	Spearman's Rank Value	Statistical Significance Level
Check for tornado watches	.570	0.01
Sought information	.317	0.05
Have heightened awareness in tornado prone months	.308	0.05
Tornado experience	.288	0.05
Made physical adjustments to home	.279	0.05

Table 12b. Significant statistical correlations associated with whether the respondent modifies their actions during tornado watches in Huntsville.

area is under a watch. Therefore attitudes toward the usefulness and reliability of tornado watches appears to greatly influence whether respondents check for watches and then modify their actions. The differences in response to watches between the two cities can be also explained by prior disaster experience and risk perception that exhibited statistical correlations in both cities. False tornado warnings have produced minimal detrimental affects on respondent's trust of tornado warnings in both cities. The overall majority accepted that tornado warnings are not always precise and would rather be informed of a tornado in their county than not being informed at all. These findings contradict a common theory that residents may ignore warnings after being conditioned by past warnings where no personal impact followed. (Legates et al. 1999).

f. Local education

The majority of respondents in Huntsville stated that they were aware of severe weather awareness week compared to just under half of the respondents in Abilene. Residents in Huntsville may be more receptive to information on severe weather due to past experiences, compared with Abilene where residents may not pay as much attention to severe weather articles due to a low risk perception. Statistically, there are some significant correlations with those that received information being more likely to have spoken to their children about severe weather and also more likely to have created a severe weather plan. This suggests that residents who are presented information may be prompted to find further information and then adopt preparedness measures. Statistical correlations are detailed in Tables 13(a-b) and 14(a-b).

The awareness of respondents to severe weather talks and lectures in their cities show similar

levels in both cities. It was noted in Huntsville that after the 1989 tornado there was an upsurge in talks available to the public. In the following sixteen years the number of talks appears to have declined to a similar level to Abilene and other cities on the periphery of tornado alley. In school or college, 60% of respondents in Abilene stated they received some form of education on severe weather or participated in tornado drills, compared with 40% in Huntsville. Not all respondents were born and raised in these cities so respondents who grew up in other states

Abilene Aware of Severe Weather Awareness Week Correlations	Spearman's Rank Value	Statistical Significance Level
Have severe weather plan	.413	0.01
Talked to children	.336	0.05
Modify actions in watches	.286	0.05

Table 13a. Significant statistical correlations associated with whether the respondent was aware of severe weather awareness week in Abilene.

Huntsville Aware of Severe Weather Awareness Week Correlations	Spearman's Rank Value	Statistical Significance Level
Impacts expected	.374	0.01

Table 13b. Significant statistical correlations associated with whether the respondent was aware of severe weather awareness week in Huntsville.

Abilene Had Severe Weather Information Presented to Correlations	Spearman's Rank Value	Statistical Significance Level
Modify actions in watches	.443	0.01
Can define tornado warning	.316	0.05
Have severe weather plan	.299	0.05

Table 14a. Significant statistical correlations associated with whether the respondent was presented severe weather information in Abilene.

Huntsville Had Severe Weather Information Presented to Correlations	Spearman's Rank Value	Statistical Significance Level
Own NOAA radio	.262	0.05
Talked to children	.259	0.05

Table 14b. Significant statistical correlations associated with whether the respondent was presented severe weather information in Huntsville.

have influenced the validity of these percentages. Local education variables may in part have been influenced by the city or states past tornadic history, affecting how seriously the residents respond to the information presented to them. This may be further influenced by personal tornadic experiences effecting whether a resident pays attention to information presented to them or instead decides that such information is irrelevant to them.

5. Conclusions

Risk perception was found to be influenced by previous tornadic experience for the majority of respondents answering to surveys taken during May 2005 of residents in Huntsville, Alabama and Abilene, Texas. Risk perception in turn was shown to correlate well with many preparedness variables, further exemplifying the widespread influence of tornadic experience. Belief in false tornado safety myths is low in both cities, revealing that educational drives are performing well to eradicate such myths.

The analysis of risk, preparedness, awareness, and response variables showed higher levels of adoption and compliance in Huntsville. This can be attributed to a variety of factors including previous tornadic experiences, risk perception, and for Huntsville the persistent media coverage of past tornado events which helps to impede residents from becoming complacent.

The lack of sirens, adequate storm shelters or basements, and low ownership rates of NOAA Weather Radios in Abilene is greatly increasing the vulnerability of residents to a disaster should a violent tornado impact the city. This vulnerability would be augmented further should a tornado strike during the night when the majority of residents have no means of receiving tornado warnings once their televisions and radios are turned off for the night.

Local warning and educational systems are equally sufficient in both cities. Lack of previous tornadic experiences in Abilene has moulded potentially counterproductive attitudes towards severe weather safety and preparedness that may possibly only be remedied by a tornado strike in the city. In contrast, residents in Huntsville are aware of previous tornado related disasters in their city which in turn has made them more interested and receptive to preparedness measures.

Appendix

Spearman's Rank Correlation is a method used to investigate the direction and strength of the relationship between two variables. It shows whether any one set of numbers has an effect on another set of numbers.

To determine Spearman's Rank (ρ), the raw scores from two data sets (x and y) are converted to ranks and the differences (d_i) between the ranks are calculated. ρ is then calculated by applying the values to the following equation:

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

where:

d_i = the difference between each rank of corresponding values of x and y.

n = the number of pairs of values.

Author

Andrew Pennell received his B.Sc. in Geography from Royal Holloway, University of London in 2004 and his M.Sc. in Geophysical Hazards from University College London in 2005. He now works for a London based reinsurer as a natural risk analyst.

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