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Outdoor Siren Systems: A review of technology, usage, and public response during emergencies

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Abstract

The National Institute of Standards and Technology (NIST) Technical Investigation of the 2011 Joplin, MO tornado identified that no widely accepted standards exist for emergency communications in tornado events and more specifically, policies involving the use of outdoor siren systems to alert the public in advance of tornadoes. As a result, siren usage, testing, education and training, and all-clear procedures vary widely across the U.S.; leading to distrust and confusion among community residents surrounding emergency communications.

This study is designed to develop evidence-based guidance for communities on the creation and provision of public alerts, including both alerts provided by outdoor siren (warning) systems and “short messages” sent by social media or other short message service (SMS) platforms. It is the hope that this guidance can eventually be used as a basis for standardization, through codes and standards, of the procedures and policies for outdoor siren systems and social media used by communities across the United States. Standardization of emergency communication policies and procedures could occur at multiple levels, including among multiple jurisdictions, state-wide, regionally, or even nationally.

This document focuses on outdoor siren systems, specifically presenting a review of technology, usage and public response. First, an overview is provided on the current status of siren systems in the United States, i.e., the current siren technology available to communities and the ways in which this technology is used in communities across the United States. Second, a review of the literature is presented on the ways in which people respond to alerting signals (including siren systems) and the current limitations of siren systems in light of these findings. This document concludes with a discussion on the key findings and recommendations from the literature on the ways in which to improve current outdoor siren systems, based on the methods by which people receive and process alerts. Following this work, a review will be performed and published on “short messages”, which will also be used, along with the work published here, to develop the overall evidence-based guidance for communities on the creation and provision of public alerts.

Keywords: tornadoes, alerts, emergency communication, mass communication, outdoor siren systems, public response, emergency warnings

Table of Contents

1. Introduction 1
2. Report Organization and Methods 3
3. Current Status of Outdoor Siren Systems 6
   3.1 Siren Technology 6
   3.2 The Usage of Siren Systems in U.S. Communities 9
4. Siren Systems and the Public 11
   4.1 How People Receive, Process, and Respond to Emergency Alerts 12
   4.2 Potential Limitations with Siren Systems 13
5. Research Questions on Potential Improvements to Siren Systems 16
6. Key Findings and Recommendations from the Literature on Improvements to Siren Systems 18
   6.1 Reaching a Wider Audience (Perception and Attention) 18
   6.2 Increasing Comprehension 19
   6.3 Increasing the Credibility and Ability to Personalize the Risk 23
7. Unanswered Questions 23
8. Conclusion 24
References 26
Appendix A. Source Summaries 27

1. Introduction

Tornadoes pose a significant threat to life and property in the United States. In an average year, these windstorms are responsible for the most fatalities and insured losses of any natural hazard in the U.S. For example, in the ten years from 2001-2010, the U.S. *averaged* nearly $1B in insured losses and 56 fatalities per year from tornadoes according to the National Oceanic and Atmospheric Administration (NOAA, 2014a).

A tornado occurred on May 22, 2011 in a populated area, Joplin, Missouri as a National Weather Service (NWS) rated EF-5 tornado on the Enhanced Fujita tornado intensity scale. This tornado touched down just to the west of Joplin and proceeded to cut a swath through the entire length of the city. The tornado directly affected 41 percent of the city's population (20 820 people, out of the 50 175 estimated), damaged or destroyed nearly 8 000 structures and caused nearly $2B in insured commercial and residential property losses, and generated approximately 3M yd^3 of debris (Kuligowski et al., 2014). More importantly, the structural damage and associated windborne debris were responsible for the majority of the 161 fatalities, the most caused by a single tornado since the NWS started keeping records in 1950. Windborne debris was also a major factor in the over 1 000 injuries reported from the tornado, which included debris impacts.

Given the unprecedented number of fatalities and injuries, as well as the scope and extent of structural damages caused by the May 22, 2011 Joplin, MO tornado, the National Institute of Standards and Technology (NIST) conducted a preliminary reconnaissance of building performance and emergency communications during the tornado and deployed four researchers/engineers to Joplin shortly after the event, from May 25-28, 2011. Based on information gathered in this preliminary reconnaissance, NIST formally established a team to investigate the disaster under the National Construction Safety Team (NCST) Act (Public Law 107-231). The team consisted of the four NIST researchers – with expertise in structural and fire engineering, wind science and engineering, and sociology – and a researcher from the National Oceanic and Atmospheric Administration's National Severe Storms Laboratory (NOAA's NSSL) with expertise in meteorology, severe storms and warnings.

The NIST Investigation's goals were to: (1) study the wind environment and conditions associated with fatalities and injuries, the performance of emergency communications systems and public response to such communications, and the performance of residential, commercial, and critical (e.g., hospital) buildings, designated safe areas in buildings, and lifelines; and (2) develop findings and recommendations that serve as the basis for potential improvements to public safety in tornadoes, including:

- Potential improvements to requirements for design and construction of buildings, designated safe areas, and lifeline facilities in tornado–prone regions;
- Potential improvements to guidance for tornado warning systems and emergency response procedures; and
- Potential revisions to building, fire, and emergency communications codes, standards, and practices.

Several findings from this investigation focus specifically on emergency communications (Kuligowski et al., 2014). First, there were the multiple ways in which individuals in Joplin, MO were made aware and received further information about the May 22, 2011 tornado emergency. Joplin's outdoor siren system, which could generally be heard indoors as well as outside, was the primary means by which individuals were alerted to a tornado event on May 22, 2011. Radio, television, and word of mouth were the primary means by which individuals were provided with warning information on May 22, 2011. Additionally, functioning as an alerting system only, the outdoor sirens prompted many Joplin residents and visitors to seek further information on May 22, 2011. However, the multiplicity of information sources, and the conflicting information provided by those sources, added to the public's confusion about the true hazard as additional information was sought. In turn, responses to the approaching tornado among members of the public, in many cases, were delayed or incomplete, as was evidenced by the fatalities that occurred among individuals located outdoors, in vehicles, or en route within buildings to safer refuges when the tornado hit. The two main factors that contributed to delays in or incomplete response to the Joplin, MO tornado were: 1) a lack of awareness of the tornado, and 2) an inability to perceive personal risk due to a) receiving conflicting or uncertain information about the tornado, b) holding pre-existing beliefs about Joplin's immunity to direct tornado strikes, or 3) distrust or confusion about Joplin's emergency communications system.

Another significant finding was that no widely accepted standards exist for emergency communications in tornado events and more specifically, policies involving the use of outdoor siren systems to alert the public in advance of tornadoes. While guidance does exist on the ways in which communities can use outdoor siren systems, the guidance is general in nature, providing little in the way of definitive requirements on the types of hazards for which to sound the siren, the appropriate number of tones, tone length, tone meaning, the provision of information in addition to a tone, specific day and time testing protocols, and all-clear procedures (FEMA 1980; SkyWatch 2015). Guidance on education and training procedures are also not specifically provided. As a result, siren usage, testing, education and training, and all-clear procedures widely vary across the U.S.; leading to the distrust and confusion among community residents surrounding emergency communications (as was seen in the 2011 Joplin, MO tornado). In response to these findings from the investigation, NIST recommended "the development of national codes and standards and uniform guidance for clear, consistent, recognizable, and accurate emergency communications, encompassing alerts and warnings, to enable safe, effective and timely responses" (Kuligowski et al., 2014).

This study is designed to develop evidence-based guidance for communities on the creation and provision of public alerts, including both alerts provided by outdoor siren (warning) systems and "short messages" sent by social media or other short message service (SMS) platforms. It is the hope that this guidance can eventually be used as a basis for standardization, through codes and standards, of the procedures and policies for outdoor siren systems and social media used by communities across the United States. Standardization of emergency communication policies and procedures could occur at multiple levels, including among multiple jurisdictions, state-wide, regionally, or even nationally.

This document focuses on outdoor siren systems. The purpose of this report is two-fold. First, this document provides an overview on the current status of siren systems in the United States, i.e., the current siren technology available to communities and the ways in which this technology is used in communities across the United States. Second, this document presents a review of the literature on the ways in which people respond to alerting signals (including siren systems) and the current limitations of siren systems in light of these findings. This document concludes with a discussion on the key findings and recommendations from the literature on the ways in which to improve current outdoor siren systems, based on the methods by which people receive and process alerts. Following this work, a review will be performed and published on "short messages", which will also be used, along with the work published here, to develop the overall evidence-based guidance for communities on the creation and provision of public alerts.

A more detailed discussion on the report's organization is included in the following section.

2. Report Organization and Methods

Overall, this report presents research that will eventually help to inform guidance for communities on the creation and provision of public alerts via outdoor siren systems. The report provides insight into the following two main questions regarding outdoor siren systems:

1. What is the current status of outdoor siren systems in the U.S., including current technologies and siren usage?
2. How does the public respond to different alerting sounds and different types of auditory signals?

2.1 Current Status of Outdoor Siren Systems

The first question asks what is the current status of outdoor siren systems in the U.S. To answer this question, two sub-questions are posed: a) What current outdoor public siren technology currently exists? and b) How are outdoor siren systems being used to alert people of impending disasters in U.S. communities?

2.1.1 What current outdoor public siren technology currently exists?

A review was conducted of current siren technologies and their capabilities in alerting and warning the public (See Section 3). A total of 53 different outdoor siren (warning) systems were reviewed from four siren manufacturers whose systems are available to communities within the United States. Since the purpose of this part of the project was to understand the capabilities of current systems and the ways in which they differ, work was performed to categorize currently available siren systems by the following: siren type, voice community capabilities, signal capabilities (including sound quality, range, and number and type of signals/sounds offered), direction of sound, continuity of sound, and testing options.

2.1.2 How are siren systems being used to alert people of impending disasters in U.S. communities?

An additional review was conducted of siren system usage in communities to alert people of impeding disasters across the U.S. One review was performed as part of the NIST Technical Investigation of the 2011 Joplin, MO tornado. An assessment of more than 75 U.S. counties, cities and towns was conducted to identify the similarities and differences among siren systems from community to community. An internet search was performed to identify at least one community from each tornado-prone state that used a siren system to alert of emergencies (Kuligowski et al. 2014). There was no systematic method for choosing communities; instead, communities were chosen for this assessment if they provided emergency communications procedures on a website that was accessible to the public, which has become a popular method for awareness and training of community members on the siren system. Additionally, three main studies of siren usage were used to confirm and add to the findings of the NIST study: Brotzge and Donner (2015); Ebner (2013); and Laidlaw (2001). The first study surveyed over 350 emergency management leaders from communities both inside and outside of the U.S. on general uses of outdoor siren technology and the diversity among procedures. The second study surveyed 28 Emergency Management Directors in the state of Missouri to analyze all the ways in which sirens in

Missouri differed, and whether or not there are any unifying procedures or guidance. The third article provides an overview on siren usage across communities in the U.S.

Overall, Section 3 provides a discussion on the ways in which siren usage widely differs from U.S. community to community. A discussion is provided on the types of emergencies for which sirens are sounded, as well as the various ways that siren usage can differ from community to community, including the types of tones used for alerting, the meaning of these tones (or what one should do when the alert is sounded), activation protocols (i.e., when or in what types of conditions the alert should be activated), and testing protocols.

2.2 Public Response to Alerts

The second question focuses on how the public responds to different alerting sounds and types of auditory signals. To answer this question, a literature review has been carried out that addresses how people respond to auditory alerts (See Sections 4-7, and Appendix A). To begin the review process, a general search for material was performed, and sources were included or not based on their relevance to outdoor siren systems, auditory alerts, and human response to alerts. More specifically, material was selected based on whether or not it provided background on the response of the public to current alerting systems, the limitations of current systems in alerting the public, and/or key findings or recommendations that would improve or advance the current methods used to alert people of impending disasters.

A total of 67 sources were collected and reviewed as part of this report. The selected material is intended to present a representative – as opposed to exhaustive – view into research and best practices. All material was drawn from publicly available resources, published in English.

Section 4 begins by first presenting evidence on the importance of outdoor siren systems as an alerting mechanism for people within a community. Acknowledging that sirens will likely remain an important and useful tool in the alerting "toolbox", this section also describes the method by which people respond to alerting sounds or signals. The method presented, known as the Protective Action Decision Model[1] or the PADM (Lindell and Perry 2004), is a decision-making process by which people receive, interpret, and respond to siren system alerts. Each stage of the PADM is described in the context of alerting sounds and signals presented in a disaster situation. Then, based upon the PADM, Section 4 also presents research on the potential limitations associated with current outdoor siren systems and their use that can inhibit the various stages of the PADM, leading to a delayed or incomplete response of the public to an impending emergency. Research findings are presented as evidence for the three main limitations identified in this section.

Based upon these limitations, a series of 11 research questions were developed to next inquire about whether potential improvements can be made to siren systems and/or their use to ensure safe and effective public response. These research questions are presented in Section 5. Next, Section 6 presents findings and recommendations from the research that identify ways to improve current siren systems and/or system usage to better meet the needs and requirements of the responding public. Section 6 specifically focuses on how public response to sirens can improved by education, other forms of alerts, and additional information provided in the event of an emergency. Research-based key findings and recommendations presented in this section will inform the later stages of this research project; i.e., the development of

[1] The PADM is a model that describes the decision-making process that occurs before taking protective action, which was used as a method to organize the literature review.

specific guidance for others to use in the standardization of outdoor siren system usage, technology and procedures. Finally, Section 8 details the "unanswered questions"; i.e., the few questions, out of the original 11, on which little or no research was found on potential improvement to siren systems.

Appendix A contains annotations of all 67 sources collected and reviewed as part of this report. A general framework was used to develop an annotation for each literature source. Each annotation lists the following:

- The source reference,
- The discipline in which the source was found,
- The rating of the article,
- A summary of the contents,
- Key findings and recommendations provided by the source.

The source reference simply provides information on the author(s), date published, title of the article, source in which the article is published, and relevant publishing details (e.g., publisher, page numbers, etc.). The discipline is listed next. The disciplines from which literature was collected included acoustics, child development, communication, crisis management/disasters, education, ergonomics, fire, medicine, meteorology, psychology, and public health. Also listed is the rating of the article. Each source was given a rating based on the type of publication, and the year in which it was published (See Tables 1 and 2). This rating was one attempt to estimate the credibility and significance of each source, rating higher (e.g., "7A") those sources that were more recent and/or were published in archival publications that require internal/external review and approval.

Table 1: Rating based on publication type

Rating	Type of Source
7	Peer Reviewed Journal Articles, Consensus Standards
6	Government Reports, Books
5	Conference Proceedings/Bulletins
4	Reports (companies/universities)
3	Masters/PhD Thesis
2	Journalism
1	Blogs

Rating	Years
A	2000 +
B	1980-1999
C	1960-1979
D	<1960

Table 2: Rating based on year published

Following the discipline and rating information, the summary text for the article is provided. Finally, underneath the summary text, the key findings and key recommendations from the source are listed. The key recommendations are also labeled with distinct identifiers – starting with the number of the source, the number of the recommendation, and the number of the research question that this source addresses e.g., [# of source_# of recommendation_# of question]. The recommendations are presented in this way to more easily use them to inform the development of specific guidance for the improvement of outdoor siren system technology, usage, and subsequent policies.

The following section begins the discussion of the current status of outdoor siren systems in the U.S. This discussion includes a review of currently available siren technology as well as the usage of these technologies across communities in the U.S.

3. Current Status of Outdoor Siren Systems

In the event of community-wide emergencies, such as tornadoes, tsunami, wildfires, or hazardous chemical spills, alerts and warnings are issued with the goal of initiating protective action among the public. Sheltering in place or evacuating to safety are two examples of protective actions. The main purpose of alerts is to capture the attention of the public in preparation for a subsequent warning message. Warnings are then used to provide *information* about the emergency, such as emergency type, when it will manifest, and the forms of protective action that should be taken (Kuligowski et al. 2014).

Depending upon emergency type, alerts are often disseminated using outdoor siren systems. These systems are meant to alert individuals located outside of structures within the community of an impending emergency; however, people often hear them indoors and many even rely upon these systems as a means of alerting them inside of structures (Stokoe 2016; Kuligowski et al. 2014).

Overall, there are many different types of siren technology, as well as many different ways in which these technologies are employed to alert community members of an impending disaster. This section will provide information on the various types of siren technology and the ways that these systems are used in communities across the U.S.

3.1 Siren Technology

Many different types of outdoor siren systems[2] are available for communities to purchase and install. As part of this project, 53 different outdoor siren systems available for community use were identified and reviewed from four different siren manufacturers. No specific siren manufacturers or model/unit types will be identified in this section; instead, it is more important to identify the variations among system types, including their capabilities and limitations. This information can provide insight on the ways in which current siren technology provides effective alerting of community populations, and possibilities for future improvements to these systems, based on the research identified in the alerting literature review (see Sections 4-7).

Based upon the review of 53 systems from four manufacturers, with a specific focus on their alerting capabilities, there are six main categories that can be used to differentiate between siren systems currently available on the market today. These six categories are the following:

- The type of system,
- Voice communication capabilities,
- Signal capabilities,
- Direction of sound,
- Continuity of sound,
- Testing options.

Also, the findings related to outdoor siren technology is summarized in Table 3. Each of these six categories will be discussed in more detail in the following section.

[2] These systems can also be called outdoor warning systems; however, they are referred to as "outdoor siren systems" throughout this report because they perform more like an alerting system rather than a warning system.

Table 3: Summary categorization of outdoor siren technology

Category	Explanation of Category	Range within Category	Significance
Type of System	Method describing how sound is provided	Electro-mechanical; Electrical	Identifies the types of sounds that can be disseminated (i.e., sound only vs. voice)
Voice Communication	Capability of disseminating information via voice.	Yes (capability is included); No	Allows dissemination of both a warning message AND an alerting sound by the siren system
Signal (number of tones)	The number of tones disseminated by the system.	1 tone to 10 tones, including custom tones	Allows communities to disseminate different types of sounds, both within the same community and across different U.S. communities
Direction of Sound	The coverage area of the siren system and its method of achieving that coverage (rotating or stationary)	180 degrees to 360 degrees	Affects the way individuals receive the tone throughout the community
Continuity of Sound	The time period allowed for continuous operation, before a cooling down period must begin	15 mins, 30 mins, to continuous	Affects the length of time that the siren's tone can sound continuously
Testing Options	The testing options available to verify that the siren is still functioning appropriately	Silent test; growl test; audible test only	Affects the frequency by which individuals hear the tone (during a test)

The first way in which siren systems differ is the type of system. The current systems available on the market are either electro-mechanical or electronic systems. The type of system mainly comprises how the sound is provided and what types of sounds can be disseminated (i.e., sound vs. voice). Electro-mechanical devices can disseminate sound only, including horns, whistles, sirens; while electronic systems can disseminate both sound and voice. Additionally, there are a lower number of tones/signals available for dissemination by electro-mechanical systems in comparison with electronic systems. The reason for this is because electro-mechanical systems disseminate sounds via "chopping the flow of compressed gas (usually air)" and the fundamental frequency of the siren (its pitch) is determined by the rate at which the flow is "chopped" (FEMA 1980), significantly reducing the types of sounds or tones that can be disseminated by the system. Of the 53 reviewed for this report, 18 of the siren systems were electro-mechanical; leaving the majority categorized as electronic systems.

Another way of differentiating outdoor siren systems is their capabilities in disseminating voice communication. Overall, from the 53 siren systems sampled, over half of the systems (31 in total) had voice-communication capabilities (i.e., all 31 were electronic systems). Only four of the electronic systems surveyed were tone-only. Voice communication capabilities allow the user to disseminate a warning message in addition to an alerting sound before and/or during an emergency event. Siren systems with voice capabilities also offered the ability to disseminate pre-recorded messages (created and recorded prior to an incident occurring, and because of this, often more general in nature) and/or a live voice (which could tailor the information in the message to the particular incident).

It should be noted that while there are obvious benefits to providing warning information at the same time as an alert (Kuligowski and Omori 2014), FEMA guidance questions whether siren system technology is the best mechanism to disseminate this information (FEMA 2006). Among other concerns, voice warnings may be unintelligible due to issues like communities' terrain and ambient noises. FEMA notes that the use of voice communication via siren systems may require installation of more devices than would be necessary for the basic alerting system to ensure intelligibility (FEMA 2006).

Signal capabilities of current siren technology also varied. The tone of a signal is a basic, yet intrinsic aspect of a siren system. The tone can refer to a sound's quality, pitch, strength or character, and is a general term used to differentiate between sounds. The electro-mechanical systems were able to disseminate either one tone or three different types of tones. For the latter, the three basic tones include the "steady" tone, the "wail" tone, and the "fast wail" tone. The steady tone can be described as a constant sound (at a particular set of frequencies) over time. The wail tone can be described as a sound that goes up and down in loudness and frequency over time (with a 10 s sweep). The fast wail is similar to the wail tone, but with a shorter sweep time (3.5 s). On the other hand, the electronic systems were able to disseminate anywhere from six to ten standard tones, with the added capability of disseminating custom-designed tones.

The types of signals available for use also vary by sound quality and range. It is important to understand the factors that may limit a person's ability to receive (or hear) the sound in outdoor settings. First, human hearing is reduced with lower frequencies; i.e., at less than 300 Hz, human hearing sensitivity is reduced and higher background noise may cause hearing restrictions (FEMA 1980). Additionally, sound decreases in magnitude (i.e., in loudness) at larger distances away from its source, known as attenuation. Attenuation occurs at a faster rate at higher frequencies (e.g., above 1 000 Hz) (FEMA 1980). Therefore, the signals available for use by siren technology normally fall between the 300 Hz to 1 000 Hz range (FEMA 1980), with the steady (or mid-range) frequencies surrounding 500 Hz or 600 Hz and dual frequencies at 460 Hz and 920 Hz. Some manufacturers discuss the benefits of signals with dual frequencies as better able to reach a wider listening audience.

The direction of sound is also an important factor for siren technologies. All systems surveyed, with the exception of two, were capable of producing 360° sound coverage. In some cases, the system included a stationary siren that was capable of producing constant sound in all directions, also known as an omni-directional system. In other cases, the system included a directional siren or horn that could rotate. On one hand, the directional siren or horn can produce a stronger, more intense sound; however, as it rotates, the stationary listener will hear a sound that goes up and down in loudness as the siren or horn turns (FEMA 1980).

The current siren technology also differs based upon its continuity of sound. Depending upon the model type, manufacturer, and power source/capabilities, the siren system is likely to have a duty-rating of some period of time, meaning that the system can be in operation for "X" minutes before it has to shut down to allow for a "cooling off" period before starting up again. Sirens can have a duty rating of (5 or 10) min, for example, meaning that they may have to shut down anywhere from 5 min to 30 min for cooling purposes. The general trend among the surveyed technologies was a (15 to 30) min duty cycle, depending upon the power sources available (e.g., battery operation, AC, AC with DC battery, and solar power). However, ten of the systems allowed for continuous sound, i.e., approximately 20 000 h, without the need for a cooling period. Note: information on continuity of sound was not readily available (online) for all 53 systems surveyed.

Finally, the currently available siren technology varies by testing options. Siren testing is the procedure by which a siren is activated for a specific amount of time on a designated date, in order to verify that it is still functioning correctly. Whereas manufacturers provided numerous testing options, including local testing, remote testing, and self-test capabilities, the electronic systems surveyed had silent test capabilities. Silent tests allow community leaders to test the system for its operational status without producing the audible siren signal. For the electro-mechanical systems, most offered the “growl” testing option; i.e., the ability to activate the system without a full audible alert of the system, producing only a growling sound (although testing information for all systems was also not readily available).

Now that the differences in siren technology have been established, it is important to understand how various communities use these systems and their capabilities throughout the U.S. The following section discusses the differences among siren usage in U.S. communities.

3.2 The Usage of Siren Systems in U.S. Communities

Many U.S. communities employ outdoor siren technology to alert community members and visitors of impending emergencies. Although this project stemmed from, and subsequently revolves around tornadoes in particular, it is important to understand that sirens are often activated for various types of rapid-onset events[3]. While research surveying over 350 emergency management leaders from communities both inside and outside of the U.S. has shown that many jurisdictions use their siren systems solely for tornadoes, especially jurisdictions located in “tornado alley” in the U.S., many communities also used them to alert for extreme winds, hail, flash flooding, lightning, hurricanes, rotating cloud walls, derechos or a combination of the above (Brotzge and Donner 2015; Kuligowski et al. 2014). Additionally, approximately 50 % of the sample use sirens to alert for non-weather events; for example, hazardous material situations, fire response and wildfires, active shooter threat, tsunami, earthquake and volcanoes (Brotzge and Donner 2015). A full list of hazard events for which outdoor siren systems are used is included in Table 4.

Table 4: Hazard events for which outdoor siren systems are used in U.S. communities

Naturally Occurring Hazards	Human- Caused Events
• Derechos • Earthquake • Extreme winds • Flash flooding • Hail storms • Hurricanes • Lightning • Rotating cloud walls • Tornadoes • Tsunami • Volcanic eruptions • Wildfires	• Active shooter threat • Chemical spill/hazardous materials situation • Civil defense emergencies

While siren systems can be used for hurricanes and far-field tsunami; these emergencies are generally classified as slow-onset events (Stokoe 2016; Brotzge and Donner 2015; Gregg et al. 2003; Mahn 2013; Ebner 2013; Donner, Rodriguez and Diaz 2012). Slow-onset events are outside the scope of this review

[3] Emergencies can be classified as either rapid-onset events or slow-onset events. Rapid-onset events are those that occur with no or almost no (in the case of minutes) notice. Slow-onset events, on the other hand, are emergencies in which we are aware of their occurrence hours or even days in advance.

since they provide more time to alert and warn the public of impending disaster, when compared with rapid-onset events.

With many communities using siren systems to alert the public, compounded by the various types and capabilities of siren technology and the lack of standardization among U.S. community siren policies (Kuligowski et al. 2014; Laidlaw 2001), it is no surprise that the usage of siren systems differs widely from community to community across the U.S. More specifically, siren system usage differs in the types of tones used for alerting, the meaning of these tones (i.e., what one should do when the alert is sounded), and activation protocols (i.e., when or in what types of conditions the alert should be activated). Testing protocols and the use of all-clear signals (i.e., additional alerts signaling the end of an emergency) also vary by jurisdiction (Brotzge and Donner 2015; Kuligowski et al. 2014). Each of these differences will be described in more detail in the following text, as well as summarized in Table 5.

The signal or tone of a siren system is a key way in which sirens differ across U.S. communities. One study surveying U.S. jurisdictions found that 60 % of the sample had multi-tonal capabilities (Brotzge and Donner 2015). The term “multi-tonal capabilities” means that the siren system can disseminate more than one type of tone. Communities with multi-tonal capabilities can choose to use different tones for different emergencies, or they can designate one tone to act as the main alert for all emergencies. Conversely, communities with single-tonal capabilities must rely on a single tone as an alert for any emergencies that require a siren signal. Since both multi-tonal and single-tonal systems are common in the U.S., alerting tones, even for the same type of emergency, often differ depending on geographic location (Kuligowski et al. 2014).

Siren tones do not inherently convey much information; however, meaning can be assigned to an outdoor siren system tone, which can then be taught to the public. This “meaning” can and does vary across U.S. communities as well. Tone meaning usually falls into one of two categories; a general “seek out information” meaning, or a more specific meaning that is linked to a particular hazard type. For example, communities using a single-tonal system to alert for multiple emergencies, may assign a more general meaning to the siren’s tone; e.g., seek out more information regarding the incoming hazard. In other cases, communities using the siren system to alert only for tornadoes and other severe weather events, may assign a more specific meaning to the siren alert; e.g., letting the public know that when the siren sounds, it means to take shelter in an interior room or basement, evacuate vehicles, and stay away from glass; continue to monitor additional information sources (e.g., Kuligowski et al. 2014). Meanings of the tones are often posted online by a community’s Office of Emergency Management, or equivalent, along with other information on the community’s siren policy.

Siren usage also differs with regards to activation procedures. Ebner (2013), in a study of Emergency Management Directors in the state of Missouri, found that some emergency managers will not only activate their outdoor siren systems for a National Weather Service (NWS)-issued tornado warning affecting their *own* community, but also for an NWS-issued tornado warning associated with *adjacent* communities. Almost a third of this sample sound the sirens for strong thunderstorms, and slightly less than ten percent use the sirens during a NWS-issued tornado watch (Ebner 2013). In a separate study surveying over 350 emergency management leaders from communities both inside and outside of the U.S., the majority of respondents reported always sounding their sirens in response to NWS-issued tornado warnings, and about half reported that they sometimes activated the sirens even before a warning is issued (Brotzge and Donner 2015). This variation in activation procedures can cause the siren system to sound more frequently in one community over another from year to year.

Outdoor siren systems can also differ in a variety of other ways. Some differences are structural, and include aspects like sectionalized versus non-sectionalized systems[4]. Non-sectionalized systems, again, may sound more frequently than systems that are sectionalized, due to their potentially larger coverage area. Other differences are more procedural, such as siren testing protocols and the use of all-clear signals. Through a survey of over 350 emergency managers, it was found that the majority of jurisdictions test their sirens once per month. However, some jurisdictions test more frequently than monthly; including 16 % of the sample that test the sirens weekly, and 4.5 % of the sample that test sirens daily (Brotzge and Donner 2015). In addition to testing procedures, tests can also vary in their duration, schedule, and tone. Additionally, although most jurisdictions no longer used all-clear signals to alert people that the emergency had ended; this finding was not consistent across all sampled communities (Brotzge and Donner 2015).

Table 5: Summary categorization of outdoor siren system usage in U.S. communities

Usage Category	Range of Usage	Significance
Types of Tones	Single-tonal; Multi-tonal	Alerting tones differ widely across U.S. communities (even for the same hazard type)
Tone Meaning	General ("seek out information"); Specific actions to hazard type	Each tone does not have one inherent "meaning"; differs across communities and across hazards
Activation Protocols	Tornado warning; Tornado watch; Emergency affecting community to emergency outside of community	Sirens may sound more frequently in one community over another
Testing Procedures	Monthly; Weekly; Daily; No standard day or time	Sirens sound (for testing) at different frequencies, days/time, across U.S. communities
All-Clear Procedures	All-clear signal disseminated; No all-clear signal disseminated	Inconsistencies exist among U.S. communities' use of all-clear signals
Structure of Siren System	Sectionalized; Non-sectionalized	Sirens may sound more frequently in one community over another

Overall, it is clear that diversity exists among outdoor siren system technology and the usage of these systems. Regardless of these differences, it is clear that outdoor siren systems represent a key component to a community's "alerting toolbox". The following section describes the reliance of the public on siren systems, how these systems are received by the public and used in the process of decision-making and response, and finally, the limitations of current outdoor siren systems in alerting people in rapid-onset emergencies.

4. Siren Systems and the Public

Outdoor siren systems are often relied upon as the main alerting/warning system for rapid-onset emergencies. In one study of a town in tornado alley, for example, 75 % of participants rated sirens as their primary choice of alerting method (Stokoe 2016). Another study of public response to three different disasters (e.g., Mt St. Helens and two train derailments in Pennsylvania), while a bit older in age, showed that sirens were the least effective at broadcasting information, but once information was sought, proved

[4] Sectionalized systems allow officials to sound portions of the siren system rather than the whole system. Therefore, if a tornado is only in a certain area of a community, the official in charge can choose to activate only those sirens in the affected area.

to be the most effective at encouraging people to share that information with others via the milling process (Rogers and Sorensen 1991). A majority of people even go so far as to rely on sirens while they are indoors. In reality, sirens are designed to alert people outdoors, and often times cannot be heard inside. Despite this, studies have shown that respondents believed that sirens should be heard inside buildings and vehicles (Stokoe 2016; Kuligowski et al. 2014). Therefore, as long as sirens remain an important tool in the alerting "toolbox", it is important to understand how people receive, process, and respond to these types of alerts, in order to assess if improvements can be made to the system and/or its use to ensure safe and effective public response.

4.1 How People Receive, Process, and Respond to Emergency Alerts

Over the last 50 years, numerous empirical studies have sought to systematically chart the social processes involved in human responses to emergency incidents (Tierney, Lindell and Perry 2001; Mileti and Sorensen 1990; Drabek 1986). Of these, the Protective Action Decision Model (PADM) is selected here as a model to understand how people respond to external alerts and information (Lindell and Perry 2004; Kuligowski 2011). The PADM provides a framework that describes the information flow and decision-making that influences protective actions taken in response to natural and technological disasters (Lindell and Perry 2004).

Specific to external alerts and information, the PADM asserts that the process of decision making begins when people are first presented with alerting signals. The introduction of these signals initiates a series of processes that must occur in order for the individual to perform protective actions, split into pre-decisional processes (PRE-DEC, which determine whether a decision-making process commences), and decisional processes (DEC – the key components of the decision-making process itself). A simplified version of this process is presented below

- PRE-DEC_1: the individual must perceive or receive the cue(s); e.g., The siren must be heard.
- PRE-DEC_2: the individual must pay attention to the cue(s); i.e., given that it is possible for the siren to be heard, the occupant actually takes note of the sound.
- PRE-DEC_3: the individual must comprehend the cue(s) and the information that is being conveyed; i.e., given that the signal is noted, that the meaning is understood.
- DEC_1: the individual must feel that the incident suggested by the cues is a credible threat.
- DEC_2: the individual must personalize the threat (i.e., feel that the incident is a threat to them) and feel that protective action is required; i.e., something needs to be done.
- DEC_3: the individual searches for what this action might be and establishes options.
- DEC_4: the options identified are assessed (given the information available) and a final action selected.
- DEC_5: the individual determines whether the protective action needs to be performed immediately.

Initially, the individual needs to receive a cue, pay attention to it, and comprehend the meaning associated with the cue (e.g., an alerting signal or warning information). These represent the three pre-decisional stages of the PADM (PRE-DEC_1-3) – the stages that determine whether external information is processed such that it can inform the decision-making process (Lindell and Perry 2004). Given that this information is processed, it then needs to be assessed to determine whether the information provided is credible (DEC_1). At this stage, the individual decides if there is actually something occurring that may require action. If the individual's answer is yes, then he or she is said to believe the threat, and subsequently moves on to consider the next question in the process.

The individual next tries to determine whether the threat is relevant to him/her (DEC_2), known as personalizing the threat (or risk). Research has shown that a person's perception of personal risk, or "the individual's expectation of personal exposure to death, injury, or property damage" is highly correlated with taking protective action (Lindell and Perry 2004:51). In this stage, also known as personalizing risk (Mileti and Sorensen 1990), the individual determines the likelihood of personal consequences that could result from the threat and asks the following: "Do I need to take protective action?" Essentially, at this point, which is also discussed in human factors research as "situation awareness" (Groner 2009), the individual tries to gain insight on the potential outcomes of the disaster and what those potential outcomes mean to his or her safety. The more certain, severe, and immediate the risk is perceived to be, the more likely the individual is to perform protective actions (Perry, Lindell and Greene 1981). If the cues are deemed to relate to them, the individual then determines whether it is relevant and pressing. This then requires the individual to determine the nature of the response required at that point in time.

At this stage, the individual engages in a decision-making process to identify 1) what can be done to achieve protection, and 2) the best available method for achieving protection. This consists of a search for protective actions, and the outcome of this stage is a set of possible protective actions from which to choose. After establishing at least one protective action option, an individual engages in protective action assessment. This involves assessment of the potential option(s), evaluating the option(s) in comparison with taking no action and continuing with normal activities, and then selecting the best method of protective action.

4.2 Potential Limitations with Siren Systems

Research has shown that there are certain limitations associated with outdoor siren systems that can inhibit the various stages of the PADM, leading to a delayed or incomplete response to the impending emergency. These limitations are organized by the steps in the PADM and discussed in the following sections.

4.2.1 Perception and Attention (Pre-Decisional Steps 1 and 2 of the PADM)

First, since the sirens provide an audible tone to community populations, and the first two steps in the PADM include receiving and paying attention to the alert (PRE-DEC_1, PRE-DEC_2), siren systems (alone) are unable to reach all people located within their alerting purview. In essence, certain members of a population become more vulnerable than others because they are unable to receive the alerting signal from the siren system (Stokoe 2016; Paul, Stimers and Caldas 2014; Donner, Rodriguez and Diaz 2012). For example, siren alerts are unable to reach the hearing impaired (Laidlaw 2001; Mogil and Groper 1977), older adults (Ashley 2007; Donner, Rodriguez, & Diaz 2012), people located in areas without siren systems (Laidlaw 2001), and people located indoors (Laidlaw 2001). During the 2011 Joplin, MO tornado, 16 % of interviewees did not hear the siren alerts or did not receive any other alert or warning information that a tornado was imminent, and thus, were unaware of the approaching tornado (Kuligowski et al. 2014).

And, while the siren system may exacerbate the vulnerabilities of some groups, it may help to lessen the vulnerabilities in others. One example is non-English speakers. This group relies heavily on siren systems to make them aware of emergency situations (Stokoe 2016; Donner, Rodriguez and Diaz 2012). They may also rely heavily on siren systems for warning purposes as well (i.e., for an understanding of what is going on and what they should do about it), since even though warning goes beyond the scope and capabilities of many types of siren systems, non-English speakers may not always understand warning messages presented in English (Bruck and Thomas 2008).

4.2.2 Comprehension (Pre-Decisional Step 3 of the PADM)

Second, aspects of siren systems may inhibit comprehension (or understanding of the meaning) of the siren alert (PRE-DEC_3). Often, no information is provided along with the siren tone (Comstock and Mallonee 2005; Reese 2005; Benthorn and Frantzich 1999; Rogers and Sorensen 1991) and the lack of information can make it difficult for the public to truly understand what the alert means, and what they should do in response to it. Additionally, as was shown in Section 3 above, siren policies, including the meaning of the siren tone, can vary from community to community (Kuligowski et al. 2014; Laidlaw 2001), making it even more difficult for transient populations to comprehend the alert that is sounding at any given time/place. For example, in Calhoun County, Alabama, approximately 45 % of residents had some understanding of the siren tones, while only 20 % of non-residents reported that same level of understanding (Plotnick, Hiltz, and Burns 2012). Non-residents or new residents may be unaware of the differences among siren policies, and thus may not understand the meaning of a siren signal in locations outside of their home town.

While the absence of standards is more difficult on non-residents, locals still exhibit a lack of comprehension when faced with a siren alert. In Joplin, Missouri, during the May 22nd, 2011 tornado, residents reported being confused by the three-min duration of the siren signal and the multiple siren activations. Some thought the second alert was an indication that a more severe event was taking place, while others believed it to be an all clear signal, i.e., signaling that the tornado emergency was over (Kuligowski et al. 2014). In a study of Hawaii communities, residents demonstrated even more confusion over a tsunami alerting siren. Less than five percent of residents understood the true meaning of the siren alert. The other ninety-five percent of the study population identified various meanings for the siren alert, including to evacuate, wait for information, or make preparations. Because of this confusion, in a real tsunami event (in 1960), many residents delayed seeking higher ground because they thought that the siren signified for them to wait for more information before taking action (Lachman, Tatsuoka, and Bonk 1961).

4.2.3 Credibility of the System (Decisional Step 1 of the PADM)

Third, there are some aspects of outdoor siren systems that inhibit the ability for a population to trust in the system and perceive that there is a credible threat to which they must respond (DEC_1). Research shows that there are particular subpopulations within a community that tend to distrust the siren system more than others. These subpopulations can include men, older adults (over 60), and people with previous disaster experience (Stokoe 2016; Paul, Stimers and Caldas 2014).

Additionally, overwarning, either due to over-testing or false alarms, can also lead to a distrust in the credibility of the siren system (Kuligowski et al. 2014; Dixon, Wickens and McCarley 2007); however, not all research supports evidence of this “cry-wolf syndrome” (Barnes 2006; Baker 1991). While tests of the siren system can be used as opportunities to familiarize the community with the sound of the siren, and the meaning that it conveys, overuse of these tests can inhibit the perceived credibility of the system. For example, building-wide alarm tests have been shown to decrease the perceived credibility of the fire alarm (Proulx 2001).

Similar to the issue with over-testing, when people are exposed to a larger number of false alarms, the time it takes for them to respond will increase (Dixon, Wickens, and McCarley 2007). This is most likely a result of the fact that high false alarm rates can also cause the public to doubt the credibility of the alert (Proulx 2001). False alarms can be a product of siren activation criteria that is set too low, which leads to over-warning of the population (Ebner 2013). For example, the NIST Technical Investigation of the 2011 Joplin, MO tornado found that the public perceived false alarms [to be] common in Joplin and this perception was reported by residents as one of the main factors that caused them to disregard the siren alerts (Kuligowski et al. 2014). This disregard for alerts is also known as complacency or desensitization, a case where people stop paying attention to the alerts because of their frequency, often without the occurrence of an actual emergency (Laidlaw 2001).

A lack of credibility can also arise from instances where the multitude of alerting and information sources, including but not limited to siren systems, disseminate conflicting messages about the same emergency incident. The 2011 Joplin, MO tornado emergency was a prime example of an instance where the siren system, NWS warnings, and television and radio broadcasts presented inconsistent information before the tornado hit (Kuligowski et al. 2014). At 5:11 PM, the sirens disseminated a 3-min signal for a storm that was to the north of Joplin, MO, two minutes after the NWS issued a warning for the same storm. At 5:17 PM, a second NWS warning was issued for the storm that eventually hit the city of Joplin; however, the siren system was not sounded again (until 5:38 PM when the tornado entered the city limits), likely because Joplin's emergency manager had already sounded the sirens six minutes earlier (for the northeastern Joplin storm that did not materialize). Also, at 5:17 PM, broadcast media continued to discuss the storm was to the north of Joplin. It wasn't until 5:38 PM to 5:40 PM, four minutes after tornado touchdown, when multiple alerting and information sources provided consistent information on the tornado that hit the city.

Research has also shown that, compared with other information sources and channels, sirens are often reported as less trustworthy. This is particularly the case when compared with television and radio (Stokoe 2016). However, it should be noted that the research does not show strong support for the public's use and perceived credibility of NOAA weather radio technology either. While many studies and officials recommend improving NOAA weather radio as a supplementary alerting method to outdoor siren systems (Laidlaw 2001), a recent study of the Oklahoma City metropolitan area shows public use of NOAA weather radios as low as 2 % (Comstock and Mallonee 2005). Other research has shown that while a majority of people own a weather radio, only 17 % view this as the best alerting/warning method (Plotnick, Hiltz and Burns 2012). In agreement with these findings, Stokoe (2016) reported that only slightly more than 20 % of a study population in Ford County, Kansas relied on their NOAA weather radio for disaster information. Overall, this shows that while sirens are not perfect, they are one of many alerting and warning technologies available to provide emergency communications to the public, some of which may warrant improvements as well (Rogers and Sorensen 1991).

4.2.4 Personalization Risk (Decisional Step 2 of the PADM)

Finally, siren systems have shown difficulty in facilitating the perception or personalization of risk (DEC_2), the last step in the PADM process before protection actions are considered. In the NIST Technical Investigation of the 2011 Joplin, MO tornado, it was found that over half the interviewees did not perceive personal risk after hearing the sirens (which were sounded twice before the tornado hit). Many residents explained that they did not take the outdoor sirens seriously, and thus did not take protective action until the tornado was upon them (Kuligowski et al. 2014). Overall, the main factor that convinced individuals to take shelter in the 2011 Joplin, MO tornado was the receipt of high-intensity cues, including hearing or seeing the tornado approaching or witnessing others' urgency related to taking protection. In turn, the siren system, itself, including attributes of the tone or siren signal does not currently help to increase perceived urgency of the public in the event of an emergency.

Research has identified limitations with current outdoor siren systems and the ways that these limitations inhibit the receipt, processing, and response of the public to these types of alerts. Overall, the potential limitations associated with siren systems and public response are the following: a lack of awareness (both due to receipt and attention paid to the alert), a lack of comprehension (or understanding), a lack of perceived credibility of the siren alert, and a lack of perceived or personalized risk from the event. These issues can inhibit the public from a safe and effective response to the impending disaster. Additionally, these issues can also affect other emergency responses as well. For instance, a news article reported that the 9-1-1 dispatch center in Brown County, WI, received 20 to 25 non-emergency calls on a Sunday morning (June 26, 2016), in response to outdoor siren system activations. Ideally, residents should have already known the meaning of the sirens, as well as appropriate places to look for more information. Instead, callers were asking 9-1-1 operators why the sirens were being sounded and what they should do in response. These non-emergency calls to 9-1-1 restrict callers with actual emergencies from obtaining the help they need from emergency responders (Fox11 News 2016).

When the public does not receive, pay attention to, or understand the alert, or trust the reliability of the system and neglect to perceive risk, their responses will likely be delayed or incomplete (Kuligowski et al. 2014). Delayed or incomplete responses can lead to injuries and deaths. In contrast, improvements to outdoor siren systems and policies can be seen as a way to increase awareness, decrease confusion, increase credibility and subsequently enhance human response to outdoor siren alerts. This idea will serve as the foundation for the following section on potential improvements to siren systems.

5. Research Questions on Potential Improvements to Siren Systems

A set of eleven research questions were developed by the authors to lead the performance of a review on the ways in which siren systems can be improved to better facilitate effective and safe decision-making and response of the public in emergencies. These research questions were constructed based on findings, gaps, and limitations identified from the review of the status of current siren systems, including a review of siren technology, siren usage among U.S. communities, and the review of siren systems and the public, including how people receive, process, and respond to emergency alerts and the potential limitations with siren systems. The list of research questions is presented below, as well as summarized in Table 6, and are organized based upon their relevance to certain steps in the PADM.

Perception and Attention: The siren system (alone) can inhibit the receipt and attention paid to the tone (or alerting signal), especially for vulnerable populations (e.g., hearing impaired, older adults, those located outside the coverage of the siren systems and those located indoors).

Therefore, the following two questions were developed to survey the research in an attempt to identify new methods to reach a wider audience:

- RQ1: *How can we better alert vulnerable populations?*
- RQ2: *What temporal characteristics, volumes, and frequencies penetrate car windows, increase the distance alerts can be heard, increase discriminability and reduce startle response?*

Comprehension: The siren system (alone) can inhibit the comprehension or understanding of the siren alert, especially in situations where the following conditions exist: a) little or no information is provided with the tone, b) inconsistencies exist among community siren policies (e.g., inconsistencies in alerting times, alerting tones, emergency types for which the siren sound, the use of all-clear alerts, etc.), and/or c) the public is not fully trained or educated on the siren system.

Therefore, the following six questions were developed to survey the research in an attempt to identify new methods to increase comprehension of siren alerts:

- RQ3: *What does the research say about accompanying alerts with information?*
- RQ4: *What are the pros/cons of standardizing siren procedures, e.g., a tone/alert?*
- RQ5: *What does the research say about alerting for different emergencies?*
- RQ6: *What is an appropriate time period for sounding the tone and why?*
- RQ7: *How can/should we provide closure after an event – i.e., letting people know that the emergency is over?*
- RQ8: *What methods exist to train/educate the public (before an event begins) about what the siren means – including testing?*

Credibility and Risk: The siren system (alone) can inhibit its perceived credibility and the ability of the public to personalize the risk, especially in locations where over-testing or overwarning occurs and in situations where inconsistent information is disseminated by multiple information sources or channels.

Therefore, the following three questions were developed to survey the research in an attempt to identify new methods to increase the credibility of siren alerts and the likelihood that individuals will personalize the risk:

- RQ9: *How can we test the siren tone? How often is too often for a population to hear a test siren before complacency occurs (due to overwarning)?*
- *RQ10: What does the research say about accompanying alerts with a <u>trusted</u> source of information?*
- *RQ11: What tones/frequencies/patterns of sound evoke a sense of urgency?*

Table 6: Research questions on potential improvements to siren systems

Reaching a Wider Audience (Perception and Attention)	
Question 1	*How can we better alert vulnerable populations?*
Question 2	*What temporal characteristics, volumes, and frequencies penetrate car windows, increase the distance alerts can be heard, increase discriminability and reduce startle response?*
Increasing Comprehension	
Question 3	*What does the research say about accompanying alerts with information?*
Question 4	*What are the pros/cons of standardizing siren procedures, e.g., a tone/alert?*
Question 5	*What does the research say about alerting for different emergencies?*
Question 6	*What is an appropriate time period for sounding the tone and why?*
Question 7	*How can/should we provide closure after an event – i.e., letting people know that the emergency is over?*
Question 8	*What methods exist to train/educate the public (before an event begins) about what the siren means – including testing?*
Increasing the Credibility and Ability to Personalize the Risk	
Question 9	*How can we test the siren tone? How often is too often for a population to hear a test siren before complacency occurs (due to overwarning)?*
Question 10	*What does the research say about accompanying alerts with a <u>trusted</u> source of information?*
Question 11	*What tones/frequencies/patterns of sound evoke a sense of urgency?*

6. Key Findings and Recommendations from the Literature on Improvements to Siren Systems

All key findings and recommendations identified from the 67 sources of the literature review were collected, organized and reviewed to discover what insights they provided on potential improvements to the current outdoor siren systems – both to the systems' technology and their usage. The goal is that evidence-based findings and recommendations to siren systems could be identified that would improve public decision-making and response to impending disasters. Findings and recommendations from the literature are provided in the three sections below. The first section will discuss findings and recommendations from the literature to improve the siren systems (and usage of these systems) such that alerts reach a wider audience. The second section will discuss findings and recommendations for improvements to siren systems (and usage) that could increase comprehension of the alert. Finally, the third section will discuss findings and recommendations for improvements to siren systems (and usage) that could increase the perceived credibility of the siren system, as well as aid individuals in personalizing the risk associated with the impending disaster.

6.1 Reaching a Wider Audience (Perception and Attention)

As mentioned earlier, certain members of a population become more vulnerable than others when responding to a disaster because they are unable to receive the alerting signal from the siren system (Stokoe 2016; Paul, Stimers and Caldas 2014; Donner, Rodriguez and Diaz 2012). For example, siren alerts are unable to reach the hearing impaired (Laidlaw 2001; Mogil and Groper 1977), older adults (Donner, Rodriguez and Diaz 2012; Ashley 2007), people located in areas without siren systems (Laidlaw 2001), and people located indoors (Laidlaw 2001).

Research shows that vulnerable populations are less vulnerable with a robust social network (Bruck and Thomas 2008; Laidlaw 2001). Therefore, emergency managers could establish or link into a pre-established social networks that would allow for dissemination of alerts via means other than the siren system. One way to do this is to engage with minority populations via their community leaders (Donner, Rodriguez and Diaz 2012).

Additionally, research provides examples of other means to disseminate alerts to vulnerable subpopulations within a community (Stokoe 2016; Mogil and Groper 1977). For example, NOAA weather radios, cell phone apps, and other technologies may be able to vibrate and/or disseminate a flashing light in lieu of an audible siren alert. Research identifies the need for these types of systems for both the hearing impaired and older adult populations (Mayhorn 2005). The more intrusive these alerts are, the better, especially for populations that are asleep, and the more that populations can remove themselves from environmental distractions, the more effective these alerts can be (Mayhorn 2005).

Research, as well as national and international standards, also identify revisions that can be made to the siren tone, itself, to reach a wider audience (Mahn 2013; National Standards Authority of Ireland 2008; International Organization for Standardization 1996). First, research shows that frequencies anywhere within the range of 500 Hz and 2 500 Hz are acceptable, but the recommended specific frequencies to reach as wide an audience as possible are 500 Hz and 1 500 Hz. Additionally, if the signal is being designed to reach those with hearing loss, frequencies below 1 500 Hz must be included at sufficient energy levels (National Standards Authority of Ireland 2008). Also important for distinctiveness is that signals should stand out from other sounds/signals in the environment (Mahn 2013; National Standards Authority of Ireland 2008; Edworthy 1998).

Finally, research has been conducted to identify frequency components of the tone that would allow for transmission through windows. This could allow for individuals inside vehicles, or even inside homes or other structures, to receive the audible siren alert. Research shows that lower frequency components should be included for better coverage, including components between 225 Hz and 355 Hz for transmission through windows (Mahn 2013).

It should be noted that many of the steady/wail tones used in current siren technology include the recommended specific frequencies at (or around) 500 Hz to 1 500 Hz, as well as sufficient energy below 1 500 Hz[5]. However, these tones rarely include frequency components to allow for transmission through windows, as it is not the purpose of current siren systems to alert individuals indoors or inside vehicles.

6.2 Increasing Comprehension

Research suggests multiple methods to increase comprehension, or the understanding of the meaning behind the tone. These methods include developing common standards and practices, providing information to accompany the tone, and educating and training the public on the siren system policy. Research findings and recommendations on these three methods are provided in the following section.

6.2.1 Develop Common Standards and Practices

One method suggested by the research for increasing comprehension is to develop common standards and practices for the usage of siren systems, which could help to minimize confusion for the public (Brotzge and Donner 2015). These common standards and practices could exist at the multi-jurisdictional level, county, state, regional, or even national level. Specific mention was made of standardizing the tone type across multiple communities, which could reduce confusion and increase overall comprehension (of the event and what protective action is required) (Edworthy 1998). Attempts have been made at standardizing tones/signals in other industries, including hospitals (Milligan, Allan and Cuthill 2012) and buildings, in the case of alerting building occupants of fire events (American National Standard 2008; Proulx 2001; Proulx et al. 2001).

Specific mention was also made of standardizing the number of tones used within a siren system, across multiple communities. Since communities currently use either a single-tonal or multi-tonal system, literature was sought to provide evidence for the benefits (or downsides) of either system. Evidence in support of a single-tonal system discussed the fact that a majority of people cannot tell tones apart from one another (Lindell and Perry 1987). While research has shown that the likelihood of confusion increases among a community's visitors or new residents (Plotnick, Hiltz, and Burns 2012), even trained professionals, in this case trained nurses and doctors, struggle to decipher the meaning of alerts within multi-tonal systems (Milligan, Allan and Cuthill 2012). On the other hand, research shows that, while difficult, it is not impossible to achieve public comprehension with a multi-tonal system. This is particularly the case with time-intensive, but less restrictive, learning or training techniques (Edworthy and Hards 1999).

Regardless, response time (i.e., the time it takes people to respond to an alert) can increase under both single- and multi-tonal scenarios. For single-tonal systems, response time can increase due to the need to search for additional information – required when a single tone is used for multiple types of emergencies. Additionally, response time has been shown to increase with the use of multi-tonal systems, since people

[5] Basic signal analysis was performed on seven wail and steady tones (from electronical-mechanical and electronic sirens from two manufacturers) to understand the frequency components included in siren tones currently available on the market.

do not always remember what each tone means, and thus, they are required to take time and seek additional information (Donner, Rodriguez and Diaz 2012). This became clear when the state of Hawaii changed their siren procedures in 1967 from a multi-tonal to a single-tonal system. Prior to the switch, studies concluded that only 5 % of the public understood the meaning of the siren tones (Lachman, Tatsuoka, and Bonk 1961); whereas after, the percentage increased to only 13 % (Gregg et al. 2007).

These findings conclude that outdoor siren systems, alone, are unable to increase comprehension of the public. Therefore, we look to research that provides other methods of increasing comprehension.

6.2.2 Provide Information to Accompany the Tone

The use of siren tones as the only alerting system is inadequate in achieving comprehension, especially for communities where multiple hazards are possible (Gregg et al. 2007; Benthorn and Frantzich 1999; Lachman, Tatsuoka, and Bonk 1961). Examples from other industries that have struggled with similar challenges are the Homeland Security Advisory System that used five color codes to resemble various levels of threat to the United States (Reese 2005; Aguirre 2004) and the use of the T-3 fire alarm signal within buildings to alert occupants of a fire event (Proulx et al. 2001). In both cases, the use of the color code or the signal, alone, did not provide sufficient "information" for people to understand what was going on and what they needed to do about it.

To complicate the issue further, people require information from multiple sources of information in order to confirm the presence of a credible threat before they can respond (Lindell and Perry 1987; Rogers 1985). This has been a well-known and verified finding in the disaster literature for some time (Rogers and Sorensen 1991). Warning information should come from a variety of sources or channels and should be consistent across all sources to ensure both comprehension, as well as credibility (to be discussed in the following section) (Woody and Ellison 2014; Paul, Stimers, and Caldas 2014; Wood et al. 2012; Plotnick, Hiltz and Burns 2012; Chandler 2010; Mayhorn 2005). Often times, informal channels are used for confirmation as well, including contacting members of a social network to ensure that the information they have is consistent with what others have heard (Rogers 1985).

Especially since sirens often already signify that people should seek more information (Rogers and Sorensen 1991), research recommends that emergency managers and other alerting officials accompany siren tones with specific, consistent information (both within and outside of the affected community) (Kuligowski and Omori 2014; Woody and Ellison 2014; Dobbs and Fung 2009; Roger 1985). This information, often referred to as warning information, should be provided by credible, familiar, and authoritative sources (Chandler 2010; Dobbs and Fung 2009; Baker 1991). These credible sources may differ from community to community, but are likely to include the community's local officials (Roger 1985). Additionally, research provides insight on the content of warning messages (Kuligowski and Omori 2014; Chandler 2010; Proulx 2001; Keating 1982), including the five most important topics to include:

- What: Guidance on what people should do
- When: An idea of when they need to act
- Where: Description of the location of the risk of hazard (<u>who</u> should be taking action and who should not be)
- Why: Information on the hazard and danger
- Who: The name of the source of the warning (who is giving it)

More information on the creation and dissemination of warning messages can be found in Kuligowski and Omori (2014).

In addition to providing information, research also recommends ways in which information should be disseminated, including the use of push technology (Woody and Ellison 2014; Chandler 2010; Rogers and Sorensen 1991). Push technologies are those that do not require individuals to take extra effort to receive the alert or warning message (e.g., public address announcements via siren systems [Paul, Stimers and Caldas 2014; Plotnick, Hiltz and Burns 2012], NOAA weather radios, or text messages [Kuligowski and Omori 2014; Woody and Ellison 2014]), whereas pull technologies require the individual to seek additional information to acquire the alert/message (e.g., internet websites or apps that require additional searching). Also important is to reach as wide of an audience as possible with warning information, including non-English speakers who would benefit from messages translated into their first or native language (Stokoe 2016; Woody and Ellison 2014; Donner, Rodriguez and Diaz 2012; Bruck and Thomas 2008).

Overall, information that is consistent and credible, provided via push technology, can increase comprehension of the siren system alert during an emergency situation. Once new systems are in place, including a standardized tone or tonal system, with the provision of alerts, the community will need to educate and/or train the public on these changes. The literature also provided insight into increasing comprehension via education and training methods.

6.2.3 Educate and Train the Public on New Policies

One of the research questions, Question 8, specifically focuses on methods that exist to train and/or educate the public about siren usage and meaning. Since many communities across the U.S. are already heavily engaged in community-wide education and training activities, and the focus of this project is eventual standardization across communities, the research collected and reviewed here will focus on education and training methods at a broader scale, e.g., state, regional, or national scales.

The first method identified in the literature is that education should be “pushed out” to the public in such a way that avoidance is nearly impossible. For example, local radio and television advertisements (Gregg et al. 2003) or public address announcements (Brotzge and Donner 2015) could run simultaneously alongside monthly tests of the siren system. Or, advertising campaigns on sirens and protective actions, similar to one as successful as the “Truth” campaign to reduce smoking behavior in adolescents, could be disseminated at a broader scale (Farrelly et al. 2002; Proulx et al. 2001). Additionally, a “Tornado day”, or equivalent, could be established in the United States, where drills consisting of receiving a siren alert (and warning information), following by taking shelter could be practiced, similar to the nationwide Earthquake “shakeout” drills (Johnson 2013; Wood and Glik 2012; Green and Petal 2010). Practices, even at a smaller scale, that can be tested out are more likely to be adopted in the future (Arndt and LaDue 2013). Success is also measured as people networking and conversing about their experiences during the drill, which could encourage future participation from others (Wood and Glik 2012). Research suggests that both parents and students should play a role in practice exercises (Wood and Glik 2012; Green and Petal 2010), and the benefits of involving schools and businesses in these types of drills (Wood and Glik 2012).

The second method involves educating students in kindergarten through high school (12th grade) on disasters, including siren systems and their usage policies in the U.S. (FEMA 2016; International Federation of Red Cross and Red Crescent Societies 2011; Vitek and Berta 1982). The research indicates the importance of surveying U.S. classrooms on whether their lesson plans currently include hazard education (Mitchell 2009); however, two surveys already performed in the state of Washington (Johnson

2013) and ten states in the southeast U.S. (Mitchell 2009) suggest that hazards are likely under-represented in social studies throughout the nation.

If it is the case that there is low participation in hazard education among schools in the U.S., research suggests that disaster education can and should be embedded in current school curricula (International Federation of Red Cross and Red Crescent Societies 2011). For example, Geography classes can be used to teach students about both human and physical hazards that exist within the locality, in addition to alerting/warning systems and their policies (Mitchell 2009). Additionally, homework can be given that promotes student and parent interaction, so that parents are also educated on the hazards that exist within their community (Gregg et al. 2003). Finally, schools should encourage preparedness among both families of the students as well as the school staff (Wood and Glik 2012).

Another education method discussed by the research is the development of adult education related to hazards and alerting/warning procedures. While many programs already exist, including spotting training courses and CERT classes (Vitek and Berta 1982), research here suggests that there are evidence-based techniques that could be applied to adult education courses and programs to improve participation and increase successful outcomes (Arndt and LaDue 2013; International Federation of Red Cross and Red Crescent Societies 2011). Examples of evidence-based educational techniques include the following non-traditional teaching styles (Arndt and LaDue 2013):

- Present case studies that are applicable to attendees' lives. These case studies help to facilitate problem solving and independent learning (i.e., adults act as collaborators in the learning process) and allow participants to see where they lack knowledge, increasing their readiness to learn.
- Initiate the "need to know" concept, in that the topics covered in class must be clearly application to real life situations to become of interest. This technique helps the participant adopt the stance that he/she can anticipate the development of hazardous weather scenarios and thus, more proactively intervene in them (becoming more than an observer).
- Recognize that there are different motivations for engaging in the educational program. One is internal, i.e., the desire to improve, and another is external, i.e., there must be some benefit in return for participation. Participants with internal motivation may achieve better results.
- Success stories should be presented; assisting participants to recognize that others who completed the course or program achieved successful outcomes as a result.
- Consider certifying the course or program as professional education. That way, career motivated individuals could benefit from this program by achieving other career success, e.g., promotions.

Research has provided new methods in the ways to improve comprehension of the siren systems and its usage among the public. These methods focus on educational courses and procedures that exist at levels broader than the individual community. That way, as siren procedures and the use of information becomes standardizes across communities, so should our educational efforts.

Now that research has been presented on the three pre-decisional steps of the PADM, our attention turns now to two decisional steps, credibility and personalization of risk. The next section discusses the recommendations from research on ways to increase the credibility of siren systems and the ability for individuals to personalize the risk.

6.3 Increasing the Credibility and Ability to Personalize the Risk

While the literature presents a good case for the lack of credibility of current siren systems, it provides little in the way of guidance or recommendations for ways to improve. The only discussion on increasing credibility of the siren system was provided when referencing the benefits of developing common standards and practices for siren systems (Stokoe 2016). Common practices could include activation procedures as well as standardized procedures for testing, which could assist in reducing warning and/or testing fatigue. Decreases in "false alarms" or frequent audible testing could reduce complacency in the current system and re-establish the perceived credibility of the siren's alerting system.

A significant amount of research; however, has been conducted on the ways to increase the perceived urgency of the siren system – with particular focus on the siren's tone. A significant study was performed in New Zealand with the intent to recommend an ideal siren tone design of the country's use (Mahn 2013). Also, an ISO standard exists for the development of signals that are more distinctive and representative of the urgency of the situation (International Organization for Standardization 1996).

Overall, signals that are perceived as more urgent in nature, or are able to increase the personalization of risk, have certain characteristics or frequencies components, according to the literature. First, multiple sources agree that alerts with higher frequency components are perceived as more urgent, which increases perception of risk (Mahn 2013; Patterson and Mayfield 1990). Additionally, alerts meant to represent an urgent or dangerous situation should include pulsating signals (or bursts), with higher speed or repetition, rather than a constant, steady tone (Mahn 2013; Giang and Burns 2012; International Organization for Standardization 1996; Haas and Edworthy 1996). Other characteristics include tones that are alternating or sweeping over time (Mahn 2013) and/or include larger pitch ranges (rather than frequency components that are similar in pitch) (Edworthy, Loxley and Dennis 1991).

As with any changes that are suggested as revisions to the tone, it will be important to understand the limitations of current siren systems and their ability to incorporate custom-designed tones. This is especially the case with all current siren technology, since few of the available tones (on the market today), if any at all, incorporate all of the tone characteristics suggested by the literature to increase perception, attention, and personalization of risk. Also, as stated earlier, any time a change is made to current siren systems, the revisions will require testing with and education of the public (Selcon, Taylor and McKenna 1995).

7. Unanswered Questions

Despite a rigorous review of the literature, there were three research questions that yielded little in the way of recommendations on improvement to siren systems. These questions were RQ6, RQ7, and RQ9. Each question and any relevant information found is included below.

- RQ6: *What is an appropriate time period for sounding the tone and why? In other words, for how long should the siren signal sound and why?*

This question was asked to uncover any research evidence for a particular amount of time for which the siren should sound in an emergency. Almost no information was found connecting a particular siren tone duration to an increase in the public's comprehension of the tone. Additionally, no information was found connecting a particular siren tone duration to an increase in perception (i.e., receipt of the tone) and attention paid. One source suggested that tone duration could be related to the perceived validity of the alarm; however, the alarms tested were sounded for a duration of either one or four seconds (Bliss, Fallon and Nica 2007). That time duration is inconsistent with siren alerts, which sound for minutes.

The fact remains that the duration of a siren signal is likely an important influence in the overall decision-making and response process of the public, but little evidence exists to support any conclusions. This question was left in the review with the hope that it will be given considerable thought when designing future siren protocols (including time durations for test sirens), and to highlight the need for more research on the effects of siren tone duration.

- RQ7: *How can/should we provide closure after an event – i.e., letting people know that the emergency is over?*

This question was asked to uncover any research evidence on the appropriate way to provide closure after an event. In this context, closure means providing people with information that the emergency is over. Little information was found regarding closure. Some research, albeit with no data to back up the claim, warned against the use of an all-clear siren. However, no research addressed the problem directly. This question, while unanswered, remains important and further research is needed in order to address the issue of closure after an event.

- RQ9: *How can we test the siren tone? How often is too often for a population to hear a test siren before complacency occurs (due to overwarning)?*

This question was asked to uncover any research evidence on the appropriate protocols for testing the siren system. Testing is used to understand the current conditions of the system (to understand if it is still working as required), as well as provides an opportunity for education and training of the public. This question is especially important when overtesting is suspected to lead to complacency among community members. While some information was found regarding the benefits of testing as an educational method, little research provided insight into testing protocols and the ways to avoid complacency. However, the question remains important, and serves to highlight an area for future research.

8. Conclusion

This report presents the research that will eventually inform guidance for communities on the creation and provision of public alerts via outdoor siren systems. The report answers the following two main questions regarding outdoor siren systems:

1. What is the current status of outdoor siren systems in the U.S., including current technologies and siren usage?
2. How does the public respond to different alerting sounds and different types of auditory signals?

First, a review was conducted of current siren technologies and their capabilities in alerting and warning the public. A total of 53 different outdoor siren systems were reviewed from four siren manufacturers whose systems are available to communities within the United States. Since the purpose of this part of the project was to understand the capabilities of current systems and the ways in which they differ, work was performed to categorize currently available siren systems by the following: siren type, voice community capabilities, signal capabilities (including sound quality, range, and number and type of signals/sounds offered), direction of sound, continuity of sound, and testing options.

Next, a review was conducted of siren system usage in communities to alert people of impeding disasters across the U.S. This reviewed showed that diversity exists among outdoor siren system technology and usage of these systems, particularly among the types of emergencies for which sirens are sounded, as well as the various ways that siren usage can differ from community to community, including the types of tones used for alerting, the meaning of these tones, activation protocols, and testing protocols.

Finally, a literature review was conducted to address how people respond to auditory alerts. A total of 67 sources were collected and reviewed. Acknowledging that sirens will likely remain an important and useful tool in the alerting “toolbox”, the method by which people respond to alerting sounds or signals, known as the PADM, was presented. Based upon the PADM, research on the potential limitations associated with current outdoor siren systems and their use was presented. Research findings provided evidence for three main limitations: 1) The siren system (alone) can inhibit the receipt and attention paid to the tone, especially for vulnerable populations; 2) The siren system (alone) can inhibit the comprehension or understanding of the siren alert, especially in certain situations; and 3) The siren system (alone) can inhibit its perceived credibility and the ability to personalize the risk, especially in certain locations and/or situations.

Based on these limitations, key findings and recommendations identified from the 67 sources of the literature review were collected, organized and reviewed to discover what insight they provided on potential improvements to the current outdoor siren systems – both to the systems’ technology and their usage. Potential improvements to outdoor siren systems were presented that would allow the alerts to reach a wider audience (i.e., increase perception and attention); increase comprehension via common standards and procedures, the provision of additional information to accompany the alert, and improvements made to education and training techniques; and increase the credibility of the system and personalization of the risk. Research-based key findings and recommendations presented in this report will inform the later stages of this research project; i.e., the development of specific guidance for the standardization of outdoor siren system usage, technology and policies.

This report ends with a discussion of “unanswered questions” and an appendix (Appendix A) which contains annotations of all 67 sources collected and reviewed as part of this report.

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All other references cited throughout the report are included in Appendix A as annotations, including the formatted reference. The annotations are listed in alphabetical order in Appendix A.

Appendix A. Source Summaries

Appendix A contains annotations of all 67 sources collected and reviewed as part of this report. A general framework was used to develop an annotation for each literature source. Each annotation lists the following:

- The source reference,
- The discipline in which the source was found,
- The rating of the article,
- A summary of the contents,
- Key findings and recommendations provided by the source.

The source reference simply provides information on the author(s), date published, title of the article, source in which the article is published, and relevant publishing details (e.g., publisher, page numbers, etc.). The discipline is listed next. The disciplines from which literature was collected included acoustics, child development, communication, crisis management/disasters, education, ergonomics, fire, medicine, meteorology, psychology, and public health. Also listed is the rating of the article. Each source was given a rating based on the type of publication, and the year in which it was published (See Tables 1 and 2). This rating was one attempt to estimate the credibility and significance of each source, rating higher those sources that were more recent and/or were published in archival publications that require internal/external review and approval.

Table 7: Rating based on publication type

Rating	Type of Source
7	Peer Reviewed Journal Articles, Consensus Standards
6	Government Reports, Books
5	Conference Proceedings/Bulletins
4	Reports (companies/universities)
3	Masters/PhD Thesis
2	Journalism
1	Blogs

Rating	Years
A	2000 +
B	1980-1999
C	1960-1979
D	<1960

Table 8: Rating based on year published

Following the discipline and rating information, the summary text for the article is provided. Finally, underneath the summary text, the key findings and key recommendations from the source are listed. The key recommendations are also labeled with distinct identifiers – starting with the number of the source, the number of the recommendation, and the number of the research question that this source addresses e.g., [# of source_# of recommendation_# of question]. The recommendations are presented in this way to more easily use them to inform the development of specific guidance for the improvement of outdoor siren system technology, usage, and subsequent policies.

1. Aguirre, B. E. (2004). Homeland Security Warnings: Lessons learned and unlearned. *International Journal of Mass Emergencies and Disasters, 2*, 103-115.

Discipline: Crisis Management/Disasters
Rating: 7A

Summary: The author begins by outlining a successful warning system, using the U.S. hurricane warning system as an example. First off, the National Hurricane Center (NHC), which disseminates these warnings, is a reliable source of information, and people take them seriously. The NHC works with many other organizations in both the public and private sectors, and is involved in providing education programs to the public.

This system can be used as an example of good practices, against which to compare the Homeland Security Advisory System (HSAS). The HSAS has five color coded levels of threat. Red corresponds to severe, orange to high, yellow is elevated, blue corresponds to guarded, and green means low. Each level also represents protective actions that should be taken.

The author takes issue with the HSAS for several reasons. First, the color codes do not contain enough information for people to truly understand the risk, and there are no education programs to help people understand the exact meanings. Furthermore, the HSAS does not implement the same level of research that the National Hurricane Center does, specifically in the wording of the messages that they disseminate to the public. This results in less than satisfactory responses from the public. Additionally, HSAS alerts are not specific with regards to location, and HSAS has limited partnerships with the media, the emergency management community and political leadership (to disseminate information about the appropriate action to be taken). Overall, the author feels as though an early warning system cannot be used to disseminate terror threats. Instead, efforts should be made to prepare the public, so that if an attack were to occur, they would know how to respond.

Key findings:

- The author expresses that the HSAS fails in several ways, especially when compared to the NHC's warning system. There are no education programs for HSAS, little to no research is done to create the most effective warning messages, HSAS warnings do not notify a specific geographical area, and they do not partner with media, emergency management officials or political leaders.
- The color codes do not convey enough information to people for them to understand the risk and act accordingly.

Key recommendations

- [1_1_8] The public should be trained on how to react if a terrorist attack was to happen. This method would favor preparedness over having advanced warnings of attacks.

2. American National Standard ANSI ASA S3.41-1990. (R2008). *Audible Emergency Evacuation Signal.*

Discipline: Standards
Rating: 7A

Summary: An international standard for an audible signal that means "evacuate the building immediately" was published by the International Standards Organization (ISO) in December 1987 as ISO-8201. Such a signal, if understood universally, may reduce confusion and reduce the time for evacuation. The American National Standards Institute (ANSI) developed a standard signal that conforms to this ISO standard. Since no sound can reliably penetrate all of the conditions of background noise, the approach taken by the ANSI standard is to specify a recognizable temporal pattern for the 'on' and 'off' periods, assuming the existence of an audible alarm signal that can penetrate a particular background noise pattern in a given building. An advantage of this approach is that the standardized temporal pattern can also be applied to visual and tactile signals to aid those who have hearing impairments. Visual and tactile signals are also useful in cases in which the background noise is so intense that no signal is capable of reliable penetration.

According to the standard, this emergency evacuation signal shall "indicate imminent danger and signify unambiguously that evacuation from the building is immediately necessary." It is only for use in the zones to be evacuated immediately, and must never be used in zones with different prescribed emergency action, e.g., relocation to a safe place or defense in the current location. The standard specifies two parameters for the audible emergency evacuation signal: 1) the temporal pattern and 2) the required minimum sound pressure level at all places within the zone intended to receive the signal. The specific requirements are:

- A 'three-pulse' temporal pattern consisting of an 'on' phase sounding for 0.5 s ± 10 %, followed by an 'off' phase for 0.5 s ± 10 %, repeated for a total of three successive 'on' periods and followed by an 'off' phase for a duration of 1.5 s ± 10 %;
- Repetition of the signal for at least 180 s, or for the length of time appropriate to carry out the evacuation;
- Sound pressure during the 'on' phase that exceeds the highest level of the background noise averaged over 60 s and is at least 65 dBA;
- Visual and tactile signals to be provided if the averaged background noise exceeds 110 dBA;
- For arousing people from sleep, sound pressure of at least 75 dBA at the normal head position of the sleeping person, with all doors closed.

A key word or phrase (e.g., FIRE!) may be inserted during the 'off' phase between the three pulses. Examples of the application of the temporal pattern are included in the appendix of the ANSI standard.

Key findings/recommendations:

- [2_1_4] A standard temporal pattern for an audible emergency evacuation signal has been developed by ANSI, with the sole meaning of "evacuate the building immediately."
- [2_2_1] [2_2_2] The temporal pattern for the ANSI standard audible emergency evacuation signal can also be applied to visual and tactile signals to aid occupants with hearing impairments and occupants in zones with intense background noise.
- [2_3_4] The ANSI standard audible emergency evacuation signal consists of an 'on' phase for 0.5 s followed by an 'off' phase for 0.5 s, repeated for a total of three successive 'on' periods and followed by an 'off' phase for 1.5 s.

- [2_4_2] The ANSI standard audible emergency evacuation signal assumes the existence of an audible alarm signal that can penetrate a particular background noise pattern in a given building.
- [2_5_2] The sound pressure during the ‘on’ phase of the ANSI standard audible emergency evacuation signal must exceed the highest level of the background noise averaged over 60 s and be at least 65 dBA;
- [2_6_3] A key word or phrase (e.g., FIRE!) may be inserted during the ‘off’ phase between the three pulses of the ANSI standard audible emergency evacuation signal.

3. Arndt, D. S., & LaDue, D. S. (2013). Applying Concepts of Adult Education to Improve Weather and Climate Literacy. *Physical Geography, 29*(6), 487-499.

Discipline: Education
Rating: 7A

Summary: The focus of this paper is climate literacy for adults. Many other scholars and scientists have researched weather hazard education, but much of this body of research focuses on climate literacy for school aged children and their teachers. The authors of this article instead use two adult education frameworks to address the different learning needs for adults, and how those can be used to increase weather hazard knowledge among older populations.

The two education models used are the andragogy framework and the diffusion of innovation framework. The end goal of adult education programs designed around these models is to change the behavior and decision making of the affected public. One example of a program designed based on the andragogy and diffusion frameworks is the OK-First program, implemented by Oklahoma. The OK-First program consists of a data service to inform weather safety personnel, as well as an educational curriculum, which is the focus of this paper. OK-First aims to increase the climate literacy of public safety officers, such as police, fire fighters and emergency managers. An initial orientation course, followed by a recertification course every 18 months makes up the bulk of this education program. The program focuses on familiarizing participants with weather terms and providing them with basic information about climate and weather forecasting.

The author follows the explanation of the OK-First program with a discussion on andragogy. Andragogy is a framework used to understand adult learning, and consists of six assumptions, all of which are reflected in the OK-First program. First, adults “need to know” why they are being educated. If the education topic does not seem relevant to their life, then they will not see any need to seek it out. For the OK-First program, relevance was obvious. The participants experienced severe weather often, and were usually those in charge of making safety decisions on such occasions. Additionally, the program highlights the fact that it will teach people better ways to deal with weather hazards, thus increasing its worth. Any education program aimed towards adults must convince them that they can be more prepared or equipped for a weather scenario after they take the course.

Similar to the previous assumption is the assumption that adults must be “ready to learn”. In the OK-First program, case studies are reenacted by participants in order for them to see the places where they lack knowledge. This instills in them a readiness to learn. Additionally, adults generally respond better to concept-based learning than for problem solving learning. The OK-First program has evolved over time, and it has learned the benefits of having the meteorologist instructors focus less on the technical weather details, and more on the management and preparation for such disasters. In an effort to implement such a learning environment, case studies are used more frequently and are introduced earlier in the curriculum.

Adults also see themselves as more independent, and thus tend to dislike overly structured learning settings. OK- First does require that adult students participate in a structured learning environment to begin with, but it also incorporates case studies that can be studied individually, and with a more independent learning style. Another key aspect of adult learning, is taking advantage of the experiences that adults bring to a learning setting. For instance, memory is enhanced when new concepts can be connected to old, ingrained ideas and memories. Often this is done through metaphor and analogy. In OK-First, velocity information from Doppler radar is compared with the changing sound waves of a siren coming closer and then fading away as an ambulance races past.

Motivation is the last key assumption of the andragogy model. Adults can be motivated externally or internally. For example, seeking out education to obtain an employment promotion is external, and wanting to be a better professional is internal. OK-First gives credit hours to participants, which can be applied towards continuing professional education requirements in a way to entice externally motivated individuals. However, internally motivated professionals are more likely to seek out the program and see it as useful towards their goals.

The diffusion of innovation education model adds five additional layers to adult education. These aspects are designed to encourage people to change their behavior, and include relative advantage, compatibility, complexity, trial ability and observability. OK-First demonstrates relative advantage because it helps safety officials better perform their jobs. It should be noted that for long term, preventative behaviors, people do not always see the relative advantage, and thus are very slow to adopt such behaviors. Compatibility with the current system in place is necessary, and some emergency managers need extra support from OK-First to implement change, especially if they are not as integrated into the local government. Less complex innovations are also easier for people to adopt. Any education program must spend extra time on more complex topics. Trial ability is the feasibility of testing a new system before implementing it entirely. This is offered by OK-First through case studies and simulations. Observability is increased when the public can see or perceive the effects of a recent change. More visible changes with obvious positive outcomes are reinforced by the public. OK-First educates participants on all of the successful implementations of their emergency management procedures so that they can visualize the benefits. Success stories are also published online for the public to see.

The andragogy and diffusion of innovation models both contributed to the success of the OK-First program, which in 2001 won the “Innovations in American Government” award, and now serves approximately 450 public safety officials.

Key findings:

- Need to know: the relevance of an education program or topic needs to be established, otherwise adults may not be interested in it.
- Readiness to learn: a program must show what adults do not know and how education can fill these knowledge gaps.
- Orientation to learning: adults are more receptive to problem solving-based learning, rather than concept-based learning. Again, the topics learned must be clearly applicable to their real life situations.
- The learner’s Self-Concept: Adults view themselves as independent and self-driven, making structured, traditional classroom styles less effective.
- The role of experience: an adult’s experience can be used to reinforce new topics and enhance memory and retention.
- Motivation: motivation must be capitalized on by education programs. It can be internal (a desire to be better) or external (aiming to impress someone else, and get some sort of benefit in return).
- Relative advantage: advantageous practices will be adopted faster.
- Compatibility: new concepts and practices will be adopted faster if they can be integrated into existing systems.
- Complexity: less complex innovations will be adopted faster.
- Trial ability: practices that can be tested out are more likely to be adopted.
- Observability: Practices with visible benefits by the user and by the public are more likely to be positively reinforced and adopted as protocol.

Key recommendations:

- [3_1_8] Weather hazard education programs should highlight how their program will make participants more equipped to respond to common, local threats.
- [3_2_8] Case studies should be presented early in the curriculum so that participants can see where they lack knowledge. This will increase their readiness to learn.
- [3_3_8] Case studies can also be used to facilitate problem solving learning, rather than concept-based learning.
- [3_4_8] Case studies are also useful for independent learning, as opposed to a more structured lecture style education.
- [3_5_8] Analogies and metaphors can be used to connect new concepts to older, ingrained memories. For instance, difficult concepts like the distortion of waves used by Doppler radar can be related to the changing sound of an ambulance siren as it comes close, and then passes by.
- [3_6_8] An education program can become certified as professional education, so that career motivated individuals can use the hours to obtain benefits in their career, e.g., a promotion.
- [3_7_8] The advantage of new practices must be highlighted in order to facilitate behavioral change.
- [3_8_8] New practices should be developed in such a way that they are compatible with older systems, otherwise behavioral change will be slower.
- [3_9_8] Complex topics should be simplified or more time needs to be spent explaining them.
- [3_10_8] Simulations and case studies can be used to increase trial ability.
- [3_11_8] Success stories should be published, and also included in the curriculum.

4. Ashley, W. S. (2007). Spatial and Temporal Analysis of Tornado Fatalities in the United States: 1800-2005. *Weather and Forecasting, 22*, 1214-1228.

Discipline: Crisis management/Disasters
Rating: 7A

Summary: When tornado data are being collected and synthesized into a report, injuries, property damage, and deaths are often lumped into one category. Other times, only specific localities or even a specific tornado is the focus. In this report, the author attempts to spatially map all fatal tornadoes, and separate out where the fatalities occurred with regards to city or county, as well as the type of structure in which they occurred. Three different data sets are used; one from a long term study by Grazulis, another from the National Climatic Data Center's "Storm Data", and a third from the Storm Events Database. The geographical location of fatal tornadoes, the location of deaths, and structures in which death occurred were mapped onto a grid. Additionally, the data sets were analyzed to determine which populations were more vulnerable.

It was found that, from 1880 to 2005, F4 and F5 tornadoes accounted for 55.3 % of fatalities. The region with the highest concentration of killer tornadoes and fatalities was the southeast and south central portions of the U.S. This includes Oklahoma, northeast Texas, Tennessee, the Mississippi Valley and Georgia. This contrasts sharply with the tornado alley which has a higher number of violent tornadoes, but a lower number of fatalities. This can partially be explained by the lower population density in the tornado alley, but not entirely. The spatial analysis also revealed that the south and southeast have tornadoes during the "off season", when days are shorter and tornadoes are more likely to happen at night. This increases fatalities because at night, tornadoes are harder to spot, people are sleeping and do not receive warnings, and people who live in manufactured homes are less likely to be in a safe building, such as an office building.

Further explanations for the high fatality rate in the south comes from demographic and structural data from 1985 to 2005. The spatial analysis of these data showed that, country wide, tornado deaths inside manufactured homes increased from 37 % (1986-1990) to 57 % (2001-2005). The use of manufactured homes has been increasing, particularly in the south where they represent more than 20 % of the homes. The prevalence of vulnerable housing, nocturnal tornadoes, and the lack of a tornado season could all be contributing to the high number of fatalities occurring in the south and southeast.

The three datasets were also used to determine vulnerable demographics. It was found that middle aged and elderly people are more vulnerable to tornadoes and that vulnerability decreases with decreasing age.

Key findings:

- The south and southeast experience a greater number of fatal tornadoes and a greater number of tornado fatalities than tornado alley regardless of the fact that tornado alley experiences more severe tornadoes.
- Increased fatalities in the south could be due to the lack of a tornado season, resulting in decreased awareness, and more nocturnal tornadoes. Higher population density also contributes to the increased number of fatalities.
- Additionally, the number of manufactured homes is increasing in the U.S., as are the percentage of manufactured home fatalities due to tornadoes. Manufactured homes are especially prevalent in the south and southeast, which could be another explanation for the high fatality rate.
- Middle aged adults and the elderly are both vulnerable groups to tornadoes.

5. Baker EJ. (1991, August). Hurricane Evacuation Behavior. *International Journal of Mass Emergencies and Disasters*, *9*(2), 287-310.

Discipline: Crisis management/Disasters
Rating: 7B

Summary: Public response to hurricane warnings has been studied through sample surveys of U.S. coastal residents involved in twelve hurricanes between 1961 and 1989. People tend to stay in their residential area during a storm when they feel safe and to leave when they feel unsafe, so it is important to determine the factors that influence the perception of safety. Evacuation notices from public officials are effective in several ways: they convince people that they are in danger, they represent a voice of authority, and some (15 % to 25 %) believe that there will be a penalty for noncompliance. Informal networks of friends and acquaintances may reinforce safety messages and help to convince people to leave, or may pressure people to stay. The survey database has been analyzed to determine the effects of the physical hazard, warning notices, hurricane experience, hurricane awareness, length of local residence, past evacuation behavior, and demographics. Evacuation rates from high-risk areas are usually high (an average of 83 % in seven hurricanes). In moderate-risk areas, evacuation rates are usually between 55 % and 65 %, which may indicate a need for warning messages to target these areas specifically. People evacuating from low-risk areas (20 % to 40 % from locations near the coast), known as the “shadow” evacuation, contribute to traffic congestion and increase the time to evacuate those in danger. Messages for these people to stay in their homes are problematic because they carry legal risk. Residents of manufactured homes are more likely to evacuate, as are residents who believe their own house is in danger of flooding or wind damage.

Warning messages from public officials are the strongest factor in evacuation, with the possible exception of risk area. Official evacuation notices are most effective when they are specific about the area affected (convincing people the message applies to them), are delivered in a personalized way (including door-to-door), describe the specific actions to be taken (what to do and where to go), and are worded aggressively and delivered in an urgent manner. Dissemination by the news media is not sufficient. Door-to-door communication by authority figures resulted in 97 % evacuation rates from beaches in two hurricanes. People hearing official evacuation notices are more than twice as likely to leave (the difference in evacuation rate between those who heard and those who did not was 84 % to 20 % in one hurricane and 88 % to 8 % in another). The first or primary source of information about the storm, knowledge about hurricanes and hurricane safety, and demographics are not strong predictors of response.

In hurricane evacuations, past exposure to hurricanes, including false experiences and unnecessary evacuations (the “cry wolf” effect), is generally not a determining factor in whether individuals choose to evacuate or not. People that have evacuated before are more likely to evacuate again. In 1980, the city of Galveston evacuated even before the National Weather Service had issued a warning. Even though the city was not in the eventual path of the hurricane, 80 % of people that evacuated said that they would do the same thing in the future under similar conditions and 10 % said that they would leave even sooner. After hurricane Diana, only 5 % of evacuees said they would not do so in the future. Fewer than 5 % of the people that did not evacuate cited previous unnecessary evacuations as the reason that they did not evacuate. In 1985, Panama City and Panama City Beach were evacuated three times, with approximately the same percentage (78 %) evacuating from the beach area each time. While the mainland area saw a slight decline in the percentage of evacuees over the three evacuations, the differences were not statistically significant.

Key findings:

- Official evacuation notices are most effective when they are specific about the area affected, are delivered in a personalized way, describe the specific actions to be taken, and are worded aggressively and delivered in an urgent manner.
- Door-to-door communication by authority figures resulted in 97 % evacuation rates from beaches in two hurricanes.
- People hearing official evacuation notices are more than twice as likely to leave.
- The "cry wolf" syndrome, in which unnecessary evacuations result in unwillingness to leave during the next event, is not supported by the evidence.

Key recommendations:

- [5_1_4] Because "cry wolf" syndrome is not supported by the evidence from real natural disasters, evacuation notices should be given as early as possible.

6. Barnes LR. (2006, July). *Public perceptions of flash flood false alarms: A Denver, Colorado case study* (Undergraduate Paper). Colorado Springs, Colorado: Natural Hazards Center, University of Colorado at Colorado Springs.http://colorado.edu/hazards/awards/paper-competition/Barnes2006.pdf

Discipline: Crisis management/Disasters
Rating: 2A

Summary: The goal of this case study was to examine the effect of false alarms on public response to natural hazard warnings, in order to improve the effectiveness of public warning systems. Predictions of the intensity and location of natural disasters such as blizzards, hurricanes, and floods are not always accurate, and evacuations and other protective actions taken in response to a warning may be carried out in vain. Although the conventional wisdom is that such false alarms reduce people's willingness to respond to the next such event (the "cry-wolf" effect), research indicates that this may not be the case if the event and the reason for the warning are understood. In fact, false alarms may provide a learning opportunity for both the public and emergency personnel. Previous research indicates that women have higher levels of risk perception (a strong predictor of evacuation compliance), are better prepared, and are more likely to believe warning messages. Although older people have been found to be less likely to receive warnings and more likely to be injured or die in a disaster, the research is inconclusive on whether they are less likely to take protective actions. This study surveyed residents of an area that floods periodically to examine their attitudes toward false alarms and the effects of demographics on these attitudes.

Surveys were mailed between September 2004 and January 2005 to 2800 Denver residents that lived in flood plains. The response rate was 16.5 %. Percentages of respondents in different demographic groups that agreed with two statements related to false alarms are shown in Table 7. Overall a large majority (78 %) said that they would prefer having more warnings even if some of them turned out to not be accurate. Statistically significant relationships were found with gender (more females than males agreed) and with age (agreement increased with age). A large majority (77 %) also said that one or two false alarms would not reduce their confidence in future alarms, with more women than men agreeing and a significant increase in agreement with age.

Table 9: Percentage agreeing with survey questions related to false alarms.

Survey Question	**Gender (% Agree)**		**Age (% Agree)**			
	Male	**Female**	**18-35**	**36-55**	**56-75**	**75+**
Prefer more warnings even if it means more false alarms or close calls	73	83	67	81	80	93
One or two false alarms or close calls would [not] reduce confidence in future warnings	73	81	68	80	76	90

Emergency planners should not be reluctant to issue warnings given the general preference of the public for more warnings and the acceptance of the possibility of false alarms. Planners should also take into account the differences in attitude between men and women and between old and young. Women and elderly individuals tend to be more vulnerable in a disaster, which may be a factor in why they also tend to prefer more warnings and take them more seriously.

Key findings:

- Women and older residents living in a flood plain were found to be more likely than men and younger residents to prefer more warnings and accept the possibility of false alarms.

- The “cry wolf” effect is not supported by evidence. Overall, 78 % of residents living in a flood plain would prefer more warnings even if some of them turned out to not be accurate. A large majority (77 %) agreed that one or two false alarms would not reduce their confidence in future alarms.

Key recommendations:

- [6_1_4] Emergency planners should not be reluctant to issue warnings given the general preference of the public for more warnings and the acceptance of the possibility of false alarms.

7. Benthorn L, Frantzich H. (1999). Fire alarm in a public building: How do people evaluate information and choose an evacuation exit? *Fire and Materials 23*(6), 311-315.

Discipline: Fire
Rating: 7B

The first part of this study investigated the dependence of the choice of exit on distance and on whether the exit is open to the outside or closed. Emergency messages were transmitted over wireless headphones to 35 women and 29 men, ranging in age from 16 to 75, in an Ikea warehouse. An initial alarm ring signal sounded for 10 s, followed by a silent pause for 10 s and a 45 s prerecorded message to leave the building due to a “technical failure”. The spoken message was repeated twice, and did not specify leaving by any particular exit. Since trials were not simultaneous, and since other customers not participating in the study were present, no social interaction effects were included. The ring signal was perceived as an unspecified alarm by 41 % of subjects, as a fire alarm by 19 %, and as indicating the need to evacuate by 6 %. The authors speculated that the low percentage that thought of the ring signal as a fire alarm may be due to the low sound level in the headphone and the use of headphones rather than the building PA system. Most subjects understood the voice alarm to mean a serious problem (44 %) or evacuation (38 %). However, five subjects did not understand the voice alarm message or did not interpret it as indicating a problem. In the absence of information about which exit to take, subjects were more likely to choose a familiar exit (by the cash registers). Exits that were open were more likely to be used than those that were closed. In an emergency, staff may direct customers by opening emergency exits to the outside.

Key findings:

- Not all people may understand the meaning of an alarm bell; a spoken message is important.
- Spoken messages will not directly help those who do not understand the message.

8. Bjork, E. A. (1999). Startle, Annoyance and Psychophysiological Responses to Repeated Sound Bursts. *Acta Acustica United with Acustica, 85*(4), 575-578.

Discipline: Acoustics/Audiology
Rating: 7B

Sounds can be annoying and startling, but little is known on exactly what makes them this way. This study aims to assess how startle ratings and annoyance ratings interact. Additionally, heart rate (HR), skin conductance (SC), and electromyography (EMG) were measured, and their relationship with annoyance and startle ratings were investigated. SC is the phenomenon where skin momentarily becomes a better conductor when a physiologically arousing stimuli occurs. EMG records the activity of muscle tissue, which can be indicative of a startle response.

Participants of this study were 24 males and 24 females between the ages of 18 and 54. Three different stimuli were created, one with a 4 000 Hz octave band noise, one with a 500 Hz octave band noise, and one white noise stimulus. Each stimulus was played with either a sudden rise time and gradual (1 s) fall time, or a gradual rise time and sudden fall time. There was a five second plateau in between rise and fall that was played at 80 dBA.

SC was measured at participants' fingertips, HR was measured using an electroencephalogram (or EEG, which measures electrical activity in the brain), and EMG was measured at the *m. frontalis*. Ratings for startle, annoyance, fright, and conspicuousness were measured using a scale from 0 (least) and 9 (most). Participants rated the sound for all four criteria at the beginning, and again at the end of each sound block.

The rating results showed that sounds with sudden rise times were more startling and more frightening. Additionally, the 4 000 Hz sound was rated the most annoying, startling, frightening, and conspicuous. The 500 Hz and white noise sound both had lower ratings in all four categories. Over the course of a sound stimuli, startle, fright, and conspicuousness ratings went down, and annoyance ratings rose.

For the sound blocks with a sudden rise, HR was shown to have a greater increase 1 s to 9 s post stimuli. An increasing number of bursts, when present in an "startling" (by rating) sound, was also related to increased HR. SC was higher for sudden rise times, and had a positive relationship with startle ratings in the 3 s to 20 s post stimuli range. Within the 11 s to 20 s post stimuli range, SC also had a positive relationship with annoyance ratings.

Overall, rise time was found to be related to the startle reaction. However, as the sound block progressed, startle reaction decreased and annoyance increased. Furthermore, it was determined that the startle capacity of a noise does not also determine the annoyance capacity. HR and SC are most likely related to the startle response, while EMG was more closely related to rise time and annoyance ratings.

Key findings:

- Sudden rise times were related to the startle response.
- Startle response diminished over the course of a sound block and annoyance increased.
- What makes a noise startling, does not necessarily also make it annoying.
- Heart rate and skin conductance increased for sound blocks with sudden rise times, and are most likely related to the startle response.
- Electromyography more closely indicated annoyance, but was also related to rise time.

9. Blanford, J. I., Bernhardt, J., Savelyev, A., Wong-Parodi, G., Carleton, A. M., Titley, D. W., & MacEachren, A. M. (2014). Tweeting and Torandoes. *11th International ISCRAM Conference* , (pp. 319-323). University Park.

Discipline: Crisis Management/Disasters
Rating: 5A

Social media is becoming increasingly important in disaster information dissemination. This particular study focused on the use of Twitter during the EF-5 tornado that hit Moore, Oklahoma on May 20, 2013. Geolocation was used to find tweets that were posted near the tornado, from the dates May 19, 2013 through May 21, 2013. This strategy yielded a total of 86 100 tweets that were then analyzed to find those with relevant content. This was done by searching for certain key words, including “tornado”, “storm”, “weather”, “shelter”, “pray”, “emergency”, and “donate/donations”.

It was found that tweets posted the day before the tornado and during the tornado contained a higher proportion of keywords like “tornado” and “storm”, whereas the day after, the most common keywords were “pray”, “donate” and “devastation”.

The authors then focused on the tweets from May 20, 2013, the day of the tornado. Before the tornado hit, the keywords present were mainly “storm”, “tornado” and “watches/warnings”. During the tornado words like “sirens”, and “shelters” were more common, and after the tornado some important keywords were “destruction”, and “damage”.

Additionally, a total of 2 583 re-tweets stemmed from 36 official tweets issued by the National Weather Service (NWS). Some of these 36 messages requested that Twitter users retweet the message. Of all the NWS tweets, those that contained such a request were the most retweeted messages. This suggests that official tweets requesting retweets could be beneficial for disseminating warnings and information. Furthermore, the tweets analyzed provided a wide variety of information including personal observations of the tornado, giving shelter locations, posting safety tips, and communicating with friends and family.

Further research should be conducted to understand the best message phrasing to use, how to motivate retweets, and to better understand how twitter performs in different types of disasters.

Key findings:

- The content of tweets changed over the course of the 2013 Moore, OK tornado. Pre-tornado tweets had a higher volume of keywords like “tornado”, “watches/warnings”, and “storm”. During the tornado, warnings encouraging people to take cover in shelters as well as tweets with the word “siren” were more prevalent. Post-tornado tweets focused more on the destruction and need for donations and help.
- The 36 tweets issued by the NWS were retweeted a total of 2 583 times.
- A request to retweet weather information by the NWS prompted more people to retweet those messages.
- Twitter is an effective way to communicate emergency warnings and messages.

Key recommendations:

- [9_1_3] More research should be conducted in order to produce the most effective message to post on Twitter.
- [9_2_3] Message content should be researched with the goal of promoting the most retweeting as possible.

- [9_3_3] An analysis of tweets should be done for other disasters to gain a more holistic understanding of how twitter works in different situations.

10. Bliss, J. P., Fallon, C. K., & Nica, N. (2007). The Role of Alarm Signal Duration as a Cue for Alarm Validity. *Applied Ergonomics, 38*, 191-199.

Discipline: Psychology/Cognition
Rating: 7A

When people hear an alarm they will either decide to ignore it, or listen to it, depending on how valid they perceive that alarm to be. Various aspects of alarm signals can be manipulated to increase the perceived validity of an alarm, and one of these aspects is duration. Duration of an alarm is the time from the onset of the stimulus to the offset of the stimulus, and can vary for many reasons; verbal alarms need to be long enough to convey a message, medical alarms stay on until the problem is rectified, and smoke alarms stay on as long as they are detecting smoke. This study aimed to examine the relationship between alarm duration, and human response to alarms with various true alarm rates. The study consisted of two experiments.

For the first experiment, 13 males and 32 females were recruited as participants. They were randomly assigned to an alarm that was either true 60 % of the time or true 80 % of the time. They were informed of the true alarm rate of the alarm to which they were assigned, in order to instill the correct amount of alarm mistrust. Participants were given a primary task that consisted of gauge monitoring and tracking sub-tasks on a computer. When the alarm sounded, they were instructed to click on a button that said “respond”, but only if they believed it was a true alarm. The respondents were then exposed to a total of 15 short duration alarms (1 s), and 15 long duration alarms (4 s), randomly spread throughout three, ten minute sessions. After the test, participants completed a survey that asked them about the alarm system, and why they chose to respond in the way that they did.

The dependent variable, alarm reaction, was determined by two measurements, reaction frequency and response time. The results showed that participants responded to short duration alarms more frequently and faster, in the second two sessions than in the first. However, for all three sessions, response frequency was higher for long duration than for short duration alarms. This trend was consistent across all true alarm rate categories. Additionally, the reaction times for the 80 % group with long alarms were faster than those for the 60 % group with long alarms. Overall, reactions were faster for long duration alarms than for short duration alarms. The data from the surveys showed that participants believed that true alarm rate was the main factor that influenced their decision to react. Participants also believed that long signal duration (4 s) was a better match, and more accurately portrayed a valid signal.

The second experiment performed was meant to test how people respond to two different alarm signals, when one uses a short signal and the other uses a long signal. This would show whether alarm duration will affect perceived alarm validity across different systems. The participants of this study were 16 male and 23 female undergraduate students. As in the previous study, they were randomly assigned to 80 % and 60 % true alarm rate groups, but in this study they were informed that the short and long signals came from different alarm systems. Surveys were again administered after the testing. Participants performed the same computer task in experiment one, and were told to click on the respond button when they heard a sound, and believed it was a true alarm. Three ten-min sessions were completed.

It was found that participants responded at a significantly higher frequency for long duration signals. However, participants in the 80 % group responded to both signals at a significantly higher frequency than participants in the 60 % group. As in experiment one, participants believed that long duration signals were a better representation of true alarms. Additionally, participants’ decisions to respond were influenced more significantly by the true alarm rate, when the alarm was a long duration alarm. Although some participants did rely on alarm duration to indicate false or true alarms, many participants employed other decision making strategies. Some relied on the true alarm rate, some used a combination of true alarm rate and signal duration, others responded to all alarms, and some participants had no particular decision making pattern. The most likely reason that the results differ from experiment one, is that when participants knew that the durations represent two different systems, and that both systems exhibited a true alarm rate, they knew that one system could not consistently be true, while the other was consistently false. Further analysis revealed that those with significant computer knowledge were more likely to rely on the true alarm rate, and older participants were less likely to rely on signal duration to make a decision.

These findings show the importance of signal duration as an alarm characteristic that could make signals seem more valid. Signal duration is clearly just one of many factors, but this study shows that it does effect the response rate to alarms.

Key findings:

- When presented with short duration and long duration alarms from the same system, participants responded to long duration alarms at a higher frequency, regardless of the true alarm rate.
- When presented with short duration and long duration alarms from different systems, participants still responded to long duration alarms at a higher frequency, but the trend was not as strong.
- When presented with two alarm systems, participants used multiple strategies to decide whether to respond or not, including alarm duration, true alarm rate, or simply responding to every alarm.

Key recommendations:

- [10_1_6] The findings of this study should be used in alarm design, specifically by making important alarms sound for a longer duration of time. However, it must be noted that many other aspects are factored into a person's decision making process of whether to respond or not.

11. Brotzge, J., & Donner, W. (2015). General Policy for Activating Outdoor Warning Siren Systems for Severe Weather: Survey of emergency managers. *Natural Hazards Review, 16*(2).

    Brotzge, J. A., & Donner, W. R. (2015). The General Use of Outdoor Sirens: A preliminary survey of emergency managers. *Journal of Emergency Management, 18*(1), 61-69.

Discipline: Crisis Management/Disasters
Rating: 7A

Policies and practices for using outdoor warning sirens were studied by sending an online survey to all members of the International Association of Emergency Managers. Of the 593 respondents, 366 of them were eligible to complete the entire survey. The survey was designed to gain a better understanding of "the general uses of outdoor siren technology, the geographic variability of siren warning system deployment, and the diversity in siren warning policy and procedures". This survey consisted of 31 questions, not including several follow-up questions.

The study participants were from a wide variety of locations and jurisdictions. 30 states were represented, as were 25 large U.S. cities and three Canadian cites. About 35 % of respondents were from a county jurisdiction, 11 % were from a large city jurisdiction, just over one quarter were from a small city, approximately 16 % represented a town or village, and approximately 15 % were from a fire or law enforcement district. Other jurisdictions included universities, statewide offices, Native American tribal nations, coast guard facilities, U.S. laboratories, and a U.S. air force base.

When questioned about the uses of their siren systems, 51.8 % reported that they use the sirens exclusively to alert for tornadoes, 17.6 % also use them to alert for wind, and 20.2 % use them for tornadoes, wind, and hail. Many respondents listed that they also used them for events like flash flooding, lightning, hurricanes, rotating cloud walls, and derechos.

When asked about the criteria for sounding an alert, over half the respondents reported always sounding the siren for a National Weather Service (NWS) tornado warning. On the other hand, 28 % sometimes sounded the siren and 11.1 % never sounded the siren for a NWS warning. When the NWS issues a thunderstorm warning, 3.7 %, 25 % and 68.7 %, always, sometimes and never sound the siren, respectively. Also, 45.5 % admitted to sounding the siren before a NWS alert.

Of those that sounded the sirens for wind or hail, less than 10 % sounded them for a lower speed of wind than recommended by the NWS, but about a quarter of respondents sounded them for hail smaller than severe hail, as defined by the NWS.

Additionally, 27 % of the emergency managers reported that their jurisdiction participated in a regional siren plan. When discussing sectionalized systems, 65.4 % reported having the capability to sound only certain sections of their sirens. Also, 15.2 % reported having and using an all clear signal for tornado warnings; however, a large portion of those were universities, military bases or private companies. Around 60 % had multiple sound options, however many officials commented on the difficulty of using multiple tone options. Some commented that they were confusing or too difficult to educate people on. Of those who did use the multiple tones, they were most often used for thunderstorms, tornadoes, hazmat, civil defense, general weather emergencies, or calling the fire department. Other officials mentioned voice options and the ways in which they utilized them. Mainly voice options were used in outdoor areas that attracted large amounts of people in a small space, such as a park or baseball fields.

Testing protocols were also examined. The data showed that 4.5 % of the respondents tested their sirens daily, 16.2 % tested them weekly, 65 % tested the sirens monthly, and 10 % chose the "other" option.

Those who selected “other” provided various clarifications, including testing protocols that were based on semesters, no testing, and silent testing every week with a monthly, full volume test.

Only 14.5 % indicated that there was no attempt to educate or publicize information about siren policies and procedures. More than forty percent of respondents used more than four methods to educate the public. These methods included press releases, websites, weather awareness events, reports to city council, media interviews, notices in utility bills, and letters to schools.

Overall, there is clearly a wide variety of practices regarding outdoor siren activation. No geographic or regional trends were found. It is clear that almost nothing is standardized. The uses for sirens, types of sirens, the guidelines for making decisions, and the personnel making those decisions all vary.

Key findings:

- Around half of respondents use sirens only for tornado warnings, about 17 % use them for tornadoes and heavy wind and about 20 % use them for tornadoes, heavy wind and hail.
- Over half the respondents always sound the sirens when the NWS issues a tornado alert, 28 % sometimes sound them and 11.1 % never sound them.
- 45.5 % sometimes sound the sirens before a NWS alert is issued.
- 27 % of the jurisdictions participated in regional siren plans.
- 65.4 % had the capability to sound portions of their siren system, rather than all sirens within the entire system.
- Around 60 % had multiple signal options and used them for other weather emergencies, military attacks, and alerting fire personnel.
- 4.5 % tested the sirens daily, 16.2 % tested the sirens weekly, 65 % tested the sirens monthly and 10 % tested their sirens on some other schedule.
    - Of those that chose “other”, some tested the sirens on a semester schedule, others did not test the sirens, and several reported weekly silent tests with monthly, full volume tests.
- More than forty percent had more than four methods of education and/or publicizing efforts.

Key recommendations:

- [11_1_3] Alerting specificity could be improved through greater use of network subset capabilities.
- [11_2_8] Educational efforts should be expanded and diversified in order to minimize confusion for the general public.
- [11_3_4] Common standards and practices should be adopted in order to minimize confusion for the general public.

12. Bruck D, Thomas I. (2008). Comparison of the Effectiveness of Different Fire Notification Signals in Sleeping Older Adults. *Fire Technology, 44*(1), 15-38.

Discipline: Fire
Rating: 7A

The subjects in this study were 42 adults ages 65 to 85 years old. Four different auditory signals were tested to determine which was the most effective at waking the subjects. The first was a mixed frequency T-3 signal (500 Hz to 2 500 Hz) from a fire alarm audio demonstration CD. This signal included odd harmonics in addition to the fundamental tone at about 520 Hz. The second was a male voice (200 Hz to 2 500 Hz) that warned of danger from fire and instructed the person to get up and investigate. (A male voice was used rather than a female voice because pilot studies showed that a male voice was more effective at waking young adults). The third was a high pitched (3 000 Hz) T-3 signal recorded from an actual fire alarm. The fourth was a low pitched (500 Hz) T-3 signal, generated synthetically. The auditory arousal threshold (AAT), i.e., the minimum volume level that results in awakening, was measured for each subject over two nights. Two different signals were tested during a single night, and the other two signals were tested three to seven days later. To ensure that all subjects were familiar with the different signals, the signals were played for the subjects before they went to sleep. In the test, the signal started at 35 dBA for 30 s and then increased by five dBA every 30 s until the subject awakened. At the loudest volume level of 95 dBA, the sound was played continuously for 3.5 min or until awakening. At the 75 dBA level, 4.6 % slept through the mixed T-3 alarm, while 14 % to 18.3 % slept through the other alarms. At 95 dBA, the mixed T-3 alarm woke all subjects, while not all subjects were awakened by the other alarms. Ranked by response time, the mixed T-3 performed the best and high T-3 was the worst. No gender differences were found, but older individuals were more likely to sleep through higher pitch alarms. When compared with young adults (18 to 26 years old) studied previously, the AAT was significantly less for the mixed T-3 signal (57.9 dBA for young adults, 48.0 dBA for older adults), whereas no significant differences were found for arousal by the male voice. The authors noted that language barriers could be a problem for people responding to voice alarms, based on the failure of the voice alarm to awaken two subjects that did not speak English.

Key findings:

- Voice alarms with English text may be unsuitable for populations that include non-English speakers.

13. Burt, J. L., Bartolome, D. S., Burdette, D. W., & Comstock Jr, J. R. (2007). A Psychophysiological Evaluation of the Perceived Urgency of Auditory Warning Signals. *Ergonomics*, 2327-2340.

Discipline: Human Factors/Ergonomics
Rating: 7A

Auditory warnings have many benefits. In plane cockpits, they can alert a pilot regardless of the direction s/he is looking. These types of warnings are also commonly used in hospitals and industrial settings, where the increasing use of technology necessitates more monitoring. However, auditory warnings also have disadvantages. They can be startling, distracting, too loud, and annoying. Additionally, many pilots complain that auditory warnings do not indicate priority levels. Previous studies have shown that priority levels could be assigned to auditory warnings by manipulating their perceived urgency.

This study aims to see if this perceived urgency is reflected in response time, and in physiological responses of the body to the signal. Additionally, tones with different perceived urgencies were tested in scenarios with varying situational urgencies in order to see how these interact. Six students between the ages 20 and 30, three male and three female, participated in this study.

Three signals were created, one with high perceived urgency, one with moderate perceived urgency, and one with low perceived urgency. These tones were created based on previous studies relating frequency and harmonics to perceived urgency. The high urgency signal had a fundamental frequency of 146.8 Hz and random harmonics. The moderate urgency signal had a fundamental frequency of 523.3 Hz and 10 % irregular harmonics. The low urgency signal had a fundamental frequency of 523.3 Hz and regular harmonics.

The situational urgency was essentially a video game with either manual or automatic options. For manual tracking, participants had to keep a round target inside a square box using a joystick. If a participant failed, they had to immediately push a button on the joystick to restart. For automatic tracking, participants had to monitor the computer as it tracked the target, and if the computer failed, they had to immediately push the button. Different versions of the situation had different probabilities of failing; high (0.9), medium (0.5) and low (0.1). A higher probability of failure corresponded with a higher situational urgency. Urgency mapping was used to assign an auditory signal to a probability of failure. All different combinations of perceived urgency (auditory signal) and situation urgency (probability of failure) were tested. One combination was assigned to each participant. The response time for this action was measured.

In order to measure physiological responses, an electroencephalogram (EEG) was performed and the event related potential (ERP) of each participant was tracked. EEG measures the electrical activity of the brain and estimates arousal. This was measured continuously. ERP measures amplitude and represents the intensity with which the brain is responding. This was measured every 30 s, directly following an auditory signal.

However, before situational urgency, EEG, or ERP was introduced, the participants were asked to rank the signals from most to least urgent. They were also asked to rate them on a scale from not urgent (0) to very urgent (100). These tasks were then repeated after the situational urgency trial.

The ranking and rating results are as follows. Before the session began, participants were able to accurately rank and rate the three auditory signals. However, after the session, there were no significant differences in how participants ranked or rated the auditory signals. This suggests that they reassigned urgency to the signal based on the task they had been assigned.

Reaction time was found to be slower for manual tracking than for automatic tracking, although it is possible that this could be different if the task was performed for more than 15 min. There was no significant difference in reaction time for the three signals.

The EEG recorded increased alpha frequencies for low to moderate probabilities of failure. This suggests that participants became more relaxed as situational urgency decreased. There was no change in EEG measurements for the different auditory signals.

Attentional engagement was measured using EEG ratios and ERPs. Situational urgency produced significantly different responses for both EEG ratios and ERPs. Specifically, the lowest attentional engagement was during the moderate failure rate scenario and for the automated tracking. Perceived urgency (auditory signals) also had an effect on attentional engagement. Participants were most alert during automated tracking with high urgency signals and least alert during manual tracking with low urgency signals.

Overall, participants mostly reacted to situational urgency, but did have some reaction to perceived urgency caused by the auditory signals. It was noted that further studies should be done to test signals with a wider range of differences, as well as studies with more participants.

Key findings:

- Perceived urgency can be reassigned to signals based on experience, even if it does not match their inherent urgency.
- Perceived urgency had no effect on reaction time in the controlled, video game environment.
- Situational urgency affected how relaxed a person was based on their EEG measurements.
- Perceived urgency had no effect on how relaxed a person was.
- Participants were least engaged when situational urgency was moderate.
- Participants were least engaged when using manual tracking with low perceived urgency signals.
- Participants were most engaged when using automatic tracking with high perceived urgency signals.
- Situational urgency elicited the majority of physiological responses, however perceived urgency did have some affect.

Key recommendations:

- [13_1_11] Auditory warnings with a larger range of sound should be studied.
- [13_2_11] A study should be conducted comparing direct urgency mapping (i.e., matching the urgency of a signal to the urgency of the situation) reaction times with inverse urgency mapping (e.g., a high urgency signal mapped with a low urgency situation) reaction times.
- [13_3_11] Once more knowledge is collected, signals should be manipulated in a way to signify urgency.

14. Catchpole, K., & Mckeown, D. (2007). A Framework for the Design of Ambulance Sirens. *Ergonomics, 50*(8), 1287-1301.

Discipline: Human Factors/Ergonomics
Rating: 7A

Ambulance sirens are important for decreasing transit time for ambulances, and lessening the likelihood of a traffic accident. However, ambulance siren design is over 25 years old, and it is likely that there is room for improvement. Currently, there are three major alarms used for ambulances. The yelp alarm is a continuous warbling sound at 55 cycles per min, between (500 and 1 800) Hz. The wail alarm is a continuous rising and falling sound at 11 cycles per min, between (500 and 1 800) Hz. The hi-lo sound is a two-toned sound at 55 cycles per min, between (670 and 1 100) Hz.

Designing a new and more effective siren tone is different than designing alarms for airplane cockpits. In a cockpit, the background noise can be measured, as can the necessary distance that the sound needs to travel. For ambulance sirens, the distance traveled, topography, and ambient noise is constantly changing, which requires a much more comprehensive siren.

For this study, an ambulance was fitted with the normal siren system, and a new siren system that was designed to contain frequencies up to 11 000 Hz and a speed of 55 cycles per min. This new siren was placed inside the ambulance grill to improve localization, and attenuation of the sound in the ambulance cab and patient area.

The sound pressure was measured for both sirens at varying distances from the front, back, and drivers side of the ambulance. Then, the siren sound pressure was measured inside a second car at varying distances from the ambulance. Finally, the researcher attended all call-outs for the ambulance over a three-month period and recorded transit time. Mean transit times were calculated, as were proportional transit times to account for variations in trip distances. The localization potentials and attenuation within the ambulance were also tested, but this is less applicable to tornado sirens.

At one m and 30 m from the front of the ambulance the sound levels were 110 dBA and 83 dBA, respectively, for all three original, standard sirens. Inside a vehicle five meters away, the sound levels were 71 dBA for the standard yelp siren, 72 dBA for the standard wail siren, and 69 dBA for the newly designed, test siren. At ten meters away, inside a car, the sound levels decreased to 68 dBA, 69 dBA and 64 dBA for the yelp, wail and test siren, respectively. However, while the test siren had an overall lower intensity, it did have better high frequency penetration of the second vehicle and was more likely to be detected than the standard sirens, according to an effective detection model. Additionally, the predicted effective range on urban roads for the test siren was 30 m, which was double the predicted effective range for the standard sirens.

No statistically significant differences were found in the mean transit times of the ambulance for the standard versus test sirens. However, when the proportional transit times were calculated, there was a significant difference in times. Specifically, the test siren resulted in shorter transit times than the standard sirens. It is possible that the lack of difference in mean transit times is due to the varying degree with which drivers respond, as well as the fact that the standard sirens are easily recognized, while the test siren is new, and unknown.

Key findings:

- The test siren had lower overall sound intensity levels inside other vehicles than the standard sirens.

- The test siren had better penetration with higher frequencies inside other vehicles.
- When applied to a model for effective detection, the test siren was the most detectable.
- The predicted effective range for the test siren was 30 m, and only 15 m for the standard sirens.
- Only proportional transit times showed a statistically significant difference between the standard sirens and the test siren, with the test siren having shorter transit times.

Key recommendations:

- [14_1_2] The sound patterns of sirens should be modified to include a high frequency component, such as the 11 000 Hz component in the test siren.
- [14_2_2] However, any modification should still allow them to retain the familiar yelp, wail or hi-lo (two-toned) sound that people recognize.

15. Chandler RC. (2010). *Emergency Notification.* Santa Barbara, CA: Praeger. Crisis Management/ Disasters

Discipline: Human Factors/Ergonomics
Rating: 6A

The purpose of this book is to discuss the challenges and opportunities for communicating more effectively with the public during emergency situations The book begins with a review of legal requirements, industry standards and public expectations related to emergency communication, then describes the latest efforts by the Department of Homeland Security (DHS) to develop an effective, integrated, reliable, and comprehensive system to alert the American people, including efforts to alert and warn individuals via their personal mobile devices.

Chapter 2 presents the basics of emergency notification, beginning with an overview of public alert systems and communication channels that could provide more focused and specific warning information. The latter include telephones (e.g., through phone trees, reverse 911, hotlines, and call centers), digital signage, SMS and text messaging, pagers, email, instant messaging, web pages, and social networking services. A standardized alert message format known as the Common Alerting Protocol has been developed. The chapter concludes with a brief history of mass notification systems, including Emergency Broadcast Systems, Emergency Alert Systems, and call centers; as well as a discussion on specialized alert systems, including the Health Alert Network, J-ALERT System, action shooter warnings, AMBER alerts, and Silver alerts, and the benefits of automated notification.

Chapter 3 discusses the challenges associated with emergency communication, along with some techniques to overcome them. The challenges include potential breakdowns of the communication system and technologies, the compressed timescale and evolving information for rapidly occurring events, the difficulty in conveying accurate meaning, and collaboration issues. The first notification message is critical for effective emergency management. In crisis communications, all messages should be brief and precise. Communicators should assume that the public will process only the first 30 s (about 30 words) of a message; because of this, it is important to front load each message with the most relevant and critical information at the time. There are several barriers to effective communication with the public. People are continuously faced with multiple cues during an emergency and must decide which most deserve their attention. The varied backgrounds of individuals in the target audience affect the process by which they make sense of and respond to this information. Specific issues that need to be considered for effective emergency communication include native language reversion, selective attention and perception, impaired mental functioning during stress, and the importance of the source of the message. Multilingual or foreign language alerts may be necessary, because in crisis situations people have a tendency to revert back to thinking and understanding in their native language. Emergency communications must recognize that the amount of message information that people can process decreases in a state of stress. Individuals may selectively notice and remember certain things during an emergency, and they may also experience impaired mental functioning. Verbal comprehension has been found to drop an average of approximately four grade levels at high levels of stimulation, stress, and distraction; emergency notification messages should therefore be written for no more than a sixth grade reading level to ensure the widest possible range of comprehension among the target audience. Additionally, individuals in high stress situations are only able to process three distinctive issues or pieces of information in a single message unit. The source of the message is important because an audience is likely to pay more attention to those who are perceived as most trustworthy, honest and without motives to deceive them. The best sources are those to whom the public can relate, especially if personally known by the public. The five communication steps for success are: 1) execute a solid communication plan, 2) be the first source for information (especially since the first message carries more weight), 3) express empathy early, 4) show competence and expertise, and 5) remain honest and open.

Chapter 4 describes the process of planning for emergency communication and urges the creation of a document that can guide emergency communication in the future. The important stages of emergency planning are : 1) delegate responsibility and authority for emergency communication, 2) manage the information provided to effectively utilize emergency communication strategies, 3) manage the message and get accurate, well-crafted information out as quickly as possible (and even develop some phrases, sentences and vocabulary words that are appropriate and approved by management before a disaster occurs), 4) acknowledge the range of notification systems and technology, 5) understand the audience that will be receiving information, 6) build a contact database of a variety of different sources you will need to contact in an emergency, 7) develop an information policy including what information will be needed at what times and for which people, 8) understand the legal review and issues that may affect your organization, 9) plan the message, 10) plan ways in which to communicate with your organizations' employees, 11) anticipate common hazards and needs, 12) educate and train personnel on the plan, and 13) test and validate the emergency communication plan. Scientific concepts, probability analyses, and variables/information on how the warning was prepared are too complex to include in emergency messages. Two-way communication can be used to monitor public knowledge and beliefs, misunderstandings, behavioral compliance, and the progress of the response. This is an effective way to correct rumors and misinformation.

Chapter 5 describes the six phases of an emergency crisis: warning, risk assessment, response, management, resolution, and recovery, of which the first three phases are of central interest in this document.

Chapter 6 discusses using automated notification to address some of the challenges of contacting a large number of people in a small amount of time. The four basic types of automated notification systems are: on-premise model systems, hosted model systems, hybrid systems, and the Software-as-a-Service (SaaS) model systems. The benefits of these systems include: 1) individuals can choose/prioritize methods of receiving information; 2) individuals can receive messages that are accurate and consistent with other information; 3) the sender can track whether messages were delivered successfully; 4) many systems allow for two-way communications; 5) the systems are redundant in that messages can be sent to the receiver via multiple pathways; and 6) reliability can be built in by using multiple data centers to store contact information, leasing dedicated phone lines from multiple national carriers, and allowing messages to be initiated from multiple places. Chapter 7 deals with the development of the emergency messages themselves. The four main functions of an emergency message are to provide vital information about the hazard, communicate the implications of the event and its urgency or seriousness, instruct on what to do next, and explain how recipients can respond. Ways in which emergency message content can be improved include:

- Design a template to prepare warnings in advance of emergencies.
- Use a "danger-action" formula for messages – keywords and phrases describing dangers (e.g., 'active shooter' or 'hazardous materials [HAZMAT] warning') and actions (e.g., 'evacuation now' or 'take shelter now') can be vetted in advance of the emergency.
- Provide complex information and instructions using simple, brief and concrete language.
- Tell people how and where to get further information.
- Use the 3 & 30 principle, placing the most important elements of the message in the first three sentences and 30 words. The message may be an alert to get people's attention and direct them to a place with additional information.
- Use the 60 & 6 principle, writing the notification message at a sixth-grade or lower reading level and with a reading ease score of at least 60 on a scale of 100, to simplify the grammar, syntax, vocabulary, and reading level for people under stress.

- Risk communication research has found little evidence supporting trends in danger symbols, font choices, and other typographical features, including caps, bold, colors, exclamation marks, and spacing that significantly affect attention, perception, or behavioral response.
- An 'all clear' message is important to indicate that there is no longer a threat. This type of message can be longer and more complex than initial alerts.
- Be honest about the event – there is little evidence that honesty causes panic.
- Describe what you know and do not know and what you are doing about it.
- Reduce the number of negatively-dominated messages.
- Test and validate the effectiveness of messages.
- The final chapter describes a method for message mapping that enables emergency messages for all audiences to be drafted in advance of the crisis.

Key recommendations:

- [15_1_3] A variety of communication channels should be explored for providing specific warning information to specific audiences.
- [15_2_3] The first notification message is critical for effective emergency management.
- [15_3_3] All messages should be brief and precise.
- [15_4_3] People are continuously faced with multiple cues during an emergency and must decide which most deserve their attention.
- [15_5_3] Communicators should assume that the public will process (i.e., pay attention to) only the first 30 s (about three sentences or 30 words) of a message. Each message should be front-loaded with the most relevant and critical information at the time. (3 & 30 principle)
- [15_6_3] The varied backgrounds of individuals in the target audience affect the process by which they make sense of and respond to this information.
- [15_7_3] Multilingual or foreign language alerts may be necessary, because in crisis situations people have a tendency to revert back to thinking and understanding in their native language.
- [15_8_3] Verbal comprehension has been found to drop an average of approximately four grade levels at high levels of stimulation, stress, and distraction; emergency notification messages should therefore be written for no more than a 6th grade reading level.
- [15_9_3] Individuals in high stress situations are only able to process three distinctive issues or pieces of information in a single message unit.
- [15_10_3] An audience is likely to pay more attention to those who are perceived as most trustworthy, honest and without motives to deceive them. The best sources are those to whom the public can relate, especially if personally known by the public.
- [15_11_3] The five communication steps for success are: 1) execute a solid communication plan, 2) be the first source for information (especially since the first message carries more weight), 3) express empathy early, 4) show competence and expertise, and 5) remain honest and open.
- [15_12_3] Scientific concepts, probability analyses, and variables/information on how the warning was prepared are too complex to include in emergency messages.
- [15_13_3] Two-way communication can be used to monitor public knowledge and beliefs, misunderstandings, behavioral compliance, and the progress of the response. This is an effective way to correct rumors and misinformation.
- [15_14_3] Automated notification can be used to address some of the challenges of contacting a large number of people in a small amount of time.
- [15_15_3] The four main functions of an emergency message are to provide vital information about the hazard, communicate the implications of the event and its urgency or seriousness, instruct on what to do next, and explain how recipients can respond.

- [15_16_3] Use a “danger-action” formula for messages – keywords and phrases describing dangers (e.g., ‘active shooter’ or ‘HAZMAT warning’) and actions (e.g., ‘evacuation now’ or ‘take shelter now’) can be vetted in advance of the emergency.
- [15_17_3] Provide complex information and instructions using simple, brief and concrete language.
- [15_18_3] Tell people how and where to get further information, especially in the case of alert messages (or messages with a limited number of characters)
- [15_19_3] Risk communication research has found little evidence supporting trends in danger symbols, font choices, and other typographical features, including caps, bold, colors, exclamation marks, and spacing that significantly affect attention, perception, or behavioral response.
- [15_20_7] An ‘all clear’ message is important to indicate that there is no longer a threat. This type of message can be longer and more complex than initial alerts.
- [15_21_3] Be honest about the event – there is little evidence that honesty causes panic.
- [15_22_3] Describe what you know and do not know and what you are doing about it.
- [15_23_3] Reduce the number of negatively-dominated messages.
- [15_24_3] Test and validate the effectiveness of messages.

16. Chou, P. T.-M. (2010). Attention Drainage Effect: How background music effects concentration in Taiwanese college students. *Journal of the Scholarship of Teaching and Learning, 10*(1), 36-46.

Discipline: Music
Rating: 7A

Attention drainage effect is thought to happen when multiple stimuli are present, and one must divide their attention between them. This study aimed to assess how auditory stimuli, like music, distract students from school work. The capacity model of attention states that there is only so much distraction that can be present before one starts to fail at whatever main task they are trying to perform. However, it is not only distraction, but arousal that influences attention drainage. The study tested both classical music and hip hop as possible distractions, hypothesizing that hip hop would create a greater arousal, and thus command more attention.

133 Taiwanese, technical college students participated in the study. They were divided into a control group with no music, an experimental group with Mozart, and a second experimental group with hip hop. Each student was given three reading passages from the Test of English as a Foreign Language (TOEFL) manual, and assigned to read the passages and answer 30 reading comprehension questions. The TOEFL passages were screened and only selected if it is reasonable to assume that participants would be familiar with the themes of the passage. However, participants were not tested for English fluency.

The authors stated that, as the students read and responded to the passages, music was played at a noticeable volume; although no definition was given for “noticeable”. For the hip hop music, popular hip hop songs were played from 2006. These songs tended to have a faster tempo. For the classical music experimental group, a playlist of Mozart songs was played, all of which had a slower temp. For the control group, no music was played. Students were given 35 min to read the passages and answer the questions.

Scores were calculated based on the number of correct answers given by the students. The mean scores were calculated for each group with 67.69, 64.41 and 58.32 corresponding to the control group, Mozart group and hip hop group, respectively. No statistically significant differences were found between the hip hop and classical group scores or the classical group and control scores. However, statistically significant differences were found between the scores from the hip hop group and the control group.

The findings are in line with the capacity attention model, but do not support the findings of previous studies that found that classical music improved test scores.

Key findings:

- The students listening to hip hop music scored significantly lower than those listening to no music.
- The students listening to Mozart had slightly higher scores than those listening to hip hop, and slightly lower scores than those listening to no music. However, the differences were not statistically significant.

17. Comstock, R. D., & Mallonee, S. (2005). Comparing Reactions to Two Severe Tornadoes in One Oklahoma Community. *Disasters, 29*(3), 277-287.

Discipline: Public Health
Rating: 7A

Moore, Oklahoma was struck by an EF5 tornado during the tornado outbreak in May 1999. The city was struck again by an EF3 on May 8, 2003. This sequence of events offered a unique opportunity to understand how warning dissemination and protective actions in Moore, OK have changed and what factors influenced these changes. It is also possible to determine if people affected by both tornadoes changed their responses.

After the May 3, 1999 tornado, the Centers for Disease Control and Prevention (CDC) and Oklahoma State Department of Health (OSDH) conducted an investigation in the affected communities. This was primarily done through a questionnaire that was designed to collect information on the protective actions taken by residents, warning methods employed by the City and others, the property damage from the storm, and the injuries sustained among the public. A similar questionnaire was administered after the May 8, 2003 tornado; however, in order to obtain a more comprehensive understanding, several questions were added to the original questionnaire, e.g., inquiring about the warning time that residents received, how residents had responded differently, and if they received different warnings. Overall, 250 residents were surveyed in 1999 and 324 residents were surveyed in 2003. The mean ages of respondents were 48.7 and 51.4, for 1999 and 2003 respectively.

The results showed that there were two important differences between the two tornadoes that affected public response. First, the 1999 tornado occurred at 7:25 PM, while the 2003 tornado touched down at 5 PM. This time difference explains the results that showed significantly more residents at home when they received news of a possible tornado in 1999 compared to 2003. Secondly, the warning time for the first tornado was estimated as 30 min (by media reports), compared to the less than 10 min warning time reported by over 50 % of respondents in 2003. Despite this shorter warning time, 36.2 % of respondents from 2003 were located in a storm shelter by the time the tornado passed, which is a higher percentage than the 22.4 % that were located in a storm shelter by the same time period in 1999. However, there was no significant difference found between the percentages of people who were in a safe location when the tornadoes struck. Additionally, sirens and television were the most important sources of information for both tornadoes; however, television became significantly less important in 2003. Also, weather radios were used by only 2 % of respondents in both 1999 and 2003.

Of those who experienced both the 1999 and 2003 tornadoes, 21.9 % of the sample took less action to reach safety and 26.8 % took more action during the second tornado. Receiving better warnings, an increased warning time, and clear directions from the television or radio were the most common reasons that respondents reported for their improved responses. Conversely, having less warning time, having access to less warnings, not understanding the risks of an EF3 tornado compared with an EF5, and not having access to a place of safety were all reasons that respondents listed for taking less action.

Overall, respondents who were affected by the 1999 tornado most likely had more time to respond to the tornado, and more detailed instructions for that response. However, in 2003, a greater proportion of respondents sought refuge in storm shelters. The authors attributed this to a “community-level gain in knowledge”, following the 1999 tornado. There were several education programs implemented after 1999, but it is unclear whether some, or all, of this gain can be attributed to these programs.

Key findings:

- About 75 % of the Moore, OK residents were located in safe locations when the tornadoes struck in 1999 and 2003.
- A higher proportion of residents sought refuge in storm shelters in the 2003 tornado.
- Of those who experienced both the 1999 and 2003 storms and who took a lower level of protective action, many reported the reasons for their actions as follows: the warnings were inadequate (likely due to a shorter lead time) or there was no suitable shelter available.

Key recommendations:

- [17_1_8] Annual tornado preparedness education should be conducted for residents living in tornado prone areas, especially if they are new residents or are in hard to reach locations or populations. This could be done through the presentation of videos, photos and survivor stories.
- [17_2_3] Common alerting and warning systems should be improved, including television and tornado sirens.
- [17_3_3] Weather radios should be improved and consumer education should be provided on how to use them.
- [17_4] Access to storm shelters should be increased.

18. Dixon SR, Wickens CD, McCarley JS. (2007, August). On the Independence of Compliance and Reliance: Are automation false alarms worse than misses? *Human Factors: The Journal of the Human Factors and Ergonomics Society, 49*(4), 564–572.

    Dixon SR, Wickens CD, McCarley JS. (2006, March). *On the Independence of Compliance and Reliance: Are automation false alarms worse than misses?* (Technical Report AHFD-05-16/MAAD-05-04). Prepared for Micro Analysis and Design. Savoy, Illinois: Aviation Human Factors Division, Institute of Aviation, University of Illinois at Urbana-Champaign.

Discipline: Human Factors/Ergonomics
Rating: 7A/4A

An ideal alarm system is reliable. If an alarm on a piece of equipment tends to sound when there is no reason for the alert (i.e., false alarm-prone) or fails to sound when the alert condition exists (i.e., miss-prone), the operator will not be able to trust the system. It is difficult to make diagnostic aids perfectly reliable. A designer may choose to set the criteria for alarm with a liberal bias (tending toward false alarms) or a conservative bias (tending toward misses), or at a neutral point. The optimal setpoint may depend on the relative costs and benefits of correct or incorrect responses as well as on operator response.

It is theorized that operator behavior differs depending on whether there are more false alarms, expected to result in longer times to respond to the alarm (or no response at all – the “cry wolf” effect), or more missed alarms, expected to result in closer monitoring of the raw data behind the alarm, potentially disrupting concurrent or main tasks. Previous research indicates that these two behaviors (labeled as compliance and reliance, respectively) may not be independent, and that the task at hand may also be disrupted by false alarms. This study looked at the effects of an unreliable alarm system on operator performance.

Thirty-two undergraduate students at the University of Illinois participated in 100 trials (20 practice and 80 experimental) that lasted 30 s each. In each trial, participants had to carry out two simultaneous tasks. The first was to use a joystick to track a target, and the second was to press a button when a gauge exceeded a specified value, which changed trial-to-trial. For some participants, the gauge task was accompanied by an auditory alert. Participants were notified after each trial whether or not they had been successful. The four experimental conditions were: baseline (no audible alarm), alarm with perfect accuracy, 40 % false alarms, and 40 % misses. Participants were told in advance whether or not the alarm was reliable, and if not, in which direction the alarm failures would lie. Both the false alarm and missed alarm conditions resulted in significantly higher tracking errors than both no alarm and perfect alarm conditions, indicating that participants paid more attention to the gauges when systematic failures occurred, independently of the type of failure. The detection of an out-of-range gauge level and the response time were significantly worse for the false alarm condition than for the other conditions, supporting the hypothesis that compliance is an issue for false alarms only.

Key findings:

- With an unreliable alarm system (either false alarms or missed failures), operators are distracted from other tasks by monitoring the information that the alarm should be handling.
- An unreliable alarm system causes more task disruption than no alarm system at all.
- In a system prone to false alarms, the time to respond to the alarm is significantly longer, suggesting that the information is double-checked first.

19. Dobbs M, Fung A. (2009). *Enhancing occupant response through neuro linguistics* (Poster Paper). Umow Lai Pty. Ltd., Victoria, Australia. http://www.umowlai.com.au/pdf/publications/Fire/Enhancing%20Occupant%20Response%20Through%20Neuro%20Linguistics.pdf

Discipline: Human Factors/Ergonomics
Rating: 5A

Rapid building evacuation in an emergency depends on a good warning system. The design of this system needs to expedite the decision-making process in order to reduce delay time. The warning system needs to encourage evacuation, discourage delay, and counter the tendency to dismiss alarm cues. Factors that delay evacuation include the individual's role (such as a bystander or visitor), commitment to a task, affiliation (assembling to form a group), and avoidance (denying or minimizing the situation). Factors that encourage evacuation include responsibility, desire for safety, and physical evidence, such as smoke. Case studies of occupant behavior in actual fire scenarios, such as the 1987 King's Cross station fire and the 1985 Bradford City Stadium fire, suggest that the factors that delay evacuation often outweigh factors that encourage evacuation. In accounts of fires in multi-story buildings, groups of people tend to evacuate much more slowly than individuals, delaying until fire cues were apparent and authority was recognized. Because of differences in prior experience and other individual characteristics, individuals often respond differently to the same environmental cues. Understanding this may lead to more effective warning methods.

People can be categorized into four groups by communication preference: visual (40 % of the population), kinesthetic (instinct- and emotion-driven, 40 %), auditory (8 % to 12 %), and digital (data-driven, 5 % to 8 %). Good decision-making can be promoted by tailoring the warning message to each preference. For visual communicators, announcements should be made by a person in authority and visual distractions should be ended. Kinesthetic communicators are more likely to act when they are uncomfortable, which can include the disseminating loud alarms, cutting TV and internet signals and ending other activities, and allowing the smell of smoke to pervade the space. Since kinesthetic communicators learn by doing, fire evacuation drills are beneficial. Auditory communicators alert to uncomfortable sounds such as the fire alarm signal. They may need to have their attention drawn from other auditory devices. A live voice message in an urgent tone is more effective than a prerecorded message, and a familiar (authoritative) voice is best. For digital communicators, information about the fire situation will prompt them to evacuate; they need to know what has happened and what actions need to be taken. A specific, live or dedicated prerecorded message and a crowd moving in a direction where they could learn more are beneficial.

Key findings:

- People can be categorized into four groups by communication preference: visual, kinesthetic, auditory, and digital. Tailored warning methods can be used to move each group toward evacuation. Key recommendations:
    - To attract attention and get people to act, add to discomfort through loud alarms (for kinesthetic and auditory communicators).
    - Use fire evacuation drills to teach and practice the proper actions (for kinesthetic communicators).
    - Provide a live warning announcement by a familiar authoritative source (for visual and auditory communicators).
    - Provide specific information about the emergency situation, including what is happening, what is being done, and what actions need to be taken (for digital communicators).

20. Donner, W. R., Rodriguez, H., & Diaz, W. (2012). Tornado Warnings in Three Southern States: A qualitative analysis of public response patterns. *Journal of Homeland Security and Emergency Management, 9*(2).

Discipline: Crisis Management/Disasters
Rating: 7A

Although improved tornado detection technology should be decreasing the number of deaths from tornadoes, tornado seasons such as the recent 2011 season continue to have high death and injury tolls. It has become clear that there is a need for more psychological and social research on tornadoes. Overall, tornado warnings consist of three subsets. The detection subset, management subset and response subset. When analyzing the social aspects that affect tornado warnings and responses, one is primarily focused on the response subset. Responding is further broken down into six categories; hearing the warning, understanding, believing, personalizing, deciding and responding, and confirming. The data collection for this study was used to analyze how people go through this response process and what influences their decisions.

Missouri, Louisiana and Tennessee were chosen as research sites based on the following criteria: they had experienced multiple tornadoes during the 2007 tornado season and warnings had been issued. Participants were purposefully selected from a variety of communities within the overall population, including Hispanics, women, elderly and people with disabilities. From there, snowball sampling was used to identify additional participants. Overall, there were 21 participants from Louisiana, 20 from Missouri and 14 from Tennessee. Each participant was interviewed with open ended questions designed to inquire about their knowledge on tornadoes and tornado warnings, their belief of official warnings, and how they took action when confronted with a warning.

This paper covered the understanding of verbal and written warnings, accessibility to tornado tracking, specific versus general warnings, local business behavior and cultural myths. However, what is of interest for this literature review, is the section on outdoor siren systems and the use of social networks within vulnerable communities.

It was found that informal social networks played a large role among the Hispanic community. Many of the community members could not speak English, and thus relied on their religious leaders for guidance, and at times, for shelter during a tornado or tornado warning. One community member estimated that 20 % of Hispanics spoke English, and most did not understand tornado warnings. The elderly were also affected by social networks, but in the opposite way. They were found to be vulnerable due to their isolation and lack of social network usage during a tornado.

Additionally, outdoor sirens caused a great deal of confusion in the three states. In some communities, different siren tones were used to alert for different hazards (e.g., tornado, hurricane, chemical spill, etc.). People did not remember which tone stood for which hazard, and their response time was delayed as they sought more information. Even when only one tone was used for multiple hazards, response time was still delayed as they sought more information to determine which hazard was approaching.

Many residents were also concerned with the false alarm rate, and brought to light that residents' perceptions of a false alarm are very different from the authorities' perceptions. If a tornado falls within the designated polygon, an authority would not consider it a false alarm. However, if the tornado did not personally affect a resident, then was considered a false alarm. This causes residents to perceive much higher false alarm rates than would be expected from the tornado data. The high false alarm rate does not necessarily stop people (e.g., residents) from responding, but it can prolong their response times.

Key findings:

- Vulnerable communities, e.g., the Hispanic community, rely on social networks in order to compensate for the lack of other resources available to them.
- A lack of social networks can increase vulnerability.
- The use of one tone to alert for multiple hazards via an outdoor siren system can cause people to delay as they seek more information about which hazard is taking place.
- The use of multiple tones via an outdoor siren system (to alert for various hazard types) can also cause people to delay as they search for more information about what the particular tone means.
- Many residents are concerned with false alarm rates, and have different perceptions of what constitutes a false alarm when compared with authorities' perceptions.

Key recommendations:

- [20_1_1] Emergency managers should develop means of engagement with minority community leadership and should provide alerts/warnings written in both English and Spanish.
    - Officials could provide computers, transportation and other support to community leaders who are better equipped to help the Hispanic community.
- [20_2_8] Cultural myths should be targeted through education. The public should be educated on how and why alerts and warnings are issued, and what constitutes a false alarm.
- [20_3_5] Ideally, outdoor sirens should only be used for tornadoes, however if this is not possible, different tones could be used for different hazard events (coupled with public education).
    - Fire departments and police departments could also announce the incoming hazard.
- [20_4_1] More research should be performed on local businesses and minority leadership.

21. Ebner, N. W. (2013, December). A Study of Emergency Management Policy Regarding the Use of Tornado Sirens During Severe Weather in the State of Missouri. *Proposed Masters Thesis*. Columbia , Ohio, United States.

Discipline: Crisis Management/Disasters
Rating: 3A

One of the biggest concerns regarding outdoor siren systems (often used for tornadoes) is the lack of standardization, and the confusion and desensitization that this causes. This study aimed to analyze the ways in which outdoor siren systems in Missouri differed, and whether unifying policies existed. A 42 question survey was sent out to the Emergency Management Directors (EMDs) of all Missouri counties. The survey was designed to gain a better understanding of which county personnel makes the decision to activate sirens, where they receive their information and on what basis they make the decision. A total of 28 EMDs responded to the survey. To supplement survey data, archival research was performed using Hazardous Mitigation Plans for Missouri communities.

Data for several different categories were collected, including siren activation, siren jurisdiction, training, and hazard mitigation plans. It was found that, while 96 % of EMDs activate the siren system when an official National Weather Service (NWS) warning was issued, 15 % activate them if an adjacent county receives a similar warning. Also, percentages of EMDs reported that they activate the sirens for hazards potentially less severe than tornadoes, including strong thunderstorms (31 %), severe weather during a tornado watch (4 %), and severe hail storms (4 %). Regarding other uses of sirens, 92 % do not issue an all clear siren once the threat is passed. Additionally, if the EMDs believe there is a credible threat, 85 % of them activate the sirens before a NWS warning. Conversely, nearly a third wait to activate their sirens after a NWS warning is issued. Usually, this delay occurs when EMDs search for additional information.

Siren jurisdiction was another aspect of outdoor siren systems that the survey attempted to understand. It was found that only 37 % of EMDs are in charge of activating the sirens. In many cases the decision falls within the purview of police, the fire department, or individual municipalities within the county, rather than residing as a county-wide decision. It was also shown that 46 % of EMDs reporting having sectionalized siren systems within their counties, meaning that certain sections of the siren system could be activated instead of the entire system.

The survey also addressed training as a possible area of standardization. The results showed that, while 100 % of EMDs had taken a NWS spotter training, only lower percentages knew which levels of wind (25 %) and hail (35 %) posed a significant risk. These differences in knowledge could lead to sirens being activated without the presence of a serious threat.

Hazardous mitigation plans for many of the counties in Missouri were also analyzed for policies or procedures directing the use of outdoor siren systems. This analysis was performed on a total of 90 documents. First, 29 % of the plans did not contain policies on outdoor siren systems and 45 % had insufficient information (i.e., meaning that only the number of sirens in the system and their locations were listed in the plans). Of the 26 % that did have sufficient information, the plans stipulated who had jurisdiction over activating the siren, how many sirens were present, their locations, when they were to be tested, and generally what they should be used for.

Key findings:

- Jurisdiction over siren activation varies between counties and can be assigned to EMDs, the fire department, the police or other local officials.
- Slightly less than half of the counties in Missouri have sectionalized outdoor siren systems, which could lead to the desensitization of the people located in areas with non-sectionalized systems.
- EMDs use sirens to alert for strong winds, thunderstorms and at times hail, but they are not well trained on when these types of weather are extreme enough to pose an actual threat.
- Most EMDs will activate sirens if they believe there is a threat, even without a NWS warning. Conversely, if a NWS warning is issued, almost a third of EMDs will seek further information before activating sirens.
- The majority of hazardous mitigation plans contained no information or insufficient information regarding protocols for the activation of tornado sirens.

Key recommendations:

- [21_1_4] Sirens should not be used in response to a NWS warning in an adjacent county, and they should only be activated when a NWS warning occurs within the county in question.
- [21_2_4] Reports of tornadoes or funnel clouds should be carefully evaluated before being considered a threat.
- [21_3_4] EMDs should undergo further training, specifically for radar interpretation.
- [21_4_4] Sirens should not be activated during a tornado watch, but only if there is an actual tornado warning, even if there is a thunderstorm.
- [21_5_4] Sirens should only be activated for thunderstorms or severe winds if the wind speed exceeds 75 mph.
- [21_6_4] [21_6_7] Sirens indicating an “all clear” should not be used.
- [21_7_4] If the community has a sectionalized system, sirens should only be activated in the sections that are at risk.
- [21_8_4] [21_8_9] A statewide set time for audibly testing sirens should be mandated to end confusion. This testing should be done once per month.
- [21_9_4] [21_9_9] Sirens should not be tested in threatening weather.
- [21_10_4] Irregular siren policies should be abandoned. For instance, sirens should not be used to indicate a weather watch, or to alert the fire department of a fire call.
- [21_11_4] All communities within the same county should use the same procedures, and more widespread standardization would be even more beneficial.

22. Edworthy J. (1998). What Makes a Good Alarm? *IEE Colloquium Digest on 'Medical Equipment Alarms: The Need, the Standards, the Evidence'* (pp. 5-8). Ref. No 1998/432, The Institution of Electrical Engineers.

Discipline: Buildings/Engineering
Rating: 5B

Alarms are used in a variety of environments to warn individuals of danger or the potential for danger. Unlike visual alarms, it is possible for audible alarms to attract the attention of the individual independent of what they are doing and where they are looking. The author presents information on the characteristics of a successful alarm. Although the emphasis is on medical care settings, many of these characteristics apply to all types of buildings and settings.

A good alarm gets people's attention without startling them. People have been known to turn off alarms that are startling and forget to reactivate them. The alarm should be resistant to masking by any other sounds and should be easy to localize. For medical situations, the staff and the patients should all hear the alarm. The meaning of the alarm should be clear to the medical staff, and its characteristics should convey the level of urgency. A good alarm sounds only in the presence of danger, with no false alarms. Alarms should be 15 dBA to 25 dBA above the masked threshold level to be easily heard. In a normal office setting, 70 dBA to 75 dBA is a suitable level. Alarms should not be much louder than this level because there is nothing to gain except startling the people in the building. In a location where there is an unpredictable fluctuating noise level, adding harmonics within the 500 Hz to 4 000 Hz band should minimize the chances of not being heard. Alarms with a lot of harmonics in this frequency range can be played at a lower signal-to-noise ratio than more simple tones, allowing the noise levels to be minimized. These alarms are also easier to localize.

Once an alarm is detected, it is important that the meaning is understood and that communication can still take place. Also, it is important that alarms can be heard within all environments of a building, such as in operating rooms. Standardizing the meaning of alarms within similar settings (e.g., hospitals and other health care facilities) would reduce confusion and increase the understanding of medical alarms. Traditional continuous alarms are inappropriate because they can easily be confused, are hard to localize, and stay on until they are manually deactivated. They also distract from the task at hand and interrupt communication. A key factor that causes confusion in alarms is sharing similar temporal patterns like the same rhythm or repetition rate. Temporal patterning can help to communicate the level of urgency. Research has not determined definitively which sounds make the best alarms. In addition to traditional types such as horns, bells, and buzzers, more natural sounds that signal a specific action may be advantageous, especially if they reduce the need to learn a set of alarms. In environments where there are many natural sounds, an emergency alarm or alert that differs significantly from the ambient sounds may be best. As people become familiar with an alarm's reliability, they will match their response rates to the reliability of the alarm; if the alarm is 90 % reliable, they will respond 90 % of the time.

Key recommendations:

- [22_1_2] Alarms should attract attention but not startle.
- [22_2_11] The meaning of the alarm should be clear to the staff, and its characteristics should convey the level of urgency.
- [22_3_4] A good alarm sounds only in the presence of danger, with no false alarms.
- [22_4_2] Alarms are easily heard when they sound at 15 dBA to 25 dBA above the masked threshold level. In normal office settings, this is achieved by setting the level of alarm between 70 dBA and 75 dBA.

- [22_5_2] In environments with unpredictable and fluctuating noise, the masking of alarms can be minimized by including several harmonics within the 500 Hz to 4 000 Hz band. Alarms with rich harmonic content within this frequency range can be played at a lower signal-to-noise ratio than more simple tones, allowing the noise levels to be minimized. These alarms are also easier to localize.
- [22_6_2] Alarms need to be audible within all environments of a building, such as in operating rooms. The sound level should allow people to communicate.
- [22_7_4] Standardizing the meaning of alarms within similar settings (e.g., hospitals and other health care facilities) would reduce confusion and increase the understanding of medical alarms.
- [22_8_2] Traditional continuous alarms are inappropriate because they can easily confuse, are hard to localize, and stay on until they are manually deactivated. They also distract from the task at hand and interrupt communication
- [22_9_2] A key factor that causes confusion in alarms is sharing similar temporal patterns like the same rhythm or repetition rate. Alarms for different purposes should have different temporal patterns.
- [22_10_11] Temporal patterning can help to communicate the level of urgency. In addition to traditional alarms such as horns, bells, and buzzers, more natural sounds that signal a specific action may be advantageous, especially if they reduce the need to learn a set of alarms.
- [22_11_2] An emergency alarm or alert should differ significantly from the ambient sounds. In environments where there are many natural sounds, a more traditional alarm may be a better choice.
- [22_12_4] As people become familiar with an alarm's reliability, they will match their response rates to the reliability of the alarm; if the alarm is 90 % reliable, they will respond 90 % of the time.

23. Edworthy, J., & Hards, R. (1999). Learning Auditory Warnings: The effects of sound type, verbal labelling and imagery on the identification of alarm sounds. *International Journal of Industrial Ergonomics*, 603-618.

Discipline: Human Factors/Ergonomics
Rating: 7B

This study aims to analyze different methods of learning sounds, and whether or not these improve retention. Additionally, three different sound categories were tested, in order to see if this had an effect on learning and retention. Overall, 12 different sounds were created. Four were abstract sounds that were already used in hospital settings. These included an air call signal, a humidifier alarm, a pulse oximeter alarm and a ventilator alarm. Four semi-abstract sounds were created as well, with information on their exact acoustic parameters provided in the study. The four “real” or “natural” sounds were jingling bells, footsteps on dry leaves, ocean waves, and an approaching train. The study included 32 undergraduate participants who were asked to learn all twelve sounds using one of four methods. The first method consisted of the researcher assigning verbal labels to each sound, and asking the participant to learn these labels. For the second method, the participant was able to choose their own verbal labels for each sound, then they had to memorize them. The third method consisted of the researcher assigning graphic labels (visual) to each sound, and asking the participant to learn these labels. For the fourth method, the participant drew their own graphic labels (visual) for each sound and memorized them. The given names for the first learning method were purposefully difficult to link to graphics, and included words like “concept”, “belief”, and “false”. The graphics given in the third learning method were drawings of the waveforms, which can only be broadly linked to a verbal label.

For the first phase of the study, each sound was played, and the label was given, or created. Each sound was randomly played an additional six times, and participants were asked to correctly identify it. They were corrected if they chose the wrong label. Phase two took place two weeks later. The sounds were randomly played four times, and each time, the participant was asked to correctly label that sound. All available labels were laid out in front of the participant at the beginning of testing.

Overall, participants retained real sounds better than semi-abstract sounds, which were better retained than abstract sounds. Additionally, participants performed better when using verbal rather than graphic labels. However, these differences in performance disappeared when participants were allowed to use their own labels. In other words, neither sound type was easier or more difficult to remember, and neither verbal nor graphic was easier or more difficult to use when participants created their own labels. This is most likely due to the fact that when participants created their own labels, they were likely subconsciously using both verbal and graphic means of remembering. For example, if they chose waves for one of the sounds as a verbal cue, they probably also pictured waves in their head, and vice versa. It was also found that participants had better recall in phase two than phase one, suggesting that training is important for remember auditory alerts. Finally, sounds for which people generally chose the same label were easier to memorize than those with a wide variety of chosen labels.

Overall, this study’s findings suggest that sounds may not be difficult to memorize. However, the structured way in which we are presented the meaning of these sounds may hinder learning. Stated a different way, sounds are not the problem, it is the restrictive labels that are given that make them potentially more difficult to learn.

Key findings:

- Participant-created labels rendered all sound and cue types equally easy to learn.
- Sounds where there appeared to be a consensus on the appropriate label (when chosen by participants) were easier to learn.
- Participants performed better at recognizing the sounds after the two-week interim.

Key recommendations:

- [23_1_5] [23_1_8] If auditory alerts could be learned in a way that is less restrictive, and in a way where the learner could choose their own labels, then memorization of multiple alarms could be much easier.
- [23_2_5] [23_2_8] If alarms are still taught in a structured way, then natural sounds are easier to learn, however these may not always be appropriate for alerting situations. Further research should be conducted to find out if natural sounds would work as alarms.

24. Edworthy, J., Loxley, S., & Dennis, I. (1991). Improving Auditory Warning Design: Relationship between warning sound parameters and perceived urgency. *Human Factors, 33*(2), 205-231.

Discipline: Acoustics/Audiology
Rating: 7B

Sound consists of many different fundamental parts. A sound pulse is defined as having an amplitude envelope with a short onset and offset time. A pulse usually lasts about 100 to 300 ms and includes a fundamental frequency with several other harmonics. A pulse that is repeated at different pitches and amplitudes, with different inter-pulse time intervals, is considered a burst of sound. In this study, eight experiments were carried out in order to quantify the effects of pulse and burst parameters on perceived urgency. These eight experiments were divided up into three experimental series.

Experimental series 1 primarily focused on pulse parameters and consisted of two experiments. The first experiment tested two fundamental frequencies, two levels of harmonic regularity and three amplitude envelope shapes. The fundamental frequencies were 150 Hz and 530 Hz. Some pulses consisted of regular harmonics while others were 10 % irregular. In these particular irregular harmonics, 10 % of the frequencies were not whole integer multiples of the fundamental frequency. In the regular harmonics, all the frequencies were whole integer multiples of the fundamental frequency. The experiment also tested a standard envelope shape, a slow offset shape and a slow onset shape.

The second experiment tested the effects of fundamental frequency, delayed harmonics and harmonic regularity. In this trial, delayed harmonics were represented by pulses in which the higher harmonies did not start playing until after the first 100 ms. Fundamental frequencies of 200 Hz and 350 Hz were tested as were 10 % irregular harmonics, 50 % irregular harmonics and random harmonics.

Experimental series 2 focused on testing the effects of burst parameters on perceived urgency. These parameters consisted of temporal parameters and melodic parameters. The temporal parameters tested were speed, rhythm and repetition. A burst with a regular rhythm had the same inter-pulse interval throughout the entire burst, where as a burst with an irregular rhythm consisted of varying inter-pulse intervals. Repetition referred to the number of times a burst is repeated.

The melodic parameters tested consisted of pitch contour, pitch range and musical structure. In this study, two levels of pitch contour were tested. For bursts with random pitch contour, perceived frequency can change as many times as possible, and it can go up or down. The second pitch contour, up/down, referred to a burst where the perceived frequency can either ascend only or descend only. Pitch range is the difference between the highest and lowest pitch within a burst. Musical structure consisted of three different levels; atonal, unresolved and resolved. Atonal bursts have no center, unresolved bursts have a center but sound incomplete and resolved bursts have a center and sound complete.

In total, seven experiments were performed with each one consisting of 12 unique pulses, or 12 unique bursts, made from various combinations of the parameters explained above. Participants were asked to rank the pulses, or bursts, from most urgent to least urgent. They were then asked to assign each pulse/burst with a number between 0 and 100, with 100 being the most urgent and 0 being the least urgent.

It was found that rank ordering and magnitude assignment were fairly consistent. Among pulse parameters, fundamental frequency, amplitude envelope, harmonic regularity and delayed harmonics all had an effect on perceived urgency. The standard pulse envelope was rated the most urgent, followed by the slow onset and then the slow offset. Additionally, irregular harmonics were rated the most urgent.

10 % irregular harmonics were perceived as slightly less urgent than irregular harmonics, but more urgent than 50 % harmonics. Regular harmonics had the lowest perceived urgency. This is most likely due to the fact that irregular harmonics were the least predictable, and regular harmonics were the most predictable. Fundamental frequency had a lower than expected effect on perceived urgency, with higher fundamental frequencies causing increased perceived urgency only when coupled with slow offset or standard pulse envelopes.

Among temporal burst parameters, speed had the strongest effect on perceived urgency, with faster bursts resulting in a higher perceived urgency. Bursts with regular pulse rhythms were perceived as more urgent, as were those with increased repetitions.

The effects of the melodic burst parameters, while not as strong, were also significant. A large pitch range resulted in higher perceived urgency. The small pitch range had a slightly higher perceived urgency than the moderate pitch range. With regards to musical structure, atonal bursts were rated as the most urgent, followed by unresolved, and then resolved bursts. The effects of pitch contour were barely significant, but the authors hypothesized that this parameter did have effects on the discriminability of the alert.

Experimental series 3 used the results obtained from the first two experimental series in order to create 13 different alerts. Each alert was designed to have a specific ranking of perceived urgency, relative to the other 12 alerts. To give an example, the burst designed to have the highest perceived urgency consisted of pulses with standard envelope shapes, random harmonic regularity, and 150 ms inter-pulse intervals. The burst itself had a regular rhythm with an average pitch of 600 Hz, a pitch range of 300 Hz and a random pitch contour. In comparison, the burst designed to have the lowest perceived urgency consisted of pulses with a slow onset envelope, regular harmonics, and a 550 ms inter-pulse interval. The burst had a slowing rhythm, an average pitch of 290 Hz, a pitch range of 75 Hz and a downward pitch contour.

These 13 bursts were then presented to participants: nine females and five males. Participants were asked to rank the bursts from most urgent to least urgent, as well as assign a magnitude based on the 0-100 scale used in the earlier experiments. The experimental rankings were strongly correlated with the predicted rankings.

Overall, this study shows how parameters can be manipulated to produce more or less urgent signals. Additionally, the results display low levels of variability between participants, which suggests that manipulating alerts using these parameters could effect a large proportion of people.

Key findings:

- The effects of fundamental frequency were less pronounced than expected, but in Experimental series 1, the 530 Hz signal resulted in a higher perceived urgency than the 150 Hz signal. In Experimental series 2, signals with a 350 Hz fundamental frequency were perceived as more urgent than signals with a 200 Hz fundamental frequency.
- Standard envelope (20 ms onset and 20 ms offset) was perceived as more urgent than the slow onset or slow offset envelope.
    - Slow onset envelopes were perceived as more urgent than slow offset envelopes.
- The 530 Hz fundamental frequency had an effect on perceived urgency with slow offset and standard envelope stimuli.
- The harmonic series that is least predictable was perceived as more urgent. Random harmonics evoked a higher perceived urgency than 10 % irregular harmonics. Regular harmonics had the lowest perceived urgency.
- Temporal parameters (Burst Parameters):

- Speed had the strongest effect on the perceived urgency of a burst, however it may not produce the desired effect when heard without a lower speed to compare it too. Instead, speeding up the burst might more effectively increase perceived urgency, because the latter end of the burst would be compared to the beginning of the burst.
    - Regular rhythms were perceived as more urgent than irregular rhythms.
    - More repetitions of a burst resulted in a higher perceived urgency. Four repetitions of a burst were perceived as more urgent than two repetitions, which were more urgent than one.
- Melodic parameters (Burst Parameters):
    - Effects on perceived urgency are weaker for melodic parameters than temporal parameters.
    - Large pitch ranges that consisted of eight semitones resulted in a higher perceived urgency, but small pitch ranges that consisted of three semitones were still perceived as more urgent than five semitones, moderate pitch ranges.
    - For musical structure, atonality evoked a higher perceived urgency than unresolved bursts, which evoked a higher perceived urgency than resolved bursts.
    - Pitch contour had a relatively small effect on urgency, but can be included in a signal to increase discriminability without drastically changing the perceived urgency.
- Unpredictable bursts/pulses increased perceived urgency.

Key recommendations:

- [24_1_11] Sound/tonal parameters can be used to manipulate sirens to reflect the urgency of the situation.
    - For instance, to create a very urgent signal, the pulses could have a fundamental frequency of 530 Hz, a standard envelope, and a random harmonic series.
    - The burst parameters for an urgent signal could consist of a short inter-pulse interval (speed), a regular rhythm, and more repetitions, such as four. Additionally, the burst could have large pitch range consisting of eight semitones, with an atonal sound.
- [24_2_11] The examples in the third experimental series can be used as examples for how to manipulate siren sounds.
    - The most urgent signal in Experimental series 3 could be used as an example for making other urgent signals. This signal had a standard envelope, random harmonic regularity, a 150 ms inter-pulse interval, regular rhythm, an average pitch of 600 Hz, a pitch range of 300 Hz and a random pitch contour.
    - Conversely, a low urgency signal could be modeled after the least urgent signal that was created in Experimental series 3. This signal had a slow onset, regular harmonics, a 550 ms inter-pulse interval, a slowing rhythm, an average pitch of 290 Hz, a 75 Hz pitch range and a down pitch contour.

25. Farrelly , M. C., Healton, C. G., Davis, K. C., Messeri, P., Hersey, J. C., & Haviland, M. L. (2002). Getting to the Truth: Evaluating national tobacco countermarketing campaigns. *American Journal of Public Health*, *92*(6), 901-907.

Discipline: Public Health
Rating: 7A

This study analyzes the impact of the “Truth” anti-smoking campaign, in comparison to the “Think, Don’t Smoke campaign” on teenagers in the U.S. (specifically, their attitudes, beliefs, and intentions regarding tobacco use). More traditional messages, such as “just say no”, are not used in the “truth” campaign. Instead, information is provided to the audience in the form of facts about tobacco companies. For instance, the “truth” campaign publicized historical statements from tobacco companies that showed the lies that were told about the health effects of cigarettes. Additionally, the campaign uses advertisements that show teens rebelling against tobacco companies. One specific advertisement portrays body bags being lined up outside the tobacco company’s headquarters. Just as is practiced in many product advertisements, the actors in this video are teenagers. Overall, the strategy is to market the act of not smoking as a brand, rather than a health message.

A baseline telephone survey was completed before the implementation of the “truth” campaign, and another was conducted seven to nine months after the start of the “truth” campaign. High numbers of African Americans, Asians and Hispanics were sampled due to the fact that the “truth” campaign has several programs that are tailored towards these demographics. However, this oversampling, among other factors, was adjusted for in the analysis portion of this study. An effort was also made to accurately represent urban and non-urban demographics.

Participants were between 12 and 17 years old and were asked a series of questions that were designed to indicate their attitudes, beliefs and behavioral intent regarding tobacco use. Survey questions were also designed to assess how socially acceptable smoking was for teens, and whether or not they intended to smoke. Responses were compared between the baseline and follow-up survey to show changes over time, and two logistic regressions were used to show the differences between campaigns.

From the baseline to the follow-up survey, awareness of anti-tobacco campaigns doubled, with 75 % of respondents aware of the “truth” campaign and 66 % of respondents aware of the “Think. Don’t smoke” campaign. Additionally, negative beliefs about tobacco industry behavior, attitudes towards tobacco, social acceptability of tobacco and the intention to smoke increased from 6.6 % to 26.4 %. These negative perspectives reflected the messages broadcasted by the “truth” campaign. Using logistic regressions, it was possible to see that increased exposure to the “truth” campaign had a positive relationship with negative attitudes towards the tobacco industry, while “Think. Don’t smoke” had no relationship with teens’ attitudes towards tobacco. After exposure to the “truth” campaign, participants were more likely to be aware of the dishonest practices of tobacco companies. The “Think. Don’t smoke” campaign was found to have had the exact opposite effect.

One model constructed by the authors demonstrated that exposure to the “truth” campaign correlated with a 35 % increase in youths wanting to “get involved in efforts to get rid of smoking” and a 163 % increase in youths wanting to “take a stand against smoking”. Both campaigns were associated with youths agreeing that “not smoking is a way to express independence” and disagreeing with the statement that “smoking makes youths look cool or fit in”.

The likelihood of agreeing with statements like “I want to be involved in efforts to get rid of cigarette smoking” and all other negative attitudes about tobacco companies were negatively associated with an intent to smoke. According to the author, this suggests that the "truth" campaign could have a large and important effect not only on attitude, but also on behavior.

Key findings:

- Increased exposure to the "truth" campaign had a positive relationship with teenagers' negative attitudes about the tobacco industry.
- Those who had been exposed to "truth" were more aware of the negative practices of tobacco companies than those who had no exposure to anti-tobacco campaigns.
- Those who had been exposed to the "Think. Don't smoke" campaign were less likely to be aware of the negative practices of tobacco companies.
- There was a 35 % increase in teenagers wanting to get involved in efforts to reduce smoking, and a 163 % increase in youths wanting to take a stand against smoking, both related to exposure to the "truth" campaign. No such increase was seen for the "Think. Don't smoke" campaign.
- Having negative attitudes towards tobacco companies was negatively associated with the intent to smoke.

Key recommendations:

- [25_1_8] Counter marketing campaigns such as the "truth" campaign could be used to change attitudes about smoking, which can lead to behavior changes.
- [25_2_8] Directive messages, such as "Think. Don't smoke" should not be used when addressing teenagers.

26. Giang, W., & Burns, C. M. (2012). Sonification Discriminability and Perceived Urgency. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 56*, pp. 1298-1302.

Discipline: Acoustics/Audiology
Rating: 5A

Sonifications are a type of auditory signal that are continuously present, but change in some way if the system they are monitoring changes. The author uses the example of the pulse often heard in a hospital room that monitors heart rate and oxygen levels using tempo and pitch. Designing a useful sonification requires that the operator be able to detect changes in the signal, as well as understand the meaning of the change. This can be described as the discriminability and perceived urgency of a sonification.

In this study, auditory sonifications were designed to represent the rotations per minute (RPM) of an Uninhabited Aerial Vehicle (UAV). Two of the sonifications had a harmonic timbre that resembled the sound of a propeller engine, and two of the sonifications had a pure tone, smooth timbre, that only contained the fundamental frequency. Each timbre was either played without any breaks, or it was pulsed, creating four unique sonifications. As the engine RPM increased, the fundamental frequency of all sonifications would increase and the pulse rate, where present, would also increase.

The discriminability of the sonifications was tested by asking participants to pinpoint when a change in the sonification occurred. In order to do so, the sonifications were randomized, and each of the ten participants was exposed to all four sonifications for a total of 20 times. The speed and accuracy with which participants detected the change was used as measurements of the discriminability.

In order to test perceived urgency, participants were exposed to the sonifications representing five different RPM levels. They were then asked to rate the urgency of the situation on a scale of 1 (least urgent) to 100 (most urgent). Each test was randomly repeated ten times. Participants' perceptions of the sonifications were also addressed through a questionnaire that aimed to assess which sonifications were preferred and which were easiest to understand.

It was found that participants were able to more quickly determine changes in the sonification for the pure timbre, possibly due to the fact that it contains less harmonics. Pulse rate did not have a significant effect on discriminability; however, increased pulse rate was shown to increase perceived urgency. The sonifications had higher urgency ratings as the pitch increased but there was no significant difference in urgency ratings for either timbre. The author noted that this may have been due to the fact that, while the timbres were different, they were not as different as those tested in previous studies that had come to the opposite conclusion. Participants also noted that the pure timbre was more annoying, and that they preferred the propeller timbre.

Key findings:

- Participants were better at detecting pitch and pulse rate changes in pure, smooth timbres. Participants had more difficulty detecting changes in natural, harmonic timbres, like that of an airplane propeller engine.
- Higher frequency and increased pulse rate both increased perceived urgency.
- Neither timbre was more effective at increasing perceived urgency.
- The smooth, pure timbre was more irritating to listen to than the harmonic, propeller timbre.

Key recommendations:

- [26_1_11] Increased pitch and pulse rate can be used in a sonification to convey increased urgency in a situation.
- [26_2_2] Pure timbres, while beneficial for discriminability, may be more annoying to listen to on a constant basis.

27. Green, R., & Petal, M. (2010). *Lessons Learned from School Participation in the 2008 Shakeout*. Bellingham: Western Washington University .

Discipline: Crisis Management/Disasters
Rating: 4A

In 2008, California hosted the first Shakeout week. This weeklong intervention organized by the Earthquake Country Alliance Organization featured multiple events and activities designed to increase earthquake preparedness. On the last day of the week, a voluntary earthquake drill was performed in Southern California in the region surrounding the San Andreas Fault. This region was chosen to best represent an earthquake happening along the fault. The campaign was widely successful, in that nearly four million people participated. However, its effectiveness in motivating people to be more prepared is unknown.

The purpose of this study was to analyze the impact of Shakeout, specifically regarding school district preparedness. In order to assess this, online, pre- and post-event surveys were sent out to schools. During the Shakeout drill, observations of four different schools were made as they participated in the earthquake drill. The initial survey resulted in 197 schools responding, and the follow-up survey was completed by 378 schools.

The results from the pre-event survey indicated that 95 % of schools have a preparedness committee, which are made up of (in order from most common to least) administrators, teachers, staff, parents, students and community representatives. Additionally, around 75 % of schools reported that all of their staff had read the school emergency plan. Only about a third of schools actively participated in educating their students about disaster preparedness outside of school. Earthquake drills were apparently practiced by 80 % of the schools on a regular basis, such that they felt comfortable reporting that *all* of their students had practiced “drop, cover, and hold on” procedures.

Results from the follow-up questionnaire showed that only 30 % of schools participated in the full Shakeout drill, while 55 % performed both the “drop, cover, and hold on” and evacuation drills. The remaining elected to forgo the evacuation portion and practice only the “drop, cover and hold on” procedures. Schools that had never performed earthquake or evacuation drills were more likely to have done one during the Shakeout drill and schools who regularly initiated full disaster drills were less likely to have participated in the full Shakeout drill.

During the shakeout drill, the two main problems faced were non-compliance (by teachers) and distractions from the event; however, these were only reported by 10 % and 14 % of schools, respectively. A large majority of schools were pleased with the outcome of the Shakeout drill event and believed a) it helped improve their own response (88 %), b) it increased public awareness (84 %), and c) it collectively improved responses (80 %). Almost 75 % of schools agreed that the Shakeout drill should be an annual event.

The following findings were identified during observations of the earthquake drills in the four schools: the evacuation was orderly, older students helped the younger students, and separate procedures were included for disabled students. However, the students and parents showed much less knowledge about the school response plans, especially with regards to family reunification.

Overall, the main success of the Shakeout program was that it prompted first time participation in earthquake drills for many schools. If this were repeated annually, it could increase the number of schools that practice these types of drills.

Key findings:

- During the Shakeout drill, only 10 % of schools had issues with teachers not complying and 14 % had issues with distractions.
- Schools viewed the Shakeout drill as an opportunity to improve individually (88%) and collectively (80 %); 84 % believed that it improved public awareness.
- 75 % of schools and districts supported the Shakeout drill becoming an annual event.
- The Shakeout drill prompted schools that had never participated in an earthquake drill to do so for the first time.
- Schools that regularly participated in earthquake drills were less likely to participate in the Shakeout drill.

Key recommendations:

- [27_1_8] Future drills should focus more on participation, student family reunification, representation of more realistic conditions, and plans for disasters occurring directly before or after school when students are being transported.
- [27_2_8] Students and parents should play a greater role in the process.
- [27_3_8] The Shakeout drill should be repeated, but the specific time should not be disclosed in order to increase its realism.

28. Gregg, C. E., Houghton, B. F., Paton, D., Johnston, D. M., Swanson, D. A., & Yanagi, B. S. (2007). Tsunami Warnings: Understanding in Hawai'i. *Natural Hazards, 40*(1), 71-87.

Discipline: Crisis Management/Disasters
Rating: 7A

Outdoor sirens are used in Hawaii to alert the public of impending disaster. The meanings of the sirens in Hawaii have changed over the years. Originally, multiple signals (or siren tones) were used, with each one corresponding to a specific threat. In 1967, this policy was changed. Now, one signal, i.e., the attention/alert signal, is used to alert the public for all natural hazards. This new policy requires residents to seek out information about the type of hazard and associated protective action, upon hearing the siren signal. Previous studies found that, in the 1960s before the siren policy was changed, only about 5 % of the public understood the meaning any specific siren signal. In this study of siren signal comprehension in Hawaii, it was hypothesized that this lack of consistency in siren policy throughout the years has led to increased confusion with regards to the meaning of the siren.

A survey was created to assess how well the public understood the meaning of the sirens. The survey was administered on the islands of Hawaii, Maui, O'ahu and Kaua'i. Respondents in the study involved 440 students and 516 adults. Overall, 77 % of students and 92 % of adults knew that the sirens were tested, with decreasing awareness for students located in areas that had experienced tsunami that were less severe in nature. While 77 % of all respondents were aware of testing procedures for sirens, when questioned about the meanings of the sirens, only 1 % of students and 13 % of adults knew that the sirens were meant to inform the public that an emergency was possible and to check television or radio for further information.

The authors concluded that further education was needed on siren meaning, and the actions that people should take when they receive siren alerts. The authors also posited that education outreach will most likely be easier with the current siren policy (i.e., one tone used to alert for multiple hazards), since people will not be required to learn the meaning of multiple tones. It should also be noted that this study indicates that a single warning system is not adequate when multiple hazards are possible. This most likely means that other methods should be employed to alert the public, rather than just relying on the siren system.

Key findings:

- A large majority of the public in Hawaii knew that the outdoor sirens were tested and when they were tested.
- A very small portion of the public knew the meaning of the sirens. This lack of knowledge could possibly be due to the changes in siren policy/meaning over time, and a lack of educational efforts.

Key recommendations:

- [28_1_8] It is necessary to increase education on the meaning of outdoor siren tones.
- [28_2_3] Additionally, a single warning system is not adequate when multiple hazards are possible. In other words, other methods, in addition to outdoor siren systems, should be employed to alert the public.

29. Gregg, C. E., Houghton, B. F., Paton, D., Swanson, D. A., & Johnston, D. M. (2003). Community Preparedness for Lava Flows from Mauna Loa and Hualalai Volcanoes, Kona, Hawai'i. *Bulletin of Volcanology, 66*(6), 531-540.

Discipline: Crisis Management/Disasters
Rating: 5A

Hawaii is subject to several different types of hazards including hurricanes, tsunami, and the topic of this paper, lava flows. Specifically, this paper aims to analyze whether or not people understand siren tones, how prepared the population is for evacuation, and general knowledge of emergency responses. Surveys were administered to 9th grade students in a north Kona high school and a south Kona high school. The parents of the student participants were also given surveys, as was a general adult population taken from mailing addresses and people at the airport. This resulted in 462 respondents.

It was found that 45.9 % of the surveyed population knew the meaning of the siren tone (i.e., "alert, listen to radio or television"), with 65 % of adults and 27.1 % of students understanding the tone and its inherent meaning. However, understanding the siren was found to have no relationship with having read disaster awareness material. The authors hypothesized that the public's knowledge was coming from other sources, possibly through the monthly testing of the siren system. Additional analysis of survey data addressed whether or not people had emergency evacuation plans, if they had practiced them, and their knowledge of lava flow hazards.

The authors recommend that, to increase understanding of siren meaning, the monthly siren tests should be accompanied by radio and television advertising. Additionally, regular testing of the public's understanding should be conducted in order to ensure that awareness is increasing. Finally, education programs should be targeted towards the residents of Kona, and could be delivered by several different means, including "public seminars, media coverage, a web site, video and school lessons plans which have a homework component that promotes student and guardian interaction".

Key findings:

- 45.9 % of the surveyed population (65 % of the adults and 27.1 of students in the sample) knew that the meaning of the siren was "alert, listen to radio or television".
- There was no relationship between having read the disaster preparedness material and understanding the siren tone. This suggested that people learned about the siren tone through different means, perhaps through the monthly testing.

Key recommendations:

- [29_1_8] [29_1_9] The monthly siren tests should be accompanied by radio and television advertising about the sirens and their meaning.
- [29_2_8] Regular tests/studies of the public's understanding of the siren tone should be conducted.
- [29_3_8] Public education about lava flow hazards should be increased. This information could be delivered through public seminars, websites, media, and school lesson plans with homework that promotes parent and student interaction.

30. Gustafson, G. E., & Green, J. A. (1989). On the Importance of Fundamental Frequency and Other Acoustic Features in Cry Perception and Infant Development. *Child Development, 60*(4), 772-780.

Discipline: Child Development
Rating: 7B

An infant's cry is essentially the child's only means of communication. The act of crying is meant to alert parents or caretakers that something is wrong. However, the cry must also be correctly interpreted by the caregiver in order for them to respond properly. This study aims to analyze how different cry parameters affect parents' perception of the child and its needs.

The methods used to analyze perception of infant cries were somewhat novel for this study. Previous research used stimulated pain cries, usually obtained by snapping a rubber band and the sole of an infant's foot. Additionally, many of the studies addressed the difference in cries of healthy infants, and infants at risk for neurological disorders. This study addressed how adults perceive spontaneous cries (not stimulated through pain), in healthy infants. To carry out this study, 100 healthy, full term, infants were recorded in order to capture a spontaneous cry. 12 different cries were selected based on the representativeness of their acoustics relative to the group of 100. There were 42 participants in this study, including 20 parents, 11 non-parent females and 11 non-parent males.

Multiple acoustic parameters for each cry were measured. Duration was measured by totaling up the length of all the respiratory phases, or the entire time that noise was being made, not including breaths. The fundamental frequency of the cry was measured at ten intervals, and peak frequency was measured as the frequency "played" at the highest volume. Additionally, the proportion of total power and the degree of phonation was measured.

Participants' reactions to the cries were measured using a set of aversive ratings and semantic ratings. The aversive ratings identified the following: degree of urgency, how sick the child sounded, and how arousing, grating, discomforting, piercing and aversive the cry was. The semantic ratings were used to estimate how unpleasant, sharp, rugged, awful, fast, heavy, bad, active and hard a cry sounded. Participants listened to each of the 12 cries and rated all of the aforementioned aspects of the cry.

Results showed that longer cries were positively related to more aversive ratings, which includes perceived urgency. More dysphonated cries, cries with less energy in the 0 kHz to 2 kHz range and more energy in the 3 kHz to 4 kHz range were also positively related to perceived aversiveness. Unlike previous studies, fundamental frequency did not have a significant effect on semantic or aversive ratings. This could possibly be due to the fact that there was a smaller range of fundaments frequencies in this study compared with previous studies. Results were relatively similar across mothers, fathers and non-parents.

Key findings:

- Longer duration cries were positively correlated with aversive ratings, including perceived urgency ratings.
- More dysphonated cries were positively correlated with aversive ratings.
- Cries with less energy in the 0 kHz to 2 kHz range and more energy in the 3 kHz to 4 kHz range were also positively correlated with aversive ratings.
- Fundamental frequency had no significant correlation with any ratings.
- Results were similar for mothers, fathers and non-parents.

31. Haas EC, Casali JG. (1995). Perceived Urgency of and Response Time to Multi-tone and Frequency-modulated Warning Signals in Broadband Noise. *Ergonomics, 38*(11), 2313-2326.

Discipline: Human Factors/Ergonomics
Rating: 7B

The design of auditory warning signals can affect operator performance. Certain signal characteristics can be modified to match the urgency perceived by the listener with the urgency required by the situation. Warnings must also be designed to be audible within the environment in which they are used, without being so loud and distracting that people endanger themselves by shutting them off. Many industrial and military environments contain continuously-operating machinery, which generate noise that can mask certain signals and make them difficult to hear. One type of signal that can be tailored to specific situations uses a short pulse of sound as a building block that can be combined with intervals of silence to generate a sound burst. Many acoustical and timing parameters can be adjusted to improve the audibility in a noisy environment as well as elicit a desired response from the listener. This set of experiments studied the effect of pulse parameters in these auditory warning signals on perceived urgency and response time in the presence of background noise.

In this study, the pulse parameters studied were pulse format (a sequential pulse, a simultaneous pulse, and a sawtooth frequency-modulated pulse format), pulse level (65 dBC and 79 dBC) and inter-pulse interval (0, 150, and 300) ms. The simultaneous pulse consisted of four pure tones at (500, 1000, 2 000 and 3 000) Hz, sounding simultaneously during a single pulse duration. The sequential pulse consisted of four pure tones at (500, 1 000, 2 000, and 3 000) Hz, sounding sequentially during a single pulse duration. The sawtooth frequency-modulated pulse format consisted of a pure tone carrier that rose and fell in a sawtooth pattern between 500 Hz and 3 000 Hz during a single pulse duration. The inter-pulse interval is defined as the time duration between the end of the offset of one pulse to the onset of the next. The pulse level is defined as the root mean square (RMS) sound pressure level (SPL) of the pulse in dBD as measured at the center of the participant's head.

The environments of interest for this study were military or industrial settings that contain machinery generating steady-state noise, in which operators experience a high level of demand for their attention. The noise in these environments can be represented by pink noise, which contains equal amounts of energy in octave bands. In the experiment, 36 participants (18 men and 18 women), ranging in age from 18 to 22, were exposed to pink noise at 68 dBC while seated in a semi-reverberant acoustic chamber in the U.S. Army Research Laboratory at Aberdeen Proving Ground in Maryland. They were given a standard workload task in order to impose demands on their attention. Participants were presented with auditory signals containing combinations of the three independent variables tested in this study (pulse format, pulse level, and inter-pulse interval), which resulted in 18 different auditory signals (i.e., a 3 x 3 x 2 full factorial study), each of which was presented twice in random order. Each signal consisted of a train of eight pulses, each pulse lasting 350 ms. Participants first rated the urgency of each signal. After a 10 min break, their response time to each signal was measured by how long it took to press a button on a one-button-keypad with their dominant hand while performing the workload task. After a 30 min break, the participants were presented with 153 signal pair combinations (all unique combinations of 18 signals taken two at a time) in random order and asked to indicate which signal from each pair was more urgent. The workload task was assessed to be sufficiently demanding on the attention of the participants for the purposes of this experiment.

The results showed that perceived urgency increased strongly with increasing pulse level. Signals with shorter inter-pulse intervals were perceived as significantly more urgent, with signals with no inter-pulse interval (zero ms) considered the most urgent. For each signal type, urgency was rated highest when the pulse level was the highest and inter-pulse interval was the shortest. Finally, sequential signals were rated as significantly less urgent than simultaneous and frequency modulated signals.

Response time was significantly shorter for the highest pulse level than for the lowest, with a difference of 60 ms. Although this is a very short delay, it can make a difference in a job requiring immediate response, such as piloting a fighter jet. The mean response time for sequential signals was significantly greater (up to 40 ms) than for simultaneous and frequency modulated signals. Response time was independent of inter-pulse interval. The correlation between results for perceived urgency and response time indicates that response time is fastest when perceived urgency is greatest.

Through variation of parameters, proper design of pulse-based signals can assist listeners in deciding how urgently they need to respond.

Key findings:

- For pulse-based signals in background noise consistent with continuously operating machinery, perceived urgency increases with increasing pulse level and with decreasing inter-pulse interval, and also depends on pulse format.
- Certain signal characteristics can be modified to match the urgency perceived by the listener with the urgency required by the situation.
- Through variation of parameters, proper design of pulse-based signals can assist listeners in deciding how urgently they need to respond.
- For operators engaged in a task in a noisy environment, response time was shorter by 60 ms for a higher pulse sound level compared to that for a lower pulse level. This is enough to improve the performance of a fighter jet pilot.

Key recommendations:

- [31_1_2] Warnings must be designed to be audible within the environment in which they are used, without being so loud and distracting that people endanger themselves by shutting them off.

32. Haas, E. C., & Edworthy, J. (1996). Designing Urgency Into Auditroy Warnings Using Pitch, Speed and Loudness. *Computing and Control Engineering Journal* , *7*(4), 193-198.

Discipline: Acoustics/Audiology
Rating: 7B

Auditory signals are often used to monitor high risk situations, such as patients at a hospital, or gauges in an airplane cockpit. However, it has been shown that the urgency of these signals do not always match the urgency of the situation at hand. This results in people either ignoring the signals, or turning them off due to their annoying and distracting nature. This study aimed to test how the fundamental frequency, the inter-pulse interval, and the pulse level of an auditory signal affected response time and perceived urgency. This could be used to better match signals to the warning they are meant to convey.

15 male and 15 female college students between the ages of 18 and 40 were exposed to 27 different auditory signals. The three main variables in this study were pulse fundamental frequency, inter-pulse interval and pulse level. The three fundamental frequencies used were 200 Hz, 500 Hz, or 800 Hz. Three different inter-pulse intervals were used; 0 ms, 250 ms, and 500 ms. The pulse levels were set at (5, 25 or 40) dB LIN SPL (linear sound pressure level) above ambient noise. In order to determine perceived urgency, participants were randomly exposed to each signal twice, and asked to rate the urgency as a number greater than 0. Next, response time was tested, and each participant was again exposed to the 27 signals twice. This time they were asked to push a button as soon as they heard the signal.

The results showed that there was a lower perception of urgency for signals with a fundamental frequency of 200 Hz, compared with those with fundamentals of 500 Hz and 800 Hz. The signal with a fundamental frequency of 500 Hz was only perceived as less urgent than the signal with a fundamental of 800 Hz at the highest sound pressure level (40 dB LIN). Additionally, shorter inter-pulse intervals resulted in higher perceived urgency with the 0 ms interval being rated as the most urgent. The pulse level also affected perceived urgency with increased sound pressure above ambient resulting in increased perceived urgency. Pulses with the combination of higher fundamental frequency, shorter inter-pulse interval, and higher sound pressure levels above ambient were judged as more urgent than other signals. However, the response time task showed that only higher pulse level and fundamental frequency corresponded with decreased response time.

Key findings:

- Signals with fundamental frequencies of 500 Hz and 800 Hz produced higher perceived urgency ratings, compared with those with a fundamental frequency of 200 Hz.
- The signals with a fundamental frequency of 800 Hz produced higher perceived urgency ratings than the signal with a fundamental frequency of 500 Hz, at the highest sound pressure level (40 dB LIN).
- Shorter inter-pulse intervals resulted in higher perceived urgency ratings. The perceived urgency decreased as inter-pulse intervals increased from 0 ms to 250 ms and finally to 500 ms.
- The signals played at 40 dB LIN above ambient were rated as significantly more urgent than those 25 dB LIN above ambient, which were subsequently perceived as more urgent than those 5 dB LIN above ambient.
- Response times were significantly shorter for signals with a fundamental frequency of 800 Hz, when compared with signals with a fundamental of 200 Hz.
- Response times were shortest for signals 40 dB LIN above ambient, followed by signals (25 and 5) dB LIN above ambient.

Key recommendations:

- [32_1_11] Signals for urgent situations should have a higher fundamental frequency, a shorter inter-pulse interval, and a higher pulse level.

33. Hellier E, Edworthy J, Weedon B, Walters K, Adams A. (2002, Spring). The Perceived Urgency of Speech Warnings: Semantics versus acoustics. *Human Factors: The Journal of the Human Factors and Ergonomics Society 44*(1), 1-17.

Discipline: Human Factors/Ergonomics
Rating: 7A

This study looks at the ways in which the meaning of a speech warning and the tone in which it is delivered interact to convey urgency. This paper addresses the following questions:

- Can speakers imbue urgency in their utterances when asked to do so?
- Can listeners understand the level of urgency the speaker is trying to convey?
- To what extent do acoustic variables underpin the relationship between speaker and listener?
- To what extent do semantic effects occur independently of acoustic effects?

In Experiment 1, a male and a female actor were asked to speak a series of ten warning signal words (DEADLY, DANGER, WARNING, CAUTION, RISKY, NO, HAZARD, ATTENTION, BEWARE, and NOTE) using three different styles: urgent, non-urgent (normal speaking voice), and monotone. When presented in visual warnings, the arousal strengths of these ten words are known to vary in a consistent manner. The 31 participants in the experiment were 15 males and 16 females between the ages of 18 and 36. They were asked to listen to a recording of the 60 signal words (10 words in three speaking styles by two speakers), presented in one of four random arrangements, and judge the level of hazard implied by each word. The style in which the signal words were spoken was found to have a significant effect on urgency ratings, with words spoken in the urgent style rated as being significantly more urgent than those spoken in the non-urgent style. This suggests that speakers are reliably able to convey different levels of urgency to listeners by intent. The meaning of the signal words also had a significant effect on the urgency ratings. DEADLY was perceived as being more urgent than DANGER, which was more urgent than WARNING, with NOTE at the bottom of the list. The ranking order agrees with the ordering of the same words in visual warnings. The female speaker's words were generally rated as more urgent than the male's, although this was not true for all words (e.g., NOTE and ATTENTION). The range of urgency ratings across the three presentation styles was much larger for some words than for others, which may reflect a wider range of common usage for those words (NO, for example). Finally, the female voice was found to produce a greater range of urgency across the three styles than the male voice.

Acoustic analysis was performed on the signal words for each presentation style. Three measures of acoustic properties, the mean fundamental frequency (Hz), the pitch range (Hz), and the amplitude (dBA), were found to vary consistently as a function of presentation style, while the speed of the word (seconds per syllable) did not. The urgent versions of the words were higher in pitch, louder, and had a wider pitch range than the non-urgent versions. This indicates that listener response may be partially based on changes in acoustic patterns. The female speaker produced a higher fundamental frequency and greater pitch range than the male speaker.

Participating in Experiment 2 were 31 individuals, 20 females and 11 males, ranging in age from 18 to 41 years old. The participants listened to and rated urgency for five signal words (DEADLY, DANGER, WARNING, CAUTION, and NOTE) that were produced using male and female synthesized voices. The amplitude, fundamental frequency, and pitch range of synthesized signal words were altered individually from a non-urgent to an urgent value. For example, one set of stimuli consisted of a male voice speaking the five signal words with an urgent mean amplitude, non-urgent mean frequency, and non-urgent mean pitch range. No effect due to the sex of the speaker was found in the results. Overall, increases in the amplitude, fundamental frequency, and pitch range were associated with increases in perceived urgency, although the effect was not statistically significant for pitch range. Urgency ratings again depend on the meaning of the signal word, with DEADLY perceived as most urgent and DANGER more urgent than WARNING.

Changes in all three parameters were found to produce larger changes in perceived urgency than changes in only one or two parameters. This is not unexpected, since in real speech increases in urgency are a result of systematic changes in all three parameters. This experiment also demonstrated that it is possible to imbue synthesized speech with urgency through the use of three acoustic parameters: amplitude, fundamental frequency, and pitch range. Intelligibility was a problem for a few of the words in Experiment 2, and the authors acknowledge the importance of messages that are realistic, intelligible, and believable. Word meaning was again found to be important, with the words DEADLY and DANGER rated as more urgent that other words. Finally, although a difference in urgency rating was found between real male and female voices in Experiment 1, no difference was found between male and female synthesized voices in Experiment 2.

Key findings:

- Speakers are reliably able to convey different levels of urgency to listeners.
- Urgency is transmitted through both the acoustic characteristics of the message and its meaning.
- A female voice transmits a greater range of urgency than a male voice over styles from monotone to non-urgent to urgent.
- Urgency can be imbued into synthesized speech through the use of three acoustic parameters: amplitude, fundamental frequency, and pitch range.

Key recommendations:

- [33_1_3] [33_1_10] Synthesized speech messages need to be realistic, intelligible, and believable.

34. Ho, A., & Burns, C. M. (2013). Music as an Auditory Display: Interaction effects of mode and tempo on perceived urgency . *Annual Meeting of the Human Factors and Ergonomics Society* . Waterloo.

Discipline: Music
Rating: 5A

Auditory warning displays are often criticized for their tendency to be annoying. This can cause people to shut off the warning, and thus render it useless. In this study, music is offered as an alternative auditory warning. Music can be advantageous in that it is much more complex than pure tone sonifications. Music can also be less intrusive and annoying, while still evoking strong human emotions. Past studies have shown that minor modes and a slow tempo evoke a sad response, while major modes and a fast tempo evoke a happy response. However, these responses vary based on gender.

This study aims to test the effects of mode and tempo on perceived urgency. Ten male and ten female students from the University of Waterloo were recruited as participants. Participants were also asked to report their years of musical experience. The participants were randomly presented with 48 different musical phrases, and asked to rate their urgency on a scale from 1 (least urgent) to 100 (most urgent). Each musical signal was repeated five times, resulting in a total of 240 trials per person. The signals consisted of four different phrases, played in either minor or major mode, and played at 80 beats per minute (bpm), 100 bpm, 120 bpm, 140 bpm or 160 bpm.

As tempo increased (bpm), perceived urgency increased as well. There was no significant difference between major or minor modes. Although, at (60 to 80) bpm the minor mode was perceived as slightly more urgent and at 160 bpm the major mode was perceived as slightly more urgent. At lower tempos men found the music more urgent than women, but the difference diminished at higher tempos. There was no significant effect on perceived urgency from musical experience.

Key findings:

- Perceived urgency increased with increasing tempo, such that the music that played at 80 bpm was rated as the least urgent and the music that played at 160 bpm was rated as the most urgent. Those that fell in between were rated in ascending order of tempo.
- Men found the music more urgent at lower tempos than women.
- At higher tempos there was no significant difference between genders.
- Past musical experience and minor and major modes had no significant effect on perceived urgency.
- Tempo is not the same thing as inter pulse interval. Inter pulse interval is more closely related to inter note interval when referring to music. Increased tempo will lower the average inter pulse interval, but not necessarily individual inter pulse intervals.

Key recommendations:

- [34_1_11] Music can be used to display urgency, and potentially other information to users.
- [34_2_11] Further investigation should be undertaken in order to design useful auditory warnings with music.

35. International Federation of Red Cross and Red Crescent Societies . (2011). Public Awareness and Public Education for Disaster Risk Reduction: A Guide. *Guidance Document*. Geneva, Switzerland: International Federation of Red Cross and Red Crescent Societies.

Discipline: Education
Rating: 6A

A guide on public education for disaster risk reduction was created from the review of over 300 documents and websites; interviews with National Society staff; and research on risk communications, social marketing, and public education for behavioral change. The guide began by recommending that the demographics of a particular population be identified, as well as ways to target each subgroup within that population. A full list of methods to reach various subgroups is provided.

The guide continues on to list specific findings about learning and behavioral change that can be used to design successful education campaigns for disaster risk reduction. These findings are listed here (*information provided as bullets are quotes taken directly from the document*):

- People need to be stimulated to seek information.
- People seek consensus, and want validation from many sources (for example, friends, experts, public authorities, respected community leaders, radio, television and web sites) before they act.
- People go along with what they think others are doing. (This means that it is important to focus on all of the positive and local examples: negative threats do not work.
- Three types of people start ‘pro-social epidemics’: connectors who bring people together, information specialists (in other words experts), and salespeople who have the ability to persuade.
- The most memorable lessons are learned from stories that are simple, unexpected, concrete, credible, and emotional.
- The gradual process of behavior change moves from contemplation to planning, then to action and finally to maintenance.

These findings are all important to consider when designing a public education campaign; however, one must also consider the partnerships that could aid in the dissemination of educational materials. Partnerships can help spread the message further, as well as develop a platform whereby a unified message can be provided from many different sources, which will aid in message reinforcement. It is recommended that partners include national societies, as well as representatives from the beneficiaries of the program. These are by no means the only possible partnerships, and a more exhaustive list of options is provided within the guide.

The next pertinent section is about the four types of initiatives that can be used to educate the public. These are campaigns, participatory learning, informal education, and formal school-based interventions. First, campaigns are used to reach a large number of people with usually one or two unified messages. One example given by the guide is the seatbelt campaign. Campaigns can include the use of, but are not limited to, publications (i.e., billboards, posters etc.), slide presentations, arts, games, social media components and online activities. This guide lists specific parameters important to campaigns, including message types, audience, strategy and timescale. In order to gain the most publicity, it is often beneficial to use commemorative events, or anniversaries to spread the message of a campaign. School assemblies, farmers’ markets, art events and advocacy visits can also be useful places/events to publicize the campaign.

Campaigns are also advantageous in that they can cover a large amount of people, take advantage of media attention, and include multiple partners. However, they require a high level of organization, extensive support, and stamina on the part of those running the campaign.

Participatory learning is the second type of initiative. This method is founded on the assumption that people will be more engaged and willing to change if they feel a part of the solution. Participatory learning often uses the following modes of dissemination within a particular community: publications, curricula, modules, group work and discussions, risk-assessment mapping, drills, social media, and polling. The goal of participatory learning is to influence change, advocacy for change, or at the very least encourage the community to think more about the hazards they could face.

A step by step guide for planning and implementing a participatory learning program is listed in the guide and discussed briefly here:

- Step 1: develop a guideline for what needs to be taught
- Step 2: practice skills that must be learned, e.g., constructing a shelter or performing response drills
- Step 3: provide response training, including first aid, triage, search and rescue, emergency communications and family reunification
- Step 4: practice/perform drills in different situations or emergency scenarios

The advantages of participatory learning are that it aids the community in realizing the threats that they face, and then demonstrates the tools used to combat these threats. It also allows organizations to work with others, including volunteers, local partnerships to be established, and communities to develop or "own their own data and plan". However, there are some disadvantages as well. This method requires a high level of work to implement, and may only reach a small group of people. Educators also need to be trained in participatory learning.

Informal education is the third approach towards hazard and disaster education. In short, informal education is used to disseminate a message wherever there is an opportunity to do so. It is more fluid than a campaign, but still uses many of the same methods. Volunteers are heavily relied upon, not only as educators, but as role models who can offer proof of success of the educational program. One form that informal education can take within the school system is a youth led Red Cross group, which would allow peers to teach each other about hazard reduction in a non-institutionalized way.

The advantages of informal education are that it uses volunteers to their full potential (and can be fun in the process), the activities can be tailored to many different ages and other demographics, and it can lead into formal education. On the other hand, informal education is not always uniform, and the quality and message coordination can vary across location and time. It cannot be implemented within institutions (e.g., schools) without the administrators' consent, and those not in school may require different outreach activities.

Formal school education is the fourth initiative listed in this guide for hazards and disaster education. This type of initiative involves the development of a school-wide disaster plan and associated training for hazard response procedures, including fire suppression, sanitation, evacuation, first aid, communications, and shelter. Drills should also be used to educate students and faculty on disaster responses. School curricula can also be used to enhance disaster education and can consist of standalone courses, modules integrated into current courses, or individual lessons combined with multiple other subjects, such as reading comprehension activities that are also about disaster preparedness. With any approach, it is important that the curricula include local hazards and weather trends, as well as local evacuation or shelter in place areas.

Formal education has many benefits. Learning through a curriculum can ensure that the level and quality of education remains consistent. Also, hazard education materials can be used in a variety of class exercises and applied to many different subjects/disciplines already taught within the curriculum. However, teachers may feel that the curriculum is already too full, and in turn, the courses may only be offered as electives. Additionally, teachers may not have the necessary expertise on hazard education. Finally, this type of education program requires a long term commitment from school administrators.

In order for any of these education initiatives to be effective, the messages must be standardized and consistent, and originate from legitimate and credible sources. Also, the programs must be easily scaled up if they are successful, and they must be sustainable. People will also be more receptive if those educating them practice what they preach. One example of this is the Columbian Red Cross. They are advocating for the public to reduce their waste in order the help the environment, and in order to increase their legitimacy, their own office has made strides to become paper free.

The guidance document also gives recommendations on how to make an effective program more scalable. First, the tools used in the program should be free and online for other organizations to use; costs should be shared among multiple parties in order to reach a larger population; cascading models of training should be used to create a large, high quality staff; radio and television can be used to disseminate information; online learning and billboards should be used; events that draw a large crowd should be taken advantage of; and any smaller disaster prevention program can “piggy back” off of other larger programs or businesses. Disaster response should be promoted especially after a disaster has occurred to take advantage of heightened awareness.

This guide concludes by defining all the different message dissemination tools, which programs they should be used for, which demographics they best target, and the advantages and disadvantages they have.

Key findings:

- People need to be prompted to seek information.
- People seek validation from many sources before they act.
- People go along with what they think others are doing.
- There are four types of education initiatives: campaigns, participatory learning, informal education and formal, school-based education.
- Campaigns can be used to reach a large number of people with a single, unified message.
- Participatory learning programs engage the public so that people learn through actions. First, it prompts the public to analyze what hazards they may have to face, then it gives them the tools for facing these hazards. People will be more engaged and willing to change if they feel that they are a part of the solution.
- Informal education focuses on taking advantage of opportunities to disseminate a message, rather than relying on a structured campaign model. These often focus on opportunities within the school system.
- Formal education relies primarily on curricula development for hazard education. The curriculum can include a standalone course, modules integrated into a particular subject, or multiple sources of information infused into many subjects.

Key recommendations:

- [35_1_8] Within all education initiatives (i.e., campaigns, participatory learning, informal education and formal, school-based education):
    - Messages must be standardized and consistent.
    - Those giving the message must be legitimate and credible.
    - The program must be scalable.
    - The program must be sustainable.

36. International Organization for Standardization . (2003, 10 15). Ergonomics- Assessment of Speech Communication . *International Standard: ISO 9921*. Switzerland: International Organization for Standardization .

Discipline: Standards
Rating: 7A

This report consists of guidelines for assessing the quality of different types of speech communication so that recommendations can be made for speech communication intelligibility and quality levels. One speech type that is discussed is warning and alert communication in hazardous situations, in turn, guidelines are provided for the level of quality of outdoor warning, public address systems.

This report describes communication quality using two parameters: intelligibility and vocal effort. Commonly used methods to determine speech intelligibility include Speech Interference Level (SIL), the Speech Transmission Index (STI), and the Speech Intelligibility Index (STI). This document provides information on all three methods.

For intelligibility for alert and warning situations, a rating of “poor” is deemed the minimum rating. According to Table F.1 in the document, a rating of “poor” corresponds to a “sentence score” of 70 % to 100 %, a meaningful phonetically balanced word score of 60 % to 80 %, a “consonant-vowel-consonant” non-sensical word score of 31 % to 53 %, an STI of 0.3 to 0.45, and an SIL of 3 dBA to 10 dBA.

The additional parameter for speech communications is the vocal effort. The maximum vocal effort required is determined to be “loud”. A vocal effort of “loud” is equal to a 72 dBA output.

Key recommendations:

- [36_1_2] For speech communication in alerting/warning situations, the intelligibility of the speaker needs to have a minimum rating of “poor” and a maximum vocal effort of “loud” (i.e., 72 dBA).

37. International Organization for Standardization. (1996, 12 15). Ergonomics- System of Auditory and Visual Danger and Information Signals. *International Standard: ISO 11429*. Switzerland: International Organization for Standardization.

Discipline: Standards
Rating: 7B

This standard focuses on the increased comprehension of visual and auditory danger signals. In order to do this, recommendations for making the signals more distinctive and representative of the urgency of the situation are listed.

A pattern should be used to make the signal easier to remember. However, other changes must be made to the signals, such as echoes or acoustical delays, because most people can only remember a few patterns.

The author notes that ISO 7731 and ISO 9921-1 must still be followed when designing new signals as well. In addition, the frequency components for signals that are used for urgent situations should be sweeping, alternating, or varying in some way. If a signal contains a constant frequency, it can be pulsed in order for it to be used for urgent situations. However, only a maximum of two pulse lengths should be used, and the longest pulse length should be at least three times longer than the shorter pulse length. This can be combined with a higher pitch to signify more urgent situations. Ideal temporal and spectral characteristics are specified within the report and matched to their specific urgency. The types of urgency range from “all clear”, “announcement/information”, “command”, “caution”, and “danger”.

Key recommendations:

- [37_1_2] A pattern should be used to make the signal easier to remember.
- [37_2_11] The frequency components for signals that are used for urgent situations should be sweeping, alternating, or varying in some way.
- [37_3_2] If the signal frequency does not vary, then the signals should be pulsed. Only a maximum of two different pulse lengths should be used, and the longest pulse must be three times longer than the shortest pulse.

38. Johnson, V. A. (2013). *An Impact Evaluation of ShakeOut, an Earthquake and Tsunami Drill in Two Coastal Washington State School Districts.* Wellington: GNS Science Report.

Discipline: Crisis Management/Disasters
Rating: 4A

In 2012, Washington state schools performed the Shakeout earthquake drill. Some schools followed the earthquake drill with a tsunami drill, since they were located in tsunami inundation zones. The authors of this study administered a pre-drill and a post-drill questionnaire to the students from two different coastal school districts. These questionnaires were nearly identical in order to assess whether or not there was any increase in knowledge about earthquake and tsunami response and preparedness after the drill (versus beforehand). A third survey was administered to teachers in order to understand their perspectives on the Shakeout drill.

Through comparing the results of the surveys it was found that after the Shakeout drill, there was no change in the students' knowledge about earthquakes (i.e., what to do in the event of an earthquake). There was no significant difference in the number of students who knew the correct response to "drop, cover and hold on", or the reason why this action is necessary during an earthquake. Additionally, around the same number of students (65 %), pre- and post-drill, responded incorrectly and said they would go to a doorway if a desk was not available under which to hide. With regards to tsunamis no change was apparent in student knowledge of the correct response to tsunami.

However, positive changes were seen in other areas of earthquake/tsunami knowledge after the Shakeout drill. For example, a higher number of students knew the following: not to go outside during an earthquake if they were already indoors, to drop to their knees and cover their heads, and that the biggest cause of injuries during earthquakes was flying objects and broken glass. Additionally, student perspectives varied when asked about their knowledge levels: 24 % of students felt that they were more aware following the Shakeout drill, while 64 % of students felt that their knowledge of earthquake response did not change, and another 10 % felt that they knew less. Similar percentages were reported when asked about their knowledge on tsunami events as a result of the Shakeout drill.

Teachers were also administered a survey on their perspectives on the drill. Also noted were their preparedness actions in response to earthquakes and tsunami: e.g., approximately 50 % of teachers assigned earthquake and tsunami preparedness home or class work, and 75 % reported that less than an hour is spent on these activities. The majority (62.9 %) of teachers thought that their school should perform an earthquake drill twice per year. They also offered several statements regarding what they think should be changed or added to disaster preparedness drills. One teacher stipulated that a simple but effective plan was needed, while others wanted to practice the drill more times per year and to impress upon their students the seriousness of disaster situations.

Key findings:

- Some improvements in increased knowledge or appropriate response were found as a result of the Shakeout drill; i.e.,
    - 15 % more students knew not to go outside during an earthquake.
    - 10 % more students knew to drop to their knees and cover their heads.
    - 7 % more students were able to correctly identify the biggest causes of injuries during earthquakes.
    - Approximately 25 % of students felt that they had increased their knowledge about earthquake/tsunami preparedness after the Shakeout drill.

- Slightly less than half the teachers administered classroom or homework activities about earthquake or tsunami preparedness.
- 75 % of teachers reported spending less than an hour on earthquake and tsunami preparedness activities.
- 62.9 % of teachers thought that their school should perform earthquake drills twice per year.

39. Keating JP. (1982, May). The myth of panic. *Fire Journal*, 57-62.

Discipline: Fire
Rating: 7B

In most fires, people do not panic. However, they may become intensely focused and in turn, unable to process all elements in the environment. Instead, they may only focus on the elements that are perceived as relevant to the situation. Under stress, they tend to fall back on familiar responses that may or may not serve them well in an emergency. The author presents recommendations for notification that take these factors into account. First, messages must be simple so that they represent a predominant cue that can be processed under stress. Second, international symbols should be used in signage, both to simplify the information and to allow occupants not familiar with the language to know what they are to do. Finally, occupants should be given all needed information. Instructions telling occupants to use the stairs, for example, should also indicate where the stairs are.

The effectiveness of notification is enhanced by education in advance of the emergency situation and by human factor considerations in building design. In this light, tragedies may be seen as opportunities to educate people about lifesaving behavior should they find themselves in a similar situation.

Key findings:

- Under stress, people may become intensely focused and be able to process only major elements in the environment that are perceived as relevant to the situation. They also tend to fall back on familiar responses that may or may not serve them well in an emergency.

Key recommendations:

- [39_1_3] Messages must be simple in order to represent a predominant cue that can be processed under stress.
- [39_2_3] Use international symbols in signage to both simplify the information and inform occupants not familiar with the language.
- [39_3_3] Give occupants all needed information, such as directions on where to go in addition to what to do.

40. Lachman, R., Tatsuoka, M., & Bonk, W. J. (1961). Human Behavior during the Tsunami of May 1960. *Science, 133*(3462), 1405-1409.

Discipline: Human Factors/Ergonomics
Rating: 7C

On May 23, 1960, a massive tsunami hit Hawaii. This tsunami, caused by an earthquake along the coast of Chile, was anticipated and warnings were disseminated 10 h before its arrival. However, 61 people died in this event. The authors of this article attempted to understand what people thought after receiving the alerts, and why they behaved in the way they did. In order to do this, a questionnaire was administered to a subset of the adult population living in Hilo, the city most affected by the tsunami. Questionnaires were first distributed at a Red Cross shelter, and additional participants were identified via snowball sampling techniques. Additionally, displaced people were identified through address directories of church congregations. A total of 327 people participated in this study, 28 of which had lost an immediate family member, and 50 of which were injured in the tsunami event.

One of the main alerting methods was the outdoor siren system. The intended meaning of the siren signal was an “alert” – i.e., the population should be alerted of something imminent. No further meaning or instructions were meant to be associated with the siren signal at that time. The authors reported that the sirens had been activated four hours prior to the wave hitting, for a duration of 20 min.

The study’s results showed 95 % of the participants heard the siren and that 94 % reported that they understood what the sirens meant. However, when asked specifically what they meant, only 4.8 % answered correctly; i.e., that the siren meant “alert” and nothing further. Instead, 4.5 % thought it signified “warning”, 24.4 % thought it was a signal that preceded evacuation, 28.9 % thought that it meant for people to evacuate, 8.9 % thought it meant to await further information, 6.2 % believed that the siren was signaling them to make preparations, and 22.3 % did not give any information regarding its meaning.

Over one-third of the respondents in the sample chose to wait in response to the sirens; more specifically, 46 % waited for ‘another or final siren signal’ and 27.3 % waited to receive information via the television or radio. The remainder of the sample did not provide a reason for waiting.

Additionally, portions of the sample sought additional information through a variety of means, including television or radio (68 %), relatives or friends (17.2 %), or some combination of both (8.4 %). A small number of people reported that they received information from the government, or a combination of the government and the previous sources mentioned. When asked what information they received, 61 % said they were told of the possibility of a tsunami, 8 % received word about the tsunami’s impact on Tahiti, 6 % received conflicting information either confirming or denying flooding in Hilo, and 6 % learned of an evacuation order. The remainder of the sample failed to answer this question.

Overall, this study shows the lack of understanding related to the sirens’ meaning and the resulting actions that should have been taken.

Key findings:

- The sirens signaled an alert four hours prior to the tsunami, and sounded for 20 min.
- 5 % of respondents did not hear/receive the sirens.
- 4.8 % of respondents understood the true meaning of the sirens as “alert”.
    - 4.5 % believed the sirens meant “warning”.
    - 24.4 % thought the sirens were a preliminary signal preceding the evacuation signal.

    - 28.9 % thought the sirens meant to “evacuate now”.
    - 8.9 % thought the sirens meant to await further information.
    - 6.2 % thought the sirens meant that they should make preparations.
- Of the 131 people who waited after the siren signal, 46 % said that they expected another siren signal; and 27.3 % said they thought more information would be provided through the television or radio.
- Respondents received additional information from television or radio, friends or relatives, government source, or some combination of these.

41. Laidlaw, E. (2001). The Controversy over Outdoor Warning Sirens. *Weatherwise*, *63*(1), 16-25.

Discipline: Human Factors/Ergonomics
Rating: 7A

This review outlines the negative aspects of sirens, as well as the reasons for their use. Limitations do exist for siren technology, including an "unrealistic societal dependence" on them; public desensitization toward them; outdoor placement where geographic factors, such as wind direction and varying topography, can limit sound quality; difficulties reaching certain populations (e.g., older adults and hearing impaired populations), the lack of standardization, and an inability to penetrate buildings. One of the main issues discussed in this review is the dependence that people have on sirens. On one hand, this dependence can cause unsafe practices in public response, for example, in locations where sirens are not working or are out of service. On the other hand, this dependence is also one of the main factors influencing current usage of siren technology. Many officials would prefer people use the weather radios to alert the public of impending severe weather; however, this would require everyone acquire, program, and maintain this technology. Furthermore, a general consensus has been reached across multiple studies that weather radio use by the public falls between 2 % and 5 %. Additionally, other alerting methods like email, phones, or text messages, can be negatively affected by carrier restrictions and bandwidth limitations. Finally, for most of these alerting options, other than siren systems, public participation is necessary for their successful dissemination.

This article also discussed differences among mechanical and electronic sirens, including the positive and negative aspects of their use.

Key findings:

- Outdoor siren systems may have or have to contend with certain limitations, including an unrealistic dependence by the general public, desensitization, sound limiting geography, difficulties in alerting the hearing impaired, a lack of standardization, and an ineffectiveness at penetrating buildings.
- The public relies heavily on sirens as an alerting system in severe weather events, including tornadoes.
- Sirens will likely remain part of the alert system for the foreseeable future and should be improved upon.
- Weather radios are used by around 2 % to 5 % of the public, and in order for this system to be effective, they must be acquired, programmed, and maintained by all individual users.
- Other alerting methods, such as email or text messages, can be negatively affected by bandwidth limitations or carrier restrictions.

Key recommendations:

- [41_1_5] If multiple emergencies are being alerted for, then an electronic siren may be more useful because it can broadcast many different tones. However, if only one or two emergencies are being alerted for, then mechanical sirens may be more beneficial because they last longer, and there is no need for multiple tones.

42. Lindell , M. K., & Perry, R. W. (1987). Warning Mechanisms in Emergency Response Systems. *International Journal of Mass Emergencies and Disasters, 5*(2), 137-153.

Discipline: Crisis Management/Disasters
Rating: 7B

Warning messages can be disseminated in a variety of ways. This paper aims to review the different methods of communicating warning messages and to analyze how effective informal, community warning networks are in comparison. The author reviews seven formal alerting or warning methods, including face-to-face warnings, route alert, sirens, telephones, television and radio, National Oceanic and Atmospheric Administration (NOAA) weather radio, and newspapers. *(Note: social media had not been developed when this article was published.)*

Face-to-face warnings are often used in flood emergencies, long range tsunami events and possibly hurricanes. They are best for getting full coverage of an at risk population, for instance a beachfront neighborhood. Costs are low, message distortion is minimal, but this type of warning also takes a long time to disseminate. Route alert is when a vehicle drives through at risk neighborhoods and, equipped with a PA system, broadcasts the warning. This method also takes a large amount of time as the message can only be understood if the vehicle moves slowly.

Sirens are classified as an alert rather than a warning because of the lack of specificity in the information that they provide. The author maintains that people must first be taught the meaning of a siren signal, and this meaning should be relatively simple. In the same vain, using different tones for different hazards increases the complexity of the meaning assigned to the siren, and is less likely to be remembered. Therefore, the author discourages this practice, in favor of having one, all-hazard alert in combination with a significant educational effort with regards to its meaning.

The benefits of radio and television include their ability to broadcast specific messages in a relatively fast period of time. However, people must already be watching or listening in order to receive the message, and the message can reach people outside the risk area. NOAA weather radios are relatively cheap, and their messages are short but specific. However, not all residents may have a radio and 10 % to 20 % of the U.S. is not covered by NOAA weather radios. Telephones, used in the form of a calling tree, can send a specific warning, but this does run the risk of distorting the message as it travels further from the source. Additionally, the telephone systems can become saturated, or the system can break down if people are not home to receive calls.

The author states that newspapers are less useful for emergency warning dissemination, as they are publicized too slowly. Before a disaster occurs they can be useful for public education about emergency procedures.

In order to assess how informal message networks supplement formal warning dissemination, in person interviews were conducted in three towns in Washington State affected by the Mount Saint Helens eruption. Toutle and Silverlake were approximately 32 km (20 miles) from the mountain peak and Woodland was 56 km (35 miles) from the mountain peak. The Toutle/Silverlake region was more at risk than the Woodland region, had received more disaster training, and likely felt a higher level of threat. Random samples were drawn from phone directories and a city directory.

Within the first 15 min following the eruption, 68 % of the Toutle/Silverlake communities knew about the eruption and only 15 % of the Woodland community had received similar information. It took between 51 min and 70 min for the same percentage of the Woodland community to receive the warnings. In the

Toutle/Silverlake region, 30 % saw evidence of the eruption as their first awareness of the disaster, 58 % received information from informal social networks, 6 % received official warnings, and 6 % saw/heard the evidence on television or radio. Conversely, 34 % of the Woodland community got their first set of information on the disaster from radio or television, 47 % from informal social networks, and 14 % saw the eruption, or signs of it.

The first warning that specifically told people to evacuate was disseminated to 37 % of the Toutle/Silverlake population by informal social networks, either face-to-face or over the phone, and 28 % of the Woodland community was warned in the same fashion. Also, 44 % of the Toutle/Silverlake region and 11 % of the Woodland region were warned through official means, telephone calls, and route alert; 10 % of both populations were warned to evacuate through television or radio. Conversely, 50 % of the Woodland population and 6 % of the Toutle/Silverlake population did not receive an evacuation warning at all.

Overall, this paper showed that multiple warning methods are required in order to effectively disseminate warnings. Additionally, informal social networks were used to spread warning messages throughout the communities, especially when a high level of threat was perceived by residents.

Key findings/recommendations:

- [42_1_8] Sirens lack specificity, and thus a “meaning” needs to be taught to the public that they can then associate with the siren sound or signal.
- [42_2_8] A strong sense of risk and increased hazard education improves alert and warning dissemination speed and breadth. Additionally, it promotes more use of informal social networks, which increase dissemination and help people confirm the threat.
- [42_3_5] When meanings become more complicated, the public is less likely to remember them. Meanings can become especially difficult to remember when there are different meanings attached to different tones.
- [42_4_5] Sirens should have only one, simple meaning attached to them, and multiple tones should not be used.
- [42_5_3] There was no one type of warning method that reached the majority of people.
- [42_6_3] Multiple warning methods must be used, usually something that can reach a large number of people combined with something that can deliver a specific message. For instance, sirens and radio or television.

43. Mahn, J. (2013). *An Evaluation of the Signals Used for Tsunami Warnings in New Zealand.* Christchurch, New Zealand: Acoustics Research Group: Department of Mechanical Engineering.

Discipline: Acoustics/Audiology
Rating: 4A

This report consists of a review of the literature on tsunami warning systems. The author begins by listing the requirements for danger signals as published by the International Standards Organization (ISO). These requirements are broken into the following categories: audibility, distinctiveness, unambiguity, moving sources, spectral characteristics, and temporal characteristics.

ISO requires a minimum sound pressure level of 65 dBA in its warning area of the signal, and that the signal must be played at a higher volume than ambient noise. Several methods for measuring ambient versus signal noise are listed, followed by the stipulation that the signal level cannot surpass 118 dBA.

It was also stated that ISO requires danger signals to be distinctive. In order to increase distinctiveness, impulse sound should be avoided. Impulse sounds include horn blasts, or something similar that are associated with happy, celebratory events. ISO also requires that the warning be unambiguous, and that the meaning of the siren should be clear. No specific instruction is given beyond that. However, the literature reviewed by the author shows that only one signal should be used versus multiple tones, and that public education is necessary. The author continues to list ISO standards, and states that, moving source sirens must be audible no matter which direction they are facing. With regards to spectral characteristics, ISO maintains that a frequency between 500 Hz and 2 500 Hz must be included within the signal. However, a frequency below 1 500 Hz should also be included in order to reach those with hearing loss or impairments.

A series of temporal characteristics are required by ISO. Tones should contain pulses, rather than simply containing a steady signal. The pulses should be repeated at frequencies between 0.5 Hz and 4 Hz, and the pulses should not mimic a noise present in the ambient noise. Furthermore, discrimination between two signals with fast, but similar pulse rates and different frequencies becomes difficult for the majority of people. Changing fundamental frequencies are preferential for signal tones. Finally, the temporal characteristics of the signals should correspond with a specific alerting tone.

Using these guidelines as a framework, as well as sources on acoustics and alerting systems, the author provides recommendations on how to improve tsunami warning systems used in New Zealand. The author concludes that in order to increase audibility, the signal should contain a frequency of 1 000 Hz or less. Higher siren placement can also decrease attenuation and increase audibility. It was also found that frequencies of 250 Hz, 1/3 octave, are most effective at penetrating windows, and thus can be used to increase audibility.

It is also possible to increase perceived loudness by adding a 4 000 Hz frequency to the alarm and by including longer pulses and a rising or sweeping frequency. Perceived urgency is also explored and it was found that a higher frequency, rapid pulse rate, and random or irregular harmonics can increase perceived urgency of the receiving public. Furthermore, multi-toned signals are deemed advantageous, because they are more distinctive and can be designed to prevent masking from ambient noise.

The author ends by recommending the ideal siren design, listed below.

Frequency components for each pulse:

- [43_1_2] 225 Hz increasing in time to 355 Hz to allow the signal's sound to penetrate windows.
- [43_2_2] 500 Hz plus three harmonics increasing with time to 1 000 Hz (recommended by ISO7731).
- [43_3_11] 3 000 Hz increasing to 4 000 Hz to impress a sense of urgency among the public.

Signal shape:

- [43_4_2] Pulse level and rate start out low to minimize startle reaction, the level and rate gradually increase, pulse level and rate then start to decrease again, and this burst of sound repeats.

Other findings/recommendations:

- [43_5_2] Discrimination between two signals with fast, but similar pulse rates and different frequencies becomes difficult for the majority of people. Changing fundamental frequencies are preferential for signal tones.
- [43_6_2] The temporal characteristics of the signals should correspond with a specific alerting tone.

44. Mayhorn CB. (2005, November). Cognitive Aging and the Processing of Hazard Information and Disaster Warnings. *Natural Hazards Review*, *6*(4), 165-170.

Discipline: Crisis Management/Disasters
Rating: 7A

This paper reviewed findings regarding the cognitive effects of aging in the context of the Protective Action Decision Model (PADM), which defines the relationships among the source (message originator), channel (delivery method), and receiver (decision-maker). Recommendations are made for modifications to public risk communication messages and delivery that will be more effective for older adults. Effective communication of hazards and protective action recommendations can reduce the incidence of trauma and fatalities within this vulnerable population. The cognitive processing of the message by the receiver is affected by many factors, including perception, attention, memory, text comprehension, and decision-making, and may be influenced by the design of the message and its delivery.

Perception: For auditory alerts, higher frequencies (above about four kHz) become harder to hear due to both noise-induced and age-related hearing losses, and background noise is harder to filter. Information from multiple speakers in a noisy environment (e.g., from the radio, telephone, PA system, or face-to-face) is often missed. Auditory alerts should be transmitted at frequencies below four kHz that are not affected by hearing loss. Multiple modes of alert and warning message transmission are advised, both to reinforce the alert/message and to make sure that at least one alert/message is perceived and understood.

Attention: Older adults have a harder time using selective attention to filter out irrelevant auditory information. This is especially problematic in noisy or chaotic environments that may be encountered in a disaster. Intrusive alarms should be used to disrupt other tasks (including sleeping) and gain attention.

Comprehension: Older adults are less able to draw inferences from novel warnings (messages). Warnings that are specific (hazard, location, time, and guidance), clear, and accurate reduce the need to make inferences and thus improve comprehension. The text of the messages should only include simple words (no technical words or jargon) and sentence structure to avoid confusion. Testing should be done before deployment of the warning to make sure that it is comprehensible by the intended audience.

Memory: Different types of memory are used to process alert and warnings. Semantic memory is the store of information built by experience, which is not affected by age, and can be improved with training. Age does affect working memory, which can be taxed by complex tasks such as safety procedures. Older adults may choose less protective procedures over more complex ones (e.g., with more steps) because they are aware of their limitations. To avoid overtaxing working memory, warning messages should use simple sentence structure and break protective actions to be taken into a few, simple steps. Presenting alerts and warning information in a familiar way both counters memory limitations and improves credibility. Feedback from the community is required to assess what alerts and warning messages are most effective.

Decision making: More research is needed on decision-making processes for older adults. Studies indicate that older adults consider fewer pieces of information than younger adults and are susceptible to biases. They may be more cautious than younger adults, but the speed and quality of decisions appear to be similar. The number of feasible options available to older adults may be reduced due to physical disabilities, low financial means, and inadequate social networks.

Protective action recommendations should include options that allow everyone to be protected regardless of age, ability, or financial means. Improving risk communications for older adults is likely to improve them for everyone.

Key findings:

- For auditory alerts, higher frequencies (above about four kHz) become harder to hear for older adults due to both noise-induced and age-related hearing losses, and background noise is harder to filter.
- Information from multiple speakers in a noisy environment (e.g., from the radio, telephone, PA system, or face-to-face) can be missed by older adults.
- Older adults have a harder time using selective attention to filter out irrelevant auditory information.
- Older adults are less able to draw inferences from novel warning messages. Warnings that are specific, clear, and accurate reduce the need to make inferences and thus improve comprehension.
- Semantic memory, the store of information built by experience, is not affected by age and can be improved with training
- Age affects working memory, which can be taxed by complex tasks such as safety procedures. Older adults may choose less protective procedures over more complex ones because they are aware of their limitations.
- When making decisions, older adults consider fewer pieces of information than younger adults and are susceptible to biases.
- Older adults may be more cautious in decision-making than younger adults, but the speed and quality of the decisions appears to be similar.
- The number of feasible options available to older adults may be reduced due to physical disabilities, low financial means, and inadequate social networks.

Key recommendations:

- [44_1_2] [44_1_1] For elderly populations, transmit auditory alerts at frequencies below four kHz that are not affected by hearing loss.
- [44_2_2] [44_2_1] Eliminate background noise, especially for elderly populations.
- [44_3_3] Multiple modes of alert and warning message transmission are advised, both to reinforce the alert/message and to make sure that at least one alert/message is perceived and understood.
- [44_4_1] Intrusive alerts should be used to disrupt other tasks (including sleeping) and gain attention.
- [44_5_1] Presenting alerts and warning information in a familiar way to older adults both counters memory limitations and improves credibility.
- [44_6_3] [44_6_1] Protective action recommendations should include options that allow everyone to be protected regardless of age, ability, or financial means.
    - New technology may be very useful, but should be tested before deployment

45. McGregor, J. D., Elm, J. P., Stark, E. T., Lavan, J., Creel, R., Alberts, C., Woody, C., Ellison, R. & Marshall-Keim, T. (2014). *Best Practices in Wireless Emergency Alerts.* Software Engineering Institute.

Discipline: Standards
Rating: 4A

Wireless Emergency Alerts (WEA) is a system that allows public safety officials to disseminate short messages to cell phones located in specific locations. These are sent through Commercial Mobile Service Providers (CMSPs) using the Federal Emergency Management Agency's (FEMA) Integrated Public Alert and Warning System Open Platform for Emergency Networks (IPAWS-OPEN).

This article discusses the importance of educating the public about WEA, which can be done using state-generated materials, press releases, media interviews, social media, the emergency management agency's website, presentations at town hall and civic group meetings, among other methods. For public education, the authors suggest conducting outreach and informational programs before the WEA system is in place and operational. There are some educational materials provided by the IPAWS program management office. These include public service announcements, a webpage, and an online training called "IPAWS and the American People". These training programs focus on informing the public of what WEA is used for and how to access the system. Supplemental education material can include press releases, local media interviews, social media or, website posts, and presentations to local groups.

Training materials should focus on questions that are often asked about WEA. These include questions like, "What is it? Who issues WEA messages in my area? Will I have to pay for WEA messages? How is WEA different from subscriber-based Short Message Service alerts? and What carriers and what mobile devices support WEA?" It is important to inform the public of when WEA will become operational, and what events warrant the use of WEA messages. Education efforts can also lessen doubts about privacy issues, over alerting, and nighttime alerts. CMSPs can be referred to as information sources about WEA capable devices and coverage area.

Key findings/recommendations:

- [45_1_8] Conduct outreach and informal programs before the WEA system is in place.
- [45_2_8] Use the educational material provided by IPAWS.
- [45_3_8] Press releases, television, radio interviews, social media posts, website posts, and presentations can also be used to educate the public.
- [45_4_8] The educational materials should answer questions such as: What is WEA? Who issues WEA messages in my area? Will I have to pay for WEA messages? How is WEA different from subscriber-based Short Message Service alerts? What carriers and what mobile devices support WEA?
- [45_5_8] Education can lessen doubts about privacy issues, over alerting and nighttime alerts.

46. Milligan , P., Allan, J., & Cuthill, J. (2012). 'Name That Tune': Alarms in critical care - How good are we at recognizing them? *Journal of the Intensive Care Society*, *13*(2).

Discipline: Medicine/Critical Care
Rating: 7A

The Intensive Care Unit (ICU) in any hospital is filled with alarms that represent the status of the patients. The purpose of this study was to understand recall of alarm meaning for multiple signals by hospital staff, including nurses and doctors. A total of 14 ICU alarms were tested: multiple ventilator alarms, multiple syringe driver alarms, an abnormal heart rate alarm, a charged defibrillator alarm, infusion pump alarms, feeding pump alarms, an emergency bedside alarm and the door alarm. The study's participants included 17 nurses and nine doctors who had some experience working in the ICU. Each alarm was played twice for the participant, after which each participant was asked to identify the piece of equipment associated with that alarm and what issue the sound represented, if applicable. Overall, each participant could score a maximum of 23 points if all alarms were identified correctly.

The median scores were 83 % for nurses and 43 % for doctors. Additionally, three alarms deemed the most important were analyzed. These three alarms were the ventilator alarm, recognized by 88 % of nurses and 58 % of doctors, the emergency buzzer, recognized by 71 % of nurses and 29 % of doctors, and the abnormal heart rate alarm, recognized by 88 % of nurses and 57 % of doctors. Overall, the study showed that a higher percentage of ICU nurses were able to recall alarm meaning for multiple signals, when compared with the doctors in this study. This difference in results, although not statistically significant, could be due to the fact that nurses spend more time at the patient's bedside, handle the equipment more often, potentially have more training on the equipment, and/or had been working in the ICU longer than the doctors.

Key findings:

- ICU nurses were able to identify 83 % of the 14 alarms, while ICU doctors were able to identify 43 % of the 14 alarms.
- For the most critical alarms, nurses were consistently better at recognizing them.

Key recommendations:

- [46_1_4] Different companies producing similar hospital equipment should standardize the alarm signals that are used.
- [46_2_4] Alarm technology and equipment technology should be improved to increase the specificity of alarms and minimize false alarms.
- [46_3_5] Unnecessary alarms should be eliminated from hospital technology.

47. Mitchell , J. T. (2009). Hazards Education and Academic Standards in the Southeast United States. *International Research in Geographical and Environmental Education*, *18*(2), 134-148.

Discipline: Education
Rating: 7A

Much of the hazard education currently researched and practiced focuses on educating professionals, homeowners, first responders, and adults. However, the K-12 school system could be a very useful place to teach younger generations about hazards, and how to prepare for them. In this study, the author reviewed the academic standards for ten different states; i.e., Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia. Academic standards are state-by-state guidelines outlining the teaching requirements for each grade. Teachers and schools are held responsible for teaching these mandated topics, and students are tested periodically to make sure that they are learning the required material. Reviewing academic standards would identify if hazard education is mandatory and if standards vary by geographic area and/or grade level.

A review of the academic standards for the ten U.S. states revealed that hazard terms, such has earthquake, drought, and evacuation, were more prevalent in the science curriculum than in the social studies curriculum. The science curriculum was more focused on the physical aspects of hazards, such as what types of meteorological conditions resulted in a hurricane, rather than the human aspects of hazards. Also, geophysical topics, especially earthquakes and volcanoes, were overrepresented in science curricula.

Conversely, the social science curricula did not focus as much attention on geophysical hazards and generally provided vague descriptions of what should be taught. Rather than discussing specific hazards, terms like “natural disasters” were used to indicate what should be taught. Furthermore, there was almost no evidence to show integration of the human and physical aspects of hazards within a curriculum.

One final aspect noted was that many of the academic standards required that teachers educate their students on hazards in different countries rather than hazards that could happen in their own community. This gives rise to the common notion that “it’s always going to happen somewhere else” and that it is unnecessary to prepare for such an event.

According to the author, the subject of geography was seen as a solution to the lack of hazard education, and particularly the lack of integration. Geography deals with both the physical aspects of the environment, as well as the cultures and communities that inhabit them. This discipline could be used to present the physical aspects of hazards in conjunction with learning about human response to those hazards.

Key findings:

- Hazard terms were much more prevalent in science than in social studies academic standards.
- Geophysical hazards, mainly earthquakes and volcanoes, were overrepresented in science academic standards.
- Hazards were underrepresented in social studies academic standards, and specific hazards were rarely listed.
- Hazards were taught in a way that gives students the impression that they may never experience such an event.
- There was little integration between the human and physical aspects of hazards.

Key recommendations:

- [47_1_8] The subject of geography could be used to teach students about hazards. This subject can focus on the physical and human aspects of hazards.
- [47_2_8] Classrooms across the U.S. should be sampled, because it is possible that teachers are teaching about hazards, even though it may not be required.

48. Mogil, H. M., & Groper, H. S. (1977). NWS's Severe Local Storm Warning and Disaster Preparedness Programs. *Bulletin of the American Meteorological Society, 58*(4), 318-324.

Discipline: Crisis Management/Disasters
Rating: 5C

This document outlines the efforts by the National Weather Service (NWS) to increase community preparedness for severe weather and storms. In order to take advantage of improved forecasting techniques, the NWS puts a large emphasis on disaster preparedness programs. Preparedness protocols can help minimize deaths and injuries due to severe storms, as statistics within the report show.

Currently, the NWS has 19 Weather Service Forecast Offices (WSFO) that employ a disaster preparedness meteorologist. These offices have five different responsibilities regarding disaster preparedness. First, they must hold preparedness meetings with government agencies, which address local warning communication systems, spotter networks, and any other methods for increasing preparedness. They also partner with qualified professionals, such as scientists or engineers, in order to gather weather safety information. This often focuses on schools, and officials at the WSFO often work with superintendents to encourage tornado drills. The disaster preparedness meteorologist must also work with the media and develop partnerships that will aid in the dissemination of disaster information, including watches and warnings. Finally, they work to educate the public using methods such as publications, including news releases and films.

The rest of the report focuses on forecasting programs, and how the information obtained can be disseminated. The NWS states that weather watches and warnings are disseminated using television and radio, NOAA weather wire service, NOAA weather radio, hot-line telephones, sirens, and national press wire services.

Key findings:

- The implementation of disaster preparedness programs aids in minimizing death and injuries due to severe storms.
- Weather Service Forecast Offices have five responsibilities. They hold preparedness meetings, design safety information in partnership with scientists and other professionals, engage with schools to encourage tornado drills, communicate with the mass media to disseminate information, and distribute severe weather and response information through publications, videos, and news releases.

49. National Association of the Deaf. (n.d.). *Emergency warnings: Notification of deaf or hard of hearing people*. Silver Spring, MD: NAD (Author).
http://tap.gallaudet.edu/emergency/nov05conference/EmergencyReports/NADEmergency.doc

Discipline: Human Factors/Ergonomics
Rating: 4

The National Association of the Deaf provides this document to inform broadcasters and public emergency management about their legal responsibilities to modify alerting and warning information procedures to meet the needs of the deaf and hard of hearing community. Listed here is some of the guidance provided by this document that is specifically related to emergency messages and dissemination practices:

- All television broadcasters, cable operators, and satellite television services that provide local emergency news are required by the Federal Communication Commission (FCC) to relay all essential emergency information via captioning or other visual means. A simple crawl at the bottom or top of the screen is adequate if it matches the information provided to other customers. However, broadcasters must provide critical information in visual form about all emergencies, including circumstances that require interrupting a program with live information and special news updates. A feed to a live real-time captioner or an on-side steno captioner is the best way to provide this information. Care must be taken not to block the visual emergency information, including with other captioning.
- Examples of critical information to be communicated during an emergency are: specific details about the affected areas; evacuation orders, including the areas to be evacuated and evacuation routes; approved shelter locations and/or instructions on sheltering in place; instructions on how to protect property; road closures; and instructions on obtaining relief assistance.
- Federal, state, and local governments are legally required to make their emergency notification systems accessible to deaf and hard of hearing people.
- National Oceanographic and Atmospheric Administration (NOAA) Weather Radio broadcasts only an auditory signal. Textual information from NOAA National Weather Service radio broadcasts is now available through modified radio receivers, which provide an alert through a strobe light, an auditory signal, and, if requested, a pillow vibrator or bed shaker to awaken the person. The receiver displays the type of warning (watch, warning, or advisory) that has been issued, although not the full text of the National Weather Service warning. This information is available through more sophisticated units connected to a satellite feed or through a pager system.
- Some communities, especially in areas frequented by tornadoes, have added a visual cue such as a powerful strobe light to outdoor siren systems. This can aid in alerting individuals, but is limited to those who are awake and in direct line of sight from the tower.
- Interpreters for the deaf need to be part of emergency training and disaster relief assistance programs for the public.
- A possibility being considered by some communities is the use of Reverse 911 systems to alert deaf or hard of hearing populations. These systems are set up to enable an emergency notification agency to initiate "teletype" (TTY) calls to warn individuals in specific areas of an impending emergency.

Key findings:

- All television broadcasters, cable operators, and satellite television services that provide local emergency news are required by the FCC to relay all essential emergency information via captioning or other visual means in order to reach the deaf and hard of hearing population.

- Federal, state, and local governments are legally required to make their emergency notification systems accessible to deaf and hard of hearing people.
- Textual information from NOAA National Weather Service radio broadcasts is available through modified radio receivers, which provide an alert through a strobe light, an auditory signal, and, if requested, a pillow vibrator or bed shaker to awaken the person.
- The full text of a National Weather Service warning is available through receivers connected to a satellite feed or through a pager system.
- A powerful strobe light added to an outdoor siren tower can aid in alerting individuals but is limited to those who are awake and in direct line of sight from the tower.

Key recommendations:

- [49_1_1] Care must be taken by television broadcasters not to block the visual emergency information, including with captioning.
- [49_2_1] Examples of critical information to be communicated to the public during an emergency are: specific details about the affected areas; evacuation orders, including the areas to be evacuated and evacuation routes; approved shelter locations and/or instructions on sheltering in place; instructions on how to protect property; road closures; and instructions on obtaining relief assistance.
- [49_3_1] Interpreters for the deaf need to be part of emergency training and disaster relief assistance programs for the public.
- [49_4_1] Reverse 911 systems, which enable an emergency notification agency to initiate TTY calls, can be used to alert deaf or hard of hearing populations.

50. National Standards Authority of Ireland. (2008, 09 24). Ergonomics- Danger Signals for Public and Work Areas- Auditory Danger Signals. *Irish Standard EN ISO 7731*. Dublin, Ireland: National Standards Authority of Ireland.

Discipline: Standards
Rating: 7A

This report specifies guidelines for ensuring that auditory danger signals are audible and recognizable. In order for a signal to be audible, it must be 15 dBA above ambient noise, and the overall volume of the signal must not be lower than 65 dBA. It should be noted that a sudden increase in sound pressure level could cause a fright reaction. Frequencies anywhere in the range of 500 Hz and 2 500 Hz are acceptable, but the recommended specific frequencies are 500 Hz and 1 500 Hz. However, if the signal is being designed to reach those with hearing loss, frequencies below 1 500 Hz must be included at sufficient energy levels. The pulsating pattern and frequencies of signals should not be similar to any other ambient noise. Finally, the signals should have multiple and changing fundamental frequencies. For example, the fundamental frequency could sweep up.

Key findings/recommendations:

- [50_1_2] A signal must be 15 dBA above ambient noise, and a minimum of 65 dBA.
- [50_2_2] The frequencies of 500 Hz and 1 500 Hz should be included in the signal.
- [50_3_1] [50_3_2] If recipients of the signal have hearing loss, frequencies below 1 500 Hz must be played at a sufficient volume.
- [50_4_2] The fundamental frequencies should change throughout the signal, for instance, by sweeping up.
- [50_5_2] The pulse pattern should not resemble that of any other ambient noise.

51. Patterson, R. D., & Mayfield, T. F. (1990). Auditory Warning Sounds in the Work Environment. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 485-492.

Discipline: Human Factors/Ergonomics
Rating: 7B

Many alarm systems used in indoor environments are generally too loud, and induce a startle response. Furthermore, they inhibit communication, and drive the receiver of the alert to shut off the alarm before dealing with the situation at hand.

The authors of this paper focused on answering four questions in order to design more effective alarms. Through reviewing the literature, they aimed to find the ideal volume for alarms, the frequencies that would render the alarm audible and discriminable, the temporal characteristics that make the alarm attention grabbing, but not startling, and finally, temporal characteristics that make the alarm easier to memorize.

First, regarding volume, the correct level for an alarm was found to be 15 dB above the auditory threshold, not the ambient noise. Next, in relation to spectral characteristics, the alarm should contain four or more pitches that are all at the appropriate volume level. This reduces the risk of masking by unexpected noises. Regarding temporal characteristics, a pulse should ascend to its full volume over the course of 20 ms, in order to reduce startle response. A series of pulses make up a burst, and a series of bursts represents the overall alarm. Within a burst, the first two pulses should be at lower sound pressure levels, and successive pulses should be at higher sound pressure levels. The time between pulses and between bursts can be shortened to increase urgency, or lengthened to decrease it. Pitch can also be increased to increase perceived urgency. These aspects could change throughout the alarm as a function of the urgency of the situation. In other words, if the situation becomes more urgent, the pitch and speed could increase.

Key recommendations:

- [51_1_2] An alarm should have a sound level of 15 dB above the noise threshold in order to be audible and attention grabbing.
- [51_2_2] The alarm should consist of four or more pitches that are all 15 dB above the noise threshold in order to decrease masking effects, and for the signal to be audible.
- [51_3_2] A pulse should ascend over the course of 20 ms to avoid a startle response.
- [51_4_2] The first two pulses in a burst should be at lower sound levels, with the subsequent pulses at higher sound levels. This will also decrease startle responses.
- [51_5_11] Time between pulses and between bursts can be shortened to increase perceived urgency.
- [51_6_11] Pitch can be increased to increase perceived urgency.
- [51_7_11] The perceived urgency of the alarm should change to match changes in the urgency level of the situation.

52. Paul, B. K., Stimers, M., & Caldas, M. (2014). Predictors of Compliance with Tornado Warnings Issued in Joplin, Missouri in 2011. *Disasters*, *39*(1), 108-124.

Discipline: Crisis Management/Disasters
Rating: 7A

Many factors are associated with increased compliance to tornado alerts/warnings, including the lead time before the tornado hits, knowledge on how one should respond to an alert/warning, lack of experience with tornadoes, and being at home. This study administered a survey to residents of Joplin, Missouri in order to examine the factors associated with seeking shelter during the 2011 tornado. Using online surveys, phone surveys, and face-to-face interviews, residents were questioned about knowledge of tornado alerts/warnings, their responses, and demographic information, including age, gender, income, educational level, and marital status. The results were then analyzed using a multivariate logistic regression and odds ratios.

The study showed that past tornado experience is negatively associated with seeking shelter, as is being male. Furthermore, the use of multiple alerting/warning systems and being outside when these were disseminated, are positively associated with seeking shelter. However, while the odds ratio of having multiple alerting/warning systems and being at home was greater than 2, the data was not statistically significant, most likely due to the small sample. Finally, many reported that they heard sirens often, and because of this, did not respond to the alert.

Key findings:

- Males and people with tornado experience can be more vulnerable in tornado events because they are less likely to comply with the alerts/warnings.
- Being outside and having access to multiple alerting/warning systems can increase compliance.
- The majority of residents admitted to ignoring the outdoor sirens because they heard them so often.

Key recommendations:

- [52_1_8] Implementing an education program could be useful to inform the public of tornado alerts/warnings and how they should respond.
- [52_2_4] Policies for sounding the outdoor siren system during severe weather should address false alarms.
- [52_3_3] Multiple information and alert methods should be used to increase compliance.

53. Plotnick, L., Hiltz, S. R., & Burns, M. (2012). For Whom the Siren Sounds: Public perceptions of outdoor warning sirens in Northeast Alabama. *9th International ISCRAM Conference* . Vancouver.

Discipline: Crisis Management/Disasters
Rating: 5A

Two surveys were administered to the residents of Calhoun County, Alabama regarding alerting/warning systems for tornadoes. The first survey was administered in 2010, and the second survey was administered in 2011, directly after a tornado struck that resulted in 300 fatalities. Both surveys were administered online, through Jacksonville State University. The authors used these surveys to reveal the extent to which participants relied on outdoor siren alerts and other alerting/warning methods. The surveys were also designed to observe problems related to the outdoor siren system as well as changes in residents' perceptions and practices between 2010 and 2011.

The first survey was administered to 289 people, 119 of which were Calhoun County residents. The survey inquired about response to the most recent siren activation (in 2010). Around one fifth of residents and non-residents reported not being able to understand the voice communication disseminated by the siren system. Note: Calhoun County disseminates verbal instructions to residents via the siren system and uses different tones to indicate different hazard types. Regarding the usage of different tones, 44.5 % of Calhoun residents and 21 % of non-residents reported "having a degree of confidence" in telling siren tones apart. When residents received siren alerts, they took the following actions (listed in order of decreasing likelihood): checked the television or radio, checked a computer, went to a safe location, or ignored the warning. Clarity of the voice via the siren system seemed to increase the likelihood that people sought shelter; however, it did not affect the likelihood of taking any specific response action over another.

The data also show that residents were reliant on the sirens, with 40.9 % residents expecting them to provide the first alert of danger, and 84.4 % finding the sirens helpful. Other sources as a first alert included weather radios (17 %), with 61.3 % reporting that they owned one, and telephone, email and text (40 %).

The second survey, administered after the 2011 tornado resulted in 251 responses, 69 % of which were Calhoun residents. Much of the data was relatively similar, although on average, Calhoun residents did not understand voice communication via the siren system or the multiple tones. Since the tornado hit, 42.8 % of respondents indicated that they had changed their behavior. Of those that changed, 76.9 % reported listening more carefully to sirens, 43.3 % prepared a shelter location, and 40.4 % downloaded a tornado weather "app" (or application). The data from the second survey also showed that voice clarity via the siren system had a positive relationship with seeking shelter and checking the media for more information, as well as a negative relationship with the act of ignoring the siren.

Key findings:

- In 2010, 17.1 % of residents and 20.1 % of non-residents could not understand the voice communication disseminated via the outdoor siren system.
- In 2010, 44.5 % of residents and 21 % of non-residents reported some degree of confidence in understanding the meaning of the different siren tones.
- In 2011, the majority of respondents did not understand the voice communication disseminated via the siren system or the meanings of the different siren tones.

- When sirens sounded for both incidents in 2010 and 2011, respondents were most likely to check the television or radio for information, followed by checking the computer, going to a safe location, or ignoring the siren.
- In both 2010 and 2011, residents found the outdoor sirens helpful, and in 2010, 40.9 % of residents expected the sirens to be their first alert.
- In 2010, voice clarity via the outdoor siren system had a positive relationship with the likelihood that respondents would seek shelter; however, in 2011, voice clarity had a positive relationship with the likelihood that respondents would seek shelter and/or information through media. Additionally, voice clarity had a negative relationship with the likelihood of ignoring the siren.
- While 61.3 % of respondents owned a weather radio in 2010, only 17 % thought it was the best alerting/warning method.
- 40 % of residents indicated that receiving alerts/warnings via telephone, email and text were the most helpful (in 2010).
- Following the 2011 tornado, 42.8 % of respondents reported changing their behavior in the following ways:
    - 76.9 % listened more carefully to sirens
    - 43.3 % prepared a safe shelter
    - 40.4 % downloaded a tornado weather app (or application) to their smartphone

Key recommendations:

- [53_1_8] Education should be provided to help residents understand the difference between siren tones.
- [53_2_3] Multiple channels of information should be provided; it is not enough to just sound the outdoor siren system.

54. Proulx G. (2001, May). Occupant Behaviour and Evacuation. *Proceedings of the 9th International Fire Protection Symposium,* Munich, Germany, 219-232.

Discipline: Fire
Rating: 5A

Building fire systems often assume certain occupant behavior that may or may not reflect how occupants actually behave in a fire. Occupants often ignore fire alarms in large public buildings, possibly out of concern about overreacting to a false alarm or a situation that is already under control. This delays evacuation and other protective measures. Occupant behavior depends on the occupant, the building, and the fire. Commitment to an activity (eating, watching a movie, waiting in line) can delay response. Other factors include social roles, the presence of smoke and other cues, time to investigate, and collecting children and valuables.

Audible alarm features that affect behavior include the alarm type, audibility, and location, the number of nuisance alarms that reduce the credibility of the alarm system, and the voice communication system. In fire drill studies, an apartment building was judged to have a good audible fire alarm system when over 80 % of residents reported that the fire alarm in their apartment was loud enough. In these buildings, the mean delay time to start evacuation was about three minutes, compared to about nine minutes in the two buildings where over 20 % of residents judged the alarm signal to be too quiet. For 1 000 occupants in three office buildings, the mean time to start evacuation was 50 s. Despite training, occupants spent time on other tasks before leaving their offices. Staff actions were credited for rapid evacuation in a retail store and got transit passengers moving in an underground station. In the absence of staff instruction, passengers did not start to evacuate after activation of the fire alarm. Voice communication informing passengers of the type of incident, its location, and what to do was as successful as staff in provoking action, with a delay time of only 15 s after the voice message. From fire victims, a delay time of 10 min after hearing the alarm was reported in a nighttime high-rise fire. In a nighttime fire where the alarm was inaudible, evacuation did not start for 10 min to 30 min. In another case with alarm sounders in every unit, delay times were five minutes, with occupants waiting for the voice communication system.

To reduce the delay time before evacuation, a recognizable fire alarm signal (the standard T-3 evacuation signal as described in ISO 8201) should be installed. Attention-getting changes should be made to the environment, such as shutting off the movie, turning off the background music, and/or turning up the lights. A voice communication system should be installed in large public buildings. Voice alarms should be given as soon as the emergency has been identified in order to reduce the delay time. The message should be simple, direct, and truthful. It should give the location of the fire and what is expected of occupants, including specific directions to the exit. A live voice should be used since recorded messages can be ineffective or dangerous. A live voice can be updated with new information, can convey the appropriate urgency, and is perceived as more credible and reliable. Closed-circuit TVs installed for security purposes can be used to monitor the situation. Staff must be well-trained, since they will be perceived as reliable sources of information. Calculation of movement should include the willingness of occupants to try to travel through smoke, which is potentially lethal and slows movement considerably.

Key findings:

- The credibility of the fire alarm system is reduced by false alarms, test alarms and prank alarms.
- Voice communication informing passengers of the type of incident, its location, and what to do was as successful as staff in provoking action, with a delay time of only 15 s after the voice message.

Key recommendations:

- [54_1_4] To reduce the delay time before evacuation, a recognizable fire alarm signal (the standard T-3 evacuation signal as described in ISO 8201) should be installed.
- [54_2_2] Attention-getting changes should be made to the environment during an alarm, such as shutting off the movie, turning off the background music, and/or turning up the lights.
- [54_3_3] A voice communication system should be installed in large public buildings.
- [54_4_3] Voice alarms should be given as soon as the emergency has been identified in order to reduce the delay time.
- [54_5_3] The voice message in an emergency should be simple, direct, and truthful. It should give the location of the fire and what is expected of occupants, including specific directions to the exit.
- [54_6_10] [54_6_11] A live voice should be used since recorded messages can be ineffective or dangerous. A live voice can be updated with new information, can convey the appropriate urgency, and is perceived as more credible and reliable.
- [54_7_8] Staff must be well-trained, since they will be perceived as reliable sources of information.

55. Proulx, G., Laroche, C., Jaspers-Fayer, F., & Lavallee, R. (2001). *Fire Alarm Signal Recognition.* National Research Council Canada.

Discipline: Fire
Rating: 6A

The temporal-3 (or T-3) pattern is an alarm that consists of three beeps followed by a pause. It has a specific length, temporal pattern, and sound pressure level, but the spectral characteristics vary depending on the environment that it is in. The goal of this new signal is to create a standardized alarm to be used worldwide to alert building occupants of an evacuation. With no formal education effort in North America, this study aims to assess if education is needed. Specifically, the study tests the public's recollection of the T-3 alarm sound, whether the public can identify what it means, and the perceived urgency of the sound.

Six alarm signals were used in this study, including the T-3 alarm, a car horn, the reverse/back up vehicle alarm, a fire alarm bell, a slow whoop alarm and an industrial buzzer warning. People who frequented buildings with installed T-3 alarms, such as shopping centers, office buildings, libraries and airports, were asked to participate in the study. Those who agreed to participate were asked to listen to each recorded sound, and after each sound, were asked the following three questions. "Have you heard this sound before? What do you think this sound means? How urgent do you feel this sound is on a scale from 1 being least urgent to 10 being the most urgent?" A total of 307 participants were tested, and an effort was made to keep the sample representative of Canada's population.

It was found that participants were able to recall the car horn (97 %), the reverse alarm (91 %), the industrial buzzer (81 %), the T-3 alarm (71 %), the fire alarm bell (58 %), and the slow whoop (52 %). In reference to which ones were easily identifiable, 98 % of participants could identify the car horn, 71 % identified the reverse alarm, 50 % identified the fire alarm bell, 23 % identified the slow whoop, 6 % identified the T-3 alarm, and 2 % identified the buzzer. Instead of identifying the T-3 alarm as a fire alarm, it was more commonly associated with a phone signal, or a reverse vehicle alarm. The T-3 alarm was also rated the least urgent of all the sounds. It should be noted that when the T-3 alarm was identified correctly as a fire alarm, its urgency rating tended to be higher.

The findings from this study suggest that public education is needed. This could come in the form of advertising, brochures, Internet websites, fire safety week themes, and the media. The study also suggests that the T-3 alarm could be installed in all schools, which would help to familiarize younger people, through drills, with the sound, the meaning of the sound, and the appropriate response. It is also recommended that the T-3 alarm be used for all fire alarms, whether or not evacuation is the goal. This would decrease confusion created by multiple alarms, and increase exposure to the alarm, which, in turn, could increase recognition. Finally, it is unlikely that residents will evacuate simply based on receiving an alarm. Instead, further instructions must be provided, possibly in the form of voice communication.

Key findings:

- The majority of participants recalled hearing the T-3 alarm before.
- Only 6 % were able to identify the T-3 alarm, or its intended meaning.
- The T-3 alarm was rated the least urgent signal out of the six alarm signals presented.
- It should be noted, that when it was known that the T-3 alarm was a fire alarm, the urgency rating was higher. This suggests that while the sound is not inherently urgent, it can be perceived as urgent if it has an urgent meaning associated with it (i.e., evacuation).

Key recommendations:

- [55_1_4] [55_1_8] Public education is necessary for the T-3 alarm to be useful.
- [55_2_4] [55_2_8] The T-3 signal should be installed in schools. This would help younger generations understand what the T-3 signal means, and the appropriate actions to take.
- [55_3_4] The T-3 alarm should be used for all fire alarms, even if evacuation is not necessary.
- [55_4_3] [55_4_4] Voice communication or other means of warning should accompany alerts to increase compliance.

56. Reese, S. (2005). *Homeland Security Advisory System: Possible Issues for Congressional Oversight.* American National Government: Government Finance Devision.

Discipline: Crisis Management/Disasters
Rating: 6A

This report outlined the main issues with the Homeland Security Advisory System (or HSAS), i.e., the color-coded system used to indicate the current terrorist threat level in the U.S. The first issue noted with the HSAS was the vagueness of its warnings. Out of the six times the threat level has been raised from yellow to orange (at the time this report was written), the reasons for increased threat were only identified once. Sources, and the quality of information, are completely unknown to the public. If the threats are not understood, they may not be deemed as credible by the general public. Additionally, if no information is provided along with the threat, it is difficult to broadcast a clear and informative public announcement.

Another problem with the HSAS, is that specifications for protective action are only tailored towards federal agencies. This is again very broad, and leaves the general public unsure of the proper course of action when presented with a change in color code.

The third problem with HSAS is the lack of any formal means of communicating the threat levels. Often, the HSAS is reliant on a variety of different communication systems to disseminate information, leading to discontinuity in message receipt among the affected population.

The report suggested that the HSAS should integrate with other federal warning systems, for instance those that warn for severe weather. However, this could be complicated due to the fact that the different warning systems use different transmitting equipment, standard messages, dissemination procedures, and training exercises.

Key findings:

- The main issues with the HSAS are the vagueness of alerts/warnings, the lack of specificity in recommendations for protective action, the lack of a formal communication systems for disseminating threat levels, and the cost incurred by states, counties and cities when a threat level is increased.

Key recommendations:

- [56_1_3] HSAS could disseminate specific, targeted warnings to areas that are at the highest risk.
- [56_2_8] Congress could encourage, or mandate, that the Department of Homeland Security implement specific guidance for each HSAS alert. However, guidance tailored towards specific groups should be implemented on a state-by-state basis.
- [56_3_3] Congress could require that all emergency warning systems update their existing technology in such a way that the various systems can work together, and so that all warnings can be disseminated to telecommunication devices, like cell phones.

57. Rogers G. O. (1985, September). *Human Components of Emergency Warning: Implications for planning and management* (Planning Report, FEMA Cooperative Agreement EMW-K-1024 with University of Pittsburgh). Washington, DC: Federal Emergency Management Agency.

Discipline: Crisis Management/Disasters
Rating: 6B

This article discussed how emergency messages could be more effective, given the human elements in dissemination. The human elements of warning dissemination (for both emergency officials and the general public) include: 1) sending the message, 2) receiving the message and evaluating its credibility, 3) evaluating the message for pertinence, 4) perceiving the threat, 5) selecting appropriate behavior, and 6) implementing the behavior.

Analysis of existing research on emergency warnings suggests the following:
1) For national emergencies, a Federal authority should alert Americans to the nature of the threat and local officials should notify the public of specific actions to be taken by local residents. This makes best use of the findings that Federal authorities have access to early warning systems, and local officials have greater credibility within the communities.
2) Warning messages should focus on simple protective or avoidance measures, since people naturally behave in familiar patterns during emergencies.
3) Take advantage of the public's willingness to participate in the warning process. In-home warning devices may be useful.
4) Make emergency warnings as specific as possible, including the nature of the threat, the area and likelihood of impact, and what simple actions can be taken alone and with others to ameliorate the situation. Nonspecific warnings encourage nonresponse in the presence of a real threat. Standard, generic warnings only lead people to seek more information since people will seek to reduce uncertainty.
5) Emergency preparedness and planning combined with drills and practice associate emergency responses with more routine and familiar behavior. Personal history matters. Enhanced adaptive response is seen with survivors of previous disasters, are more likely to act or obey authorities quickly rather than seeking additional information.
6) When evacuation occurs, an all-clear signal is needed to prevent premature return to a hazardous area.
7) Issue warning messages as early as possible, instructing local officials to transmit the warning without delay.
8) Repetition of a warning message that includes the actions that should be taken strengthens adaptive responses to the hazard. People will seek confirmation from multiple sources, so consistency is important.
9) Encouraging people to contact their neighbors with information will reduce the overloading of communication systems, warn individuals that might not have received the warning, and help to confirm the warning for those who have received the message. People are less likely to seek confirmation if with family.
10) Warning messages should be followed with a short list of easily recognized indicators of danger.
11) Warnings need to be understandable and in language with a common meaning. Messages should use simple, everyday language with declarative sentences. Officials who speak other languages should be available to help non-native speakers.
12) Emergency officials must seek to affect the perception of the hazard in the minds of the public, since perception and not the actual hazard is what determines people's response. Older people must be convinced that they are able to respond. Individual responses to any message will vary based on past experience, source of warning, and interpretation.

Key findings/recommendations:

- [57_1_10] Because they have greater credibility with local residents than Federal authorities, local officials should notify the public of specific actions to be taken.
- [57_2_3] Warning messages should focus on simple protective or avoidance measures, since people naturally behave in familiar patterns during emergencies.
- [57_3_3] Take advantage of the public's willingness to participate in the warning process, including encouraging the installation of in-home warning devices.
- [57_4_3] Make emergency warnings as specific as possible, including the nature of the threat, the area and likelihood of impact, and what simple actions can be taken alone and with others to ameliorate the situation. Nonspecific warnings encourage nonresponse in the presence of a real threat. Since people seek to reduce uncertainty, standard generic warnings only lead people to seek more information.
- [57_5_8] Emergency preparedness and planning combined with drills and practice associate emergency responses with more routine and familiar behavior. Personal history matters. Enhanced adaptive response is seen with survivors of previous disasters, are more likely to act or obey authorities quickly rather than seeking additional information.
- [57_6_7] When evacuation occurs, an all-clear signal is needed to prevent premature return to a hazardous area.
- [57_7_3] Issue warning messages as early as possible, instructing local officials to transmit the warning without delay.
- [57_8_3] Repetition of a warning message that includes the actions that should be taken strengthens adaptive responses to the hazard.
- [57_9_3] People will seek confirmation from multiple sources, so consistency is important.
- [57_10_1] [57_10_3] Encouraging people to contact their neighbors with information will reduce the overloading of communication systems, warn individuals that might not have received the warning, and help to confirm the warning for those who have received the message. People are less likely to seek confirmation if with family.
- [57_11_3] Warning messages should be followed with a short list of easily recognized indicators of danger.
- [57_12_3] Warnings need to be understandable and in language with a common meaning. Messages should use simple, everyday language with declarative sentences. Officials who speak other languages should be available to help non-native speakers.
- [57_13_3] Emergency officials must seek to affect the perception of the hazard in the minds of the public, since perception and not the actual hazard is what determines people's response. Older people must be convinced that they are able to respond. Individual responses to any message will vary based on past experience, source of warning, and interpretation.

58. Rogers, G. O., & Sorensen, J. H. (1991). Diffusion of Emergency Warning: Comparing emirical and simulation results. *Risk Analysis*, 117-134.

Discipline: Crisis Management/Disasters
Rating: 7B

For this paper, a logistic model was created in order to analyze different alerting and warning dissemination methods. The methods that are studied include a system of outdoor sirens that inform people to seek more information, a system of tone-alert radios that can disseminate a warning message, a system of automatic dialing telephones that distribute a warning message while stopping incoming calls, and a system resembling route alert. Combined systems were also analyzed. These included sirens combined with either telephones, or radios. The hazard in question was the release of airborne, toxic materials. The logistic model predicted the probability that people at varying distances from the hazard will receive a warning before the toxic material reaches them. This was analyzed for three hazard onset speeds. The mathematical representation of the message/alert dissemination curve is as follows.

$dn/dt = k[a1 (N-n)] + (1-k) [a2n(N-n)]$

k is the proportion of people who are effectively warned, while 1-k represents those who were not alerted or did not understand the broadcast. The term “a1” represents the broadcast parameter (i.e., how many were reached initially) and “a2” represents the contagion parameter (i.e., how many were reached through people informing other people). The terms “a1” and “a2” will vary significantly for each system. “N” is the proportion of the population to be warned and “n” is the proportion warned at the beginning of each time period.

The variables in the previous equation are changed depending on which system they are representing. These parameters were determined using a limited data set of different disasters. The first data set was from three communities that were 20 and 35 miles from Mount St. Helens in Washington State. The second data set was from two train derailments in Pennsylvania. The curves that were generated were then compared with the data from four different warning scenarios. Surveys were administered to the five towns affected by these disasters. It was determined that telephone, radio alert, and siren systems combined with these alerting methods relied heavily on the broadcast portion, and hardly used the contagion factor. Alternatively, a siren system alone was entirely dependent on recipients seeking out further information, and thus relied more on the contagion aspect of dissemination. Media sources represented a middle ground along the spectrum of broadcast and contagion dependency.

It was found that the telephone system was the most effective warning system, as most people will respond and listen to a phone ring. Plus, it can offer additional information through two-way communication. Radios were less effective, as they were often difficult to hear or understand, and they did not offer two-way communication for information seeking. Both radio and telephone systems had the least effective contagion parameter.

Media systems were even less effective, and only disseminated warnings if people were watching the news, listening to radio stations etc. Media systems are also somewhat dependent on the contagion factor, meaning those watching must tell others to watch when they see something of importance.

Siren systems were found to be the least effective. This is primarily because they required immediate action on the public’s part. People will not understand what a siren means unless they seek additional information. Not all people will necessarily do this, and information may not be readily available.

However, the sirens were effective at spurring people to continue to disseminate the information, once they sought it out for themselves. This represents an effective contagion parameter.

Different penetration capabilities were also analyzed to understand the most effective alerting/warning system for rapid onset events. Penetration capabilities included the ability to interrupt sleep, penetrate indoors, reach an outdoor neighborhood, reach people in transit, and reach people at work or shopping. Watching television and listening to the radio were also included as factors that could override communication barriers. These seven parameters were combined with their probability of occurrence at different times of the day. The results of the logistic function were compared to data sets from several hazards including floods, the Mount St. Helens eruption and train derailments.

The three rapid onset scenarios tested consisted of a hazard moving at 1 m/s, 3 m/s, and 6 m/s. Additionally, ten minutes were allotted to represent the time taken by officials to decide to disseminate warnings or alerts. Sirens combined with either telephones or radio-tone alerts resulted in the best warning coverage for fast moving hazards, or nearby hazards. However, for the 6 m/s speed, this combination of alerts will not sufficiently warn people within 5 km and for the 3 m/s they will not sufficiently warn people within 2 km. Individually, these systems are effective if there is a lead time of 30 min to more than an hour. Overall, this logistic analysis demonstrates the need for multiple alerting/warning systems.

Key findings:

- Telephones alone were the most effective alerting/warning systems, followed by tone-alert radios, media and sirens.
- Sirens require that people act to find more information whereas the other methods can provide this information immediately.
- Telephones and radio were the most effective at broadcasting a warning with information, and the least effective at encouraging people to share this information with others.
- Sirens were the least effective at broadcasting information, but once information was sought, were the most effective at encouraging people to share that information with others.
- The media was somewhat effective at broadcasting and encouraging the “contagion” process. It represented somewhat of a middle ground.
- A combination of sirens and radio or telephones was the most effective at alerting/warning people for rapid onset hazards.

Key recommendations:

- [58_1_3] Multiple systems should be used to alert and warn people of an imminent disaster, especially if it has a rapid onset.

59. Rothman, A. J., Bartels, R. D., Wlaschin, J., & Salovey, P. (2006). The Strategic Use of Gain- and- Loss Framed Messages to Promote Healthy Behavior: How theory can inform practice. *Journal of Communication, 56*(Supplement), s202-s220.

Discipline: Medicine/Critical Care
Rating: 7A

When faced with a health problem, people are often told how they should act in order to improve their health. Often, they are told what to eat, whether or not to exercise, what treatment regimen they should be on, etc. However, people do not always base their decisions on advice from medical professionals. Other factors, like their own opinions, what their friends and family tell them, and social norms impact their decision making. Effective health messages can combat these outside, often contradictory influences, and ensure that more people practice healthy behavior.

This paper reviews research and theories surrounding health message framing as a means of increasing compliance. Message framing is usually broken down into two categories: gain and loss framing. Gain framing informs recipients of all of the benefits they could receive by taking certain actions. Loss framing portrays all of the negative outcomes that are possible, or all of the benefits they could lose, if action is not taken.

The first premise on which this paper is built is that, when loss framed messages are used, people are more willing to take risks, and when gain framed messages are used, they are more likely to avoid risk. Therefore, if the encouraged health behavior is perceived as risky, loss framed messages would be more effective, and vice versa. The question is, how do we classify the perceived risk of different health behaviors?

The authors offer an answer that is best described by examples. One class of health behaviors that are often perceived as risky are screening tests. This is not because screenings are invasive and could result in complications, but because there is a chance that one could receive news that they have a disease. Finding out that one has a disease is seen as an unpleasant outcome. Consequently, getting screened for a disease is often perceived as risky, because there is a high (perceived) chance of an unpleasant outcome. Therefore, when encouraging people to get screened or tested, it would be most effective to use loss framing.

Conversely, prevention behaviors are often seen as low risk behaviors. An example given was wearing sunscreen. This action is not likely to result in an unpleasant outcome, and thus a gain framed message would be most effective in encouraging people to take such a preventative measure. Studies supporting the effectiveness of gain framed messages for low risk behaviors were sited, and the following was explained in more detail. Researchers distributed pamphlets on the beach that both promoted the use of sunscreen, with half using a gain framed message and half using a loss framed message. It was found that recipients were more likely to accept the free sample of sunscreen if they had read the gain framed pamphlet.

The effectiveness of gain vs. loss framed messages is contingent upon how people perceive behaviors, and this perception of a particular action can sometimes be manipulated. Perceptions of health behaviors can be changed through influences including personal experience with the behavior, friends' or family's experience with the behavior, and whether one is focusing on long term or short term effects. Additionally, studies have shown that people who are focused on their aspirations and opportunities are more affected by gain framed messages. Conversely, people who tend to focus their efforts on duties, obligations, and avoiding unfavorable circumstances are more affected by loss framed messages.

However, the authors posit that these mindsets are often produced when one is either deciding on a risky behavior or deciding on a low risk behavior.

Overall, message framing should be addressed by health professionals in order to get the maximum effect possible. It is recommended that, when advertising a detection behavior, or any behavior that is perceived as risky, loss framed messages should be used. Alternatively, when advertising a preventative or low risk behavior, gain framed messages should be used. However, it must also be noted that many other factors go into risk perception as well as message reception. Gain and loss framed messages cannot be the only means of encouraging people to practice healthy behaviors.

Key findings:

- When presented with loss framed information, people are more likely to do something originally perceived as risky, and when they are presented with gain framed messages, they are more likely to avoid doing something risky.
- Detection/screening health procedures are usually perceived as risky, while prevention health behaviors are often seen as having a low risk.
- Gain framed messages should be used to promote preventative behaviors; loss framed messages should be used to promote detection behaviors.
- Other factors, including personal experience, influence from friends and family, and personality can affect how a behavior is perceived, which could in turn affect which message framing is most suitable.

Key recommendations:

- [59_1_3] Prevention messages should be presented with gain framing and detection messages should be presented with loss framing.
- [59_2_3] Framing is not the only thing that makes messages effective and will likely not result in 100 % compliance.

60. Selcon, S. J., Taylor, R. M., & McKenna, F. P. (1995). Integrating Multiple Information Sources: Using redundancy in the design of warnings. *Ergonomics, 38*(11), 2362-2370.

Discipline: Human Factors/Ergonomics
Rating: 7B

The purpose of this study was to analyze the effects of multiple, redundant alerts/warnings on reaction time. Missile Approach Warnings (MAWs) were used as a test scenario, however the authors relate their findings to general psychology models in an attempt to generalize the findings. The authors also made several assumptions. First, they assumed that when a missile is approaching an aircraft, the pilot diverts all their attention to the task of avoiding the missile. Additionally, they make the assumption that the alert has already attracted the attention of the pilot. This allows the study to focus on how multiple alerts/warnings affect decision-making, but not attention gain.

A total of 18 employees at the Royal Air Force Institute of Aviation Medicine participated in the study. Their ages ranged from 18 to 30 years old. Four different signals were created: auditory verbal, auditory spatial, visual verbal, and visual spatial. The auditory verbal signal consisted of a synthesized voice saying “left” or “right”. The auditory spatial signal consisted of a tone played in only one of the participant’s ears. The visual verbal signal was the word “left” or “right” displayed in the center of the screen, and the visual spatial signal was a series of “X’s” displayed on the left or right side of the screen. This resulted in a total of 15 different alerts/warnings, consisting of one, two, three or four signals. “Right” signals were only combined with other “right” signals, and “left” with “left” signals. Each participant was involved in four blocks of testing, and within each block, the alerts/warnings were played twice in a random order. Each time participants heard/saw a signal, they were instructed to press either a button labeled “right” or a button labeled “left.” Data on response time and errors were collected.

A two-way ANOVA test was performed, with information levels and block numbers acting as variables. Block number was not found to have any affect. However, there was a significant difference in response times for the different information levels. Four signals (disseminated simultaneously) resulted in the fastest average response time. Three signals resulted in faster response times than two, and two resulted in faster response times than one. Going from three to four signals saved over 10 % of time, and going from one to four signals saved 30 % time. The number of errors was minimal.

The author relates these findings to the Parallel Distributed Processing model. This model states that when multiple neuro pathways are utilized that all converge on the same node, then the excitation criteria of that node will be met more quickly. In other words, the voltage threshold required to transmit the signal from one neuron to the next is achieved at a faster rate when the voltage from multiple stimuli are added together. This is supported by the data collected in this study, which showed that when redundant signals of different forms were used, the response time was faster.

However, it should be noted that in most real situations, attentional priority cannot be assumed. In other words, while multiple information sources can decrease reaction time, they can also be distracting if the recipient has to focus on multiple tasks at once. Further studies should be conducted taking into account more complex, and realistic scenarios.

Key findings:

- Four signals result in a faster response time than three signals, which resulted in a faster response time than two signals, and two signals resulted in a faster response time than one signal.

- Jumping from one to four signals resulted in time savings of 30 %, and jumping from three to four signals resulted in time savings of over 10 %.
- These findings are congruent with the Parallel Distributed Processing model.

Key recommendations:

- [60_1_3] The findings from this study could be used to design multiple, redundant alerts. In which case up to four different signals could be incorporated into the alert to achieve the fastest response time.
- [60_2_8] Before dissemination, it would be prudent to test these new alerts in a more realistic environment where the user may need to divide his/her attention between multiple tasks.

61. Simmons, K. M., & Sutter, D. (2009). False Alarms, Tornado Warnings, and Tornado Casualties. *Weather Climate and Society*, 1, 38-53.

Discipline: Crisis Management/Disasters
Rating: 7A

Emergency managers have to balance two conflicting issues when alerting and warning for tornadoes. They must avoid overwarning the public to decrease the false alarm ratio (FAR), at the same time as increasing the probability of detection (POD). In an ideal world, communities would achieve a 100 % POD and 0 % FAR, but often times in reality, as the POD increases, so does FAR, and vice versa. So, the question then becomes, which is more important; a high POD, or a low FAR?

The authors of this study used tornado fatality data from 1986 to 2004, and compared local fatalities with local FARs. The authors controlled for Fujita-scale ratings, time of day, month, whether Doppler radar was installed and storm path characteristics. They also included regression coefficients to adjust for innovations like the Internet and cell phones, as well as for years that had a strangely low or high number of tornadoes. Additionally, the data set included over 20 000 tornadoes, thus increasing the validity of the study. Each data point was a tornado and its corresponding fatality rate. The FAR for each tornado was calculated based on three geographic definitions and two time definitions. Geographically, the FAR was either based on the state, the Weather Forecast Office (WFO) warning area, or the television market area; and for timing, the FAR was either calculated for the year preceding the tornado event, or the two years preceding the tornado. This resulted in six different FARs calculated for each tornado. All six FAR calculation methods were analyzed in order to see if any changed the trends in the data.

The data showed that, as the FAR increased by one standard deviation, fatalities increased by between 12 % and 29 % and injuries between 13 % and 32 %. Additionally, there were no significant differences between the six different calculations methods for the FAR.

The fatality and injury reduction attributed to the decrease in FARs over time, was calculated to be between 4 % and 11 % for fatalities and 5 % and 12 % for injuries. Through analyzing a curve of POD versus FAR, it was found that the percentage of people saved by an increased POD was counteracted by a slightly smaller percentage of people killed due to an increased FAR. Overall, increasing the POD by 0.6 but increasing FAR by 0.2, resulted in a 0.3 % decrease in fatalities and a 1.5 % decrease in casualties.

Overall, the findings of this study presented evidence supporting false alarm effects, otherwise known as the cry wolf effect. The more that people are overwarned, the less likely they are to respond to sirens, which then puts them at greater risk when a tornado does occur. However, it is less beneficial to decrease the FAR by sacrificing a high POD, since this study shows that both are nearly equally as important.

Key findings:

- As the false alarm ratio (FAR) increased by one standard deviation, fatalities increased by a minimum of 12 % and a maximum of 29 %; injuries increased by a minimum of 14 % and a maximum of 32 %.
- The national FAR decreased over the time interval studied (1986 to 2004). It was estimated that a 4 % to 11 % decrease in fatalities and a 5 % to 12 % decrease in injuries is attributable to this decrease in FAR.
- Improving the POD at the expense of the FAR (and vice versa) nearly cancel out any beneficial effects.

Key recommendations:

- [61_1_4] Increasing the probability of detection, if it also increases the false alarm ratio, would not be beneficial.

62. Stokoe, M. R. (2016). Putting People at the Centre of Tornado Warnings: How perception analysis can cut fatalities. *International Journal of Disaster Risk Reduction, 17*, 137-153.

Discipline: Human Factors/Ergonomics
Rating: 7A

While tornado forecasting systems have been improving steadily over the years, especially with the introduction of the third generation of Doppler radar, the proportion of tornado fatalities has also been increasing. Many studies have looked at the faults and strengths of the Doppler radar, but these studies ignore the human component, and make the assumption that humans will always react in a uniform, predictable way. Other studies have focused on interviewing tornado victims directly after their experiences, but these studies reflect what the survivors believe or remember after the event, rather than their thoughts just prior to the event.

In order to gain the perspectives of people who have never, or at least not recently, experienced a tornado, this study focused its efforts on Ford County, Kansas. Ford County, while it is in the heart of tornado alley, has never experienced a tornado. A survey was administered through Facebook that contained 23 questions designed to assess the knowledge, attitude and actions of residents, regarding tornadoes and tornado alerts. Additionally, 20 open-ended questions were administered to local officials, including meteorologists, executives of FEMA and Accuweather, and representatives from Ford County government, the Local Emergency Planning Committee and the National Weather Service. Overall, 547 responses were received and analyzed as part of this study.

This study focused on quantifying the usage of Emergency Weather Services (EWS), whether or not these services were trusted, and if there were any trends in responses according to demographics. The survey inquired about a variety of possible alert and warning sources, including television, outdoor sirens, Wireless Emergency Alerts (WEA), radio, weather radios, informal networks, websites, and apps (e.g., apps from private companies, government agencies, and the media). Furthermore, it aimed to examine any differences in the perceptions of EWS between residents and officials of Ford County.

These surveys found that the majority of residents relied on sirens to alert them of tornadoes, with 75.5 % rating them as their primary choice. Hispanics and people under 30 were the most likely to rely on sirens (88 % and 85 %, respectively). White men and people over 60 were the least likely to rely on sirens (63 % and 64 %, respectively). However, while sirens were the most relied upon EWS, they were also more distrusted than television, radio, and WEAs. Between 20 % to 25 % of white men, people over 60 years old, and people with tornado experience distrusted sirens, while 8 % of Hispanics and 6 % of women distrusted sirens. The efficacy of the outdoor siren system was examined, with 40 % of people reporting that they took cover after receiving the siren alert.

Issues of understanding the alerts (specifically the outdoor siren signals) were also discussed. Specifically, 67.2 % of respondents thought that sirens were meant to be heard indoors and inside vehicles, whereas, they are meant as an outdoor warning system only.

Much of the distrust in sirens is thought to be a result of their inability to provide detailed information, the fact that they are not always heard indoors or in certain weather, and the lack of perceived severity achieved by the siren’s tone. Furthermore, there is no standardization of sirens, which increases confusion on siren meaning and protocols among visitors and residents who regularly cross into other communities.

The top four most popular EWS systems were sirens, television, weather apps, and WEAs. Also, 50 % of respondents indicated using WEA, with 59.5 % of Hispanics, 54.8 % of women, 46.3 % of men, and 29

% of people over 60 years old reporting wide-spread use. WEA was also the most trusted official alerting method, with a total of 79 % of respondents indicating that WEA was a trustworthy source. Television and radio were the only information sources that a greater percentage of people found trustworthy. However, while a high amount of trust was indicated for WEA, only 23 % of respondents took immediate cover when they received the text, compared with the 40 % of people who took cover after hearing a siren.

Conversely to how residents viewed EWS, all authority groups believed that the alerts/warnings were issued in a timely manner to the appropriate audiences, and also that trust was not an issue for the EWS sources.

Key findings:

- Sirens were the most relied upon emergency warning system; however, were distrusted as a reliable source among certain subpopulations in Ford County, KS.
    - Women and Hispanics were more reliant on, more trusting of, and more responsive to sirens than white men.
    - People under 30 years old were also more likely to rely on sirens, while people over 60 years old were less likely to rely on sirens.
    - White men, people over 60 years old, and people with past tornado experience were the most distrusting of sirens.
    - Sirens were more distrusted than television, radio and wireless emergency alerts.
- The majority of people did not understand that sirens were only meant to warn people when they are located outdoors.
- There was a disconnect between perspectives from local officials and residents in Ford County, KS. Officials believed that there were no problems with the various EWSs, but residents did not trust some of the EWS and even viewed them as inaccurate.

Key recommendations:

- [62_1_8] The public should be educated on the WEA system and the outdoor siren system.
- [62_2_8] [62_2_9] Residents should be informed when and where the sirens will be tested, and what residents should do in the event of an actual alarm.
- [62_3_4] Regulations should be introduced to standardize sirens across the United States. Alerting methods, testing protocols, all clear signals and alert length should all be standardized.
- [62_4_11] Siren signals should be developed that have graduated tones to represent the severity of the situation.
- [62_5_3] The NOAA weather radio process of alerting should be reconsidered.
- [62_6_1] Research should be performed on white males' perception of risk in order to design targeted alerting/warning systems.
- [62_7_8] Older residents could be educated on the benefits of technology as a way to increase their trust in these types of warnings.
- [62_8_1] Bilingual warnings, e.g., in Spanish and English, should be disseminated in the event of an emergency.

63. Vitek, J. D., & Berta, S. M. (1982). Improving Perception of and Response to Natural Hazards: The need for local education. *Journal of Geography, 81*(6), 225-228.

Discipline: Crisis Management/Disasters
Rating: 7B

Flint, Michigan was impacted by a large flood in 1947 and hit by a tornado in 1953. It has also experienced many other weather events over the years, like small floods and snowstorms. Three surveys were conducted in 1975, 1976 and 1978 to understand residents' perceptions of floods, tornadoes, and the K-12 natural disaster education program initiated in the City of Flint. This article synthesized the data collected through these surveys. A total of 555 people participated in the 1975 survey, 322 respondents in the 1976 survey, and 321 respondents in the 1978 survey, but no further description is given of the demographics of the participants of each study.

The surveys showed that the participants were much more aware that a tornado had touched down in Flint, MI in 1953, and about one quarter of participants knew that a flood had also taken place.

The surveys also demonstrated that many residents were not aware of the K-12 education program on natural disasters. More specifically, the data showed that 42.1 % of respondents did not know if the K-12 program was adequate. Even when the data was broken down into categories of people who had formal education on natural disasters, people who had experienced natural disasters, and people with no experience or education, no significant differences were found among these three groups and their knowledge about the K-12 program. However, when respondents were asked what role the government should take in mitigating the effects of natural disasters, the most common response was to implement educational programs. In conclusion, the residents of Flint, Michigan were unaware of the K-12 education program, and thus could offer little guidance on improvements.

Key findings:

- Residents of Flint, MI had little knowledge about the K-12 natural disaster education program that was being taught in schools within the city.
- The residents were much more cognizant of the tornado that hit their city in 1953 compared with the 1947 flood.

Key recommendations:

- [63_1_8] The K-12 natural disaster education program needs to be improved and should be mandatory for all schools.
- [63_2_8] Natural disaster education programs for adults should be offered.

64. Wood, M. M., & Glik, D. (2012). *Engaging Californians in a Shared Vision for Resiliency: Practical lessons learned from the Great California Shakeout.* Sacramento: State of California Seismic Safety Commision.

Discipline: Crisis Management/Disasters
Rating: 6A

This paper presents a general history and overview of the California Shakeout. To give some background information, the Shakeout was a statewide earthquake drill in which residents could participate. It was widely publicized to attract as many participants as possible. The earthquake drill scenario was based on a 7.8 magnitude earthquake in the San Andreas Fault. The main message of the campaign was for people to "drop, cover and hold on".

The authors also analyzed seven studies on the effectiveness of the program. Through the evaluation and synthesis of these studies, the authors developed a set of key findings and recommendations, both of which are listed, below.

Key findings:

- Wide adoption of the program by the media, as well as the Earthquake Country Alliance (ECA) and the Southern California Earthquake Center (SCEC), was one of the main factors that increased the campaign's popularity among the public.
- An event such as the Shakeout can cause people to seek additional information and practice preparedness actions.
- Schools and businesses were underutilized in this earthquake drill.
- The drill was successful in that it caused participants to share their experiences with others, which increased the dissemination of the campaign's message.

Key recommendations:

- [64_1_8] Businesses should be properly utilized during the Shakeout as they can act as role models for the wider community. Incentives should be devised to encourage businesses to provide their employees with earthquake kits and information on earthquake preparedness.
- [64_2_8] Schools should also be targeted as potential role models. Schools should encourage preparedness actions, not only among students, but among their families and school staff as well.
- [64_3_8] Testing for the commercial mobile alert system (CMAS) should be performed during the Shakeout drill.
- [64_4_8] Cost-effective evaluation of the Shakeout program is required.
- [64_5_8] A statewide, follow-up, cross sectional survey should be implemented to determine the longer-term impacts of the Shakeout program.

65. Wood, M. M., Mileti, D. S., Kano, M., Kelley, M. M., Regan, R., & Bourque, L. B. (2012). Communicating Actionable Risk for Terrorism and Other Hazards. *Risk Analysis, 32*(4), 601-615.

Discipline: Crisis Management/Disasters
Rating: 7A

The current technique for disaster preparedness education focuses on risk-communication interventions. However, this educational method is not as effective at prompting action among the public. While many risk communication models exist, few represent "actionable risk communication" models. This paper outlines a possible "actionable risk communication model" and describes how it can be used to create initiatives that will drive behavioral change, resulting in emergency preparedness among the public.

In order to create this model, the sample used was statistically representative of the population of the continental United States. Overall, the study obtained 2 772 participants (i.e., the unweighted sample). Questionnaires, administered via computer assisted telephone interviews, were used to collect information on the following topics: the content of preparedness information received following September 11, 2001, the number and type of sources from which they received preparedness information, observations of others (e.g., neighbors, friends, and family) taking actions to prepare for a future event, participants' knowledge about possible preparedness actions, how effective they believed preparedness actions to be, whether participants had sought out information about preparedness actions, and what types, if any, of preparedness actions the participants had taken.

A model was then created in order to establish which factors had the most influence on taking preparedness actions. It was found that the factor with the largest effect on action was observing others taking preparedness actions. Observing others taking action also increased participants' perceptions that the actions were effective, and thus increased actions taken by the participants themselves. Additionally, the data showed that providing actionable information from multiple sources also improves knowledge and in turn positively affects preparedness actions. Overall, this model suggests that, in order to change behavior and encourage preparedness actions to be taken, information should focus on telling the public what they should do. This information can either be provided through seeing/witnessing other people taking action, or disseminating information through more formal information sources. In short, education should focus on action and start to move away from risk.

Key findings:

- When people around an individual start to take preparedness actions then this, more than anything else, will motivate that individual to also take preparedness actions.
- An emphasis on actions that should be taken rather than the risk associated with a disaster event could be more effective at changing behavior.
- Those who received more information from a multitude of sources were more likely to take preparedness actions.

Key recommendations:

- [65_1_8] Preparedness education programs should target those who have already prepared in an effort to share their actions with others.
- [65_2_8] Educational programs should inform the public about actions that would help them prepare and respond to a disaster, rather than the risks associated with a particular disaster event.
    - Also, educational programs should demonstrate the benefits that the public will receive from taking these actions

- [65_3_8] Consistent information should be disseminated from multiple sources.

66. Wood, R. M., & Gustafson, G. E. (2001). Infant Crying and Adults' Caregiving Responses: Acoustic and contextual influences. *Child Development, 72*(5), 1287-1300.

Discipline: Medicine/Critical Care
Rating: 7A

Response time to an infant crying can be an important indicator of how urgent the cry sounds. This study addresses response time to crying, and how it is affected by context, and the distress perceived by the adults. Four experiments were performed, however only the findings from Experiment 4 can be applied to the topic of outdoor siren systems.

Experiment 4 focused on which specific acoustic parameters (of the infant's cry) were related to high distress cry ratings and a faster participant response time. Two hungry infants were recorded, with nine sample clips taken from the first infant cry recording, and six sample clips taken from the second cry recording. These clips were chosen because they represented low distress, medium distress and high distress crying. One group of 34 non-parent, university students listened to the first nine samples and a second group of 25 different, non-parent university students listened to the second set of six samples. During the first round of testing, participants were asked to rate the distress of the infant using a 9 point scale, where a value of "1" represented low distress and "9" represented very high distress. During the second round of testing, participants listened to the cry samples again, and were instructed to raise their hand once they were sure that, if it were an actual child crying, they would respond to it.

Multiple acoustic variables were measured in the cry samples, including fundamental frequency, number of wails, mean duration of wails, dysphonation and mean duration of pauses. It was found that higher distress ratings (from participants) correlated with increased dysphonation (i.e., disturbances in the rhythm of the opening and closing of the glottis, which produces arrhythmic vocalization), a higher number of wails and shorter mean duration of pauses. However, fundamental frequency and wail duration had no significant relationship with distress ratings.

Faster response time was also correlated with increased dysphonation, a higher number of wails and shorter mean duration of pauses. Furthermore, there was no significant relationship between response time and fundamental frequency, or mean wail duration. These trends were apparent in both testing groups.

The lack of relationship between fundamental frequency or wail duration and distress ratings or response times do not agree with many previous studies.

Key findings:

- Higher distress ratings correlated with more dysphonation, a higher number of wails and shorter mean duration of pauses.
- Faster response times by participants correlated with higher dysphonation, a greater number of wails and shorter mean duration of pauses.
- There was no significant relationship between fundamental frequency or wail duration and distress ratings or response times.

67. Woody, C., & Ellison, R. (2014). *Maximizing Trust in the Wireless Emergency Alerts (WEA) Service.* Software Engineering Institute.

Discipline: Crisis Management/Disasters
Rating: 4A

In order for Wireless Emergency Alerts (WEA) to be effective, two important groups must trust the alerts. First, the alert originators (AOs) must trust the capabilities of WEA, otherwise they would never choose to use them. Second, the public must also trust the alerts in order for them to respond safely and effectively. This article focused on the factors that influence trust of WEAs among AOs and the public.

First, the literature was reviewed to identify key factors. Surveys were then administered to AOs and the public. These surveys aimed to collect information on how different trust factors affected each other. These factors were then analyzed using mathematical and statistical models. Finally, these models were used to evaluate hypothetical scenarios.

Important influences on the AOs' trust in WEA included the security of the system from outside hacks or tampering, the reliability of the system, public feedback on WEA, and historical feedback documenting the performance of WEA. Key factors influencing the public's trust in WEA included public familiarity with WEA before an event occurs, the consistency of the alerts when compared with other sources, the amount of lead time given by WEA, and the ability to confirm the message through social media sites, such as Facebook or Twitter.

An AO trust model was created, which showed that improving the appropriateness, availability, and effectiveness of WEA would increase the usage of WEA by AOs. The appropriateness of use is affected by severity, certainty, and geographic breadth. Alerts should be disseminated for a severe and likely or observed threat, and they should be sent to as specific a location as possible.

Availability is the second outcome highlighted by the AO trust model. Security, system accessibility, system reliability, and cross-system integration all contribute to WEA's availability. When the WEA system is installed, Emergency Management Agencies (EMAs) are required to install a security system. Additionally, message formation is usually contracted out, and the message companies must be vetted before they are given the right to disseminate the message through WEA. Trust can also be increased if AOs can access the WEA system through computers or other devices with which they are familiar, rather than one specific device that may be less familiar. AOs must also be assured that the WEA system is going to work when it is needed. This trust can be built through system testing. Cross-system integration can also build trust, as a WEA system that works with the many other systems that AOs use will be easier to manage and comprehend.

Effectiveness is the final outcome that improves AOs' trust. Effectiveness is comprised of timeliness of dissemination, message accuracy, and historical feedback. When WEA disseminates accurate, fast messages and has a good track record for doing so, then AOs are more willing to trust the system.

Once AOs disseminate the message, the issue is whether or not the public trusts the message, and responds. One model suggested that the clarity of the message, appropriate spelling and grammar, explicit instruction of what to do, an explanation of the reasons for taking action, and messages provided in the readers' primary language were all important factors in increasing users' trust. However, since messages are restricted to 90 characters, a follow up message can be used to disseminate more information or refer people to places where additional information can be found. Also, lead time and multiple channels of information also affected whether someone took action or not.

Some aspects of WEA that should be minimized are unnecessary alerts, confusing or inaccurate information, delays in alerting, and breaches in security. Agencies and jurisdictions should work together in order to coordinate alerts, minimize confusion, and avoid over alerting.

Key findings:

- The appropriateness of using an alert, the availability of the WEA system and the effectiveness of WEA are all large contributors to alert originators' (AOs') trust in WEA.
    - Appropriateness of use is affected by the severity of the event, the certainty of the event and how geographically-specific the WEAs can be.
    - Availability is affected by the security measures taken to protect WEA from outside influences, the accessibility of the system, its reliability and its cross-system integration.
    - The effectiveness of WEA is governed by the timeliness of message dissemination, the accuracy of the messages and the historical feedback.
- In order for the public to trust a WEA:
    - The message must contain appropriate grammar and spelling.
    - The message should clearly explain what action should be taken.
    - The message must have an explanation of why an action is needed.
    - The message should be written in the first language of the target population.

Key recommendations for alert originators:

- [67_1_3] WEA should only be used for the most severe, urgent and certain incidents.
- [67_2_3] The areas where WEAs are sent should match, as closely as possible, the area affected by the threat.
- [67_3_3] Security should be implemented to protect from unwarranted physical and electronic access to the system.
- [67_4_3] The software purchased for creating WEA messages should be as reliable as possible.
- [67_5_3] WEA also has a default message constructing mode. The AO should study the types of Common Alerting Protocol inputs that result in certain message types.
- [67_6_3] Commercial Mobile Alert Message (CMAM) texts can also be used to issue WEA messages, but the AO must learn how to write a clear, accurate message. They must pay attention to grammar, spelling, meaning, and the 90-character limit.
- [67_7_3] Public feedback should be collected after sending a WEA message.
- [67_8_3] The message should clearly explain what needs to be done.
- [67_9_3] The message should also explain the reasons why these actions are necessary.
- [67_10_3] AOs should know what languages are spoken in their area, and they should disseminate messages in such languages. Messages in languages other than English can be constructed using CMAM.
- [67_11_3] Alerts should be coordinated among jurisdictions to avoid overlapping, and conflicting messages.