SHOULD SEVERE WEATHER GRAPHICS WEAR A UNIFORM? EXPLORING THE EFFECTS OF VISUAL AND SPATIAL INCONSISTENCIES ON END USER RISK PERCEPTION, UNCERTAINTY, AND BEHAVIORAL INTENTIONS

by

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(Under the Direction of Andrew J. Grundstein)

ABSTRACT

With the rise of the Internet and social media platforms, people now have access to more weather information than ever before. Although this allows end users to receive weather information from a variety of sources, the sheer volume of available information likely contributes to a perception that weather risk messages are inconsistent. Members of the weather enterprise share these concerns and believe that these perceived inconsistencies may negatively affect their many audiences. The challenge, however, is that there are only a few studies to-date that have explored message consistency in a weather context. Therefore, in its current state, the weather enterprise lacks empirical evidence that (1) demonstrates that message consistency is a relevant operational concern and (2) provides research-guided recommendations to practitioners and operational meteorologists on how to achieve a more consistent message. To address this operational need, this dissertation conceptualizes 'message consistency' for the weather enterprise and employs a social science mixed-methods approach to explore the effects of weather-related graphical inconsistencies on lay public end users. In particular, this dissertation used the Storm Prediction Center's (SPC) Convective Outlook graphic as a vehicle to investigate the role that visual design plays in keeping a weather-related message consistent.

Although having a different visual design did impact the consistency of the message, this does not mean that severe weather graphics should wear a uniform. For example, the findings in this dissertation suggest that operational meteorologists can continue to customize the basic graphical design of their Convective Outlook graphics (i.e., placement of logos, legends, etc.). However, certain graphical elements emerged as important message features (i.e., risk areas and colors), and as a result, should remain the same when sharing severe weather graphics with end users. Otherwise, the message being communicated by the Convective Outlook graphic changes, and consequently, affects end user risk perception, uncertainty, and information seeking intentions. Having said that, more research is also needed to improve the usability of the Storm Prediction Center's Convective Outlook graphic among lay public audiences. Only then can we ensure that severe weather forecast information is communicated both effectively and consistently among end users.

INDEX WORDS: message consistency, conflicting information, risk communication, meteorology, severe weather, weather communication

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DEDICATION

To the next generation of social and behavioral scientists. Your path may be a difficult one but keep fighting the fight. The weather enterprise needs you.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Colloquially, "message consistency" is considered a critical component of marketing, brand management, and effective risk communication (Mileti and Sorensen 1990), yet little exists on how practitioners should evaluate, ensure, or even achieve message consistency. Therefore, one is left to ask: what does a "consistent message" look like, and what distinguishes a "consistent" message from an "inconsistent" one? Countless marketing blogs, for example, describe the importance of having a consistent message and ways of keeping one's messages consistent; however, they lack substance and concrete suggestions for improving message consistency. Similarly, risk communication reference guides and documents, produced by national organizations (i.e., WHO n.d.; START 2012; CDC 2014; NOAA 2016) to assist practitioners with effective risk communication, only offer vague references to message consistency and fail to acknowledge specific ways of achieving it. In fact, any reference to the importance of a "consistent message" frequently appears in a long list of adjectives to describe the most effective messages (i.e., "messages must be timely, accurate, specific, sufficient, *consistent,* and understandable" (emphasis added; START, 2012, pg. 19)). Given these points, one might ask: Is message consistency even a problem worth further inquiry? In short, the examples provided above fail to frame "message consistency" in the context of an ever-expanding new media environment. As a result, the significance of message consistency changes when text and visual messages are easily accessible to anyone.

Through the evolution of the new media environment comes new challenges associated with defining and evaluating message consistency, especially as media platforms venture into the realm of visual communication. In addition to observing visualizations via the Internet, the most popular social media platforms highlight the communication of visual information (e.g., Snapchat, YouTube, Instagram, etc.). Additionally, several legacy social media platforms have followed suit and have begun integrating visual components into their preexisting services (e.g., Facebook and Twitter; Russman and Svensson, 2017). As a result, sharing images and visualizations has become a prominent vehicle for communicating information and has "arguably transform[ed] how we relate to each other and the world around us" (Russman and Svensson, 2017, pg. 1). Specifically, this shift to a visual-centric mode of communication has implications for depicting and communicating abstract concepts, such as probabilistic, uncertainty, and spatial risk information. While visual abstractions have been explored in a variety of contexts (for example, health risks: Keller and Siegrist, 2009; environmental risks: Dieckmann et al. 2012; Severtson and Myers 2013), the field of meteorology offers a myriad of visualizations that strive to depict (albeit "inconsistently" at times) weather-related uncertainty and risk. It is these intricacies that make it the perfect exemplar for empirically exploring the intersection between message consistency and the visual depiction of abstract information.

In response to the newfound focus on visual content, the weather enterprise has expanded their breadth of communication platforms (i.e., Facebook Live, Twitter, Instagram, Snapchat, and YouTube) to ensure that weather information reaches all end users. Already known for their affinity to present information in visual and map formats, operational meteorologists are now creating, disseminating, and sharing more visual information than ever before. This is especially important, as visualizations are being used to communicate difficult concepts, such as weather-related probabilities, uncertainty, and risk. One such example, is used to communicate severe weather risk and uncertainty (Figure 1.1). Referred to as the "Convective Outlook," this graphic is frequently scrutinized in the weather community for its "inconsistent" visual design among operational meteorologists in the government, private, and broadcast sectors. Although the weather enterprise lacks empirical assessments of its graphics, a study by Eosco (2008) sought to fill this knowledge gap by examining a graphic used to communicate the uncertainty associated with a hurricane's path or trajectory (also known as the "cone of uncertainty;" Figure 1.2). Interestingly, her results revealed that the hurricane community perceives inconsistencies in their own weather-related messaging. As a means to explain this result, Eosco (2008) questioned whether different visual designs associated with the "cone of uncertainty" graphic are, in fact, creating these perceived inconsistencies. To address this concern, Eosco (2008) calls for further research at the intersection of visual design and message consistency by asking, "if all institutions use the same forecast, but entirely different visual designs, then does this change the consistency of the message?" (Eosco 2008, pg. 101-102). In other words, what is the role of visual design in keeping a weather-related message consistent? Does this require our weather messages to wear uniforms? To explore these provocative questions in the context of weather communication, this dissertation proposes an **empirical examination of message consistency that seeks to evaluate the importance of having a consistent visual design when communicating weather-related risk, uncertainty, and probabilistic information.**

1.2 Research Context

The behavioral response to a weather-related message or warning represents the final, and increasingly, the most challenging stage of the forecasting process. Whereas advances in weather models and observation systems have improved meteorologists' ability to predict and detect potentially hazardous weather, communicating uncertainty and the associated risk to the public remains a formidable hurdle. The process of communicating uncertainty and risk information is further exacerbated by (1) the wide array of available information sources across the public, private, academic, and broadcast sectors of the weather enterprise[1], and (2) the mass accessibility of this ***diverse, and often inconsistent,*** weather information on the Internet, social media platforms, and mobile-based devices. Within the last decade, operational meteorologists have become increasingly concerned with this inconsistent weather messaging. Appearing in conference presentations, panel sessions, policy documents within the National Weather Service (NWS), and statements from professional meteorological organizations (e.g.,

[1] The "weather enterprise" includes the network of government agencies, private sector companies, broadcast meteorologists, emergency managers, and academic institutions that provide weather services to the nation. The term "weather community" will be used synonymously within this proposal.

American Meteorological Society 2001; American Meteorological Society 2017), for example, the weather community is elevating the importance of achieving message consistency for both internal and external communication. The challenge, however, is that the idea of message consistency, is difficult to conceptualize within the weather enterprise, and each discussion only adds more complexity to the question: What exactly does it mean to have a "consistent message?" (Eosco and Williams 2017; Klockow and Jasko 2016; National Weather Association 2017).

Members of the weather community often vocalize their concerns of inconsistent messaging during severe weather events (e.g., severe thunderstorms and/or tornados) when visual displays of uncertainty and risk use different *colors* (e.g., red vs. magenta), *risk language* (e.g., marginal vs. low), *depictions of spatial risk* (e.g., "Moderate" risk in one graphic and "Enhanced" in another), and *reference classes* (e.g., probability of severe weather within a 25 miles radius vs. 50 mile radius) to communicate a uniform threat (Figure 1.3). This is best exemplified when operational and broadcast meteorologists differ in their visual design of the Convective Outlook graphic (Figure 1.1) – a visual display produced by the Storm Prediction Center (SPC) to graphically communicate the risk of severe and general thunderstorm threats over three possible temporal scales (i.e., Day 1, Day 2, and Day 3 Convective Outlooks; Grams et al. 2014).

This static visual display, which is the focus of this dissertation, depicts both the categorical *and* probabilistic risk of severe weather. The categorical risk of severe weather is communicated graphically using numbers, words, and colors. The various categorical risk levels vary from general thunderstorm areas (i.e., TSTM – light green) to five risk types (i.e., 1-Marginal-dark green, 2-Slight-yellow, 3-Enhanced-orange, 4-

Moderate-red, 5-High-magenta) based on the coverage and intensity of the severe weather threat (Grams et al. 2014). Within each categorical risk level, resides implicit probabilistic information. For example, a 30% chance of severe weather, within 25 miles of a given point, would be associated with the 'Enhanced' categorical risk level. However, the probabilistic information associated with each categorical risk level changes with time, such that the "…day 1 outlook contains individual severe probabilities for tornadoes, wind, and hail…" whereas "…the outlooks on day 2 and 3 only forecast the combined probability of all three types of severe weather" (Grams et al. 2014; Table 1.1). Therefore, when operational and broadcast meteorologists alter the visual design of a Convective Outlook graphic, they are changing more than just numbers, words, and colors. In effect, these graphical inconsistencies may alter the communication of uncertainty information and an individual's interpretation of their severe weather risk. However, there has only been one study to-date that has examined the perceptual and behavioral implications of these graphical inconsistencies. As a result, the weather enterprise lacks empirical evidence that (1) demonstrates that message consistency is a relevant operation concern and (2) provides guidance, recommendations, and best practices on how to achieve a more consistent message. To address this operation gap, this dissertation seeks to address the following research questions:

RQ1. How do other disciplines define, consider, and measure "message consistency," and can this knowledge be used to conceptualize "message consistency" for weather enterprise researchers and practitioners?

RQ2. How do members of the general public evaluate whether two Convective Outlook graphics are consistent or not? Do members of the public describe different visual designs as 'inconsistent?' If so, how and in what ways?

RQ3. How do graphical inconsistencies associated with Convective Outlook graphics affect risk perception, uncertainty, information seeking intentions, and behavioral intentions to perform protective actions?

1.3 Literature Review

In search of answers to address the consistency concerns of the weather enterprise, the following section examines the literature from a variety of disciplines. This interdisciplinary literature review begins by establishing the foundation of consistency found in the fields of logic and philosophy. Next, warning and visual communication literature will be surveyed to understand the importance of message consistency in those disciplines. Finally, several studies from the communication studies literature will offer guidance for approaching message consistency from a theoretical perspective and aid in understanding the relationship between message consistency, behavioral intentions, and communicating uncertainty in a weather context.

1.3.1 What is Consistency? A Logical Approach

Before examining the nuances of message consistency, it is imperative to establish the abstract, foundational principles of (in)consistency. The Oxford English Dictionary (2018) offers two relevant definitions of the term ‘consistent’ that help highlight its basic principles: (1) “Not containing any logical contradictions” and (2) “Compatible or in agreement with something.” The defining feature of the first definition is its use of the word “contradictions,” as it implies that the absence of a contradictory statement or message is a key criterion for maintaining consistency. The fields of philosophy and logic share this argument in their abstract understanding of consistency. According to Wolfram (1989), a set of separate sentences is said to be ‘consistent’ if and only if there is at least one possible situation in which they are all simultaneously true. For example, statements like “it is raining outside right now” and “it is cloudy outside right now” would be categorized as consistent because it could be both cloudy and raining at the same time. However, instead of emphasizing consistency, philosophers and logicians find more value in defining, identifying, and resolving inconsistencies (Dowden 2019).

Wolfram (1989) points out two types of inconsistent statements: contradictories and contraries. Contradictory statements represent a stronger type of inconsistency because the truth of one statement results in the falsity of the other. For example, consider these sentences: (1) Oklahoma City is at risk for severe weather tomorrow at 5:00 p.m. and (2) Oklahoma City is *not* at risk for severe weather tomorrow at 5:00 p.m. The example statements above are *contradictory,* because they cannot both be true and cannot both be false. *Contrary* statements, on the other hand, occur when two sentences cannot both be true but *can* both be false (Wolfram 1989). For example, consider numerical weather prediction and ensemble forecasting. Instead of a single forecast, ensemble forecasting produces a wide range of possible future states of the atmosphere. Because there can only be one future state, all of the ensemble forecasts cannot be true; however, they could also all be false, as the weather event may not adhere to any of the ensemble forecast’s future states and could result in a completely different outcome. Like an ensemble forecast, then, contrary statements or messages cannot both be true but can both be false. Although informative, this basic interpretation of inconsistency—as deriving from contradictory or contrary statements—does not address all of the operational constraints and complexities that exist in the weather enterprise. However, it does offer a building block and key criterion for establishing a conceptual definition of message consistency: contradictions or conflicts often result in inconsistency. To open the discussion and approach some of the abstract intricacies of inconsistency described above, this review turns to the warning and visual communication literatures to build on this conceptual foundation by providing applied examples and framing inconsistency in the context of messaging.

1.3.2 Warning Communication Literature

Advocates of message consistency often cite the seminal piece by Mileti and Sorensen (1990) in the warning communication literature. This detailed report, evaluating the state of public emergency warnings, acknowledges that a warning's ability to encourage an individual to perform a given protective action is best evaluated along the following dimensions: "warning source; warning channel; *the consistency*, credibility, accuracy, and understandability of the message; and the warning frequency" (emphasis added; pg. xvii; 3-11). However, this evidence is often accepted without questioning what the authors meant when they encourage "the consistency of the message." Specifically, how do Mileti and Sorensen (1990) conceptualize "message consistency," and does their conceptualization translate to the weather enterprise? Upon further examination of their report, Mileti and Sorensen (1990) expand upon the concept of consistency by stating that "a warning message must be consistent, both within itself as well as across different messages" (pg. 3-12). At first glance, it appears that Mileti and Sorensen (1990) consider the importance of consistency (1) within a message and (2) across different messages – presumably from one source. But, the authors explain in another section that "it is typical for any warning situation to be characterized by different and inconsistent warnings from a range of sources, for example, official warnings versus informal ones" and that "multiple sources help people confirm the warning information and the situation, and reinforce belief in the content of the message (Mileti and Sorensen 1990, pg. 3-3; 5-10). Therefore, Mileti and Sorensen (1990) recognize consistency concerns in three key areas: (1) within a message, (2) across different messages from the same source, and (3) across different messages from a variety of sources. With a basic conceptualization of message consistency, it is important to next address the warning confirmation process and other mechanisms that fuel message consistency.

For message consistency to be a legitimate and compelling concern during the warning communication process, it is required that individuals seek out additional information following the receipt of a warning or message (Lindell and Perry 1983; Mileti and Beck 1975; Mileti and Sorensen 1990; Quarantelli 1984; Rogers 1985; Sorensen 1982). Within warning communication, this phase is known as the warning confirmation process. According to Quarantelli (1984, pg. 512) warning confirmation is "the almost inevitable interaction to obtain additional information or validation concerning the original message." This need to seek additional information is often caused by confusion, misunderstanding, lack of clarity, or lack of trust in the original message. As a result, underlying uncertainty forms, urging the end user to seek additional information[2] (Lindell and Perry 1983). After receiving additional information, each message or message source is internally compared and evaluated for consistency. Unfortunately, the warning communication literature is vague from this point forward, with only a few studies stating that variations in the message lead to misinterpretations

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[2] The information seeking process is an important aspect of "message consistency," and will be more thoroughly explored later in the literature review.

(McGinley et al. 2006) and result in a confused public (CDC 2014; Mileti and Sorensen 1990). Therefore, this literature fails to clearly express the cognitive and behavioral implications of inconsistent messages, and leaves one asking: what do "misinterpretations" and a "confused public" mean? To concretize the implications of inconsistent messages and to further align with the visual aspects of this proposal, this review turns to the communication of warning information via safety signs, labels, symbols, and color codes.

A more recent consistency conversation and one that closely resembles the concerns associated with Convective Outlook graphics, involves the lack of a consistent visual design among warning safety signs, labels, and placards (Wogalter et al. 1999). Specifically, the United States federal regulations do not advocate for the consistent use of signs, colors, and symbols; therefore, leading to an "inconsistent and unsatisfactory situation for warning of hazards and for communicating sometimes life-threatening information" (Wogalter et al. 1999, pg. 270). To overcome these consistency challenges, the private sector collaborated to develop voluntary standards that sought to establish consistent warning graphical formats. In coordination with the National Bureau of Standards (NBS), now the National Institute of Standards and Technology (NIST), the American National Standards Institute (ANSI) Z535 Committee on Safety Signs and Colors was formed to address these concerns. The designated committee was given the following goal: "To develop standards for the design, application, and use of signs, colors, and symbols intended to identify and warn against specific hazards and for other accident prevention purposes" (Wogalter et al. 1999, pg. 271). Through the creation of five sub-committees, each with representatives from private sector companies, as well as experts in visual communication and human factors research, five standards were passed in 1991 (ANSI 1991). Together, these standards created a coherent and uniform approach for communicating safety messages, using color, signage, symbols, labels, and tags. But, was this laborious process effective? Did the creation of a consistent system improve the communication of warning information, and impact the behavior of end users?

To evaluate the effectiveness of the standards established by the ANSI Z535 committee, several studies conducted visual experiments to determine the cognitive and behavioral implications of warning graphics that were either consistent or inconsistent with those standards. Laughery et al. (2002) compared four measures of effectiveness (noticing, reading, understanding, and complying) to warning designs that were visually consistent or inconsistent with the standards created by the ANSI Z535 committee. Not surprisingly, the warnings that were consistent with the ANSI Z535 standards were evaluated as superior to inconsistent warnings on all four dimensions of effectiveness. However, the authors warn of the potential biases associated with these self-reported indicators of effectiveness and instead suggest that these results might act as indicators of behavioral intentions. Put simply, as consistency with the ANSI Z535 standards increases, greater compliance to that warning should also increase. While various studies obtained similar outcomes (Young et al. 2002), Franz et al. (2005) describes it best by stating that "greater levels of [consistency] to the ANSI [standards] are likely to yield warnings that lay people *think* will result in greater levels of attention to and compliance with warnings, even though such differences have not actually been realized" (pg. 1788). While behavioral intentions are often correlated with actual behavior, as Laughery et al.

(2002) and Franz et al. (2005) advise, one must be cautious when interpreting these results from a behavioral perspective as they do not imply warning compliance.

Conversely, other research suggests that ANSI Z535 standards may not be effective when perceived risk is low (Heckman et al. 2010), and that in some instances older Occupational Safety and Hazard Administration (OSHA) warning designs may be more effective than warnings that are consistent with the Z535 standards (Figure 1.4; Kim and Wogalter 2009). Kalsher et al. (2016) argue that discrepancies in the literature may be due to the lack of uniformity in the methodological approach used (e.g., sample size, subject pool, aspects of ANSI guidelines used, etc.). To overcome these disparities, Kalsher et al. (2016) conducted an ANSI compliance study that avoided treating consistency as a strict binary variable by experimentally isolating the ANSI recommendations. Similar to previous studies, the experiment by Kalsher et al. (2016) revealed that most of the formatting elements established by the ANSI Z535 committee were significantly related to predicted outcomes; however, the size of the effects associated with each element were not uniform. For example, the predicted effects of introducing a warning header that is consistent with ANSI standards was far greater than the predicted effects associated with using bulleted text or increased font. By isolating the various design elements, Kalsher et al. (2016) was able to better understand the relationship between consistency and their perceptual indicators of behavior (i.e., noticing and compliance). Although beneficial from a methodological and behavioral standpoint, the concerns associated with Convective Outlook graphics extend beyond mere visual design inconsistencies. Whereas the warning graphical design for signs, labels, and placards communicate prevention information, changes in the visual design of

Convective Outlook graphics have implications on end user perceptions of risk and uncertainty. Therefore, the next section will elaborate on the use of visualization and visual displays to depict uncertainty and risk information.

1.3.3 Visual Communication Literature

To overcome the challenges associated with comprehending, interpreting, and acting upon uncertainty information, the use of visualizations and visual displays have become a popular means for expressing likelihood in science and risk communication. Inspired by the challenges of numeracy, or one's literacy with mathematical concepts and probabilities (Lipkis et al. 2001; Schwartz et al. 1997), a plethora of research has been conducted to better communicate uncertainty via visual displays and graphics. A variety of visualizations have been examined including the use of probabilities and frequencies, (Budescu et al. 2012; Dieckmann et al. 2009; Lipkis et al. 2001; Peters et al. 2011; Waters et al. 2006), risk ladders (Keller et al. 2009), numerical ranges with evaluative labels (Budescu et al. 2012; Dieckmann et al. 2009; Dieckmann, et al. 2012; Gregory et al. 2012), colors (Severtson and Henriques 2009), as well as multiple formats including, but not limited to: pictograms, scatterplots, boxplots, probability density functions, etc. (Allen et al. 2014; Edwards et al. 2012; Ibrekk and Morgan 1987; Keller and Siegrist 2009). In sum, these studies agree that individuals are better at interpreting and estimating means and probabilities when visualizations display the necessary quantitative information in an easy-to-read fashion (Allen et al. 2014; Edwards et al. 2012). But, what if a visualization does not explicitly convey uncertainty or probabilistic information? For example, the Convective Outlook graphic, depicts categorical risk levels (e.g., "High") and color coding on a map to denote implicit severe weather probabilistic information. Here, the risk levels and color coding resemble verbal evaluative labels, an explicit visualization technique used to overcome numeracy when communicating complex representations of uncertainty to a variety of stakeholders. (Dieckmann et al. 2012). Similar to the concerns of operational meteorologists, verbal evaluative labels are also subject to consistency problems: "In a recent Nation Intelligence Estimate on Iran's nuclear intentions and capabilities, analysts used (albeit *inconsistently*) verbal evaluative labels to express analytic confidence in their estimates and assessments (i.e., High confidence, Medium confidence, or Low confidence; emphasis added; Dieckmann et al. 2012, pg. 718). While this discussion has provided additional insight on the use of visualizations to communicate explicit uncertainty information and highlighted consistency concerns similar to those associated with the Convective Outlook graphic, it fails to comment on the use of visualization to convey implicit uncertainty. The literature review turns to this topic next.

Similar to the research on explicit visualization, an abundance of literature exists surrounding the topic of implicit visual displays; however, the most compelling and relevant literature utilizes cartographic theory and principles to convey implicit uncertainty information. Like the cartographic techniques employed by Convective Outlook graphics to describe severe weather risk, previous studies have explored the implications of color, hatching, or fog and fuzzy lines to depict implicit uncertainty (Leitner and Buttenfield 1992; MacEachren 1992; Tufte 2001; Brewer 2006; Severtson and Vatovec 2012; Ash et al. 2013; Severtson and Myers 2013; Cheong et al. 2016). However, the most insightful contributions are offered by Cleveland and McGill (1984), Pinkler (1990) and Severtson and Myers (2013) as they outline various factors that ultimately influence the comprehension of implicit uncertainty on graphs, diagrams, and even maps. Pinkler (1990) breaks down one's ability to interpret a visual display into four factors: units of perception and their spatial location (i.e., the unit at which risk is displayed on the map), Gestalt principles (i.e., the similarity, proximity, and continuity of visual features), representation of magnitude (i.e., a translation of the data into quantifiable means such as length or color scale), and the coordinate system (i.e., the spatial location of perceptual units). When examining Convective Outlook graphics, both the unit of perception and magnitude are of relevance. The unit of perception is often contoured areas that are shaded, colored, and/or identified using verbal evaluative labels to symbolize different magnitudes of severe weather risk.

In a similar vein, the work by Cleveland and McGill (1984) propose ten "preattentive" properties that occur prior to any cognitive processing of the visual stimuli (i.e., length, direction, area, volume, curvature, shading and color saturation). These properties are important for eliciting visual salience, or "the quality of a representation that aids to quickly focus attention on important features" (Ash et al. 2013, pg. 106). When considering the Convective Outlook graphic, the use of shading, color schemes, and the delineation of regions with bordering can be used to enhance visual salience and communicate implicit uncertainty. However, these "preattentive" properties can also produce insignificant, and at times, negative outcomes when communicating probabilistic risk information.

Within the weather enterprise, difficulties depicting and discerning visual implicit uncertainty information often emerges along risk boundaries. For example, a weather-related study among Mississippi residents sought to understand the probability associated with a visual display of a tornado warning (i.e., a tornado warning polygon). The residents indicated that the geographic center of a warning polygon would be more likely to experience a tornado than near or outside the perimeter (Sherman-Morris and Brown 2012). Therefore, the use of color and a delineated border was not enough visual information (1) to communicate that tornado likelihood would increase over time and (2) that individuals near the far edge of the polygon were also at risk. A similar meteorological study, explored the potential tradeoffs when visualizing probabilistic information for tornado warnings (Ash et al. 2013). Here, the authors sought to examine fear, protective action responses, and perceived risk along the boundaries to three warning designs: the current storm-based polygon, a color gradient of increasing risk, and a red gradient of increasing risk. Similar to Sherman-Morris and Brown (2012) and Severtson and Myers (2013), the results revealed that the type of warning design impacted the spatial communication of tornado likelihood. In fact, the current storm-based polygon increased perceptions of tornado likelihood in the center of the geographic area whereas the color spectrum and red gradient design concentrated spatial risk where tornado probability was highest. When it comes to assessing perceived risk, fear, and protective actions along the boundaries of each warning design, Ash et al. (2013) found that respondents recognize the edge of the warning as a prominent visual feature or "preattentive" property; however, the edges of the probabilistic warning designs were less critical in comparison to the edge of the storm-based polygon. Therefore, the responses to the probabilistic warning designs (i.e., color gradient and red gradient) suggest that this uncertainty visualization successfully highlights the most at-risk areas, but also fails to appropriately communicate tornado likelihood in other zones.

With the Convective Outlook graphic possessing some of the properties discussed by Pinker (1990) and Cleveland and McGill (1984), in conjunction with the risk boundary concerns outlined by Sherman-Morris and Brown (2012) and Ash et al. (2013), one could anticipate that misperceptions in spatial risk and perceived uncertainty may also exist for those (1) on the boundary between categorical risk levels and (2) on the boundary between being at-risk and not at-risk (Figure 1.5). To make matters more complicated, this literature does not address the role of inconsistency or the use of different visual designs to communicate implicit uncertainty information. As a result, several questions remain: what if the visual displays depicting spatial risk and uncertainty are inconsistent? How would these results differ? Specifically, how would these visual inconsistencies impact their spatial risk perception, uncertainty, and behavioral intentions along a risk boundary? This dissertation seeks to answer these questions by exploring the risk boundaries within Convective Outlook graphics; however, additional literature is needed to better understand the intricacies associated with inconsistent visual displays. Therefore, the next section utilizes a specialized area of health communication, called conflicting information, to build on the working definition of consistency provided by Mileti and Sorensen (1990) and to understand the theoretical implications associated with inconsistent Convective Outlook graphics.

1.3.4 Conflicting Information Literature

In an ever-growing media environment, the variety of trusted sources and sheer volume of available weather information increases the opportunity to encounter inconsistent visual information. However, the challenges of inconsistent information are not isolated to the weather enterprise and can be best approached using a small number of studies from the conflicting information[3] literature. These topics include, but are not limited to: conflicting information and medication adherence (Carpenter et al. 2010; Carpenter et al. 2014), obtaining second opinions from specialists (Elstad et al. 2012), mammography recommendations (Taplin et al. 1997; Han et al. 2006; Han et al. 2007; Niederdeppe and Levy 2007; Han et al. 2009), and nutrition and wellness (Nagler and Hornik 2012; Nagler 2014; Lee et al. 2017). The prevalence of conflicting information has been shown to vary by topic, with previous studies reporting that 18-80% of patients receive conflicting medication information (Carpenter et al. 2010; Carpenter et al. 2014; Hämeen-Anttila et al. 2014), 50-75% of individuals perceive conflicting information regarding mammography guidelines (Taplin et al. 1997; Niederdeppe and Levy 2007), as well as 72% of people reporting medium to high exposure to nutrition and wellness information (Nagler 2014). Several studies have attempted to determine the origins and most prominent sources of conflicting information, with most agreeing that the Internet, the media, and interpersonal communication are among the leading causes for conflicting information. But, what about the negative impacts of conflicting information?

Despite the assumption that conflicting information results in confusion among the general public, few studies have been devoted to demonstrating the negative cognitive and behavioral implications of conflicting information – an area where health communication scholars have begun to thrive. Scholars have utilized both qualitative and

[3] Here, "conflicting information" refers to receiving contradictory information from different sources (Carpenter et al. 2010).

quantitative research methods to obtain a more robust perspective on the impacts of conflicting information. The use of qualitative methods, which allowed researchers direct access to members of the general public, has been reserved for discussing mammography recommendations and nutrition among women (Taplin et al. 1997; Allen et al. 2013). For example, Allen et al. (2013) conducted focus groups with a diverse group of women aged 40 to 50 to better understand women's awareness of the change in mammography screening recommendations, which took place in 2009. The focus groups revealed disbelief and confusion, as well as trust issues surrounding the reasons for the change. However, a recent study by Nagler et al. (2017) focused specifically on immigrant women in international communities and found little evidence of confusion and/or mistrust surrounding the controversy of altering mammography recommendations. Additional qualitative studies have revealed that conflicting information increases anxiety (Pollock et al. 2004), alters risk perceptions (Han et al. 2006), and affects patient's ability to assess the reliability of sources (McIntosh & Shaw 2003). Quantitatively, studies have linked self-reported exposure to conflicting information to public confusion and decreased trust in nutrition recommendations (Nagler 2014; Lee et al. 2017), lower medication adherence (Carpenter et al. 2010; Carpenter et al. 2014), lower medication use during pregnancy (Hämeen-Anttila et al. 2014), and increased anxiety among pregnant women (Hämeen-Anttila et al. 2014). With an arsenal of research describing the negative implications of inconsistent information, this review now turns toward improving the conceptualization of inconsistency using existing definitions and operationalizations from the conflicting information literature.

While often described as "conflicting messages" in the health communication literature, they are variously termed competing, contradictory, *inconsistent*, mixed, or divergent messages (Nagler and LoRusso 2017). Although some authors carefully distinguish between these words, especially in their conceptualizations, their applications within the extant literature can be inconsistent. The most historically prominent conceptualization involves the incorporation of two-sided information, or messages that provide both supporting and opposing evidence within the same message. This message type can be directly compared to a one-sided message, which provides a singular view point (i.e., either supporting or opposing evidence). For example, Jensen and Hurley (2012) studied the ramifications of providing participants with controversial viewpoints that were consistent (convergent condition), conflicting (divergent condition), or one-sided (control condition). These authors revealed that exposure to conflicting viewpoints affected one's perceived uncertainty and scientists' perceived credibility, but the effects varied by topic. However, one question emerges: Are these messages, in fact, offering conflicting information, or simply exemplifying competitive framing (Nisbet et al. 2013)? Here, equating 'conflict' with 'message sidedness' provides an inaccurate depiction of the *type* of conflicting information that exists within the weather enterprise (i.e.., message inconsistencies between sources).

Within the last decade, health communication scholars have sought to redefine conflicting information due to the range of information available via the Internet. The nascent literature provides two broad classes and/or conceptualizations of conflicting health messages. First, conflicting information can be categorized as exhibiting *decisional conflict,* or as Nagler (2010) describes: "messages that provide information about two distinct behaviors and their effects on the same outcome" (pg. 55). During a tornado, for example, an individual may receive a message that suggests one behavior (e.g., Take shelter now). However, he or she may seek additional information – through the warning confirmation process (Mileti and Beck 1975; Sorensen 1982; Lindell and Perry 1983; Quarantelli 1984; Rogers 1985; Mileti and Sorensen 1990) - and be exposed to a different message, this one describing a second behavior (e.g., Evacuate to another town). Both messages consistently emphasize the dangers and the likelihood of the impending tornado threat; however, they are different in that they provide two distinct behavioral options. If an individual were exposed to both messages, he or she may struggle with the decision to (1) take shelter now, (2) evacuate to another town, or (3) seek additional information to potentially clarify this situation.

The second categorization of conflicting information, and the one that this dissertation seeks to better understand within the context of Convective Outlook graphics, is best described as *informational conflict*. Informational conflict, or as Carpenter et al. (2014, pg. 1175) outlines, "can be operationally defined as two or more health-related statements or assertions that are logically inconsistent with one another." For example, suppose an individual searches for severe weather information and comes across a Convective Outlook graphic produced by the Storm Prediction Center. This visual graphic depicts a "High" severe weather risk for his/her area this afternoon. However, that same individual may seek additional information (e.g., watching their favorite local broadcast meteorologist) and be exposed to a Convective Outlook graphic with a different visual design, this one describing the threat and/or risk of severe weather as "Moderate." Here, the visual graphics are logically inconsistent with one another and force the individual to decide whether they (1) trust the government source, (2) trust their local broadcast meteorologist, or (3) seek additional information to potentially clarify this situation. The issue becomes more complicated when an individual decides to seek additional information and encounters more conflicting information. In this situation, instead of alleviating uncertainty and anxiety, through the information seeking process, we anticipate that seeking and finding a conflicting or inconsistent visual display will *increase* an individual's perceived uncertainty[4]. Thus, how do individuals resolve this added uncertainty and how does uncertainty impact decision-making? To address these questions and establish a theoretical framework for exploring message consistency, this literature review now turns to decision theory, the concept of ambiguity, and uncertainty management.

1.3.5 Decision Theory, Ambiguity, and Uncertainty Management

Recently, several scholars in the field of health communication have presented theoretical arguments that connect conflicting or inconsistent information with decision theory. Ellsberg (1961), a decision theorist, used the term *ambiguity* to depict uncertainty that is associated with risk information. Described by others as "uncertainty about uncertainty" (Einhorn and Hogarth 1985; Einhorn and Hogarth 1986; Kahn and Sarin 1988), the use of ambiguity represents a specific type of uncertainty that comprises the "reliability, credibility, or adequacy of one's [risk] information" (Han et al. 2006, pg. 52). Ellsberg (1961) adds to his discussion by stating that ambiguity is high when "there is

[4] For clarification, the use of 'uncertainty' in this sentence is different from the previous sections describing the use of visual displays to depict probabilistic or uncertainty information. Here, 'uncertainty' is used to describe an individual's perception of uncertainty after receiving a message or information. Thus, it is different from meteorological uncertainty or uncertainty in a forecast.

ample quantity of information, when there are questions of reliability and relevance of information, and particularly where there is *conflicting* opinions and evidence" (pg. 659). Here, Ellsberg (1961) and others describe the ambiguity of risk information as being imprecise or vague; however, does the definition of ambiguity address risk information that differs between two or more sources?

The concept of ambiguity has been investigated within many health contexts, especially cancer-related topics (Han et al. 2006; Han et al. 2007; Han et al. 2009), and has even shown to negatively impact risk/benefit judgements and decision-making (Einhorn and Hogarth 1986; Camerer and Weber 1992; Kuhn 1997; Han et al. 2009). This negative reaction to ambiguity has been described as "ambiguity aversion," with cancer screening and prevention studies revealing that perceptions of ambiguity lowered perceived self-efficacy and reduced one's willingness to adopt cancer-related interventions (Han et al. 2007; Han et al. 2009). Similarly, scholars have attempted to investigate responses to "ambiguity" and "uncertainty" through an examination of individual differences. For example, Brouwers and Sorrentino's (1993) paper constructed a measure to evaluate "uncertainty orientation," or the way in which an individual would "approach or avoid, attend to or ignore, such uncertainty" (pg. 103). Overall, this conceptualization of "ambiguity" converges on information clarity rather than informational conflict; however, its unique connection with uncertainty provides a bridge for (1) exploring the uncertainty communication literature and (2) connecting the theoretical and behavioral implications of uncertainty to "message consistency."

Uncertainty occurs "when details of situations are ambiguous, complex, unpredictable, or probabilistic; when information is unavailable or *inconsistent*; and when people feel insecure in their own state of knowledge or the state of knowledge in general" (Emphasis added; Brashers 2001, pg. 478). The conceptualization and theoretical frameworks of uncertainty have evolved through the years: from a fixation on reducing uncertainty (i.e., Uncertainty Reduction Theory; URT; Berger and Calabrese 1975), to understanding both the positive and negative implications of uncertainty (i.e., Theory of Uncertainty Management; TUM; Brashers et al. 2000), and finally by recognizing that uncertainty may exist as a series of thresholds (i.e., Theory of Motivated Information Management; TMIM; Afifi and Weiner 2004). Based on this perspective, the most recent theoretical development in uncertainty communication suggests that a series of thresholds exist that govern the decision on how one might manage their uncertainty (i.e., increase, decrease, or maintain; Afifi and Weiner 2004). Specifically, the authors conceptualize uncertainty as two different thresholds: actual uncertainty and desired uncertainty. For example, an individual will experience a level of actual uncertainty when they are alerted to the threat for severe weather via a Convective Outlook graphic. If that actual uncertainty is higher or lower than their desired level of uncertainty, then that individual will likely perform information management behaviors to equalize those thresholds (Kuang and Wilson 2017). According to Brashers' (2001) definition of uncertainty, if *inconsistent* information is discovered during the information management process then actual uncertainty will likely increase. Using the assumptions of TMIM, this will lead to an information management cycle that seeks to achieve one's desired level of uncertainty.

In a similar vein, extant literature on fear appeals (Witte and Allen 2000; So 2013) and the Extended Parallel Process Model (EPPM & E-EPPM) suggests that uncertainty occurs from the mere possibility of a severe weather threat. Uncertainty is derived from one's susceptibility (i.e., likelihood of harm) and severity (i.e., magnitude of threat) to the weather phenomenon, as well as response efficacy (i.e., personal belief that the recommended action will succeed in avoiding the threat) and self-efficacy (i.e., the personal belief that one can perform the recommended action). Recently, scholars have begun bridging these literatures (i.e., fear appeals and uncertainty management), as they both possess motivating factors for information management behaviors (Rains and Tukachinsky 2015; So et al. 2016). Although less informed by theoretical contributions, the results by Rains and Tukachinsky (2015) and So et al. (2016) provide evidence that receiving *inconsistent* information would impact uncertainty as individuals struggle to successfully identify the threat and/or efficacy information associated with the impending severe weather (Kuang and Wilson 2017).

Therefore, the current theoretical literature on uncertainty (from both fear appeals and uncertainty management) fails to elaborate on the perceptual and behavioral ramifications between different "waves" of uncertainty (i.e., initial uncertainty versus added uncertainty). For example, an individual will likely experience initial uncertainty after receiving a severe weather threat message (i.e., fear appeal). This should trigger a negative emotional response (e.g., fear, anxiety, etc.), which is common when uncertainty appraisals are viewed as dangerous or threatening (Brashers et al. 2000, Brashers 2001; So 2013). To reduce these emotions and/or uncertainty, URT, TUM, and TMIM all hypothesize that an individual will likely perform information management behaviors – specifically information seeking when "an individual's management goal is reduction of uncertainty" (Brashers et al. 2000, pg. 79). But, how does the discovery of *inconsistent* information, during this information seeking process, impact one's uncertainty? This literature review seeks answers by utilizing the information management literature in the following section.

1.3.6 Information Management Under Uncertainty

Brashers and colleagues (2002) describe information management best in their fundamental article on information management in health and illness contexts. According to these authors, "information management includes communicative and cognitive activities such as seeking, avoiding, providing, appraising, and interpreting those environmental stimuli" (pg. 259). Put in the frame of uncertainty management, information can be sought to reduce uncertainty (Berger and Calabrese 1975; Brashers et al. 2000), increase uncertainty in situations involving hope and/or optimism, and finally by inviting individuals to reappraise their level of uncertainty (Brashers et al. 2000). Brashers et al. (2000) provide an in-depth qualitative analysis of TUM, in the context of information management among persons with HIV. The authors distinguished several specific information management behaviors including: active information seeking to reduce uncertainty, passive information seeking to reduce uncertainty, avoiding information to maintain uncertainty, as well as seeking information to increase uncertainty. However, the most relevant finding involved participants' ability to manage uncertainty through time. Brashers et al. (2000) describe this happening when information management behaviors "…lead to additional (new) sources of uncertainty or can result in uncertainty that is unwittingly increased or decreased" (pg. 74). While not explicitly mentioning this secondary "wave" of uncertainty, Brashers et al. (2000) are making an initial connection between managing uncertainty at different time points and the potential for "inconsistent" information from newly sought information sources.

However, when approaching this idea of additional uncertainty at a secondary time point (e.g., *after* an individual performs one of the information management behaviors above), it is best to revisit the concept of uncertainty discrepancy as described in TMIM. Recall that uncertainty discrepancy represents the difference between one's actual and desired levels of uncertainty; this is closely related to the concept of "information sufficiency" proposed by the Risk Information Seeking and Processing Model (RISP; Griffin et al. 1999). The value of uncertainty discrepancy, as it relates to inconsistent information, lies in the measurement of the concept, which frequently takes place both before and after information management behaviors are performed (Rains and Tukachinsky 2015; So et al. 2016). Therefore, uncertainty discrepancy is beneficial for understanding the difference in uncertainty at different time points. The problem, is that previous research in information management has focused on the antecedents of information seeking over its outcomes. So et al. (2016) note this discrepancy and suggest that this scholarly attention toward the predictors of information seeking are a result of: (1) the methodological and/or monetary challenges associated with measuring information seeking behavior *and* its effects and/or (2) the assumption from previous risk communication literature (e.g., Rimal and Real 2003) that implies information seeking is a "positive outcome" and often leads to increased knowledge.

1.3.7 Conclusion

Taken together, this literature review has provided evidence that shows that (1) depicting visual uncertainty information often emerge along risk boundaries, (2) the warning and visual communication literatures conceptualize inconsistent information when it is contradictory or conflicting, and (3) conflicting or inconsistent information has negative impacts on anxiety, uncertainty, risk perception, and behavioral intentions. However, previous research has yet to explore the importance of visual design when communicating or conveying a consistent message. To address this gap in the literature, this dissertation will define message consistency for the weather enterprise (RQ1), qualitatively explore the general public's message consistency evaluation process (RQ2) and experimentally manipulate Convective Outlook graphics to evaluate their effects on risk perception, uncertainty, and behavioral intentions to seek information and perform protective actions (RQ3).

RQ1. How do other disciplines define, consider, and measure "message consistency," and can this knowledge be used to conceptualize "message consistency" for weather enterprise researchers and practitioners?

RQ2. How do members of the general public evaluate whether two Convective Outlook graphics are consistent or not? Do members of the public describe different visual designs as 'inconsistent?' If so, how and in what ways?

RQ3. How do graphical inconsistencies associated with Convective Outlook graphics affect risk perception, uncertainty, information seeking intentions, and behavioral intentions to perform protective actions?

1.4 References

Afifi, W. A., and J. L. Weiner, 2004: Toward a theory of motivated information management. *Communication Theory,* **14**(2), 167-190.

Allen, J. D., S. M. Bluethmann, M. Sheets, K. M. Opdyke, K. Gates-Ferris, M. Hurlbert, and E. Harden, 2013: Women's responses to changes in US Preventive Task Force's mammography screening guidelines: Results of focus groups with ethnically diverse women. *BMC Public Health,* **13**(1), pg. 1-12.

Allen, P. M., J. A. Edwards, F. J. Snyder, K. A. Makinson, and D. M. Hamby, 2014: The effect of cognitive load on decision making with graphically displayed uncertainty information. *Risk Analysis*, **34**(8), 1495-1505.

American Meteorological Society, 2001: Expectations concerning media performance during severe weather emergencies. Retrieved from: https://www.ametsoc.org/ams/index.cfm/about-ams/ams-statements/statements-of-the-ams-in-force/expectations-concerning-media-performance-during-severe-weather-emergencies/

American Meteorological Society, 2017: (In)consistency in a social media world: Communication reflections of the 2017 Hurricane Season. Retrieved from: https://annual.ametsoc.org/2018/index.cfm/programs/short-courses-workshops/workshop-the-matt-parker-communication-workshop-on-consistent-weather-messaging/

ANSI Z535.4, 1991: *Product Safety Signs and Labels*. New York: American National Standards Institute. Retrieved from: http://www.davis-inc.com/expert/docs/z535p4-1991.pdf

Ash, K. D., R. L. Schumann III, and G. C. Bowser, 2013: Tornado warning tradeoffs: Evaluating choices for visually communicating risk. *Weather, climate, and society,* **6**(1), 104-118.

Berger, C. R., and R. J. Calabrese, 1975: Some explorations in initial interaction and beyond: Toward a developmental theory of interpersonal communication. *Human communication research*, **1**(2), 99-112.

Brashers, D. E., J. L. Neidig, S. M. Haas, L. K. Dobbs, L. W. Cardillo, and J. A. Russell, 2000: Communication in the management of uncertainty: The case of persons living with HIV or AIDS. *Communications Monographs*, **67**(1), 63-84.

Brashers, D. E, 2001: Communication and uncertainty management. *Journal of communication*, **51**(3), 477-497.

Brashers, D. E., D. J. Goldsmith, and E. Hsieh, 2002: Information seeking and avoiding in health contexts. *Human Communication Research*, **28**(2), 258-271.

Brewer, C. A., 2006: Basic mapping principles for visualizing cancer data using geographic information systems (GIS). *American journal of preventative medicine,* **30**(2), S25-S36.

Brouwers, M. C., and R. M. Sorrentino, 1993: Uncertainty orientation and protection motivation theory: The role of individual differences in health compliance. *Journal of Personality and Social Psychology*, **65**(1), 102.

Budescu, D. V., H. H. Por, and S. B. Broomell, 2012: Effective communication of uncertainty in the IPCC reports. *Climatic change,* **113**(2), 181-200.

Camerer, C., and M. Weber, 1992: Recent developments in modeling preferences: Uncertainty and ambiguity. *Journal of risk and uncertainty*, **5**(4), 325-370.

Carpenter, D. M., R. F. DeVellis, E. B. Fisher, D. M. DeVellis, S. L. Hogan, and J. M. Jordan, 2010: The effect of conflicting medication information and physician support on medication adherence for chronically ill patients. *Patient education and counseling,* **81**(2), 169-176. doi: https://doi.org/10.1016/j.pec.2009.11.006

Carpenter, D. M., E. A. Elstad, S. J. Blalock, and R. F. DeVellis, 2014: Conflicting medication information: prevalence, sources, and relationship to medication adherence. *Journal of health communication,* **19**(1), 67-81. doi: https://doi.org/10.1080/10810730.2013.798380

Carpenter, D. M., L. L. Geryk, A. T. Chen, R. H. Nagler, N. F. Dieckmann, and P. K. Han, 2015: Conflicting health information: A critical research need. *Health Expectations*, **19**(6), 1173–1182, doi: https://doi.org/10.1111/hex.12438

Centers for Disease Control and Prevention, 2014: *Crisis emergency & risk communication.* Retrieved from: https://emergency.cdc.gov/cerc/resources/pdf/cerc_2014edition.pdf.

Cheong, L., S. Bleisch, A. Kealy, K. Tolhurst, T. Wilkening, and M. Duckham, 2016: Evaluating the impact of visualization of wildfire hazard upon decision-making under uncertainty. *International Journal of Geographical Information Science,* **30**(7), 1377-1404.

Cleveland, W. S., and R. McGill, 1984: Graphical perception: Theory, experimentation, and application to the development of graphical methods. *Journal of the American Statistical Association,* **79**(387), 531-554.

Dieckmann, N. F., P. Slovic, and E. M. Peters, 2009: The use of narrative evidence and explicit likelihood by decisionmakers varying in numeracy. *Risk Analysis,* **29**(10), 1473-1488.

Dieckmann, N. F., E. M. Peters, R. Gregory, and M. Tusler, 2012: Making sense of uncertainty: Advantages and disadvantages of providing an evaluative structure. *Journal of Risk Research,* **15**(7), 717-735.

Dowden, B. H., 2019: *Logical reasoning.* 586pp. Retrieved from: https://www.csus.edu/indiv/d/dowdenb/4/Logical-Reasoning.pdf

Edwards, J. A., F. J. Snyder, P. M. Allen, K. A. Makinson, and D. M. Hamby, 2012: Decision making for risk management: A comparison of graphical methods for presenting quantitative uncertainty. *Risk Analysis,* **32**(12), 2055-2070.

Einhorn, H. J., and R. M. Hogarth, 1985: Ambiguity and uncertainty in probabilistic inference. *Psychological review*, **92**(4), 433.

Einhorn, H. J., and R. M. Hogarth, 1986: Judging probable cause. *Psychological Bulletin*, **99**(1), 3.

Ellsberg, D, 1961: Risk, ambiguity, and the Savage axioms. *The quarterly journal of economics*, 643-669.

Elstad, E., D. M. Carpenter, R. F. Devellis, and S. J. Blalock, 2012: Patient decision making in the face of conflicting medication information. *International journal of qualitative studies on health and well-being*, **7**(1), 18523.

Eosco, G, 2008: *A study of visual communication: Cyclones, cone, and confusion.* (Unpublished master's thesis). Cornell University, Ithaca, New York.

Eosco, G., and C. A. Williams, C. A., 2017: *Inconsistency and weather communication: The good, the bad, and the ugly.* Panel session at the 2017 National Weather Association Conference, Garden Grove, CA.

Franz, J. P., S. L. Young, T. P. Rhoades, and E. C. Wisniewski, E, 2005: Predicted versus actual response to warning signs and labels: Examining the role of ANSI Z535 features. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 49, No. 19, pp. 1785-1789). Sage CA: Los Angeles, CA: SAGE Publications.

Grams, J., B. Bunting, and S. Weiss, 2014: SPC Convective Outlooks. Retrieved from: www.spc.noaa.gov/misc/SPC_probotlk_info.html

Gregory, R., N. Dieckmann, E. Peters, L. Failing, G. Long, and M. Tusler, 2012: Deliberative disjunction: Expert and public understanding of outcome uncertainty. *Risk Analysis,* **32**(12), 2071-2083.

Griffin, R. J., S. Dunwoody, and K. Neuwirth, 1999: Proposed model of the relationship of risk information seeking and processing to the development of preventive behaviors. *Environmental research*, **80**(2), S230-S245.

Hämeen-Anttila, K., H. Nordeng, E. Kokki, J. Jyrkkä, A. Lupattelli, K. Vainio, and H. Enlund, 2014: Multiple information sources and consequences of conflicting information about medicine use during pregnancy: a multinational Internet-based survey. *Journal of medical Internet research*, **16**(2), e60. doi: https://doi.org/10.2196/jmir.2939

Han, P. K., R. P. Moser, and W. M. Klein, 2006: Perceived ambiguity about cancer prevention recommendations: relationship to perceptions of cancer preventability, risk, and worry. *Journal of health communication*, **11**(S1), 51-69.

Han, P. K., S. C. Kobrin, W. M. Klein, W. W. Davis, M. Stefanek, and S. H. Taplin, 2007: Perceived ambiguity about screening mammography recommendations: association with future mammography uptake and perceptions. *Cancer Epidemiology and Prevention Biomarkers*, **16**(3), 458-466.

Han, P. K., R. P. Moser, W. M. Klein, E. B. Beckjord, A. C. Dunlavy, and B. W. Hesse, 2009: Predictors of perceived ambiguity about cancer prevention recommendations: Sociodemographic factors and mass media exposures. *Health communication*, **24**(8), 764-772.

Heckman, G. M., E. M. Harley, I. Scher, and D. E. Young, 2010: Helmet use in sledding: Do users comply with manufacturer warnings? In *Proceedings of the Human Factors and Ergonomics Society 49th Annual Meeting,* **49***,* 1785-1789.

Ibrekk, H., and M. G. Morgan, 1987: Graphical communication of uncertain quantities to nontechnical people. *Risk Analysis,* **7**(4), 519-529.

Jensen, J. D., and R. J. Hurley, 2012: Conflicting stories about public scientific controversies: Effects of news convergence and divergence on scientists' credibility. *Public Understanding of Science*, **21**(6), 689-704.

Kahn, B. E., and R. K. Sarin, 1988: Modeling ambiguity in decisions under uncertainty. *Journal of Consumer Research*, **15**(2), 265-272.

Kalsher, M. J., W. G. Obenauer, and C. F. Weiss, 2016: Evaluating ANSI Z535-formatted warning labels as an integrative system. In *Proceedings of the Human*

Factors and Ergonomics Society Annual Meeting (Vol. 60, No. 1, pp. 1642-1646). Sage CA: Los Angeles, CA: Sage Publications.

Keller, C., and M. Siegrist, 2009: Effect of risk communication formats on risk perception depending on numeracy. *Medical Decision Making,* **29**(4), 483-490.

Keller, C., M. Siegrist, and V. Visschers, 2009: Effect of risk ladder format on risk perception in high-and low-numerate individuals. *Risk Analysis,* **29**(9), 1255-1264.

Kim, S., and M. S. Wogalter, 2009: Habituation, dishabituation, and recovery effects in visual warnings. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 53, No. 20, pp. 1612-1616). Sage CA: Los Angeles, CA: Sage Publications.

Klockow, K. E., and S. A. Jasko, 2016: *Building a consistent message: Establishing ground rules for the weather enterprise*. Panel session at the American Meteorological Society Conference, New Orleans, LA.

Kuang, K., and S. R. Wilson, 2017: A Meta-Analysis of Uncertainty and Information Management in Illness Contexts. *Journal of Communication*, **67**(3), 378-401.

Kuhn, K. M, 1997: Communicating uncertainty: Framing effects on responses to vague probabilities. *Organizational behavior and human decision processes*, **71**(1), 55-83.

Laughery, K. R., D. L. Paige, B. R. Laughery, M. S. Wogalter, M. J. Kalsher, and S. D. Leonard, 2002: Guidelines for warning design: Do they matter? In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 46, No. 19, pp. 1708-1712). Sage CA: Los Angeles, CA: Sage Publications.

Lee, C. J., R. H. Nagler, and N. Wang, 2018: Source-specific Exposure to Contradictory Nutrition Information: Documenting Prevalence and Effects on Adverse Cognitive and Behavioral Outcomes. *Health Communication*, **33**(4), 453-461.

Leitner, M., and B. P. Buttenfield, 2000: Guidelines for the display of attribute certainty. *Cartography and Geographic Information Science,* **27**(1), 3-14.

Lindell, M. K., and R. W. Perry, 1983: Nuclear power plant emergency warning: How would the public respond? *Nuclear news*, pg. 49-53.

Lipkus, I. M., G. Samsa, and B. K. Rimer, 2001: General performance on a numeracy scale among highly educated samples. *Medical Decision Making,* **21**(1), 37-44.

MacEachren, A. M., 1992: Visualizing uncertain information. *Cartographic Perspectives,* **13**, 10-19.

McGinley, M. J., A. Turk, and D. Bennett, 2006: Design criteria for public emergency warning systems. In *Proceedings of the 3rd International ISCRAM Conference*, pg. 154-163.

McIntosh, A., and C. F. Shaw, 2003: Barriers to patient information provision in primary care: patients' and general practitioners' experiences and expectations of information for low back pain. *Health Expectations*, **6**(1), 19-29.

Mileti, D. S., and E. M. Beck, 1975: Communication in crisis: Explaining evacuation symbolically. *Communication Research,* **2**(1), 24-49.

Mileti, D. S., and J. H. Sorensen, 1990: *Communication of emergency public warnings: A social science perspective and state-of-the-art assessment* (No. ORNL-6609). Oak Ridge National Lab., TN (USA).

Nagler, R. H., 2010: *Steady diet of confusion: Contradictory nutrition messages in the public information environment*. University of Pennsylvania. *Dissertation.*

Nagler, R. H., and R. C. Hornik, 2012: Measuring media exposure to contradictory health information: a comparative analysis of four potential measures. *Communication methods and measures*, **6**(1), 56-75.

Nagler, R. H., 2014: Adverse outcomes associated with media exposure to contradictory nutrition messages. *Journal of health communication*, **19**(1), 24-40.

Nagler, R. H., J. A. Lueck, and L. S. Gray, 2017: Awareness of and reactions to mammography controversy among immigrant women. *Health Expectations*, **20**(4), 638-647.

Nagler, R. H., and S. LoRusso, 2018: Conflicting information and message competition in health and risk messaging. In R. Parrott (Hrsg.), Encyclopedia of health and risk message design and processing (S. 353–372). New York, NY: Oxford University Press.

National Consortium for the Study of Terrorism and Responses to Terrorism (START), 2012: Understanding risk communication best practices: A guide for emergency managers and communicators. Retrieved from: https://www.start.umd.edu/sites/default/files/files/publications/UnderstandingRiskCommunicationBestPractices.pdf

National Oceanic and Atmospheric Administration, 2014: Seven best practices for risk communication. Retrieved from: https://coast.noaa.gov/data/digitalcoast/pdf/risk-communication-best-practices.pdf

National Weather Association, 2017: *March Webinar Wednesday: Should weather messaging wear uniforms? The role of consistency versus uniformity of visuals and messaging within the weather community.* Retrieved from: https://www.youtube.com/watch?v=IcnXfL92orE

Niederdeppe, J., and A. G. Levy, 2007: Fatalistic beliefs about cancer prevention and three prevention behaviors. *Cancer Epidemiology and Prevention Biomarkers*, **16**(5), 998-1003.

Nisbet, E. C., P. S. Hart, T. Myers, and M. Ellithorpe, 2013: Attitude change in competitive framing environments? Open-/closed-mindedness, framing effects, and climate change. *Journal of Communication*, **63**(4), 766-785.

Peters, E., P. S. Hart, and L. Fraenkel, 2011: Informing patients: The influence of numeracy, framing, and format of side effect information on risk perceptions. *Medical Decision Making,* **31**(3), 432-436.

Pinkler, S, 1990: A theory of graph comprehension. *Artificial intelligence and the future of testing,* 73-126.

Pollock, K., J. Grime, E. Baker, and K. Mantala, 2004: Meeting the information needs of psychiatric inpatients: staff and patient perspectives. *Journal of Mental Health*, **13**(4), 389-401.

Quartantelli, E. L, 1984: Perceptions and reactions to emergency warnings of sudden hazards. *Ekistics,* 511-515.

Rains, S. A., and R. Tukachinsky, 2015: Information seeking in uncertainty management theory: Exposure to information about medical uncertainty and information-processing orientation as predictors of uncertainty management success. *Journal of health communication*, **20**(11), 1275-1286.

Rimal, R. N., and K. Real, 2003: Perceived risk and efficacy beliefs as motivators of change. *Human communication research*, **29**(3), 370-399.

Rogers, G. O., 1985: *Human components of emergency warning: Implications for planning and management.* Pittsburge, PA: University Center for Social and Urban Research, University of Pittsburgh.

Russman, U., and J. Svensson, 2017: Introduction to visual communication in the age of social media: Conceptual, theoretical and methodological challenges. *Media and Communication,* **5**(4), 1-5.

Schwartz, L. M., 1997: The role of numeracy in understanding the benefit of screening mammography. *Annals of internal medicine,* **127**(11), 966-972.

Severtson, D. J., and J. B. Henriques, 2009: The effect of graphics on environmental health risk beliefs, emotions, behavioral intentions, and recall. *Risk Analysis,* **29**(11), 1549-1565.

Severtson, D. J., and C. Vatovec, 2012: The theory-based influence of map features on risk beliefs: Self-reports of what is seen and understood for maps depicting an environmental health hazard. *Journal of Health Communication,* **17**(7), 836-856.

Severtson, D. J., and J. D. Myers, 2013: The influence of uncertain map features on risk beliefs and perceived ambiguity for maps of modeled cancer risk from air pollution. *Risk Analysis,* **33**(5), 818-837.

Sherman-Morris, K., and M. E. Brown, 2012: Experiences of Smithville, Mississippi residents with the 27 April 2011 tornado. *National Weather Digest,* **36**(2), 93-101.

So, J., 2013: A further extension of the extended parallel process model (E-EPPM): Implications of cognitive appraisal theory of emotion and dispositional coping style. *Health Communication*, **28**(1), 72-83.

So, J., K. Kuang, and H. Cho, 2019: Information Seeking Upon Exposure to Risk Messages: Predictors, Outcomes, and Mediating Roles of Health Information Seeking. *Communication Research*, **46**(5), 663-687.

Sorensen, J. H., 1982: *Evaluation of the emergency warning system at the Fort St. Vrain nuclear power plan* (No. ORNL/TM-8171). Oak Ridge National Lab., TN (USA).

Taplin, S. H., M. T. Mandelson, C. Anderman, E. White, R. S. Thompson, D. Timlin, and E. H. Wagner, 1997: Mammography diffusion and trends in late-stage breast cancer: evaluating outcomes in a population. *Cancer Epidemiology and Prevention Biomarkers*, **6**(8), 625-631.

Tufte, E., 2001: *The visual display of quantitative information*. Cheshire, CT: Graphics press.

Waters, E. A., N. D. Weinstein, G. A. Colditz, and K. Emmons, 2006: Formats for improving risk communication in medical tradeoff decisions. *Journal of Health Communication,* **11**(2), 167-182.

Wogalter, M. S., D. M. DeJoy, and K. R. Laughery, 1999: *Warnings and risk communication.* pp. 365. Taylor & Francis, Philadelphia, PA.

World Health Organization. (n.d.). WHO strategic communications framework for effective communications. Retrieved from: http://www.who.int/mediacentre/communication-framework.pdf

Witte, K., and M. Allen, 2000: A meta-analysis of fear appeals: Implications for effective public health campaigns. *Health education & behavior*, **27**(5), 591-615.

Wolfram, S, 1989: *Philosophical logic: an introduction*. Psychology Press.

Young, S. L., J. P. Franz, and T. P. Rhoades, and K. R. Darnell, 2002: Safety signs and labels: Does compliance with ANSI Z535 increase compliance with warnings? *Professional Safety*, **47**(9), 18-23.

Table 1.1 Implicit severe weather probability information associated with each categorical risk level

	Day 1 Outlook Probability				Day 2 Outlook Probability		Day 3 Outlook Probability
	Tornado	*Wind*	*Hail*		*Combined Probability*		*Combined Probability*
2%	Marginal	Not Used	Not Used		Not Used		Not Used
5%	Slight	Marginal	Marginal		Marginal		Marginal
10%	Enhanced	Not Used	Not Used		Not Used		Not Used
10% with Significant Severe	Enhanced	Not Used	Not Used		Not Used		Not Used
15%	Enhanced	Slight	Slight		Slight		Slight
15% with Significant Severe	Moderate	Slight	Slight		Slight		Slight
30%	Moderate	Enhanced	Enhanced		Enhanced		Enhanced
30% with Significant Severe	High	Enhanced	Enhanced		Enhanced		Enhanced
45%	High	Enhanced	Enhanced		Enhanced		Enhanced
45% with Significant Severe	High	Moderate	Moderate		Moderate		Moderate
60%	High	Moderate	Moderate		Moderate		Not Used
60% with Significant Severe	High	High	Moderate		High		Not Used

****NOTE:** Convective Outlook categorical risk levels are derived from probability forecasts of tornadoes, high winds, and hail on Day 1; however, a combined severe weather risk is used on Days 2 and 3 (Grams et al., 2014).

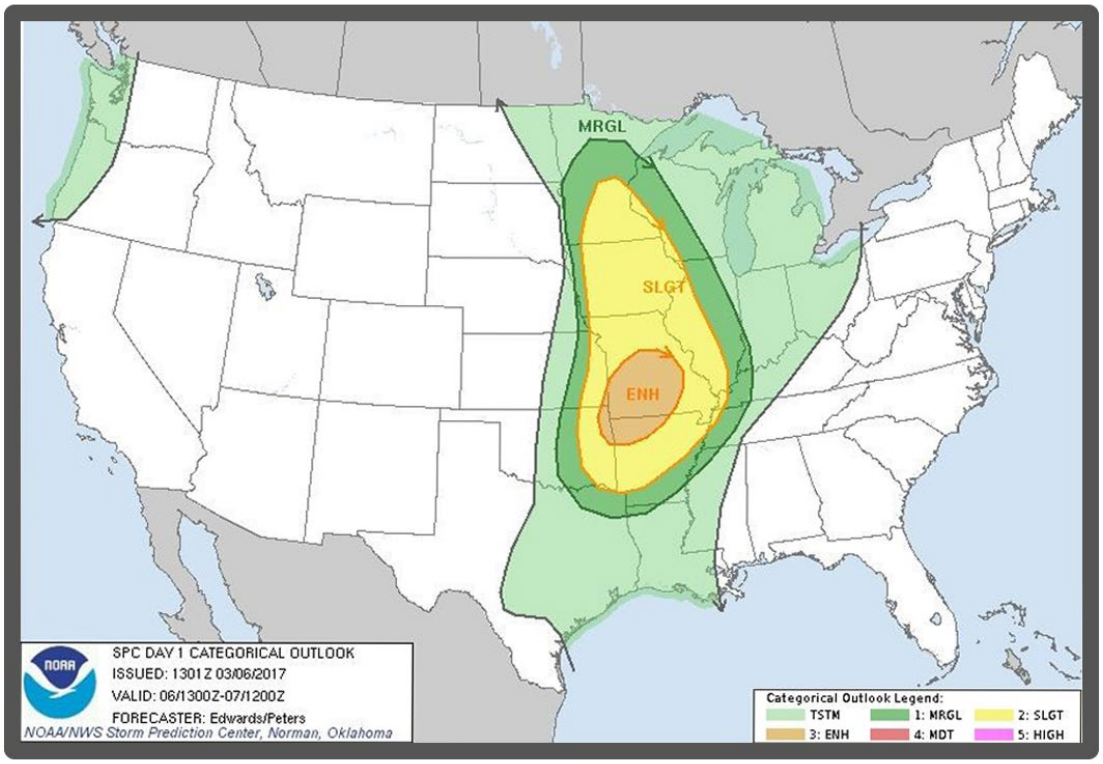

Figure 1.1. A Convective Outlook graphic created by the Storm Prediction Center to depict the categorical and probabilistic threat of severe weather to a variety end of users.

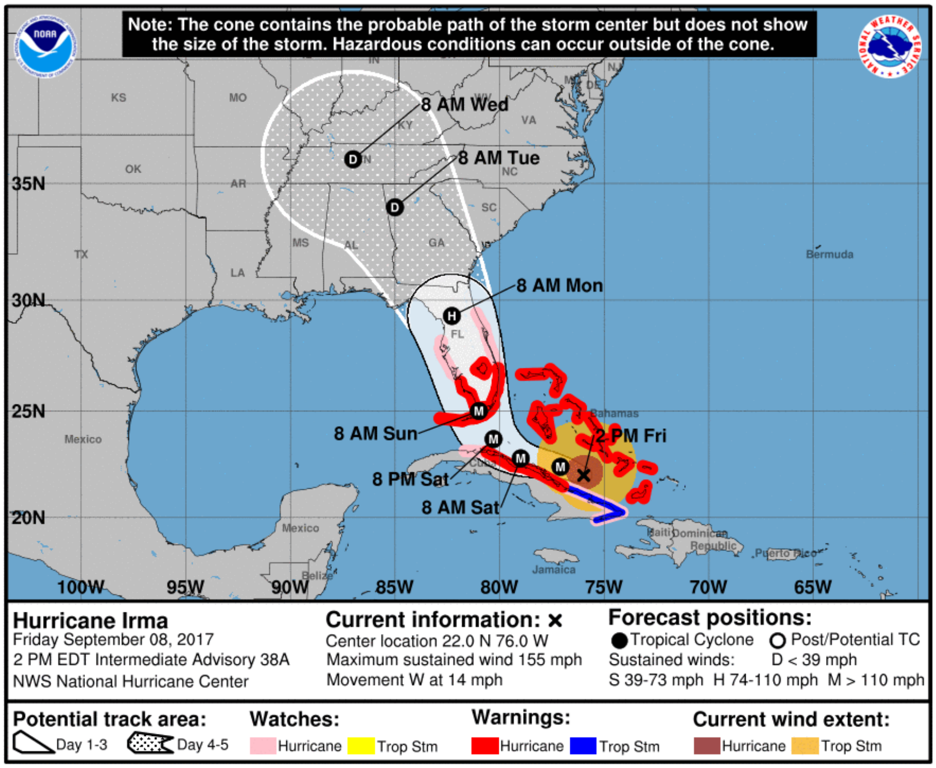

Figure 1.2. An example "cone of uncertainty" graphic for Hurricane Irma.

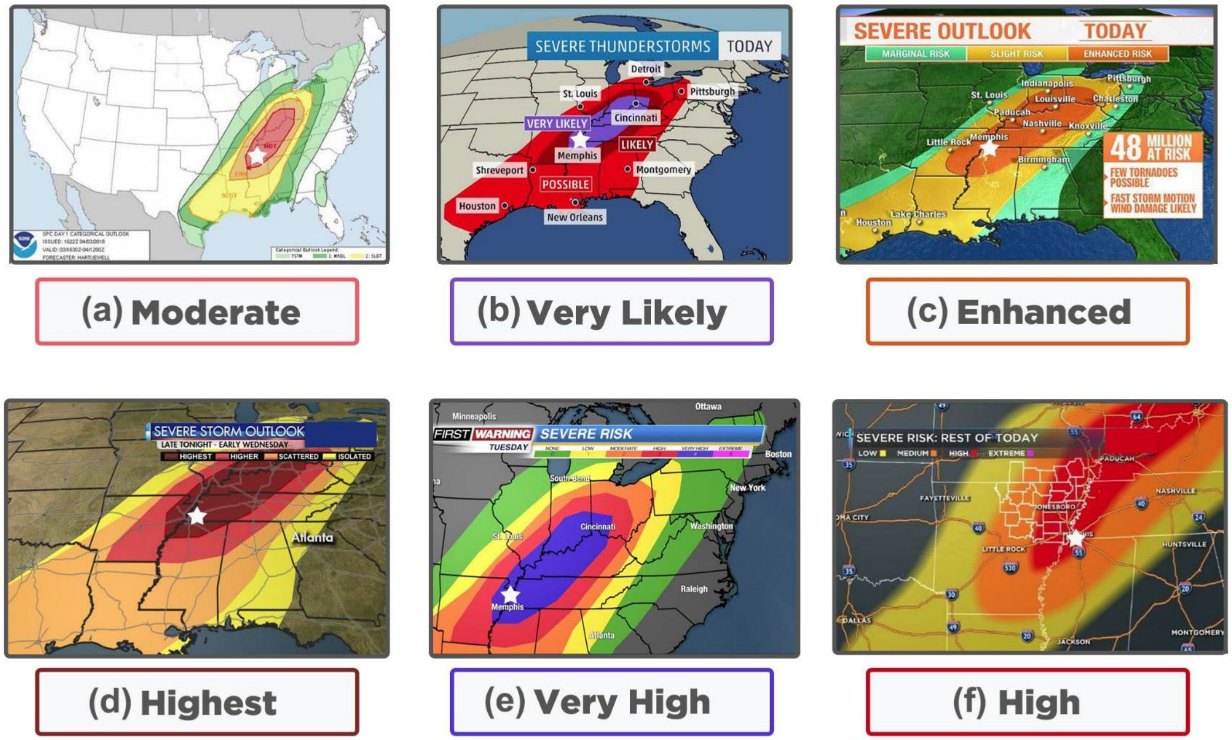

Figure 1.3. A variety of Convective Outlook graphical designs that differ from the Storm Prediction Center's graphic by using different *colors, risk language*, and *spatial risk contours*. The star indicates Memphis, Tennessee across all graphics for comparison purposes. All graphics were taken from the 20:00UTC run of the SPC Day 1 Convective Outlook on 04/03/18.

Figure 1.4. A visual comparison of the new ANSI-Z535 Standard versus the traditional OSHA safety sign design (Vulcan, 2014).

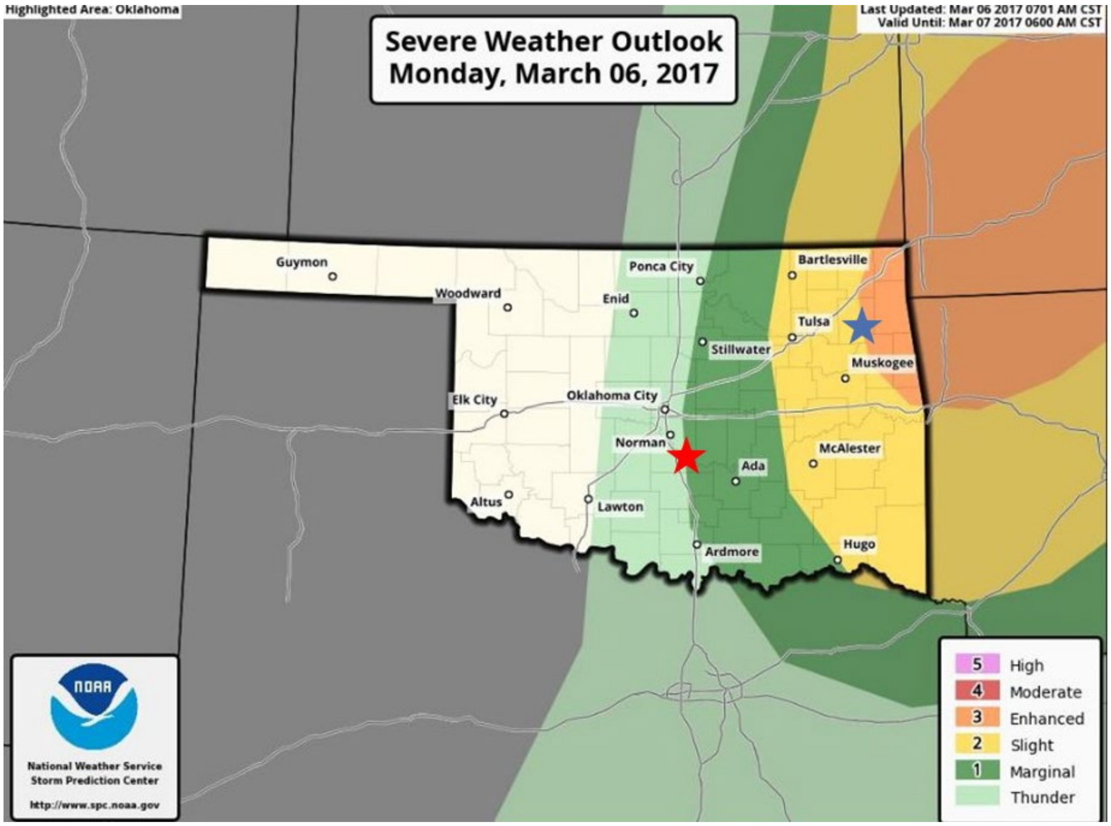

Figure 1.5. A Convective Outlook graphic depicting (1) the boundary between categorical risk levels (blue star) and (2) the boundary between being at-risk and not at-risk (red s

CHAPTER 2

IS A CONSISTENT MESSAGE ACHIEVEABLE? DEFINING 'MESSAGE CONSISTENCY' FOR WEATHER ENTERPRISE RESEARCHERS AND PRACTITIONERS[5]

[5] Williams, C.A. and G. M. Eosco. Submitted to *Bulletin of the American Meteorological Society*¸ Revised and resubmitted on May 7, 2020.

Capsule Summary

This paper combines the needs of operational meteorologists with insights from social science research to offer a definition of message consistency for weather enterprise researchers and practitioners.

Abstract

With the advent of the Internet, social media platforms, and mobile-based devices, weather information is now readily available from a variety of public, private, and academic sources within the weather enterprise. While source diversity gives end users the opportunity to seek out tailored weather information, it also contributes to the perception of message inconsistency, which is of concern to the operational meteorological community. To address these concerns, members of the weather enterprise organized conference sessions, panels, webinars, and workshops to achieve message consistency, but were unable to make progress without a definition. Fortunately, research scholars in the fields of psychology and communication studies offer important theoretical insights for defining message consistency. As such, this paper takes an important first step by combining the needs of operational meteorologists with insights from social science research to offer a definition of message consistency for the weather enterprise. While it is logical to present both a definition *and* a recommendation on how to achieve message consistency, the systematic review revealed various practical constraints that call into question the feasibility of achieving it. Therefore, to further bridge research and practice, this paper recommends that researchers and practitioners collaboratively develop a message consistency evaluation process for the weather enterprise. A persistent community effort will shed light on when and where consistency is necessary, and more importantly, move us one step closer toward achieving a *more* consistent message within the weather enterprise.

Keywords: consistency, consistent message, conflicting information, weather communication, risk communication

2.1 Introduction

The pioneers of warning communication (Mileti and Sorensen 1990) emphasized message consistency as a key attribute for successful risk communication. Putting it into practice, however, in a public, private, and academic weather enterprise, becomes more challenging. When asked to define 'message consistency,' for example, meteorologists fall into two opposing camps: (1) those that equate consistency with uniformity (e.g., no variation in language or visual products. uniform terminology across all platforms.) and (2) those that believe similarities between weather messages create consistency (e.g., similar meanings for colors and words; for example, the color red is always used to signify the same level of impact across hazards.). Not only does the weather enterprise grapple with the definition of message consistency, but members also express concern that perceived inconsistencies may negatively affect their many audiences. The availability of weather information, from a variety of trusted sources on the Internet, social media platforms, and mobile-based devices, likely contributes to this perception of inconsistency. As a result, many in the weather enterprise contend that message consistency is necessary and should be a priority in the community (American Meteorological Society 2001; Hilderbrand 2014; American Meteorological Society 2018a).

However, after organizing and discussing message consistency in conference sessions, panels, webinars, and workshops, members of the weather enterprise still do not agree on how to achieve it. In fact, achieving consistency is often challenged by the desire to be unique or different. Therefore, the private sector frequently questions what role branding and marketing may play in maintaining a consistent message. Broadcast meteorologists, for example, experience tremendous pressure to distinguish themselves from other weather sources (Eosco 2008). These distinctions, such as repurposing common weather products (e.g., the Day 1 Convective Outlook), creating new weather products (e.g., Tornado Index), and/or adhering to other strict station requirements (e.g., use of a specific color palette), may contribute to the nuances associated with achieving a consistent message. Thus, these organized efforts showed that (1) message consistency is difficult to define, and that (2) achieving a consistent message is much more complex than initially anticipated. More importantly, these insights challenge the assumption that message inconsistency is problematic and that the entire weather enterprise needs a consistent message. Therefore, without further clarity on how to define message consistency in the context of weather risk messaging, the pursuit for consistency will remain aimless, open-ended, and unachievable.

Fortunately, the path toward conceptual clarity lies beyond the weather community in the fields of political, health, and science communication—as their practitioners, like meteorologists, share a common concern for communicating a consistent message. Because this is an emerging area of research, these disciplines offer guidance to approach message consistency in a weather context. Therefore, this paper will (1) explore the recurrent themes that emerged from organized efforts in the weather enterprise, (2) synthesize and connect social science literature that can help define 'message consistency' for the weather community, and (3) offer a definition and recommended next steps for weather enterprise researchers and practitioners.

2.2 A Closer Look at the Organized Efforts in the Weather Enterprise

Throughout the last four years (2016–2019), the weather enterprise has organized various efforts to explore message consistency (Figure 2.1). The first documented effort, a panel session at the 2016 American Meteorological Conference (AMS), sought to establish ground rules to achieve consistent messaging within the weather enterprise. This diverse group of panelists, which included members from all sectors of the weather enterprise, determined that providing ground rules is difficult without first defining message consistency (Klockow and Jasko 2016). A National Weather Association (NWA) webinar sought to continue the consistency conversation by instead asking, should weather messaging wear a uniform? Like the previous panel session, the webinar panelists also struggled to conceptualize message consistency. However, using real-world examples, operational meteorologists, broadcast meteorologists, and social scientists agreed that inconsistencies frequently arise when meteorologists use different colors, numbers, and words to communicate severe weather risk information to the public (National Weather Association 2017a).

A follow-up panel session at the 2017 NWA Conference had a different perspective. This panel of public and private sector meteorologists described the need for weather messaging to be unique and different. They emphasized that a one-size-fits-all approach does not work, and that "the same message must be conveyed in multiple ways to ensure that everyone walks away with the same general message" (National Weather Association 2017b). However, the panelists did insist that protective actions provided in weather risk messaging should remain consistent, if not uniform, between sources.

Participants at the Matt Parker Communication Workshop, which was held before the 2018 AMS National Conference, also noted that a one-size-fits-all approach would not work. However, these participants essentially integrated the perspectives from the previous efforts by insisting that consistency could be implemented to certain degrees. Using the concept of "flexible consistency," they suggested that specific aspects of weather-related messages should remain consistent. For example, several individuals acknowledged the color discrepancies that exist in the weather enterprise and proposed the use of "a consistent set of colors" (American Meteorological Society 2018b).

After recognizing commonalities across the organized efforts, each recorded conversation was qualitatively analyzed to illuminate the language and content used to describe message consistency in the weather enterprise. In doing so, this analysis revealed recurring words, phrases, and themes that were used to inform a social science literature review. This methodological approach began with the first author transcribing, analyzing, and examining each recorded conversation via an inductive content analysis (Hsieh and Shannon 2005). If the conference did not provide professional recording services, the author first obtained verbal consent from each participant and then used a personal recording device to document the discussion. The recordings ranged from 60 to 90 minutes; however, presentations and round table discussions at the Matt Parker Communication Workshop spanned over a three-hour period. Through this qualitative analysis, themes and categories emerged based on words, phrases, or ideas that repeatedly appeared throughout the transcripts. These themes were then collected into a single document and further connections were made between the responses. A final set of themes was determined after several iterations of collapsing and combining thematic codes. The author then shared the final set of thematic categories with the second author to discuss, synthesize, and combine any redundant codes. These interactive discussions with the second author helped establish intercoder reliability, a measurement commonly used in qualitative research to determine the agreement between two or more independent coders (Lombard et al. 2002). Finally, it should be noted that this analysis does not include the most recent panel session at the 2019 AMS National Conference. However, a separate section in this manuscript is devoted to some of the themes that arose in this panel session on consistency (see the section in this manuscript titled: Addressing the Effects of Inconsistent Information: Insights from the 2019 AMS Session on Conflicting Information). For more information about the organized efforts discussed above, please see Table 2.1.

2.3 Five Emerging Themes from the Organized Efforts

Although not an exhaustive list, five prominent themes emerged from the content analysis. These data show that members of the weather enterprise frequently mentioned that:

- (1) a working definition of message consistency is needed;
- (2) inconsistencies often arise in the individual parts of a message;
- (3) specific message features likely play a role in maintaining consistency;
- (4) protective action information should remain consistent, or even uniform, across messages; and

- (5) a weather authority is needed to help facilitate message consistency within the weather enterprise.

Throughout each and every organized effort, panelists, presenters, and participants remained hyper-focused on defining message consistency (*theme 1*; Klockow and Jasko 2016; NWA 2017a; NWA 2017b; AMS 2018b). Without an established definition, individuals found it difficult to discuss operational best practices, ground rules, and recommendations for approaching consistency in the weather enterprise (Klockow and Jasko 2016). As a result, establishing a working definition emerged as the first compelling theme.

Without agreement on a definition, panelists sought to redefine the problem by instead asking: what makes a weather message *inconsistent*? Using a severe weather threat as an example, participants explored weather messages and called attention to the parts that often differ across sources (NWA 2017a). While they identified differences in color, number, and word choice as "inconsistent," they felt that maintaining the overarching message (i.e., that a severe weather threat exists) was more important. This discussion exposed a need to strike a delicate balance between allowing differences in the individual parts of a weather message without interfering with the overarching goal of the message (*theme 2*). In other words, at what point do these differences in colors, numbers, or words, for example, promote or hinder the communication of a similar overall message that a weather threat exists?

Maintaining similar message goals across sources in the weather enterprise feels easier than discovering the exact point where differences in the individual parts of a weather message result in inconsistency. This balancing act, then, implies that certain variables or message features may affect the consistency of a message. The challenge, however, is identifying *which* message characteristics are important (*theme 3*). For example, conference panelists frequently emphasized the importance of consistency and, in some instances, argued for uniformity when considering the behavioral or protective action information associated with weather messages (*theme 4*). But, what about other message characteristics? Do other message-related variables result in inconsistencies that interfere with the weather community's mission to protect lives and property?

Beyond the need to establish a working definition and maintain a balance between weather messages, the final theme that emerged was the desire for a weather authority (*theme 5*). Throughout the organized efforts, participants repeatedly asked, *who* is going to help the weather enterprise achieve consistency? Does consistency need a form of enforcement, such as media monitoring? Finally, *who* should identify and recommend best practices to the weather enterprise?

Together, these five themes outline a problem statement relating to message consistency in the weather enterprise. Therefore, the following sections will explore each of these themes in more detail and connect relevant interdisciplinary literature to help contextualize the points that emerged during these organized efforts. By doing so, this manuscript takes an important first step by using insights from social science research and the needs of the operational meteorological community to question the feasibility of communicating a consistent message across the weather enterprise.

2.4 Defining Message Consistency

As noted earlier, when members of the weather enterprise were asked to define 'message consistency,' they fell into two opposing camps: (1) those that equate consistency with uniformity (e.g., no variation in language or visual products; uniform terminology across all platforms.) and (2) those that believe similarities between weather messages create consistency (e.g., similar meanings for colors and words; for example, the color red is always used to signify the same level of impact across hazards.). Although a tedious process, obtaining conceptual and definitional clarity of message consistency has numerous implications for the weather community (*theme 1*). Specifically, these dichotomous viewpoints, from members of the weather enterprise, embody different operational goals, challenges, and best practices for alleviating consistency concerns. Therefore, consensus is needed before moving forward. As a starting point, the weather enterprise should ignore the nuances of message consistency and instead consider what 'being consistent' means at a fundamental level.

The Oxford English Dictionary (2018) offers two relevant definitions of the term 'consistent' that help highlight its basic principles: (1) "Not containing any logical contradictions" and (2) "Compatible or in agreement with something." The defining feature of the first definition is its use of the word "contradictions," as it implies that the absence of a contradictory statement or message is a key criterion for maintaining consistency. The fields of philosophy and logic share this argument in their abstract understanding of consistency. According to Wolfram (1989), a set of separate sentences is said to be 'consistent' if and only if there is at least one possible situation in which they are all simultaneously true. For example, statements like "it is raining outside right now" and "it is cloudy outside right now" would be categorized as consistent because it could be both cloudy and raining at the same time. However, instead of emphasizing consistency, philosophers and logicians find more value in defining, identifying, and resolving inconsistencies (Dowden 2019).

Wolfram (1989) points out two types of inconsistent statements: contradictories and contraries. Contradictory statements represent a stronger type of inconsistency because the truth of one statement results in the falsity of the other. For example, consider these sentences: (1) Oklahoma City is at risk for severe weather tomorrow at 5:00 p.m. and (2) Oklahoma City is *not* at risk for severe weather tomorrow at 5:00 p.m. The example statements above are *contradictory,* because they cannot both be true and cannot both be false. *Contrary* statements, on the other hand, occur when two sentences cannot both be true but *can* both be false (Wolfram 1989). For example, consider numerical weather prediction and ensemble forecasting. Instead of a single forecast, ensemble forecasting produces a wide range of possible future states of the atmosphere. Because there can only be one future state, all of the ensemble forecasts cannot be true; however, they could also all be false, as the weather event may not adhere to any of the ensemble forecast's future states and could result in a completely different outcome. Like an ensemble forecast, then, contrary statements or messages cannot both be true but can both be false. Although informative, this basic interpretation of inconsistency—as deriving from contradictory or contrary statements—does not address all of the operational constraints and complexities that exist in the weather enterprise. However, it does offer a building block and key criterion for establishing a conceptual definition of message consistency: contradictions or conflicts often result in inconsistency.

The Oxford English Dictionary's second relevant definition describes 'consistent' as "compatible or in agreement with something." Although sharing similar characteristics with the previous definition, as it describes the need for logical agreement, this definition uniquely identifies a secondary requirement: a subject, object, trait, behavior, feature, or attribute that must be evaluated for consistency. This ambiguous "something" ultimately prevents the weather community from establishing a definition of message consistency and agreeing on best practices. During the 2016 AMS Panel Session, for example, Dr. Gina Eosco grappled with the definition of consistency and attempted to pinpoint the "something" that the weather community needs to evaluate the consistency between two messages:

> "If we don't mean identical, then what do we mean by [consistency]? Do we mean similar? Similar doesn't mean identical, but it means that part of the message is similar but not necessarily all of it. Therefore, what part of the message do we want to be similar? The science part? The design part? The words that we use?" (Dr. Gina Eosco, Klockow and Jasko 2016).

This perspective closely mimics a definition put forward by the weather enterprise, and highlights that certain parts of a message may need to be similar to attain consistency.

However, in the same panel session, a broadcast meteorologist acknowledged the importance of key messages and described message consistency from a broader, more encompassing viewpoint. Dr. Josh Eachus stated that:

> "One [person] might watch my competitor, because he/she likes the way he looks better, likes the way he speaks better, or likes the way he delivers the weather [information] better. But, if we have the same message, maybe worded a bit differently, but still get the same points across, then that is consistency in the

> message. So, consistency or harmony in the key points, [even though] we might all word it differently" (Klockow and Jasko 2016).

Together, these competing perspectives highlight that the key to message consistency lies in the similarities between messages. Identifying and determining which similarities are the most important, however, is more challenging. Based on conversations in the community, the criteria (i.e., the "something") for evaluating a weather message's consistency is best described as a spectrum of possibilities ranging from messages that use different words but exhibit a similar goal (i.e., to inform the end user of a weather threat) to messages that must retain certain parts (e.g., words, colors, numbers). Therefore, a question and recurring theme emerges: What is more important, maintaining consistency in the key points or ensuring that parts of the message remain consistent across the weather enterprise (*theme 2*)? The next section will explore this notion further, utilizing both extant social science literature and previous conversations in the weather enterprise.

2.5 Inconsistencies Often Arise in the Individual Parts of a Message

Risk communication is important to operational meteorologists; as such, understanding how changes in the different parts of a message (e.g., color, numbers, words) affect the communication of a similar overall message is at the core of their questions. Communication scholars share this interest in a message's discrete parts, as they frequently break down persuasive messages, manipulate a part of the message, and determine its effect on attitude and/or information processing (Shen and Bigsby 2013). As a result, the communication and persuasion literatures identify and describe the different parts of a message as ‘message elements,’‘message features,’ or ‘message characteristics.’ Although their conceptual definition often varies between studies, Shen and Bigsby (2013) offer three broad categories of message features: (1) the content (i.e., what the message is about), (2) the structure (e.g., number of arguments the message contains, presence of counterarguments), and (3) the style (e.g., word choices, visual design, music; Shen and Bigsby 2013). More importantly, this literature offers clear evidence that message features significantly affect persuasive outcomes (for review, see O’Keefe 2018). One could argue, then, that when a weather source alters the features of a message (e.g., color, numbers, words, etc.), it likely also impacts the consistency of the overall message.

Like the persuasive communication literature, psychologists are also interested in the relationship between the general and the specific. However, the psychological literature offers more insight into how people process conflicting or inconsistent information. For example, in medical settings, doctors who examine a patient’s symptoms holistically accurately diagnose a patient more often than those who analyze the individual symptoms (Reyna 2008). Fuzzy-trace theory—a psychological theory of cognition that explores the relationship between memory encoding and reasoning processes—provides context as to why. At its core, this theory explains that individuals separately and simultaneously encode two types of representations when presented with any kind of information (Rahimi-Golkhandan et al. 2017). Like the weather community’s distinction between the parts of a message and its key points, the two types of representations associated with fuzzy-trace theory vary in precision from detailed *verbatim* traces to vague *gist*. Although these conceptual definitions do not quite match those put forward by meteorologists, there are clear connections that warrant further exploration of fuzzy-trace theory.

According to previous studies, individuals exhibit a fuzzy processing preference (Reyna and Adam 2003), meaning they rely heavily on and prefer gist representations of risk when performing judgement and decision-making tasks (Reyna 2012). However, gist representations may not always lead to the best risk interpretations. Women, for example, often underestimate their risk of cardiovascular disease because they presume older men are more at risk (Reyna and Adam 2003). Weather risk perception is also plagued by gist representations, as people often overestimate or underestimate their risk of experiencing various weather hazards (Hoekstra et al. 2011). Although individuals mostly benefit from gist representations when making decisions, the research in this area has yet to consider the role of conflicting or inconsistent messages. This presents more questions than answers. For example, while people prefer to process information holistically, would conflicting or inconsistent information prompt individuals to look more closely at the details? A related area of research, known as memory suggestibility and interference (Reyna and Brainerd 1995), provides some evidence that this may be true.

Memory suggestibility and interference research aims to understand whether misleading or contradictory information impacts an individual's recollection of a given event. Similar to the manipulation of certain message features in the communication and persuasion literatures, these studies often alter specific details about an event to determine its effect on memory recall (e.g., changing the color of the car involved in an accident; Reyna and Brainerd 1995). Although previous fuzzy-trace theory studies have acknowledged that individuals prefer and rely on gist representations when making decisions, by manipulating the details of an event and affecting an individual's ability to recall that event, these studies demonstrate that verbatim details matter. In fact, whether an individual relies on a gist or verbatim representation is a function of time. Individuals can recall and rely on verbatim details in the short term, but after a delayed period of time, only gist representations remain (Reyna and Kiernan 1994). As a result, differences in the details or features of a message likely have the most impact on message consistency in the short term. This becomes important as individuals search for more information after seeing a weather message (for review, see Wood et al. 2018). Consider, for example, that two local news stations use different color schemes to convey the same severe weather risk (Figure 2.2). If an individual were to see TV Station A's graphic and then change the channel and see the graphic produced by TV Station B, according to the memory suggestibility literature outlined above, the individual would likely be able to remember the verbatim details of both severe weather graphics (i.e., the color scheme; Reyna and Brainerd 1995). As a result, the weather community's speculation that color and other message features may "get in the way" of communicating a consistent message becomes more noteworthy:

> "The colors seem to be the first thing people notice and if we or some middle school blogger has a color that is different or a word that is different, it comes back to 'Well, who do I trust? Your opinions are different.' In this case, *sometimes the details get in the way* of saying: 'Hey, today is the day that you've got to watch out for either severe thunderstorms, fire weather, or [other extreme weather]'" (emphasis added; Tim Brice, NWA 2017a).

Taken together, the communication and psychological literatures call attention to both the key points and the parts of a message. While these literatures do not explicitly reference message consistency, as their findings pertain to memory encoding, reasoning, and persuasion processes, they do offer some evidence that manipulating parts of a message may affect the overall takeaway message. Therefore, inconsistent message features or verbatim details may, in fact, stand in the way of communicating a consistent overall message. The psychological literature explains that this relationship may depend on time, such that individuals may evaluate the consistency between messages using message features or verbatim details (e.g., colors, words, and numbers) in the short term and the key points in the long term. As a result, both the key points *and* the parts of a message may be important when evaluating the consistency of weather messages. The challenge, however, is identifying the message features that may interfere with the consistency of two or more weather risk messages. For example, meteorologists, psychologists, and communication scholars alike share a common concern about color inconsistencies. Apart from the use of conflicting colors, what other message features might interfere with the weather enterprise's mission to protect lives and property? In search of answers, the next section will explore a specialized area of health communication known as conflicting information.

2.6 The Role of Specific Message Features in Maintaining a Consistent Message

The weather enterprise is not isolated in its concern for communicating a consistent message. In fact, the fields of political, health, and science communication similarly struggle to conceptually define 'message consistency' and identify the specific message features that affect it. However, these disciplines have slowly begun to untangle and explore these topics in a specialized area of health communication known as 'conflicting information' (for review, see Nagler and LoRusso 2017). While often described as conflicting messages in the literature, they are variously termed competing, contradictory, inconsistent, mixed, or divergent messages. Within the last decade, however, health communication scholars have sought to refine the definition of conflicting information by offering two distinct conceptualizations. The weather enterprise can use these definitions to (1) better understand how to conceptually define message consistency and (2) discover message features that may be important for maintaining consistency.

The nascent literature identifies two broad conceptual definitions of conflicting health messages. First, conflicting information can be categorized as *decisional conflict,* or as Nagler (2010, pg. 55) describes, "messages that provide information about two distinct behaviors and their effects on the same outcome." During the 2013 El Reno tornado, for example, members of the public reported receiving messages from different sources that recommended conflicting protective actions (NWS 2013). According to the National Weather Service (NWS) Service Assessment (2013), some individuals received a message suggesting they should shelter in place, while others reported receiving instructions that they should evacuate if they could not shelter underground. Although both messages consistently emphasized the dangers and the likelihood of the impending tornado threat, they differed by providing two distinct behavioral actions. If an individual were exposed to both messages, they would be forced to decide whether to (1) take shelter now, (2) evacuate to another town, or more likely, (3) search for additional information to clarify the conflicting behavioral information (Lindell and Perry 2012).

The second conceptual definition of conflicting information is best described as *informational conflict*. Informational conflict, as Carpenter et al. (2015, pg. 1175) outlines, "can be operationally defined as two or more health-related statements or assertions that are logically inconsistent with one another." For example, suppose an individual looks for the latest snow forecast and comes across a NWS visual graphic indicating that their area will likely receive 4 to 6 inches of snow tomorrow. That same individual then seeks additional information (e.g., watching their favorite local broadcast meteorologist) and is exposed to a different snow forecast graphic, this one suggesting that their area will receive 8 to 10 inches of snow tomorrow. Here, the forecast information is logically inconsistent and forces the individual to decide whether they should (1) trust the government source, (2) trust their local broadcast meteorologist, or more likely, (3) search for additional information to clarify the conflicting information (Lindell and Perry 2012).

These two conceptual definitions hint at several themes raised throughout previous consistency efforts. In particular, the weather enterprise has struggled to identify the message features that might lead to a message being perceived as inconsistent (*theme 3*). The 2016 AMS Panel Session (Klockow and Jasko 2016) offers a prime example of this dilemma. During an exchange, Dr. Kimberly Klockow-McClain pushed the panelists to describe their interpretation of "having the same message." Through this conversation, several key message features arose:

> "You said something really interesting back there. We can all say different things, but still all have the same message. What do you think the 'message' means, then? If it's not about the words or the appearance, then what are you defining the 'message' to be?" (Dr. Kimberly Klockow McClain, Klockow and Jasko 2016)

> "The action that we're recommending you make in a situation... If we all inspire the same [action], that's consistency but not necessarily [using a] bland, boring, same exact message" (Dr. Josh Eachus, Klockow and Jasko 2016).

> "Let me define it a little differently. As opposed to the same action, what about inspiring the same feeling of risk?" (Justin Accardo, Klockow and Jasko 2016).

Like the discussion above, some members of the weather enterprise argue that the communication of risk information can be inconsistent, while others focus on the behavioral components of a message. However, according to the conceptual definitions offered by the conflicting information literature, both the risk information and the recommended actions can be inconsistent.

Throughout previous consistency conversations in the meteorological community, the role of decisional conflict or the need for decisional consistency has remained a recurrent theme (*theme 4;* Klockow and Jasko 2016; NWA 2017b; AMS 2018b). During the NWA panel session (2017b), for example, participants explicitly acknowledged the need for consistency (if not uniformity) when sharing protective action statements during a weather event:

> "Perhaps there are many parts of the message. So there's the risk aspect that maybe we can be a little bit different on, but at least in this case [we are] consistent that it is, indeed, a tornado. But, it sounds like what you're saying is the efficacy message, the protective action part of the message, may be the most critical [part of the message] where we should be in melody with one another versus perhaps harmony" (Dr. Gina Eosco, NWA 2017b).

Several of the organized efforts strongly echoed this sentiment, highlighting the importance of the recommended actions or behavioral dimensions of a message (also known as self-efficacy and response efficacy among communication scholars; Table 2.2; for review, see Meczkowski and Dillard 2017). Therefore, this message feature is likely essential when evaluating message consistency in the weather enterprise.

Although less tangible and more elusive to pinpoint, the risk information provided in a weather message is also an important message feature to consider. For example, meteorologists often vocalize their concerns of inconsistent risk messaging during severe weather events (i.e., severe thunderstorms and/or tornadoes) when visual graphics use "...different colors, different words, different numbers, and different categories" to communicate a uniform threat (Rick Smith, NWA 2017a, Figure 2.3). These visual inconsistencies are thought to be very confusing for members of the public and may, in fact, alter an individual's interpretation of their severe weather risk:

> "There are a lot of ways that [severe weather] is being messaged out there. We occasionally hear from people that say, 'Well I don't know, I'm in the orange on this channel and purple on this channel, and you're telling me I'm in yellow. I don't think any of you know what's going to happen because none of you can agree on your wording or how you're conveying the information.' So that happens anytime we have severe weather, we'll hear comments about that" (Rick Smith, NWA 2017a)

Therefore, like the behavioral dimensions described above, some message features also correspond to the dimensions of risk information (also known as susceptibility and severity to communication scholars; Table 2.2; for review, see Meczkowski and Dillard 2017). As a result, the conflicting information literature acknowledges that both the efficacy and risk portions of a message are critical for evaluating whether two weather messages are consistent.

Beyond the basic understanding that these message features are likely important for maintaining consistency, the cognitive and behavioral significance of changing these message features deserves more attention. Previous meteorological research, for example, has shown that altering a message feature has implications on risk perception and behavioral intentions (Klockow 2013; Eosco 2014; Rickard et al. 2017). Rickard et al. (2017) varied the type of visual information participants received about a hurricane risk. This experimental study revealed that including a single, real-life photograph in a hurricane risk message produced higher risk perceptions and behavioral intentions to evacuate, in comparison to showing a map or no visual information at all. These results showed that changing a message feature has cognitive and behavioral repercussions. However, two important questions remain: (1) Which message features are the most important when considering the consistency between two weather messages? (2) Is there a tipping point where differences in these message features affect an individual's risk perception and/or behavioral intentions? Although the conflicting health information literature has yet to address these important questions, it does offer some evidence regarding the implications of conflicting or inconsistent information. Therefore, the next section will explore both the positive and negative effects of conflicting messages.

2.7 Addressing the Effects of Inconsistent Information: Insights from the 2019 AMS Session on Conflicting Information

Until this point, conversations in the weather community have remained very abstract and fixated on defining consistency. As a result, the implications or effects of inconsistent messages have not received much discussion in the weather enterprise. However, after discovering the conflicting information literature and connecting with several scholars in this field, AMS held a presentation and panel session strictly devoted to the effects of inconsistent information on end users at its 2019 annual meeting (Williams et al. 2019). Here, presenters were able to provide insight on the prevalence, causes, and effects of inconsistent information from their respective fields.

The prevalence of conflicting information has been shown to vary by topic, with previous studies reporting that anywhere from 18 to 80 percent of people have received conflicting health information (Carpenter et al. 2010; Carpenter et al. 2014; Hämeen-Anttila et al. 2014; Nagler 2014, Niederdeppe and Levy 2007; Taplin et al. 1997). Despite the assumption that conflicting information confuses members of the public, few studies have been devoted to demonstrating the cognitive and behavioral effects of conflicting information—an area where health communication scholars have begun to thrive. Previous research in this area, for example, has revealed that conflicting information increases feelings of anxiety (Hämeen-Anttila et al. 2014; Pollock et al. 2004), alters risk perceptions (Han et al. 2006), affects a patient's ability to assess the reliability of sources (McIntosh and Shaw 2003), causes public confusion and decreased trust in nutrition recommendations (Lee et al. 2017; Nagler 2014), and reduces the use of and adherence to medications (Carpenter et al. 2010; Carpenter et al. 2014; Hämeen-Anttila et al. 2014)

Evidence from the conflicting information literature has acknowledged the negative effects of exposure to inconsistent information, but does it provide any benefits? During the Matt Parker Communication Workshop (AMS 2018b), one participant asked this provocative question, suggesting that forecasters could use inconsistencies to communicate uncertainty:

> "Instead of considering inconsistency as harmful, in actuality, could it be helpful? Does inconsistency among messages or graphics better convey inherent uncertainty associated with the forecast?" (AMS 2018b).

The same question arose during the 2019 AMS Session, where conflicting information scholars agreed with this assessment—noting the informational value of inconsistency to convey scientific disagreement (Williams et al. 2019). However, they warned that in order for this implicit scientific uncertainty to be valuable, purposive inconsistencies must be eliminated:

> "I think we need to reduce reducible uncertainty and reduce reducible conflict—especially if it is being created for commercial reasons. [For example,] weather stations competing with one another for eyeballs. That we need to get rid of, but some of this conflict is just scientific uncertainty. We are never going to make that go away" (Dr. Paul Han, Williams et al. 2019).

Given the discussion above, communicating scientific uncertainty may actually be a larger consistency problem. Dr. Paul Han hints at this point when he describes the two types of consistency affecting the weather community: (1) conflict and uncertainty that results from inconsistencies in the messaging and (2) conflict and uncertainty that results from scientific uncertainty. Although we cannot escape scientific uncertainty or the challenges associated with communicating uncertainty information, we *can* reduce any unnecessary conflicting information within our weather risk messaging. Therefore, the drawbacks and benefits of inconsistency, outlined above, will be critical as meteorologists create and refine strategies for crafting consistent messages in the weather enterprise.

2.8 A Working Definition of Message Consistency for the Weather Enterprise

The weather enterprise's deep-rooted concern for achieving message consistency stems from the sheer volume of diverse weather information that individuals can access from a variety of public, private, and academic sources. Underlying this concern is an implicit feeling that message inconsistencies may have negative repercussions. On the other hand, source diversity also gives end users the opportunity to seek out weather information that is tailored to their individual needs. As a result, operational meteorologists likely experience this push and pull between achieving consistency and providing their end users with a personalized forecast. The ambiguous use of the term 'message consistency' in our community is likely responsible for this tension. In the absence of a working definition, 'message consistency' tends to adopt the qualities of uniformity, thereby instantly eliminating any differences found across weather messages. In theory, uniformity feels more concrete and easily attainable. Using identical messages in practice, however, calls into question the value of having a *diverse* weather enterprise. Although the previous section outlined literature that demonstrates the negative consequences of inconsistent information, message uniformity also creates impracticality.

Drawing on the social science literature outlined in this paper, and the need to strike a balance between research and practice, **we define message consistency as two or more weather messages that must attain an optimal amount of similarity without producing any negative or adverse effects. By definition, then, the messages must convey the same overall message, even though their individual features may differ.** Weather risk communication is complex; as such, this definition does not account for all of its intricacies. However, the simplicity of this definition is purposeful, as it takes into consideration the evolution and uncertainty of weather forecast messages.

Although this definition offers a constructive way to conceptualize message consistency, it does not yet address how to achieve it. While it is logical to present both a definition *and* a recommendation on how to achieve message consistency, this systematic review revealed various practical constraints that call into question the feasibility of achieving it. For example, while it is ideal to assess end user perceptions prior to sharing a weather risk message, practitioners often do not have the time and/or resources to evaluate message consistency, especially in real-time as new messages become available. As such, we further pose that achieving message consistency requires a dynamic evaluation process to determine whether two or more weather messages are consistent with one another. At this time, however, this process is informal and ad hoc and needs more development. Therefore, as a next step, it is strongly recommended that both the researcher and practitioner communities work together to design, iterate, and develop a message consistency evaluation process. It is only through this blended process that both the fast-paced nature of operational meteorology, and the findings from ongoing social science research, can be combined to accommodate these practical constraints and set the stage for achieving message consistency in the weather enterprise.

2.9 Moving Forward: Recommendations for the Weather Enterprise:

Moving forward, we invite and encourage the research and practitioner communities to critique and refine the definition offered in this manuscript, collaborate on research initiatives to further develop a message consistency evaluation process, and work together to create best practices. As such, we offer the following recommendations to the weather enterprise:

2.8.1 Establish and Support a New Research Agenda:

Although previous studies (for review, Nagler and Russo 2017; Weyrich et al. 2018) offer some initial insights on message consistency, the current literature concentrates more on theory as opposed to providing practical advice on how to deliver a consistent message. However, with a working definition of message consistency, there is an opportunity for the weather enterprise to establish a new research agenda that addresses the practicality of the message consistency evaluation process and the intricacies associated with inconsistent weather messages. Therefore, the following research questions are offered for further inquiry: (1) How do meteorologists, members of the public, partners, and other end users describe message inconsistencies? How are these descriptions similar or different, and why? (2) Which message features are *the most important* for achieving consistency and subsequently minimizing any negative or adverse effects? (3) Do changes in the stylistic features of a message (e.g., color, word choice) affect an individual's interpretation of the overall message? If so, how and in what ways? (4) At what point do differences in these message features affect an individual's risk perception and/or behavioral intentions?

2.8.2 Form an Ad Hoc Committee to Develop Enterprise-Wide Best Practices

While we recommend the development of a message consistency evaluation process, there are practical constraints that must first be considered. For example, an evaluation process would be useful when comparing and contrasting a limited number of messages; however, weather events are always evolving and constantly generating a stream of new information. Therefore, evaluating and implementing message consistency on a larger scale will require further guidance. Previous consistency conversations, for example, have highlighted the desire for a "weather authority," with many recommending that the NWS should lead the charge and help facilitate message consistency across the weather enterprise (*theme 5*; Klockow and Jasko 2016). Given the different roles and responsibilities of each sector; however, it is unlikely that any one sector can (or should) create standards and force others to comply with those rules. Instead, we recommend that the weather enterprise come together as a community to consider relevant research and propose best practices.

Pulling from various committees (e.g., NWA Committee on Societal Impacts), boards (e.g., AMS Board on Enterprise Communication), organizations (e.g., Impact360 Alliance), and outside experts (e.g., risk communication experts, linguists, graphic designers), the weather enterprise could form a diverse and representative ad hoc committee to explore message consistency from an enterprise-wide perspective. This strategy is adapted from the field of warning communication, where warning safety signs, labels, and placards once lacked a consistent visual design. To overcome these consistency challenges, private sector companies collaborated and developed voluntary standards that helped establish a consistent warning graphical format (Wogalter et al. 1999). Drawing on their successes, an ad hoc committee could consider the strengths and weaknesses of developing voluntary graphical standards for weather-related graphics (e.g., uniform colors, risk language) and other enterprise-wide best practices that promote message consistency in the weather community.

2.10 Conclusion

Like the pioneers of warning communication, the meteorological community values the importance of consistent weather risk messaging. As such, understanding how to 'achieve' message consistency and what encompasses it are critical areas of interest within the weather enterprise. Research scholars in the fields of psychology and communication studies, for example, offer important theoretical insights for approaching message consistency in a weather context. Weather enterprise practitioners, however, seek concrete recommendations and best practices for maintaining a consistent message. To address this gap, this paper takes an important first step by combining insights from social science research with the needs of the operational meteorological community to offer a definition of message consistency. To further bridge research and practice, this paper recommends that researchers and practitioners collaboratively develop a message consistency evaluation process.

While this recommendation gives the impression that consistency is achievable, the constant influx of new weather messages calls into question the practicality of achieving consistency on a larger scale. For this reason, we emphasize that achieving consistency is a dynamic and evolving process that requires the full participation of the entire weather enterprise. While this paper primarily focuses on the effects of message consistency at the individual level, we urge members of the weather enterprise to explore the positive and negative effects of message consistency at different levels of analysis (i.e., micro-, meso-, and macro-level). The effects of message consistency within an organization or at various geographic scales, for example, may have unique consequences that differ from those at the individual level. Understanding if there are differences across these levels of analysis will determine how to best implement message consistency on a large scale. To work toward this common goal, we ask that the research and practitioner communities' critique and refine the definition offered in this manuscript, collaborate on research initiatives to further develop a message consistency evaluation process, and work together to develop research-guided best practices. A persistent community effort will shed light on when and where consistency is necessary, and more importantly, move us one step closer toward achieving a *more* consistent message within the weather enterprise.

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2.12 References

American Meteorological Society, 2001: Expectations concerning media performance during severe weather emergencies. *Bulletin of the American Meteorological Society,* **82**(4), 705-707.

American Meteorological Society, 2018a: Best practices for the dissemination of weather warnings to the public. Retrieved from: https://www.ametsoc.org/index.cfm/ams/about-ams/ams-statements/statements-of-the-ams-in-force/best-practices-for-the-dissemination-of-weather-warnings-to-the-public/

American Meteorological Society, 2018b: (In)consistency in a social media world: Communication reflections of the 2017 hurricane season. *Matt Parker Communication Workshop*, Austin, TX, Amer. Meteor. Soc. Retrieved from: https://annual.ametsoc.org/2018/index.cfm/programs/short-courses-workshops/workshop-the-matt-parker-communication-workshop-on-consistent-weather-messaging/

Carpenter, D. M., R. F. DeVellis, E. B. Fisher, D. M. DeVellis, S. L. Hogan, and J. M. Jordan, 2010: The effect of conflicting medication information and physician support on medication adherence for chronically ill patients. *Patient education and counseling,* **81**(2), 169-176. doi: https://doi.org/10.1016/j.pec.2009.11.006

Carpenter, D. M., E. A. Elstad, S. J. Blalock, and R. F. DeVellis, 2014: Conflicting medication information: prevalence, sources, and relationship to medication adherence. *Journal of health communication,* **19**(1), 67-81. doi: https://doi.org/10.1080/10810730.2013.798380

Carpenter, D. M., L. L. Geryk, A. T. Chen, R. H. Nagler, N. F. Dieckmann, and P. K. Han, 2015: Conflicting health information: A critical research need. *Health Expectations*, **19**(6), 1173–1182, doi: https://doi.org/10.1111/hex.12438

Dowden, B. H., 2019: *Logical reasoning.* 585 pp. Retrieved from: https://www.csus.edu/indiv/d/dowdenb/4/Logical-Reasoning.pdf

Eosco, G. M., 2008: A study of visual communication: Cyclones, cones, and confusion. Thesis, Cornell University, 153 pp.

Eosco, G. M., 2014: Exploring risk and uncertainty perceptions in weather broadcasts using real-time response to measure visual effects. Ph.D. dissertation, Cornell University, 169 pp.

Hämeen-Anttila, K., H. Nordeng, E. Kokki, J. Jyrkkä, A. Lupattelli, K. Vainio, and H. Enlund, 2014: Multiple information sources and consequences of conflicting information about medicine use during pregnancy: a multinational Internet-based survey. *Journal of medical Internet research*, *16*(2), e60. doi: https://doi.org/10.2196/jmir.2939

Han, P. K., R. P. Moser, and W. M. Klein, 2006: Perceiving ambiguity about cancer prevention recommendations: Relationship to perceptions of cancer preventability, risk, and worry. *Journal of health communication,* **11**(S1), 51-69. doi: https://doi.org/10.1080/10810730600637541

Hawkins, M. D., V. Brown, and J. Ferrell, 2017: Assessment of NOAA National Weather Service methods to warn for extreme heat events. *Weather, Climate, and Society*, **9**(1), 5-13. doi: https://doi.org/10.1175/wcas-d-15-0037.1

Hilderbrand, D., 2014: Building a weather-ready nation. *WMO Bulletin,* **63**(2), 26-27. Retrieved from: https://www.weather.gov/media/wrn/bulletin63-26-27p.pdf

Hoekstra, S., K. Klockow, R. Riley, J. Brotzge, H. Brooks, and S. Erickson, 2011: A preliminary look at the social perspective of warn-on-forecast: Preferred tornado warning lead time and the general public's perceptions of weather risks. *Weather, Climate, and Society,* **3**(2), 128-140. doi: https://doi.org/10.1175/2011wcas1076.1

Hsieh, H. F., and S. E. Shannon, 2005: Three approaches to qualitative content analysis. *Qualitative health research,* **15**(9), 1277-1288. doi: https://doi.org/10.1177/1049732305276687

Klockow, K. E., 2013: Spatializing tornado warning lead-time: Risk perception and response in a spatio-temporal framework. Ph.D. dissertation, University of Oklahoma, 155 pp.

Klockow, K. E., and S. A. Jasko, 2016: Building a consistent message: Establishing ground rules for the weather enterprise. *11th Symposium on Societal Applications,* New Orleans, LA, Amer. Meteor. Soc., PD2.1, Retrieved from: https://ams.confex.com/ams/96Annual/webprogram/Session39835.html

Lee, C. J., R. H. Nagle, and N. Wang, 2017: Source-specific exposure to contradictory nutrition information: Documenting prevalence and effects on adverse cognitive and behavioral outcomes. *Health Communication*, **33**(4), 453-461. doi: https://doi.org/10.1080/10410236.2016.1278495

Lindell, M. K, and R. W. Perry, 2012: The protective action decision model: theoretical modifications and additional evidence. *Risk Analysis*, **32**(4), 616-632. doi: https://doi.org/10.1111/j.1539-6924.2011.01647.x

Lombard, M., J. Snyder-Duch, and C. C. Bracken, 2002: Content analysis in mass communication: Assessment and reporting of intercoder reliability. *Human communication research,* **28**(4), 587-604. doi: https://doi.org/10.1111/j.1468-2958.2002.tb00826.x

McIntosh, A., and C. F. Shaw, 2003: Barriers to patient information provision in primary care: patients' and general practitioners' experiences and expectations of information for low back pain. *Health Expectations*, **6**(1), 19-29. doi: https://doi.org/10.1046/j.1369-6513.2003.00197.x

Meczkowski, E. J., and J. P. Dillard, 2017: Fear appeals in strategic communication. *The International Encyclopedia of Media Effects*, 1-9. doi: https://doi.org/10.1002/9781118783764.wbieme0160

Mileti, D. S., & Sorensen, J. H. (1990). *Communication of emergency public warnings: A social science perspective and state-of-the-art assessment* (No. ORNL-6609). Oak Ridge National Lab., TN (USA). doi: https://doi.org/10.2172/6137387

Nagler, R. H., 2010: *Steady diet of confusion: Contradictory nutrition messages in the public information environment*. University of Pennsylvania. Unpublished Dissertation.

Nagler, R. H., 2014: Adverse outcomes associated with media exposure to contradictory nutrition messages. *Journal of health communication*, **19**(1), 24-40. doi: https://doi.org/10.1080/10810730.2013.798384

Nagler, R. H., and S. M. LoRusso, 2017: Conflicting information and message competition in health and risk messaging. *Encyclopedia of Health and Risk Message Design and Processing.* doi: https://doi.org/10.1093/acrefore/9780190228613.013.292

National Weather Association, 2017a: Should weather messaging wear uniforms? The role of consistency versus uniformity of visuals and messaging within the weather community. *Wednesday Webinar Series,* Retrieved from: https://www.youtube.com/watch?v=IcnXfL92orE

National Weather Association, 2017b: Inconsistency and weather communication – The good, the bad, and the ugly. *Broadcasters Workshop,* Retrieved from: https://nwas.org/annual-meeting-events/past-meetings/2017-annual-meeting-agenda/

National Weather Service, 2013: Service Assessment – May 2013 Oklahoma tornadoes and flash flooding. Retrieved from: https://www.weather.gov/media/publications/assessments/13oklahoma_tornadoes.pdf

Niederdeppe, J., and A. G. Levy, 2007: Fatalistic beliefs about cancer prevention and three prevention behaviors. *Cancer Epidemiology and Prevention Biomarkers*, **16**(5), 998-1003. doi: https://doi.org/10.1158/1055-9965.epi-06-0608

O'Keefe, D., 2018: Message characteristics and persuasion. In *Oxford Bibliographies.* doi: https://doi.org/10.1093/obo/9780199756841-0206

Oxford English Dictionary, 2019: "consistent." *Oxford Living Dictionaries.* Retrieved from: https://en.oxforddictionaries.com/definition/consistent

Pollock, K., J. Grime, E. Baker, and K. Mantala, 2004: Meeting the information needs of psychiatric inpatients: staff and patient perspectives. *Journal of Mental Health*, **13**(4), 389-401. doi: https://doi.org/10.1080/09638230410001729834

Rahimi-Golkhandan, S., D. M. Garavito, B. B. Reyna-Brainerd, and V. F. Reyna, 2017: A fuzzy-trace theory of risk and time preferences in decision making: Integrating cognition and motivation. *Impulsivity*, J. R. Stevens, Ed., Springer, 115-144.

Reyna, V. F., and C. J. Brainerd, 1995: Fuzzy-trace theory: An interim synthesis. *Learning and Individual Differences,* **7**(1), 1-75. doi: https://doi.org/10.1016/1041-6080(95)90031-4

Reyna, V. F., and M. B. Adam, 2003: Fuzzy-trace theory, risk communication, and product labeling in sexually transmitted diseases. *Risk Analysis,* **23**(2), 325-342. doi: https://doi.org/10.1111/1539-6924.00332

Reyna, V. F., 2008: A theory of medical decision making and health: Fuzzy-trace theory. *Medical Decision Making,* **28**(6), 850-865. doi: https://doi.org/10.1177/0272989x08327066

Reyna, V. F., 2012: Risk perception and communication in vaccination decisions: A fuzzy-trace theory approach. *Vaccine,* **30**(25), 3790-3797. doi: https://doi.org/10.1016/j.vaccine.2011.11.070

Rickard, L. N., J. P. Schuldt, G. M. Eosco, C. W. Scherer, and R. A. Daziano, 2017: The proof is in the picture: The influence of imagery and experience in perceptions of hurricane messaging. *Weather, Climate, and Society,* **9**(3), 471-485. doi: https://doi.org/10.1175/wcas-d-16-0048.1

Shen, L., and E. Bigsby, 2013: The effects of message features. *The Sage Handbook of Persuasion: Developments in Theory and Practice*, 20-35.

Taplin, S. H., M. T. Mandelson, C. Anderman, E. White, R. S. Thompson, D. Timlin, and E. H. Wagner, 1997: Mammography diffusion and trends in late-stage breast cancer: evaluating outcomes in a population. *Cancer Epidemiology and Prevention Biomarkers*, **6**(8), 625-631.

Weyrich, P., A. Scolobig, and A. Patt, 2018: Dealing with inconsistent weather warnings: Effects on warning quality and intended actions. *Meteorological Applications.* doi: https://doi.org/10.1002/met.1785.

Williams, C. A., D. M. Carpenter, P. K. J. Han, and S. Joslyn, 2019: Identifying and assessing the effects of forecast and warning communication (in)consistency on different recipients. *14th Symposium on Societal Applications: Policy, Research, and Practice,* Retrieved from: https://ams.confex.com/ams/2019Annual/meetingapp.cgi/Paper/350959?fbclid=IwAR0MJMOChAQxhR5ML3zqhtszSW-qlKQOoN_sfJvbR4FMVv-MVis3UPvCQmg

Wogalter, M. S., D. M. DeJoy, and K. R. Laughery, 1999: *Warnings and risk communication.* pp. 365. Taylor and Francis, Philadelphia, PA.

Wolfram, S., 1989: *Philosophical logic: An introduction.* Psychology Press, 308 pp.

Wood, M. M., D. S. Mileti, H. Bean, B. F. Liu, J. Sutton, and S. Madden, 2018: Milling and public warnings. *Environment and Behavior,* **50**(5), 535-566. doi: https://doi.org/10.1177/0013916517709561

Table 2.1. The weather enterprise's organized efforts on message consistency.

Name of Organized Effort	**Type of Organized Effort**	**Number of Participants**	**Backgrounds Represented**
Building a consistent message: Establishing ground rules for the weather enterprise **(Klockow and Jasko 2016)**	Panel session	7	Public sector meteorologists, private sector meteorologists, broadcast meteorologists, social scientists, and emergency managers
Should weather messaging wear uniforms? The role of consistency versus uniformity of visuals and messaging within the weather community (**NWA 2017a)**	Webinar	5	Public sector meteorologists, broadcast meteorologists, graphic designer, social scientists
Inconsistency and Weather Communication – The Good, the Bad, and the Ugly (**NWA 2017b)**	Panel Session	4	Public sector meteorologists, private sector meteorologists, broadcast meteorologists, and social scientists.
Matt Parker Communication Workshop – (In)Consistency in a Social Media World: Communication Reflections of the 2017 Hurricane Season (**AMS 2018b)**	Workshop - presentations, panel session, and round table discussions	70	Public sector meteorologists, private sector meteorologists, broadcast meteorologists, and social scientists.
Identifying and Assessing the Effects of Forecast and Warning Communication (In)Consistency on Different Recipients (**Williams et al. 2019)**	Presentation and panel session	5	Health communication scholars, medical professionals, and psychologists.

Table 2.2. Message-related variables in the risk communication and fear appeals literature. Definitions taken from Meczkowski and Dillard (2017).

Message-Related Variable	**Definition**
Susceptibility	Information that references the likelihood that the individual will experience these consequences.
Severity	Information that is relevant to the undesirable consequences of an external threat.
Response Efficacy	The belief that the advocated recommendation will constitute an effective response to the external threat.
Self-Efficacy	The belief concerning an individual's ability to execute the recommended response.

2.13 Figure Captions

Figure 2.1. A timeline of message consistency organized efforts in the weather enterprise.

Figure 2.2. An example of two local news stations using different colors schemes to convey the same severe weather risk. Local news station graphics were taken from the same 8:00UTC run of the SPC's Day 3 Convective Outlook on 03/17/18.

Figure 2.3. A variety of Convective Outlook graphical designs that differ from the Storm Prediction Center's graphic by using different *colors, risk language*, and *spatial risk contours*. The star indicates Memphis, Tennessee across all graphics for comparison purposes. All graphics were taken from the 20:00UTC run of the SPC Day 1 Convective Outlook on 04/03/18.

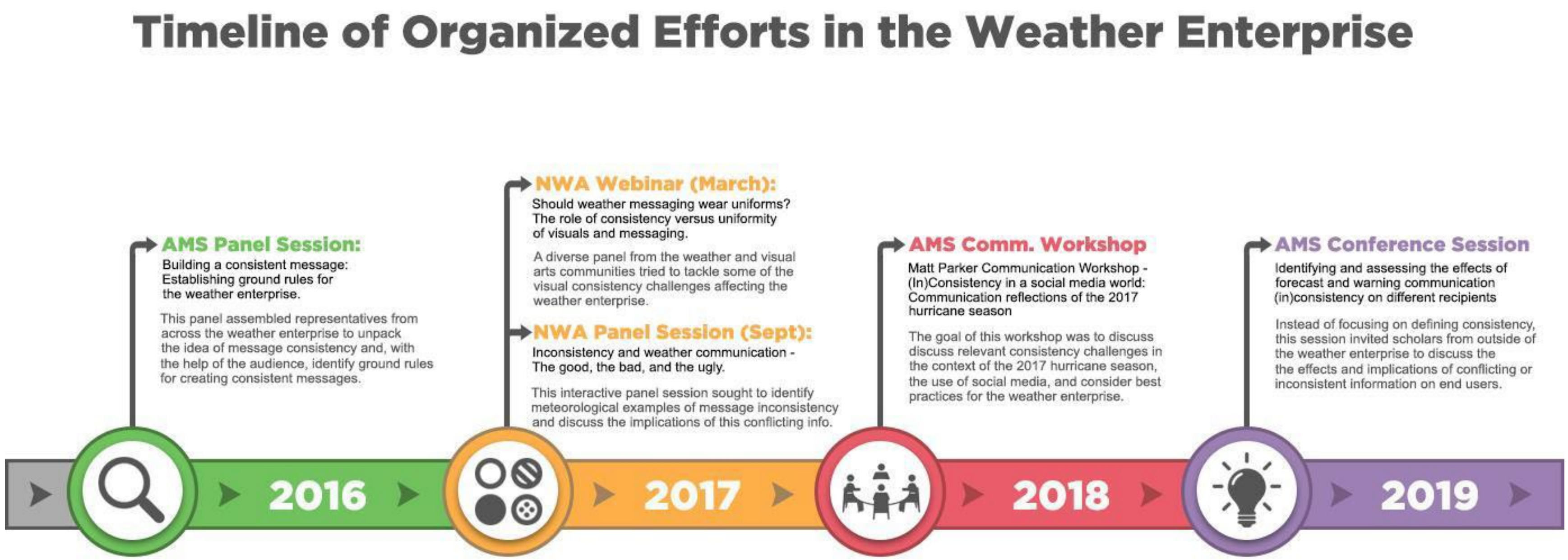

Figure 2.1. A timeline of message consistency organized efforts in the weather enterprise.

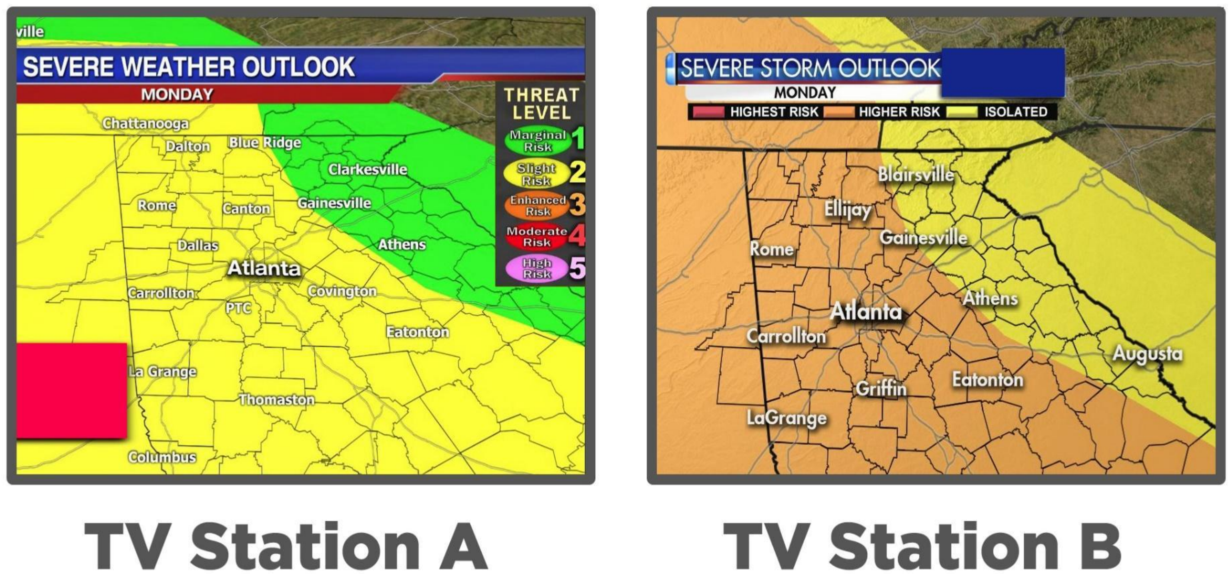

Figure 2.2. An example of two local news stations using different colors schemes to convey the same severe weather risk. Local news station graphics were taken from the same 8:00UTC run of the SPC's Day 3 Convective Outlook on 03/17/18.

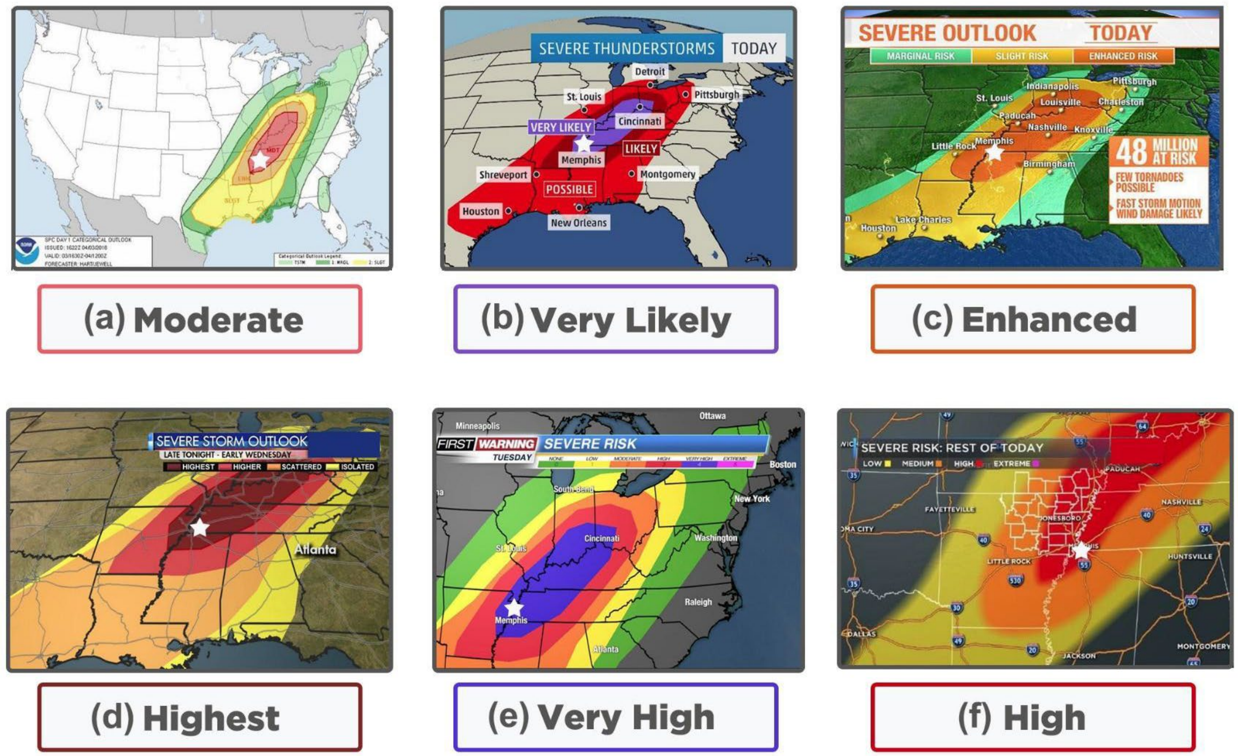

Figure 2.3. A variety of Convective Outlook graphical designs that differ from the Storm Prediction Center's graphic by using different colors, risk language, and risk categories. The star indicates Memphis, Tennessee across all graphics for comparison purposes. All graphics were taken from the 20:00UTC run of the SPC Day 1 Convective Outlook on 04/03/18.

CHAPTER 3

"INCONSISTENCIES MAKE ME QUESTION THE FORECAST" USING GRAPHICAL WEATHER INFORMATION TO UNDERSTAND THE PUBLIC'S MESSAGE CONSISTENCY EVALUATION PROCESS[6]

[6] Williams, C.A, Grundstein, A J., and J. So. To be submitted to *Weather, Climate, and Society*

Abstract

With the rise of the Internet and social media platforms, the weather enterprise has raised concerns that the availability of diverse weather information may contribute to a perception that weather risk messages as inconsistent and cause end users to suffer negative consequences. Although previous studies have offered some guidance to weather enterprise practitioners on how to define message consistency, input from the lay public is needed to fully understand how to achieve a consistent message. To address this operational gap, this study uses the Storm Prediction Center's (SPC) Day 1 Convective Outlook graphic as a vehicle to qualitatively explore the general public's message consistency evaluation process. A diverse sample of 30 community members from Athens-Clarke County, Georgia were interviewed, asked to step through four hypothetical scenarios, and presented with Convective Outlook graphics with different visual designs to better understand the public's message consistency evaluation process.

According to participants, when two graphics depict a location in the same risk area and/or color zone, they inevitably communicate a consistent message. Naturally, these criteria similarly appeared when participants described why two graphics *did not* convey the same message; however, participants also mentioned other specific ways in which two Convective Outlook graphics differed (e.g., geographical scale, risk language). A closer look at these qualitative data revealed that these graphical differences are likely tangible ways that likelihood and severity information is being unintentionally manipulated. As a result, when operational meteorologists alter specific graphical elements in a Convective Outlook (e.g., risk areas, geographical scale, risk language),

they likely also unintentionally affect the likelihood and/or severity information in the process. Although more generalizable research is needed before evidence-based practices can be established, this work offers preliminary recommendations to operational meteorologists on how to achieve a more consistent message when sharing Convective Outlook graphics with members of the public.

3.1 Introduction

The behavioral response to a weather-related message or warning represents the final, and increasingly, the most challenging stage of the forecasting process. Whereas advances in weather models and observation systems have improved meteorologists' ability to predict and detect potentially hazardous weather, communicating uncertainty and the associated risk to the public remains a formidable hurdle. To further complicate matters, the rise of the Internet and social media platforms has increased the accessibility of weather information from a variety of expert and amateur sources. Therefore, operational meteorologists, and the weather enterprise more broadly, have raised concerns that the availability of this diverse weather information may contribute to a perception that weather risk messages are inconsistent (Williams and Eosco 2020). Not only that, but the practitioner and operational meteorological communities worry that, without a consistent message, their many audiences may suffer negative consequences. What is needed then, is further guidance and best practices on how these operational communities might achieve a more consistent message in the weather enterprise.

Message consistency is often emphasized as a critical component of effective risk communication in both research (Mileti and Sorensen 1990) and practice (CDC 2014; NOAA 2016), yet little empirical literature exists that outlines how to evaluate, ensure, or even achieve a consistent message. To fill this gap, Williams and Eosco (2020) considered both the extant social science research and the operational needs of the meteorological community to develop a working definition of message consistency for the weather enterprise. Although an important first step, these authors note that this definition does not quite address how to achieve a consistent message and that more collaborative research is needed to further explicate this process. In particular, Williams and Eosco (2020) highlight that practitioners often do not have time and/or resources to evaluate end user perceptions before sharing a weather risk message. Therefore, these authors strongly encourage that researchers explore both the message consistency evaluation process among meteorologists and their end users.

The concerns raised by the weather enterprise and the study by Williams and Eosco (2020) both call attention to end user perceptions and point out that input from the lay public is needed to fully understand how to achieve a consistent message. Operational forecasters and broadcast meteorologists have explained that their end users report that weather risk messages are inconsistent. However, there is a lack of empirical evidence that demonstrates this to be true. Fortunately, a specialized area of health communication, known as conflicting information, can be used to help address this shortcoming (for review, see Nagler and LoRusso 2017). Previous studies have shown that 18-80% of people self-report being exposed to conflicting information (Carpenter et al. 2010; Carpenter et al. 2014; Hämeen-Anttila et al. 2014; Nagler 2014; Niederdeppe and Levy 2007; Taplin et al. 1997). Further, these studies reveal that exposure to conflicting information increases anxiety (Polluck et al. 2004; Hämeen-Anttila et al. 2014), alters risk perceptions (Han et al. 2006), affects patient’s ability to assess the reliability of sources (McIntosh and Shaw 2003), and interferes with behavioral intentions to perform a given action (Carpenter et al. 2010; Carpenter et al. 2014, Hämeen-Anttila et al. 2014). Therefore, like the concerns raised by the weather enterprise, it is likely (1) that members of the public do, in fact, perceive weather risk messages as inconsistent and (2) that end users are negatively affected by these inconsistencies. What deserves more attention; however, is how end users evaluate whether two or more messages are consistent. Only then will operational meteorologists, weather enterprise practitioners, and other message designers have the knowledge they need to create and construct more consistent weather risk messages.

To address this operational need, this study uses the Storm Prediction Center's Day 1 Convective Outlook graphic as a vehicle to qualitatively explore the general public's message consistency evaluation process. The Convective Outlook graphic is a static visual display that meteorologists use to communicate both the categorical and probabilistic risk of severe and general thunderstorm threats across the United States (Grams et al. 2014, Figure 3.1). Although the Convective Outlook graphic was not originally designed for members of the public to use when making weather-related decisions, with operational forecasters and broadcast meteorologists more frequently using this product on-air and sharing it via social media, it has gained visibility among these audiences (NOAA 2014). Not only that, but consistency concerns often emerge when public, private, and broadcast meteorologists share the SPC's Convective Outlook graphic and alter its color scheme, risk category language, and/or spatial depiction of severe weather risk (NOAA 2014, Figure 3.2). Although a concern among meteorologists, members of the public have not been asked whether they view these differences as notable or impactful. Therefore, this study utilized semi-structured interviews and hypothetical scenarios to expose members of the public to Convective

Outlook graphics with different visual designs. Section 2 describes the study's methodology in greater detail. This is followed by a presentation of the major results in Section 3 whereby participants elaborated on the graphical elements that promote or interfere with communicating a consistent message. Finally, Section 4 summarizes the research findings, connects relevant literature to better understand the public's message consistency evaluation process, and further refines the working definition of message consistency put forward by Williams and Eosco (2020).

3.2 Methodology

3.2.1 Participant Recruitment

Thirty individuals from Athens-Clarke County, Georgia and the surrounding counties were incentivized ($25 dollar Walmart gift card) to participate in semi-structured interviews. Due to the range of socioeconomic status in Athens-Clarke County (U.S. Census Bureau, 2017), it was determined that this would be an optimal location to obtain a diverse sample of participants. Not only that, but Georgia and several other southeastern states exhibit unique meteorological (e.g., night-time tornadoes; Ashley 2007) and social vulnerability challenges (e.g., mobile-home populations; Sutter and Simmons 2010) associated with severe weather hazards, thereby making this geographical region an important area of study for examining the effects of visual inconsistencies on severe weather forecast communication. A flyer was created and placed in public spaces (i.e., public libraries, local coffee shops, local businesses, child daycares, local organizations, local community centers) to advertise the study. Additionally, the research team drafted an email that was sent to various neighborhood and community listservs advertising the study. The research team was deliberate in the public spaces and neighborhoods that were selected in order to encourage diversity in the participant sample. It is important to remember that a qualitative study, such as the one described here, does not typically target a statistically representative sample. Instead, the goal of qualitative research is to prompt an in-depth discussion and conversation with a small group of individuals, in hopes that their thoughts and perceptions will mirror *some* of the more meaningful concerns found in the larger population.

3.2.2 Vignette Development

To qualitatively explore message consistency in the weather enterprise, a vignette-based semi-structured interview instrument was developed. After conducting a literature review, the use of scenarios or vignettes was determined to be the most effective methodology given its previous success when evaluating conflicting information concerns associated with medication adherence (Elstad et al. 2012). Beyond their use in the health (Anthony 2007; Vellinga et al. 2005) and meteorological domains (Schultz et al. 2010; NOAA 2018), vignettes are a common research tool that enable participants to experience an issue, situation, or scenario in real-time (Barter and Renold 1999). Therefore, by using vignettes, we can better understand how members of the public would hypothetically resolve situations in which they received inconsistent graphical forecast information.

Our interdisciplinary research team collaboratively developed the four vignettes that were used in the semi-structured interview instrument. To promote ecological validity, the research team first identified severe weather events that occurred over the past three years (2016-2019) and collected relevant Convective Outlook graphics that were shared by broadcast, private sector, and public sector meteorologists on social media platforms. After compiling and examining the available graphics, reviewing the findings from previous efforts in the weather enterprise (for review, please see Williams and Eosco 2020), and speaking with operational meteorologists, four vignettes were created. Each vignette, which included two Convective Outlook graphics, was designed to expose members of the public to different graphical inconsistencies that frequently arise when meteorologists communicate severe weather risk information to the public (i.e., the use of different colors, risk category language, and risk areas). The research team also agreed that the vignettes should offer source and geographical diversity. Therefore, as participants progressed through the four vignettes, they encountered different sources of weather information and were told to imagine they were visiting different geographic locations in the United States. The vignettes were piloted with six individuals with different socioeconomic and educational backgrounds. Using both this pilot study and the personal conversations with operational meteorologists, the vignettes and semi-structured interview instrument were further refined to improve clarity and remove any irrelevant interview questions. For additional information on the vignettes used in this study, please see Table 3.1. The Convective Outlook graphics that were used in the vignettes can be found in Appendix A.

3.2.3 Interview Instrument and Procedure

The semi-structured interviews began with several broad questions relating to the participants' weather information habits. Although used to initiate the conversation and make the participants feel more comfortable, these interview questions also provided context on their frequency and use of weather information (e.g., sources used, frequency, etc.). This is important, as receiving conflicting or inconsistent information becomes more likely when individuals use multiple sources on a regular basis. After providing information on their weather information habits, the participants then transitioned to the vignette portion of the interview. Within each vignette, participants were first shown a single Convective Outlook graphic and then asked several usability questions (Kain and Smith 2010; Demuth, Lazo, and Morss 2012; So, Kuang, and Cho 2019) to gain insight on their abilities to use, interpret, and understand the graphic[7]. After seeing the first graphic, participants either asked for more information or were told to imagine that they came across a second Convective Outlook graphic. Participants were asked identical usability questions about this second graphic, and then shown both graphics side-by side.

After giving the participants some time to process the two graphics, individuals were asked: "Do you think these forecast graphics are communicating the same message? If so, why or why not?" (Backhaus 2004; Williams and Eosco 2020). After providing their answer, the first author spent additional time clarifying and understanding why the participants believed or did not believe that the two graphics were communicating the same message. Additional follow-up questions were asked relating to whether the participants believed there was any conflicting information between the two graphics (Elstad et al. 2012), understanding the participants' reaction to this conflicting

[7] Although not explored in this paper, the usability of the Day 1 Convective Outlook graphic will be addressed in a future manuscript.

information, and addressing how this conflict, if any, would impact their trust in the graphics. The findings from these questions will be the focus of this manuscript.

After progressing through each of the four vignettes, participants were shown all of the Day 1 Convective Outlook graphics that they had seen over the course of the interview and asked to comment on the graphical variety that meteorologists use to communicate severe weather risk information. After the interview, participants completed a demographic questionnaire and were thanked for taking part in the study. For more information on the semi-structured interview guide, please see Appendix B.

3.2.4 Data Collection and Analysis

The interview process began on February 18, 2019 and ended on March 27, 2019. After receiving informed consent, each interview was audio recorded and transcribed for completeness. The length of the interviews ranged from 41 to 108 minutes (mean 73:53 mins, SD 14:33 min), with the transcripts ranging from 5657 words to 14256 words (mean 9349.53 words, SD 2172.84 words). These transcripts were then analyzed and explored via an inductive content coding analysis (Hsieh and Shannon 2005). The first author read the transcripts and identified initial codes using the MAXQDA software suite (VERBI Software 2019). After all the interview transcripts had been examined and analyzed, all codes were collected, and further connections were made between the responses. A final set of content codes was determined after several iterations of collapsing the thematic categories. The transcripts were then reanalyzed a second time by the first author using this final set of thematic codes. Due to the intricacies associated with in-depth interview data, the responses to some interview questions were assigned multiple codes. This occurred when a participant addressed different thematic categories during their discussion. To improve the reliability of this data analysis process, a second coder was used. First, a codebook was created that described each of the content codes and offered an example to help train the second coder. Each of the analyzed segments were then collated and sent to the second coder to evaluate independently. We then evaluated the consistency of the coding with Krippendorff's α statistic (Hayes and Krippendorff 2007). Krippendorff's α is frequently used to evaluate intercoder reliability, with higher values indicating a greater degree of consistency between the two coders. The Krippendorff's α statistic associated with each interview question was above 0.85. Based on previous work (Krippendorff 2004), this is an acceptable intercoder reliability statistic for content analyses.

3.2.5 Description of Sample

A total of 30 members of the public were interviewed. Participants' ages ranged from 22 to 84, with age being represented fairly equally across all age groupings. However, the sample consisted of slightly more adults 55 and older (n = 17, 56%). The sample contained more females (n = 17, 56%), and many of the participants identified as White or Caucasian (n = 21, 70%). Participants were asked to provide their highest degree earned, with a bachelor (n = 7, 23%) or master's degree (n = 10, 33%) being the most represented categories in the sample. In terms of annual household income, the sample was almost evenly distributed between the low (less than $10,000 to $39,999), middle ($40,000 to $79,999), and high ($80,000 to $150,000+) income categories. Participants were also asked to provide information on their family structure, because it has been shown to affect vulnerability and is often used as a vehicle to promote disaster preparedness (Ronan et al. 2015). Overall, 13 of the 30 individuals reported having children. For more information on the demographic information, please see Table 3.2.

We also asked participants about their weather information habits. Most of the respondents reported seeking out weather information multiple times per day (n = 6, 20%) or daily (n = 17, 56%); however, the remaining participants mentioned that they search for weather information less frequently (i.e., a few times a week to once per month). When asked where they obtain weather information, participants indicated that they most frequently used smartphone applications (n = 19, 63%), Internet websites (n = 19, 63%), and/or television (n = 9, 30%). On average, most of the participants indicated that they sought out weather information from more than one source and/or more than one channel on a regular basis. Those that described “flipping between channels” or using more than one source, were asked whether they regularly compare the weather information found across different sources. Thirteen individuals (43%) mentioned that when searching for weather information they actively compare that information across different sources. When asked if, for the most part, the weather information is the same across those sources, there was an even split among the thirteen participants - half thought the sources “were on the same page” (n = 7, 53%) and the other half felt it was often “telling a different story” (n = 6, 47%). Finally, participants were asked whether their frequency, channel, or number of sources consulted changes when severe weather is in the forecast. Similar to previous studies (Zhang et al. 2007), participants identified that when severe weather is in the forecast they (1) more frequently look for weather information, (2) use channels that offer frequent, real-time updates (e.g., television, radar apps), and (3) often seek out more sources.

3.3 Results

When looking across the four vignettes, participants overwhelmingly thought that the two Convective Outlook graphics associated with Vignettes 1 and 3 were consistent and the two graphics associated with Vignettes 2 and 4 were inconsistent in the messages they were communicating (Table 3.3). Apart from answers to these simple yes-or-no questions, the research team also asked members of the public to describe and elaborate on their message consistency evaluation process. Recall that two questions were used to more thoroughly explore message consistency: "Do you think these forecast graphics are communicating the same message? If so, why or why not?" (Backhaus 2004, Williams and Eosco 2020) and "Is there anything conflicting about these forecast graphics? If so, then what?" (Elstad et al. 2012). Because the responses to both questions elicited similar thematic categories, their responses have been combined and are reported in the sections below.

3.3.1 Graphical Elements that Promote Message Consistency

To better understand how members of the public describe 'message consistency,' two graphics that varied little in their graphical design were deliberately placed in the first vignette of the interview instrument (Table 3.1). Therefore, before being exposed to the different ways that Convective Outlook graphics vary in the weather enterprise, participants were asked to elaborate on their message consistency evaluation process when presented with two graphics that were nearly identical. Out of these conversations, participants described that they overwhelmingly used the risk areas/shapes and colors on a Convective Outlook to evaluate whether two graphics communicate the same message.

Risk areas, shapes, and boundaries were frequently referenced when evaluating whether two graphics convey a consistent message. One individual, for example, described this more broadly when he said that: "The storm seems to be in similar locations, if not, the exact locations." Others were more targeted with their response and identified specifics about the risk area or shapes that contributed to a consistent message: "Seeing them side-by-side, I see that the shapes are, in fact, the same," "the boundaries between the two graphics are the same," and "I'm in the Enhanced zone in both of them." Overall, when both graphics depicted their location in the same bounded risk area or risk category, individuals considered this a consistent message. Participants also used color to evaluate whether two graphics conveyed the same message. For example, one individual described this as: "Everything that's in the pink here [in the left graphic], is also pink over here [in the right graphic]." In particular, one participant explained that "it does help that the colors are mirrored." Therefore, when both graphics depicted a location in the same "color zone," the two forecast graphics were perceived as conveying the same message.

Finally, participants also considered *both* the same risk areas/shapes and their colors as combined criteria for determining whether two graphics communicated a consistent message. It should be noted that participants actually used both criteria (i.e., risk areas AND color) more frequently than just color when judging whether two graphics communicated the same message; however, it seemed appropriate to first introduce color before elaborating on the combination of the two criteria. As an example, one participant stated that “There are two main things [that I’m looking at.] I’m looking at the colors and shapes.” Another individual highlights that two forecast graphics are “conveying the same message because the areas are the same and the color coding is the same.” Therefore, whether used individually or together, these graphical elements are important when determining whether two or more Convective Outlook graphics convey the same message.

3.3.2 Graphical Elements that Interfere with Communicating a Consistent Message

Although operational meteorologists have expressed concern that graphical inconsistencies may negatively affect their many audiences, members of the public have not been asked whether they perceive these graphical differences as inconsistent. Therefore, the remaining vignettes exposed participants to differences in the Day 1 Convective Outlook graphic (i.e., different risk areas, different color schemes, different risk category language, different basic graphical designs; Table 3.1). Like the previous section, the participants offered insight into their message consistency evaluation process. However, because the remaining vignettes intentionally exposed participants to graphical differences, these conversations highlighted the specific qualities or elements that often contributed to two graphics conveying conflicting information.

Two Convective Outlook graphics that communicated different severity and/or likelihood messages most frequently resulted in a perception of conflict. One individual, for example, explains that “the NOAA [graphic] is still severe, but not as severe [as the other graphic] because it never reaches its highest color. The Channel 2 graphic goes to its highest color. So, I feel like the storm has been upgraded since then in terms of severity." Like this participants, several individuals made a connection between a change in severity and the use of different colors in the Day 1 Convective Outlook. However, this was not the case for all participants. For example, one individual thought that "...the degree of severity has gone up significantly with this [graphic], all things being equal, and assuming that the meteorologists have the same information that they use to put together forecasts. This [graphic] is significant." As a result, severity information emerges as an important detail to keep consistent between Convective Outlook graphics.

Participants also mentioned that two forecast graphics were conflicting or inconsistent when they conveyed different likelihood information. As an example, one individual described this best when she said that: "I feel like nothing is going to happen [on this graphic.] But on the other one, it's like, oh, it is definitely happening and this is where it's going to hit." Another participant similarly describes this difference in likelihood as: "This one is just telling you that there is a possibility, but this [other graphic] is showing you exactly where [the severe weather] is going to be located in the state." Apart from the fact that the severity and likelihood messages often "felt different," participants also called attention to certain graphical elements, that when conflicting between Convective Outlook graphics, led to an inconsistent message. These graphical elements included the use of different (1) risk areas/shapes, (2) color schemes, (3) color vividness or brightness, (4) types of information, (5) geographical scales or perspectives, and (6) risk category words or systems.

As prominent benchmarks for evaluating message consistency, it seems logical that risk areas and/or color would similarly be used to evaluate whether conflicting information exists between two graphics. One individual, for example, explained that two Convective Outlook graphics are not communicating the same message “because Tuscaloosa is in the red here and Tuscaloosa is in the orange [on this other graphic]. So I feel like these would be different weather storms.” For this reason, maintaining consistent, or even uniform, risk areas and colors, emerged as a prominent theme. Apart from the use of “color zones” to determine their level of severe weather risk, the participants also used a color’s brightness or vividness to infer information about a storm’s severity. A few participants, for example, noticed that some of the graphics used “muted colors” or “pastels,” whereas others used more “vibrant” and “bright colors.” When a graphic used more vivid or bright colors, it made participants “think [the weather forecast] was more severe.” Therefore, even though some of the graphics used uniform colors, if the vividness or brightness did not match, then they considered those two Convective Outlook graphics as communicating different messages.

Another element that often made participants classify two graphics as conflicting was the inclusion of different types of information. This occurred when one graphic offered a piece of crucial information that the other graphic did not provide. One participant, for example, stated that the two graphics in Vignette 2 were inconsistent, “because the one on the left doesn’t describe what [threats] the colors include and doesn’t give a clear description of what the risks are. So the addition of more information [on the right graphic] creates a different message.” Throughout the interviews, participants mentioned a variety of informational types that, if included, changed the overall message. These informational types included, but were not limited to: timing information, direction of storm movement, and the specific threats that may affect their area.

In a similar vein, some participants mentioned that providing localized graphical information would also affect the consistency of the overall message. This often occurred when one graphic provided a national or regional perspective, and the other offered a more zoomed-in, local perspective. For example, one participant explained that:

> "[These messages are] not quite [the same.] I guess since this one's more zoomed out, I feel like it's less concerned about what's happening in my area and is more like the general weather for the eastern United States. Then, when I look at this [graphic] on the right. It has actual counties and cities on it, so I feel like it's giving more specific warning information for this area and is advising people to be concerned about what's going on."

Therefore, according to some participants, the use of different geographical scales or perspectives affected message consistency. Finally, a few individuals thought that the use of different risk category words altered the overall message. For example, one individual explained that "[this graphic] is not replicating the same thing [that's on this other graphic] because the glossaries are different." Therefore, when two Convective Outlook graphics used different risk category words some participants felt it communicated two different messages.

Although often highlighted as a phenomenon that occurs between messages, it is important to remember that conflicting or inconsistent information concerns can also take place *within* graphics or messages. For example, Vignette 2 featured a graphic from the NWS Birmingham WFO (for graphic, see Appendix A) that provided identical threat information for both a 'Moderate Risk' and 'Enhanced Risk.' Participants questioned why "the two definitions are exactly the same," and wanted to know "what would be the difference between the two levels?" When asked how they interpreted the identical phrasing, some participants thought the two levels differed in terms of likelihood, others thought it meant a difference in intensity, and a few assumed the identical phrasing meant they were the same category. Therefore, this conflicting information affected how participants interpreted the severe weather information *within* a single Convective Outlook graphic.

3.3.3 Reactions to Inconsistent or Conflicting Information

In addition to understanding how members of the public evaluate message consistency, this study also sought to explore how people react to inconsistent or conflicting graphical weather information. Previous research, in the fields of political, health, and science communication, have found that conflicting information often results in "confusion" among study participants (Nagler 2014; Lee et al. 2017) and other negative outcomes. However, in the context of visual graphics and weather risk messaging, the response to and effects of conflicting information have not received as much attention. To address this gap, this study offers qualitative findings that demonstrate the ways that people react, respond to, and resolve inconsistent or conflicting graphical weather information.

3.3.3.1 Emotional Response to Conflicting Information

As participants identified conflicting or inconsistent graphical weather information, oftentimes, their immediate reaction was fueled by emotion. However, this response varied along the spectrum of emotions. Like previous conflicting information studies, some participants felt like it could “be a little bit confusing” when looking at two inconsistent Convective Outlook graphics. For example, one individual thought that looking at two inconsistent or conflicting graphics was “misleading.” Further, participants also mentioned that conflicting or inconsistent forecast graphics would make them “question the weather forecast” and “lose trust in the forecast.” Therefore, like confusion, they expressed feelings of uncertainty about the weather information they were receiving. Many participants, for example, stated that they “wouldn’t know who to trust” and “would question which [graphic] was right.” In short, the presence of conflicting or inconsistent information made some participants question the reliability of *both* Convective Outlook graphics.

In addition to feelings of confusion and uncertainty, some individuals expressed other emotions when confronted with conflicting graphical forecast information. For example, one individual passionately stated that “if I got these two [graphics], I would be mad. I would just be mad.” While some people experienced anger and frustration when they encountered inconsistent or conflicting Convective Outlook graphics, others were unfazed. Some individuals felt that “the changes in colors and words [between graphics] were not significant” and that “you would just shift a mental gear” when comparing Day 1 Convective Outlook graphics with different graphical elements. A few participants highlighted that conflicting or inconsistent information is more of a regional or geographical concern because “if you lived in Tuscaloosa, you would become familiar with the colors and the words [that are used.]" From their apathetic perspective, using different colors and words would only become a problem if and when people travel.

3.3.3.2 Strategies to Manage Conflicting Information

Apart from an initial emotional reaction, participants also sought to resolve and explain the presence of conflicting graphical forecast information. For example, a majority of participants believed that one of the graphics was "out of date," had been "updated," or was showing a "forecast for a different time of day." One participant describes this best when she says that, "I would probably imagine that the forecasts were from an earlier scenario, and then this new scenario has the storm traveling south and that will lead to my location getting into a higher risk zone." Therefore, instead of considering that the graphics could be conveying conflicting information, the participants inherently thought that time had passed or progressed between the two Convective Outlooks.

While some participants equated conflicting information with a temporal shift, others fully acknowledged the presence of conflicting information and offered strategies to resolve it. Some participants, for example, highlighted or pointed out the benefits of having a local source of information. In particular, individuals recognized the value of local knowledge and considered local meteorologists the go-to-source of information when exposed to conflicting or inconsistent Convective Outlook graphics:

> "I'd probably go with [the local graphic], partly because I would probably trust the local [meteorologists] because they would probably know their own area better. NOAA is really good, but local people tend to know what's going to happen in their area a little more and they're just more familiar with their own [weather] patterns."

Therefore, when met with conflicting or inconsistent information, some participants chose to ignore the conflict and use the information provided by local broadcast meteorologists and nearby NWS WFOs. On the other hand, a few individuals chose to ignore the conflict completely and decide on their own terms how to proceed with the severe weather threat. One individual, for example, explained that they "wouldn't know who to believe" and that they would "just try to decide [what to do] on [their] own since [they] have conflicting information." Finally, some individuals were more engaged in the process of managing conflicting information. These participants explained that they would "search for more information to clarify the situation" or "use the collective [graphical] information to discern their own risk." As a result, the participants in this study outlined several mechanisms that members of the public might use when resolving conflicting information.

3.3.3.3 Recommendations to Reduce Conflicting Information

In addition to reacting to and resolving any conflicting information, several participants also offered recommendations to reduce inconsistent graphical weather information. A majority of the recommendations revolved around the need for the graphics to "be the same." When asked to elaborate, participants offered a variety of responses. For the most part, individuals were broad in their interpretation and thought that "[the graphics] shouldn't go against one another, but build on [each other.]" Others were more specific and insisted on the use of "uniform" or "standardized" colors and risk category language across all Day 1 Convective Outlook graphics. One individual explained that "if you have consistent coding, then people can look at it and interpret it quicker. To me, consistent means the same key, the same wording, and the same color scheme.” Therefore, like some operational meteorologists, individuals thought that “it would be great if there was a little bit more uniformity” among Day 1 Convective Outlooks.

Apart from these suggestions, a few participants also offered recommendations to better explain the differences that may exist between Convective Outlook graphics at the local, regional and national scales. In short, these individuals acknowledged the benefits of providing a tailored, localized graphic; however, they asked for more transparency when Convective Outlook graphics had been updated or modified. For example, one individual suggested that “there should be some notation, on the graphic, that I should check with the local [NWS office] for more details. Something to let me know that I better check the Birmingham [NWS office] or [whatever city] I’m going to be in for more information.”

3.4 Summary and discussion

3.4.1 Message Consistency Evaluation Process

Although operational meteorologists have raised specific concerns that the use of different graphical elements may result in the perception that Convective Outlook graphics are inconsistent, members of the public have not been asked whether they view these differences as notable or impactful. Therefore, this study sought to explore how members of the public (1) identify, describe, and evaluate message consistency when examining two Convective Outlook graphics and (2) resolve situations in which they perceive the graphical weather forecast information as inconsistent. When evaluating message consistency, participants overwhelmingly thought that the two Convective Outlook graphics associated with Vignettes 1 and 3 were consistent and the two graphics associated with Vignettes 2 and 4 were inconsistent (Table 3.3). This finding hints at the fact that basic graphical design changes (e.g., placement of logos, legends, lower-thirds, etc.) do not impact the perceived consistency of the message (Vignettes 1 and 3), but what does matter are more prominent graphical elements (e.g., using different risk areas, colors, and/or risk language) that differ between two Convective Outlook graphics (Vignettes 2 and 4). Although an important first step, this simple yes/no designation only highlights the outcome and fails to capture the process used to determine whether two Convective Outlook graphics communicate a consistent message. Therefore, this study also asked participants to describe and elaborate on their message consistency evaluation process.

When asked to describe whether two Convective Outlook graphics did or did not communicate the same message, participants indicated that they used various criteria or graphical elements when evaluating message consistency. According to participants, when two graphics depict a location in the same risk area and/or color zone, they inevitably communicate a consistent message. Naturally, these criteria similarly arose when participants described why two graphics *did not* convey the same message. Participants also mentioned, albeit less frequently, other specific ways in which two Convective Outlook graphics differed (e.g., geographic scale, risk category words, more information). However, in reexamining the qualitative interview data, a larger pattern emerged. When asked to explain why these particular graphical elements resulted in an inconsistent message, participants inherently described a perceptual difference in the severity and/or likelihood information being communicated by the two graphics. One participant describes this best when she explains that "because one graphic has more detail and different colors, the severity [information] is just much more intense." As a result, the inconsistent or conflicting graphical elements that participants identified are likely tangible ways that likelihood and severity information are being unintentionally manipulated. A closer look at the persuasive communication and fear appeals literatures provide some evidence that this may be true.

When designing persuasive threat messages, communication researchers and practitioners primarily use four message components to capture their audience's attention and to maximize responsiveness: susceptibility, severity, self-efficacy, and response-efficacy (Murray-Johnson and Witte 2003; O'Keefe 2018). Originating from the Protection Motivation Theory (Rogers 1975) and the Extended Parallel Process Model (Witte 1992), these four message features are often manipulated in fear appeals studies to evaluate their effect on attitudes, information processing, and behavioral intentions. Rimal and Real (2003), for example, experimentally manipulated both the susceptibility and self-efficacy information found in skin cancer messages to determine its effect on information seeking intentions. Some individuals received statistical information that explained they were at-risk for skin cancer, while others were given statistics that indicated there was a low likelihood they would develop the disease. As a result of the risk manipulation, participants reported a higher risk perception, greater intentions to seek information about skin cancer, and greater intentions to perform skin cancer-related protective behaviors (Rimal and Real 2003). The self-efficacy manipulation, on the other hand, offered mixed results.

Like the manipulation of statistical risk information in the study by Rimal and Real (2003), when operational meteorologists alter specific graphical elements in a Convective Outlook (e.g., risk areas, colors, etc.), they likely also unintentionally affect the susceptibility and severity information in the process. Consider, for example, two Convective Outlook graphics that show an individual's location in two different risk categories (Figure 3.3). If a person were to examine each graphic individually and then evaluate their likelihood of experiencing severe weather, their perceived susceptibility would be lower when their location is in a lower risk category. As a result, changing a location's risk category inherently alters the susceptibility information being communicated by the graphic. In the same way, the remaining graphical elements, described by participants in this study, can similarly be linked to perceived susceptibility and perceived severity (Table 3.4).

More importantly, however, this finding offers further insight that may refine the definition of message consistency that is offered by Williams and Eosco (2020). To be considered consistent, their definition explains that "two or more weather messages must convey the same overall message, even though their individual features may differ." The results of this study, then, clarify this definition by demonstrating that achieving "the same overall message" likely demands that end users walk away with the same feeling of risk (i.e., perceived susceptibility and perceived severity). It is important to note, however, that Convective Outlook graphics only provide risk information. Therefore, this study is limited in its ability to discern the relevance of self-efficacy and/or response efficacy information when it comes to maintaining a consistent message. Finally, the finding that specific graphical elements may inherently alter one's susceptibility and severity, points to the need for more research that explores the hypothesized relationships outlined above (Table 3.4) and, more broadly, investigates the point at which these individual message features interfere with communicating the same overall message.

3.4.2 Reactions to Inconsistent Graphical Forecast Information

With previous health communication studies outlining the negative effects of conflicting information (for review, see Nagler and LoRusso 2017), this research study builds on that body of literature by also exploring people's reactions to inconsistent or conflicting graphical forecast information. According to the results of this study, participants exhibited a wide range of reactions to inconsistent Convective Outlook graphics. In fact, a closer look at the data, suggests that individuals progressed through three stages when resolving conflicting information: (1) an immediate emotional response, (2) managing the conflicting information, and (3) offering recommendations to reduce conflicting information. While only some participants progressed through all three stages in sequential order, each and every participant described experiencing at least one of the stages when resolving conflicting information. More often than not, individuals reported experiencing the second stage and, for the most part, acknowledged the presence of conflicting information and offered strategies to manage and/or resolve it.

When faced with inconsistent Convective Outlook graphics, participants described a variety of strategies that they used to either engage with (e.g., seeking out additional information, consensus forecasting) or ignore the conflicting information. Similar to the results offered by Elstad et al. (2012), the benefits of trusting and relying on local sources of information emerged as a prominent theme. When exposed to graphical inconsistencies in vignettes 2 and 4, for example, several individuals were more forgiving of the conflicting information and simply opted to use the graphical forecast information provided by the local meteorologist. This finding highlights the need to better understand the relationship between message consistency and geographic scale. Not only that, but it also hints at the underlying tensions that exist between achieving consistency and providing end users with a tailored forecast. Therefore, if most individuals default to local information in the face of conflict, does it matter that local WFOs alter the risk boundaries on their Convective Outlook graphics? Researchers are encouraged to partner with operational meteorologists to better understand the role of message consistency across the local, regional, and national scales, in hopes that it will determine how to best implement message consistency on a larger scale. Finally, as a limitation of this work, it should be noted that all of the local Convective Outlook graphics used in this study depicted a higher severe weather risk. Although participants qualitatively mentioned the benefits of local information, future studies should also vary the threat of the local graphic to determine whether participants still prefer a local source when it shows an individual's location in a lower risk category.

3.4.3 Conclusions and Practical Implications

Beyond the theoretical insights offered by this study, these qualitative findings can also be used to provide preliminary recommendations to operational meteorologists and the weather enterprise. Based on the results of this study, it appears that basic graphical design changes (e.g., placement of logos, legends, lower thirds, etc.) do not impact the consistency of the message (Table 3.3). What does matter, on the other hand, is whether Convective Outlook graphics share the same risk areas and colors. Therefore, when possible, it is suggested that operational meteorologists maintain the same risk areas and colors used by the Storm Prediction Center. However, if an operational forecaster, broadcast meteorologist, or other weather entity believes they need to shift or change the risk boundaries for their local area, it is imperative that they (1) consult and discuss this change with forecasters at the SPC via NWSChat and (2) be transparent with their audience about this change. For example, this could be emphasized in a social media message, indicated somewhere on the graphic, or specifically mentioned during a weather broadcast. That way, if individuals search for more information and come across an inconsistent Convective Outlook graphic, they would be more likely to understand that the conflicting information is purposeful because a local meteorologist used their knowledge of the area to modify their severe weather risk. The other graphical elements, that participants mentioned less frequently (e.g., risk category language, geographic scale, etc.), deserve more empirical attention before any preliminary suggestions or recommendations can be offered to the operational meteorological community. Not only that, but additional work is needed to compare and contrast the results of this study with a more generalizable sample. Like the study by Rimal and Real (2003), researchers might consider using experimental design methodologies to intentionally manipulate the graphical elements found in a Convective Outlook. These studies would help establish evidence-based best practices for achieving a more consistent message when sharing Convective Outlook graphics with members of the public.

3.5 Acknowledgements

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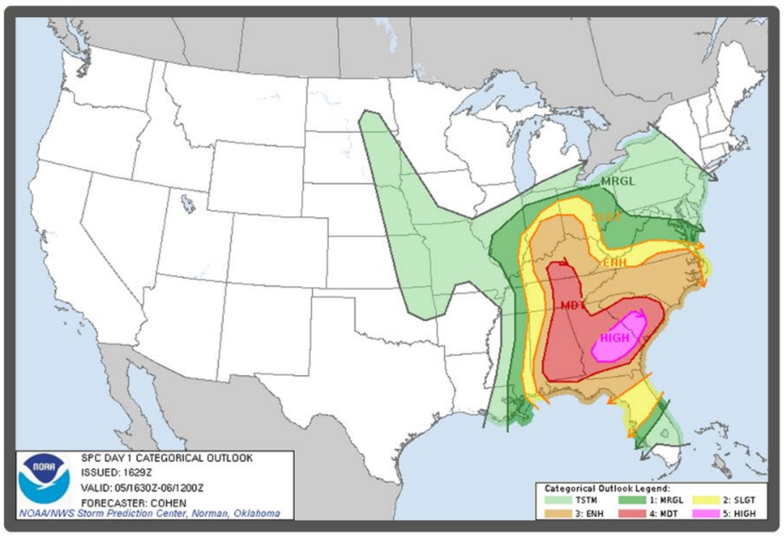
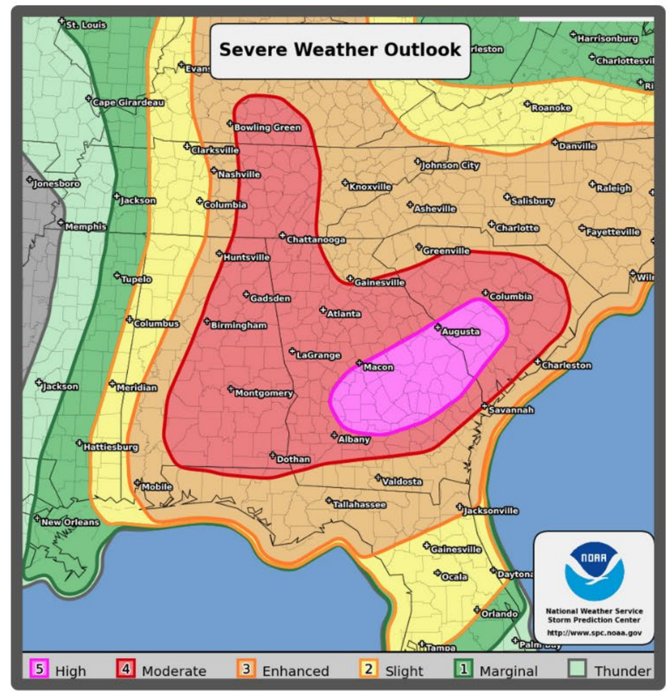
3.6 Appendix A: Graphics Used in Vignettes

Vignette #1

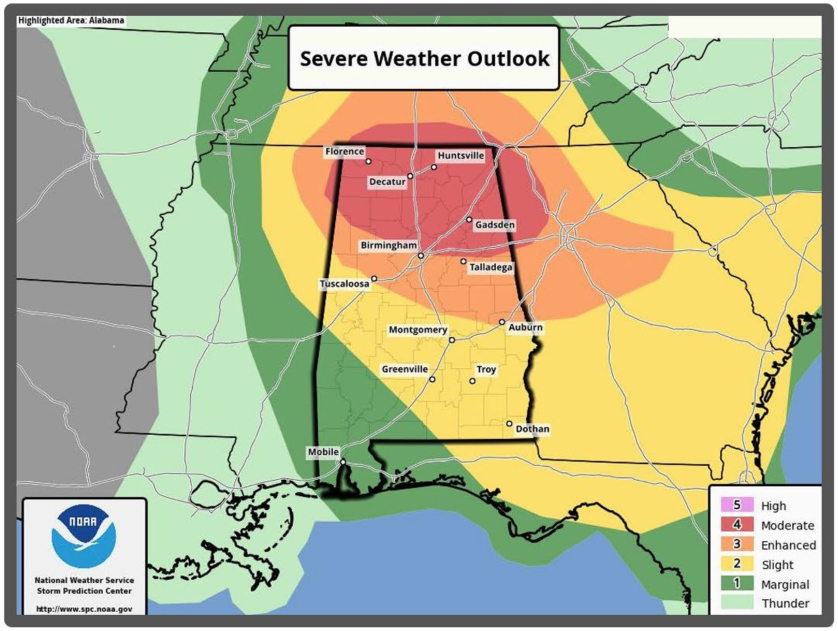
Athens, GA





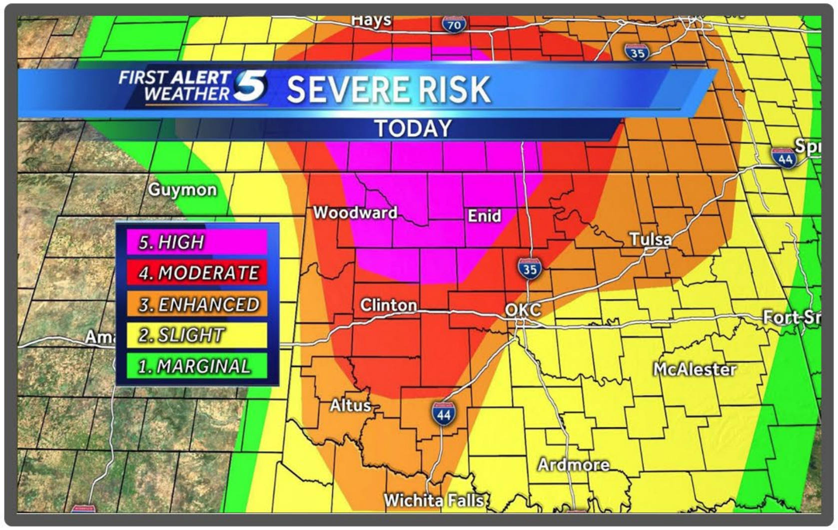
Vignette #2

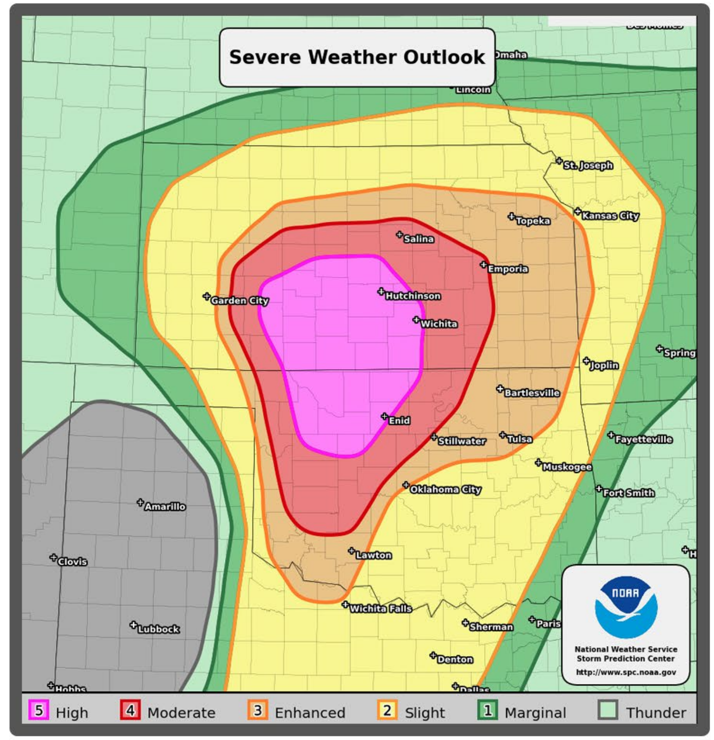
Tuscaloosa, AL



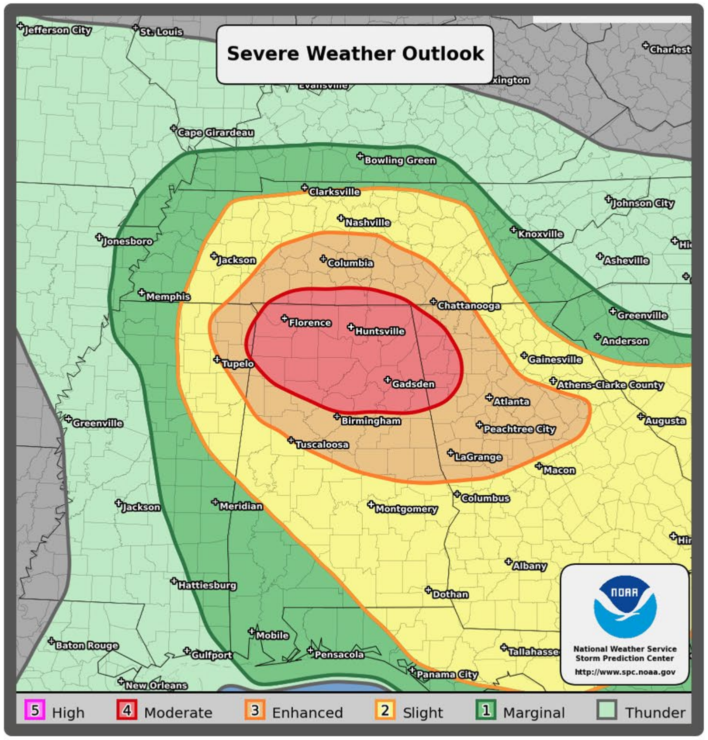
Vignette #3

Tulsa, OK





Vignette #4
Athens, GA



3.7 Appendix B: Semi-structured Interview Guide

[Ensure everyone has read and signed the informed consent document]

Topic Introduction

With a newfound focus of communicating information using visuals and graphics, meteorologists and broadcasters are creating and share more visual information now than ever before. In particular, the National Weather Service provides several types of graphical forecast information via its webpage and social media platforms. Today, we want your thoughts and opinions about some of the graphical forecast information that the NWS and other meteorologists provide during severe weather events (i.e., hail, high winds, and tornadoes). Getting feedback from people like you is important to ensure that the NWS is providing graphical information that is important and useful to you. Remember, there are no right or wrong answers! We just want your input. This research project is being funded by NOAA's Office of Atmospheric Research (OAR) and the Office of Weather and Air Quality (OWAQ).

Introductory Questions:

1. I want to first start by talking about weather information. How closely do you follow your local weather? National weather?
    a. (***frequency)*** How often do you seek out weather information?
    b. (***sources)*** How do you get your weather information? What sources do you usually get it from?
    c. (***triangulation)*** Do you consult more than one source of weather information? How many sources do you usually look at?
        i. *Probe:* Do you ever compare the information you find at one source with the information you find at another source?
    d. (***severe weather preference)*** What about during severe weather events? Does the frequency, channel, or number of sources consulted change?

Before we take a look at several graphical forecasts that the National Weather Service and other meteorologists produce during severe weather events, I want to get your input on the colors and words that the National Weather Service uses to communicate the threat for severe weather.

2. The National Weather Service uses several colors to describe the threat for severe weather (i.e., severe thunderstorms with hail and high winds, and tornadoes). The following index cards each have a color on them. Please rank the following colors from *least threatening to most threatening* (Mayhorn, Wogalter, and Shaver 2004)

3. The National Weather Service uses several risk categories to describe the threat for severe weather (i.e., severe thunderstorms and tornadoes). The following index cards

each have a risk category on them. Please rank the following risk categories from *least threatening to most threatening* (Mayhorn, Wogalter, and Shaver 2004*)*

4. The National Weather Service uses several risk categories and colors to describe the threat for severe weather (i.e., severe thunderstorms and tornadoes). The following index cards each have a risk category and color on them. Please rank the following risk categories from *least threatening to most threatening* (Mayhorn, Wogalter, and Shaver 2004)

[Show participants the sequence currently used by the SPC]

5. What if I told you this is the way the Storm Prediction Center uses these colors and words. How do you feel about that?

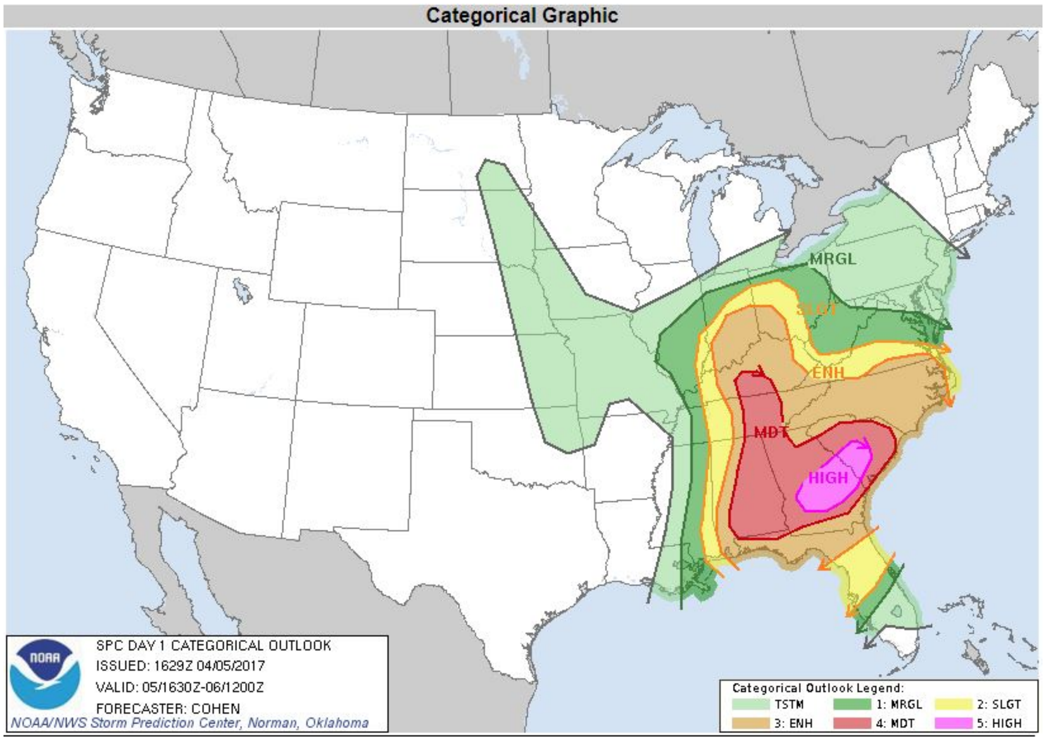
Vignettes:

Next, we are interested in your thoughts and opinions on the severe weather graphical forecasts that are produced by the National Weather Service and other meteorologists. Therefore, the next questions will prompt you with various hypothetical scenarios and graphical forecasts.

[Vignette #1 shows two different National Weather Service maps. They use uniform colors, language, and spatial risk. However, one is more "public friendly." Using this vignette to ground them in thinking about different graphics from the same source, and also teasing out whether the public would prefer the "public friendly" graphic. This vignette also does not explicitly show the location of Athens-Clarke County, allowing for a little cognitive mapping exercise as well.]

Vignette #1a:

Imagine you are home on a Saturday morning and learn that meteorologists are forecasting the threat for severe weather this afternoon. While searching for information, you come across this forecast graphic from the National Weather Service. [Hand out hard copy example of Convective Outlook Graphic]



1. ***(familiarity)*** Are you familiar with this forecast graphic? Have you seen something like this before?
    a. *Probe:* When would you say was the last time you saw something like this?
    b. *Probe:* Do you actively seek out this information?
    c. *Probe:* Did it look like this? If not, what was different about it?

2. ***(interpretation)***What does this forecast graphic mean to you?
    a. When you look at this forecast graphic, what does it tell you? Why?
    b. Where do you live relative to the threat for severe weather?
        i. What category is your house in?
            1. What does that mean to you?
        ii. What color is your house in?
            1. What does that mean to you?
    c. Is any of the information confusing?

3. (***perceived susceptibility)*** On a scale from 0 (*not at all likely)* to 100 (*extremely likely)*, how would you rate the likelihood that your location will experience severe weather today? Why?

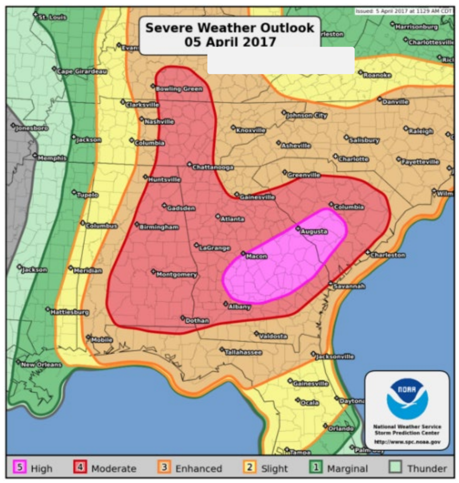
4. (***perceived severity)*** On a scale from 0 (*not at all threatening)* to 100 (*life-threatening)*, how would you rate the seriousness of the severe weather at your location? Why?

5. ***(behavior/use)*** How would you use this information?
    a. *Probe: [If says they would search for more information]* What types of information would you search for? Why?

b. *Probe: [If says they would make a decision]* What decisions would you make with this information? Why?

Vignette #1b:

After seeing the previous forecast graphic, you search for more information and come across another graphic from the National Weather Service. [Hand out hard copy example of Public Weather Outlook Graphic]



1. ***(interpretation)*** What does this forecast graphic mean to you?
   a. When you look at this forecast graphic, what does it tell you? Why?
   b. Where do you live relative to the threat for severe weather?
      iii. What category is your house in?
         1. What does that mean to you?
      iv. What color is your house in?
         1. What does that mean to you?
   c. Is any of the information confusing?

2. (***perceived susceptibility)*** On a scale from 0 (*not at all likely)* to 100 (*extremely likely)*, how would you rate the likelihood that your location will experience severe weather today? Why?

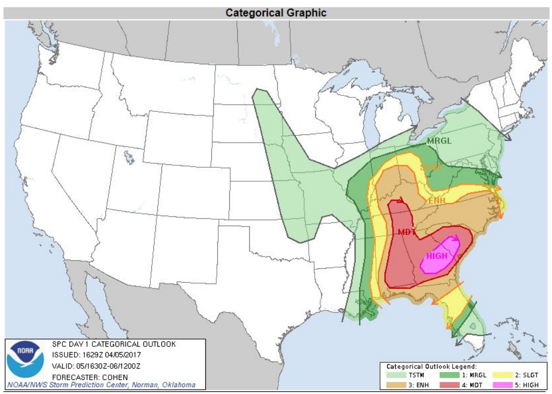
3. (***perceived severity)*** On a scale from 0 (*not at all threatening)* to 100 (*life-threatening)*, how would you rate the seriousness of the severe weather at your location? Why?

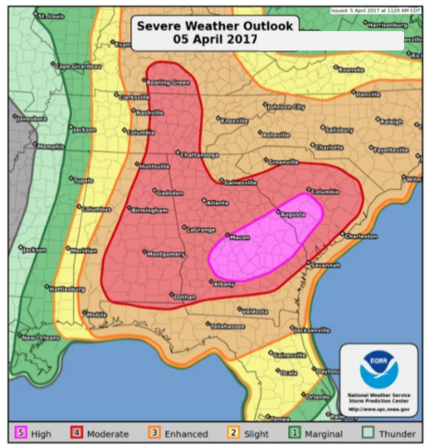
4. ***(behavior/use)*** How would you use this information?
   a. *Probe: [If says they would search for more information]* What types of information would you search for? Why?

b. *Probe: [If says they would make a decision]* What decisions would you make with this information? Why?

Vignette #1c:

After seeing both forecast graphics, you look at them both again to better understand the severe weather threat for your area.





1. ***(perceived consistency)*** Do you think these forecast graphics are communicating the same message? Why or why not?
   a. *Probe:* Is there anything different about them? Is there anything conflicting about them?
   b. *Probe:* Are they both showing your location as under the same risk for severe weather?
   c. *Probe:* When you're judging whether they are communicating the same message, what are you looking for? What qualities are you using to determine whether they are communicating the same message?
   d. *Probe:* If the two graphics are not communicating the same message, what is it about them that makes the message different?

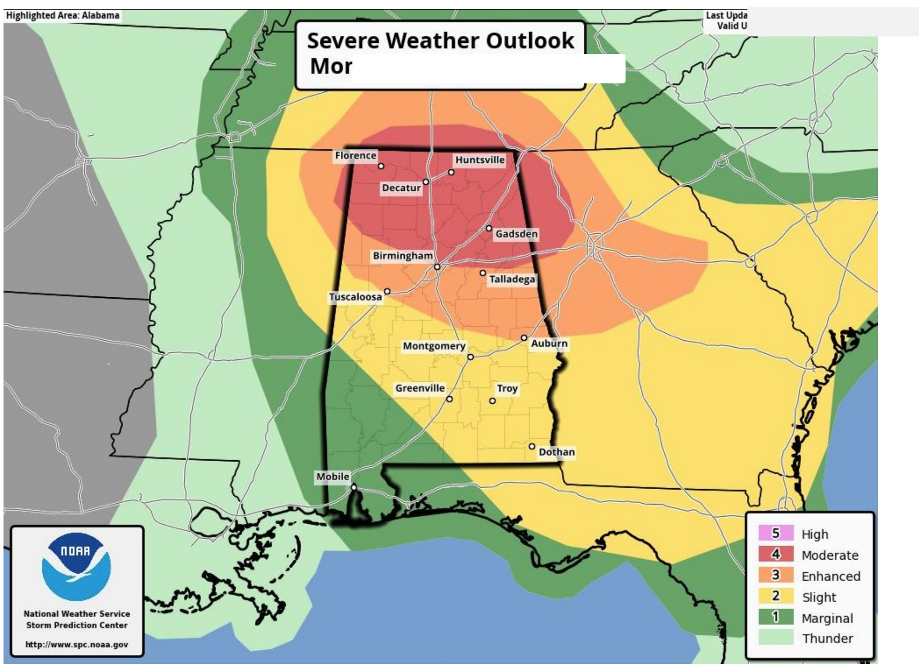
2. ***(perceived trust/source credibility)*** Which forecast graphic do you trust more? Why?

3. ***(behavior/information use)*** After seeing both of these forecast graphics, what would you do next?

[Vignette #2 shows two different graphics – one from the Storm Prediction Center and the other from a local Weather Forecast Office. They use uniform colors and language; however, the spatial risk differs between the two graphics. This vignette will allow us to understand the importance of differing spatial risk in understanding 'message consistency' and its impact on risk perception and uncertainty. It will also allow us to tease out the implications of conflicting information between two NWS sources. This vignette also offers some discussion around the boundary issue.]

Vignette #2a:

Imagine you are traveling and have stopped in Tuscaloosa, Alabama for the day. You learn that meteorologists are forecasting the threat for severe weather this afternoon. While searching for information, you come across this forecast graphic from the National Weather Service. [Hand out hard copy example of NWS Public Severe Weather Outlook]



1. ***(interpretation)*** What does this forecast graphic mean to you?
    a. When you look at this forecast graphic, what does it tell you? Why?
    b. Where is your location relative to the threat for severe weather?
        i. What category is your location in?
            1. What does that mean to you?
        ii. What color is your location in?
            1. What does that mean to you?
    c. Is any of the information confusing?

2. (***perceived susceptibility)*** On a scale from 0 (*not at all likely)* to 100 (*extremely likely)*, how would you rate the likelihood that your location will experience severe weather today? Why?

3. (***perceived severity)*** On a scale from 0 (*not at all threatening)* to 100 (*life-threatening)*, how would you rate the seriousness of the severe weather at your location? Why?

4. ***(behavior/use)*** How would you use this information?
    a. *Probe: [If says they would search for more information]* What types of information would you search for? Why?
    b. *Probe: [If says they would make a decision]* What decisions would you make with this information? Why?

Vignette #2b:

After seeing the previous forecast graphic, you search for more information and come across another graphic from a National Weather Service Weather Forecast Office that is local to the Birmingham, Alabama area. [Hand out hard copy example of Weather Forecast Office Graphic]

1. ***(interpretation)*** What does this forecast graphic mean to you?
    a. When you look at this graphic, what does it tell you?
    b. Where is your location relative to the threat for severe weather?
        i. What category is your location in?
            1. What does that mean to you?
        ii. What color is your location in?
            1. What does that mean to you?
    c. Is any of the information confusing?

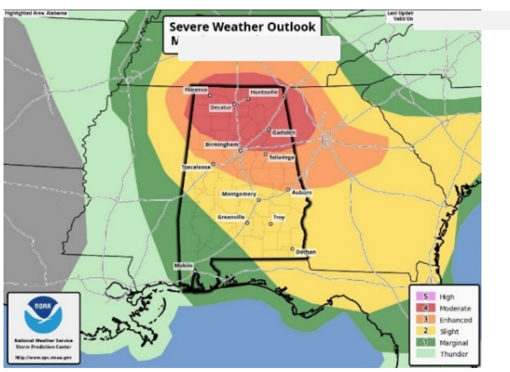
2. (***perceived susceptibility)*** On a scale from 0 (*not at all likely)* to 100 (*extremely likely)*, how would you rate the likelihood that your location will experience severe weather today? Why?

3. (***perceived severity)*** On a scale from 0 (*not at all threatening)* to 100 (*life-threatening)*, how would you rate the seriousness of the severe weather at your location? Why?

4. ***(behavior/use)*** How would you use this information?
    a. *Probe: [If says they would search for more information]* What types of information would you search for? Why?
    b. *Probe: [If says they would make a decision]* What decisions would you make with this information? Why?

Vignette #2c:

After seeing both forecast graphics, you look at them both again to better understand the severe weather threat for your area.



4. (***perceived consistency)*** Do you think these forecast graphics are communicating the same message? Why or why not?
    a. *Probe:* Is there anything different about them? Is there anything conflicting about them?
    b. *Probe:* Are they both showing your location as under the same risk for severe weather?
    c. *Probe:* When you're judging whether they are communicating the same message, what are you looking for? What qualities are you using to determine whether they are communicating the same message?
    d. *Probe:* If the two graphics are not communicating the same message, what is it about them that makes the message different?

5. (***perceived susceptibility)*** On a scale from 0 (*not at all likely)* to 100 (*extremely likely)*, how would you rate the likelihood that your location will experience severe weather today? Why?

6. (***perceived severity)*** On a scale from 0 (*not at all threatening)* to 100 (*life-threatening)*, how would you rate the seriousness of the severe weather at your location? Why?

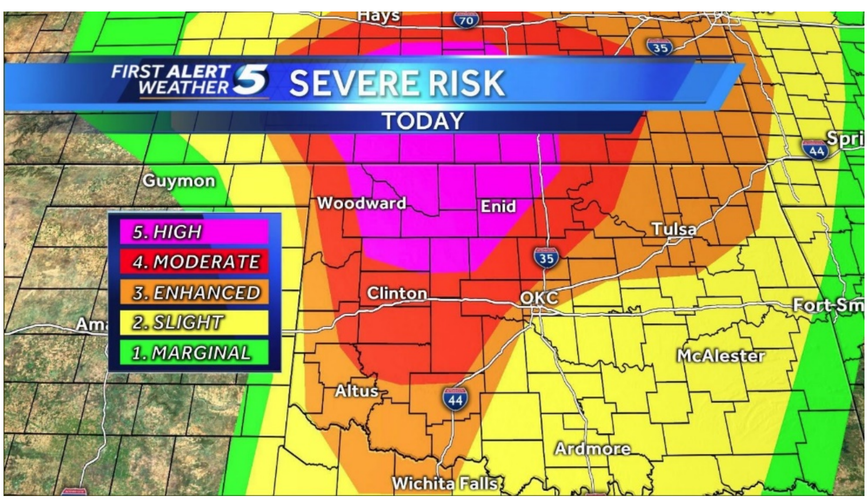
7. (***perceived trust/source credibility)*** Which forecast graphic do you trust more? Why?

8. (***behavior/information use)*** After seeing both of these forecast graphics, what would you do next?

[Vignette #3 shows two different graphics – one from a local broadcast meteorologist in the OKC area and the other from the Storm Prediction Center. They are uniform in the colors used, language depicted, and spatial risk described, however, the basic design of the graphic is different – but the information is identical. This vignette will allow us to understand the impact of being 'consistent' across two different sources in the Weather Enterprise and its impact on risk perception and uncertainty. It also varies the scenario by providing a broadcast meteorologists' forecast first, and then following it up with a NWS graphic.]

Vignette #3a:

Imagine you are now visiting Tulsa, Oklahoma and turn on the TV in the morning to listen to the local news while you eat breakfast. While watching, the TV station's meteorologist comes on and informs you that severe weather is in the forecast for this afternoon. To explain, he puts this forecast graphic up on the TV screen. [Hand out hard copy example of First Alert Weather 5 Graphic]



1. ***(interpretation)*** What does this forecast graphic mean to you?
    a. When you look at this forecast graphic, what does it tell you?
    b. Where is your location relative to the threat for severe weather?
        i. What category is your location in?
            1. What does that mean to you?
        ii. What color is your location in?
            1. What does that mean to you?
    c. Is any of the information confusing?

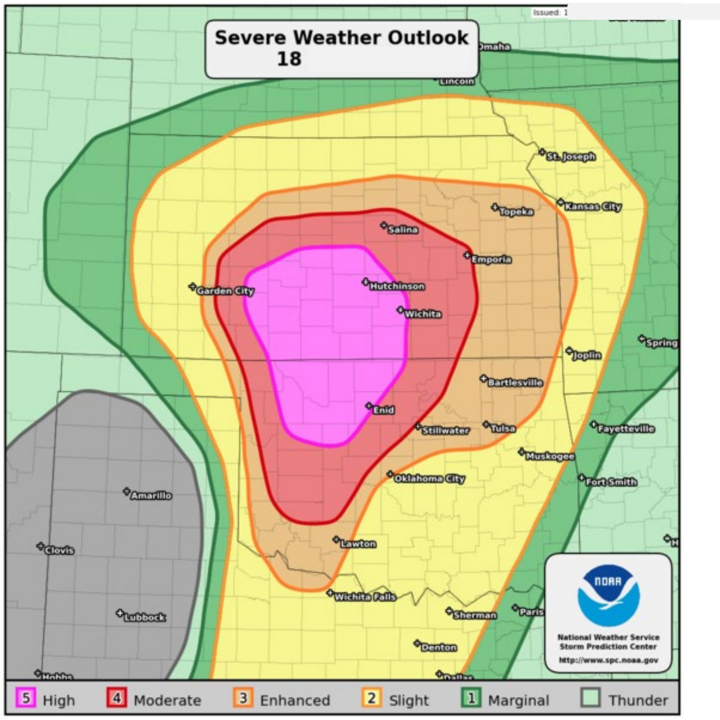
2. (***perceived susceptibility)*** On a scale from 0 (*not at all likely)* to 100 (*extremely likely)*, how would you rate the likelihood that your location will experience severe weather today? Why?

3. (***perceived severity)*** On a scale from 0 (*not at all threatening)* to 100 (*life-threatening)*, how would you rate the seriousness of the severe weather at your location? Why?

4. ***(behavior/use)*** How would you use this information?
    a. *Probe: [If says they would search for more information]* What types of information would you search for? Why?
    b. *Probe: [If says they would make a decision]* What decisions would you make with this information? Why?

Vignette #3b:

After seeing the previous forecast graphic, you search for more information and come across a graphic by the National Weather Service. [Hand out hard copy example of Severe Weather Outlook graphic produced by NWS.]



1. ***(interpretation)*** What does this forecast graphic mean to you?
    a. When you look at this forecast graphic, what does it tell you?
    b. Where is your location relative to the threat for severe weather?
        i. What category is your location in?
            1. What does that mean to you?
        ii. What color is your location in?
            1. What does that mean to you?
    d. Is any of the information confusing?

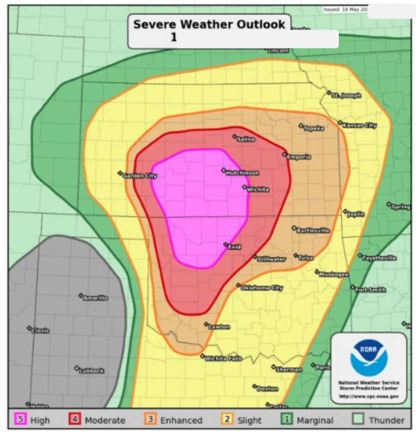
2. (***perceived susceptibility)*** On a scale from 0 (*not at all likely)* to 100 (*extremely likely)*, how would you rate the likelihood that your location will experience severe weather today? Why?

3. (***perceived severity)*** On a scale from 0 (*not at all threatening)* to 100 (*life-threatening)*, how would you rate the seriousness of the severe weather at your location? Why?

4. ***(behavior/use)*** How would you use this information?
    a. *Probe: [If says they would search for more information]* What types of information would you search for? Why?
    b. *Probe: [If says they would make a decision]* What decisions would you make with this information? Why?

Vignette #3c:

After seeing both forecast graphics, you look at them both again to better understand the severe weather threat for your area.



9. (***perceived consistency)*** Do you think these forecast graphics are communicating the same message? Why or why not?
   a. *Probe:* Is there anything different about them? Is there anything conflicting about them?
   b. *Probe:* Are they both showing your location as under the same risk for severe weather?
   c. *Probe:* When you're judging whether they are communicating the same message, what are you looking for? What qualities are you using to determine whether they are communicating the same message?
   d. *Probe:* If the two graphics are not communicating the same message, what is it about them that makes the message different?

10. (***perceived susceptibility)*** On a scale from 0 (*not at all likely)* to 100 (*extremely likely)*, how would you rate the likelihood that your location will experience severe weather today? Why?

11. (***perceived severity)*** On a scale from 0 (*not at all threatening)* to 100 (*life-threatening)*, how would you rate the seriousness of the severe weather at your location? Why?

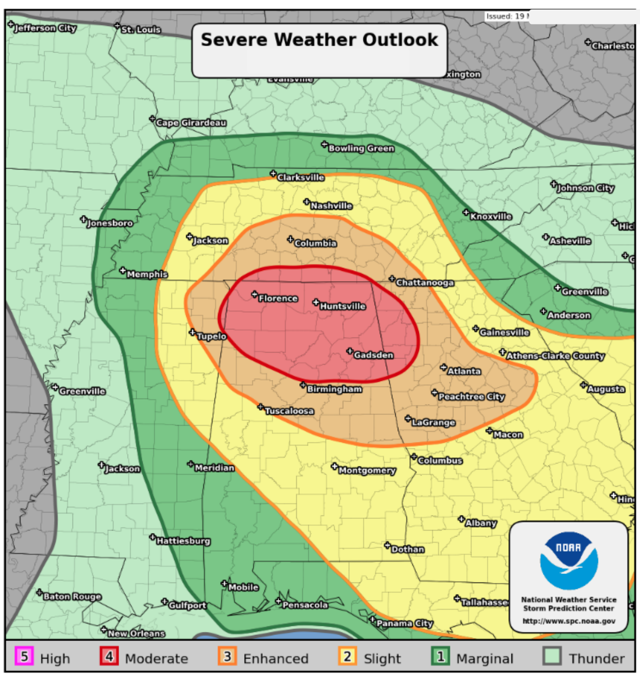
12. (***perceived trust/source credibility)*** Which forecast graphic do you trust more? Why?

13. (***behavior/information use)*** After seeing both of these forecast graphics, what would you do next?

[Vignette #4 shows two different graphics – one from the Storm Prediction Center and the other from a local broadcast meteorologist in the Atlanta area. They use uniform spatial risk; however, the language and colors differ between the two graphics. This vignette will allow us to understand the impact of differing colors and language in understanding 'message consistency' and its impact on risk perception and uncertainty. It will also allow us to tease out the implications of conflicting information between two expert sources in the Weather Enterprise. This vignette also offers some discussion around the boundary issue.]

Vignette #4a:

Imagine you are home on a Sunday morning and learn that meteorologists are forecasting the threat for severe weather this afternoon. While searching for information, you come across this forecast graphic from the National Weather Service. [Hand out hard copy example of Public Severe Weather Outlook]



1. ***(interpretation)*** What does this forecast graphic mean to you?
   a. When you look at this graphic, what does it tell you?
   b. Where do you live relative to the threat for severe weather?
      i. What category is your house in?
         1. What does that mean to you?
      ii. What color is your house in?
         1. What does that mean to you?

c. Is any of the information confusing?

2. (***perceived susceptibility)*** On a scale from 0 (*not at all likely)* to 100 (*extremely likely)*, how would you rate the likelihood that your location will experience severe weather today? Why?

3. (***perceived severity)*** On a scale from 0 (*not at all threatening)* to 100 (*life-threatening)*, how would you rate the seriousness of the severe weather at your location? Why?

4. ***(behavior/use)*** How would you use this information?
   a. *Probe: [If says they would search for more information]* What types of information would you search for? Why?
   b. *Probe: [If says they would make a decision]* What decisions would you make with this information? Why?

Vignette #4b:

After seeing the previous forecast graphic, you search for more information and come across another graphic by a TV meteorologist in the Atlanta area. [Hand out hard copy example of Severe Storm Outlook produced by Channel 2 Broadcast Meteorologist.]

1. ***(interpretation)*** What does this forecast graphic mean to you?
    a. When you look at this forecast graphic, what does it tell you?
    b. Where do you live relative to the threat for severe weather?
        i. What category is your house in?
            1. What does that mean to you?
        ii. What color is your house in?
            1. What does that mean to you?
    a. Is any of the information confusing?

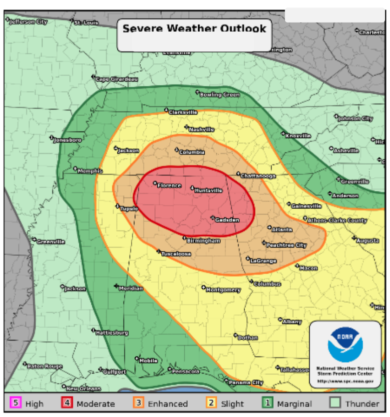
2. (***perceived susceptibility)*** On a scale from 0 (*not at all likely)* to 100 (*extremely likely)*, how would you rate the likelihood that your location will experience severe weather today? Why?

3. (***perceived severity)*** On a scale from 0 (*not at all threatening)* to 100 (*life-threatening)*, how would you rate the seriousness of the severe weather at your location? Why?

4. ***(behavior/use)*** How would you use this information?
    a. *Probe: [If says they would search for more information]* What types of information would you search for? Why?
    b. *Probe: [If says they would make a decision]* What decisions would you make with this information? Why?

Vignette #4c:

After seeing both forecast graphics, you look at them both again to better understand the severe weather threat for your area.



1. (***perceived consistency)*** Do you think these forecast graphics are communicating the same message? Why or why not?
    a. *Probe:* Is there anything different about them? Is there anything conflicting about them?
    b. *Probe:* Are they both showing your location as under the same risk for severe weather?

c. *Probe:* When you're judging whether they are communicating the same message, what are you looking for? What qualities are you using to determine whether they are communicating the same message?
d. *Probe:* If the two graphics are not communicating the same message, what is it about them that makes the message different?

2. (***perceived susceptibility)*** On a scale from 0 (*not at all likely)* to 100 (*extremely likely)*, how would you rate the likelihood that your location will experience severe weather today? Why?

3. (***perceived severity)*** On a scale from 0 (*not at all threatening)* to 100 (*life-threatening)*, how would you rate the seriousness of the severe weather at your location? Why?

4. (***perceived trust/source credibility)*** Which forecast graphic do you trust more? Why?

5. (***behavior/information use)*** After seeing both of these forecast graphics, what would you do next?

Questions to Close Out the Interview:

1. Now that you've seen these forecast graphics, do you think they are useful to you? Why or why not? *[Show examples of NWS graphics again]*
   a. *Probe:* If no, is there anything that we could change that would make it more useful to you?
   b. What do you like about the forecast information being provided in these graphics?
      i. What don't you like?
      ii. Is there any information you would like to have that is ***not*** provided?

2. *[Hand out all remaining graphics]* Out of all of the forecast graphics that you saw today, which do you like the most? Why?
   a. Which forecast graphic do you like the least? Why?

3. *[Show them PWO graphics]* I'm interested in making improvements to this graphic, do you have any recommendations or suggestions on ways that we can make this graphic better for you? What could be changed to better meet your needs?

4. Do you think you will actively search for this information the next time severe weather threatens your area? Why or why not?

   a. *Probe:* If no, is there anything that we could change that would make you more likely to seek out this information in the future?

5. In looking across all of these graphics, there are a variety of ways that meteorologists can show you severe weather risk information. How do you feel about that variety?
   a. *Probe:* What about when they show your location in a different risk area?
   b. *Probe:* What about when they use different words or colors?

6. Do you have any final thoughts or opinions on the severe weather graphics that you saw today?

7. Do you have any questions about the research project or your participation in this interview?

Before we finish up, I have a brief questionnaire that I would like you to complete that asks several demographic questions.

[*Hand out Demographic Questionnaire]*

Conclude by thanking them for their participation, providing contact information if they have any questions, and letting them know that this phase of the study will be concluded by Summer 20

3.8 References

Anthony, J. S., 2007: Self-advocacy in health care decision-making among elderly African Americans. *Journal of Cultural Diversity,* **14**(2).

Ashley, W., 2007: Spatial and temporal analysis of tornado fatalities in the United States: 1880-2005. *Weather and Forecasting,* **22**(6), 1214-1228.

Backhaus, A. L., 2004: An examination of the relationship between college students' conceptual level development and their perceptions of advertisements aimed at alcohol intervention (unpublished thesis). Emporia State University, Emporia, Kansas, United States.

Barter, C., and E. Renold, 1999: The use of vignettes in qualitative research. *Social Research Update,* **25**(9), 1-6.

Carpenter, D. M., R. F. DeVellis, E. B. Fisher, D. M. DeVellis, S. L. Hogan, and J. M. Jordan, 2010: The effect of conflicting medication information and physician support on medication adherence for chronically ill patients. *Patient education and counseling,* **81**(2), 169-176. doi: https://doi.org/10.1016/j.pec.2009.11.006

Carpenter, D. M., E. A. Elstad, S. J. Blalock, and R. F. DeVellis, 2014: Conflicting medication information: prevalence, sources, and relationship to medication adherence. *Journal of health communication,* **19**(1), 67-81. doi: https://doi.org/10.1080/10810730.2013.798380

Centers for Disease Control and Prevention, 2014: Crisis emergency and risk communication. Retrieved from: https://emergency.cdc.gov/cerc/resources/pdf/cerc_2014edition.pdf

Demuth, J. L., J. K. Lazo, and R. E. Morss, 2012: Assessing and improving the NWS point-andclick webpage forecast information. *NCAR Technical Note.* Retrieved from https://opensky.ucar.edu/islandora/object/technotes%3A504

Elstad, E., D.M. Carpenter, R.F. Devellis, and S. J. Blalock, 2012: Patient decision making in the face of conflicting medication information. *International journal of qualitative studies on health and well-being*, **7**(1), 18523.

Grams, J., B. Bunting, and S. Weiss, 2014: SPC Convective Outlooks. Retrieved from: www.spc.noaa.gov/misc/SPC_probotlk_info.html

Hämeen-Anttila, K., H. Nordeng, E. Kokki, J. Jyrkkä, A. Lupattelli, K. Vainio, and H. Enlund, 2014: Multiple information sources and consequences of conflicting information about medicine use during pregnancy: a multinational Internet-based survey. *Journal of medical Internet research*, *16*(2), e60. doi: https://doi.org/10.2196/jmir.2939

Han, P. K., R. P. Moser, and W. M. Klein, 2006: Perceiving ambiguity about cancer prevention recommendations: Relationship to perceptions of cancer preventability, risk, and worry. *Journal of health communication,* **11**(S1), 51-69. doi: https://doi.org/10.1080/10810730600637541

Hayes, A. F., and K. Krippendorff, 2007: Answering the call for a standard reliability measure for coding data. *Communication Methods and Measures,* **1**(1), 77-89.

Hsieh, H. F., and S. E. Shannon, 2005: Three approaches to qualitative content analysis. *Qualitative health research,* **15**(9), 1277-1288. doi: https://doi.org/10.1177/1049732305276687

Kain, D. J., and C. F. Smith, 2010. Risk Perceptions and Emergency Communication Effectiveness in Coastal Zones: Preliminary Findings on Interpretations of Weather Related Messages and Maps.

Krippendorff, K., 2004: Reliability in content analysis: Some common misconceptions and recommendations. *Human Communication Research,* **30**(3), 411-433.

Lee, C. J., R. H. Nagle, and N. Wang, 2017: Source-specific exposure to contradictory nutrition information: Documenting prevalence and effects on adverse cognitive and behavioral outcomes. *Health Communication*, **33**(4), 453-461. doi: https://doi.org/10.1080/10410236.2016.1278495

Mayhorn, C. B., M. S. Wogalter, J. L. Bell, and E. F. Shaven, 2004: What does code red mean? *Ergonomics in Design,* **12**(4), pg. 12-14.

McIntosh, A., and C. F. Shaw, 2003: Barriers to patient information provision in primary care: patients' and general practitioners' experiences and expectations of information for low back pain. *Health Expectations*, **6**(1), 19-29. doi: https://doi.org/10.1046/j.1369-6513.2003.00197.x

Mileti, D. S., and J. H. Sorensen, 1990: *Communication of emergency public warnings: A social science perspective and state-of-the-art assessment* (No. ORNL-6609). Oak Ridge National Lab., TN (USA). doi: https://doi.org/10.2172/6137387

Murray-Johnson, L. and K. Witte, 2003: Looking toward the future: Health message design strategies. *Handbook of health communication,* 473-495.

Nagler, R. H., 2014: Adverse outcomes associated with media exposure to contradictory nutrition messages. *Journal of health communication*, **19**(1), 24-40. doi: https://doi.org/10.1080/10810730.2013.798384

Nagler, R. H., and S. M. LoRusso, 2017: Conflicting information and message competition in health and risk messaging. *Encyclopedia of Health and Risk Message Design and Processing.* doi: https://doi.org/10.1093/acrefore/9780190228613.013.292

National Oceanic and Atmospheric Administration, 2014: Seven best practices for risk communication. Retrieved from: https://coast.noaa.gov/data/digitalcoast/pdf/risk-communication-best-practices.pdf

National Oceanic and Atmospheric Administration, 2016: Interpretation and use of the SPC Day 1 outlook and recommendations for increasing temporal and spatial resolution. Final Report.

National Oceanic and Atmospheric Administration, 2018: National Weather Service Hazard Simplification: Public Survey. Final Report. Retrieved from: https://www.weather.gov/media/hazardsimplification/HazSimp%20Public%20Survey%20-%20Final%20Report%20-%2006-01-18.pdf

Niederdeppe, J., and A. G. Levy, 2007: Fatalistic beliefs about cancer prevention and three prevention behaviors. *Cancer Epidemiology and Prevention Biomarkers*, **16**(5), 998-1003. doi: https://doi.org/10.1158/1055-9965.epi-06-0608

O'Keefe, D., 2018: Message characteristics and persuasion. In *Oxford Bibliographies.* doi: https://doi.org/10.1093/obo/9780199756841-0206

Pollock, K., J. Grime, E. Baker, and K. Mantala, 2004: Meeting the information needs of psychiatric inpatients: staff and patient perspectives. *Journal of Mental Health*, **13**(4), 389-401. doi: https://doi.org/10.1080/09638230410001729834

Rimal, R. N., and K. Real, 2003: Perceived risk and efficacy beliefs as moticators of change: Use of the risk perception attitude (RPA) framework to understand health behaviors. *Human Communication Research,* **29**(3), 370-399.

Rogers, R. W., 1975: A protection motivation theory of fear appeals and attitude change. *The Journal of Psychology,* **91**(1), 93-114.

Ronan, K. R., E. Alisic, B., Towers, V. A., Johnson, and D. M. Johnston, 2015: Disaster preparedness for children and families: A critical review. *Current Psychiatry Reports,* **17**(7), pg. 58. doi: https://doi.org/10.1001/dmp.2010.28

Schultz, D. M., E. C. Gruntfest, M. H. Hayden, C. C. Benight, S. Drobot, and L. R. Barnes, 2010: Decision making by Austin, Texas, residents in hypothetical tornado scenarios. *Weather, Climate, and Society, 2*(3), 249-254.

So, J., K., Kuang, and H., Cho, 2016: Information Seeking Upon Exposure to Risk Messages: Predictors, Outcomes, and Mediating Roles of Health Information Seeking. *Communication Research*, doi: https://doi.org/10.1177/0093650216679536

Sutter, D. and K. M. Simmons, 2010: Tornado fatalities and mobile homes in the United States. *Natural Hazards,* **53**(1), 125-137.

Taplin, S. H., M. T. Mandelson, C. Anderman, E. White, R. S. Thompson, D. Timlin, and E. H. Wagner, 1997: Mammography diffusion and trends in late-stage breast cancer: evaluating outcomes in a population. *Cancer Epidemiology and Prevention Biomarkers*, **6**(8), 625-631.

Weyrich, P., A. Scolobig, and A. Patt, 2018: Dealing with inconsistent weather warnings: Effects on warning quality and intended actions. *Meteorological Applications.* doi: https://doi.org/10.1002/met.1785.

U.S. Census Bureau, 2018: American Community Survey 1-Year Estimates, Table DP03, Selected Economic Characteristics. Retrieved from: https://data.census.gov/cedsci/table?g=0500000US13059&hidePreview=true&tid=ACSDP1Y2018.DP03&table=DP03&layer=county

Vellinga, A., J. H. Smit, E. Van Leeuwen, W. Van Tilburg, and C. Jonker, 2005: Decision-making capacity of elderly patients assessed through the vignette method: imagination or reality? *Aging and Mental Health,* **9**(1), 40-48.

VERBI Software, 2019: MAXQDA Pro 2018 [computer software]. Berlin, Germany: VERBI Software. Available from maxqda.com.

Williams, C. A., and G.M. Eosco, 2020: Is a consistent message achievable? Defining and evaluating 'message consistency' for weather enterprise researchers and practitioners. *Bulletin of the American Meteorological Society,* In Review.

Witte, K., 1992: Putting the fear back into fear appeals: The extended parallel process model. *Communications Monographs*, **59**(4), 329-349.

Zhang, F., R. E. Morss, J. A. Sippel, T. K. Beckman, N. C. Clements, N. L. Hampshire, … and S. Wang, 2007: An in-person survey investigating public perceptions of and responses to Hurricane Rita forecasts along the Texas coast. *Weather and Forecasting,* **22**(6), 1177-1190.

Table 3.1. Study vignettes.

Vignette number	Source of Convective Outlook Graphics	Location of Vignette	Vignette Explanation
1	Both from Storm Prediction Center	Athens, GA	Vignette #1 informed people they were at home on a weekend. The graphics used uniform colors, risk language, and risk categories. However, one of the two graphics was the Public Severe Weather Outlook graphic and was more public-friendly. This vignette was used to elicit an initial response to their understanding and interpretation of the Day 1 Convective Outlook and was primarily used as a baseline to understand how individuals evaluated message consistency when presented with two graphics that were nearly identical.
2	Storm Prediction Center and local NWS Weather Forecast Office	Tuscaloosa, AL	Vignette #2 informed people they were traveling. The graphics used uniform colors and language; however, the risk categories differed between the two graphics. When members of the public did not view these two graphics as consistent, this vignette also provided further insight on the implications of conflicting information between two NWS sources.
3	Local Broadcast Meteorologist and Storm Prediction Center	Tulsa, OK	Vignette #3 informed people they were traveling. The graphics used uniform colors, risk language, and risk categories; however, the basic design of the graphics was different. This vignette was designed to understand whether these two graphics would be perceived as consistent, even though they are from different sources and differ in basic graphic design (e.g. logo, lower-thirds, etc.)
4	Storm Prediction Center and Local Broadcast Meteorologist	Athens, GA	Vignette #4 informed people they were at home on a weekend. The graphics used uniform risk categories; however, the risk language and colors differed between the two graphics. This vignette was designed to evaluate whether changing the colors and risk language in the Day 1 Convective Outlook affects the consistency between the two graphics. This scenario also provided further insight on the implications of conflicting information between two expert sources, if participants believed they were inconsistent.

Table 3.2. Sample Demographics.

Variable	***N***	**%**
Gender:		
Female	17	56
Male	13	44
Children:		
Yes	13	44
No	17	56
Ethnic Identification:		
Caucasian American	21	70
African American	6	20
Asian American	2	7
American Indian	1	3
Educational Background:		
Some High School	1	3
High School Graduate	3	10
Some College Credit	2	7
Associate Degree	1	3
Bachelor Degree	7	24
Master's Degree	10	33
Professional Degree	3	10
Doctoral Degree	2	7
N/A	1	3
Total Household Income :		
Low (<$10,000 to $39,999)	10	33
Middle ($40,000 to $79,000)	9	30
High ($80,000 to >$150,000)	9	30
N/A	2	7
Age:		
18-24	1	3
25-34	5	17
35-44	6	20
45-54	1	3
55-64	10	33
65+	7	33

Table 3.3. Perceived Consistency Across the Four Vignettes.

Vignette	Difference Between Two Convective Outlook Graphics	Perceived as Consistent	Perceived as Inconsistent
1	Identical	25 (83%)	5 (17%)
2	Locations in Different Risk Categories	2 (7%)	28 (93%)
3	Basic Graphic Design (placement of logo, legend, lower thirds)	24 (80%)	4 (20%)
4	Colors and Risk Language	0 (0%)	30 (100%)

Table 3.4. Graphical inconsistencies that may affect perceived susceptibility or severity.

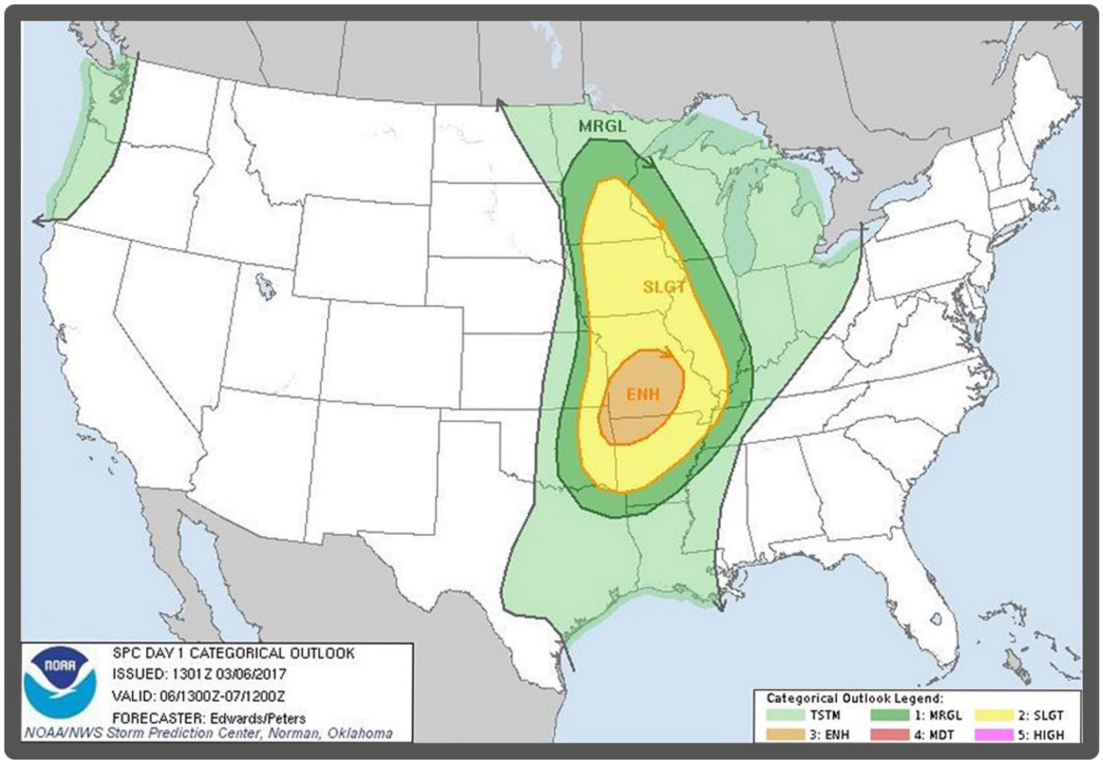
Inconsistent graphical elements	Affect perceived susceptibility or severity?	Example
Different risk areas or shapes	Perceived susceptibility	"Because the risk areas have shifted, I initially thought, 'oh, we're good, we're good.' Then, I see this [graphic] and I think we're definitely going to have storms coming."
Provided more information.	Either perceived susceptibility or severity; depends on information.	"Because the one on the left doesn't describe what [threats] the colors include and doesn't give a clear description of what the risks are [for my area.]"
Different geographic scales	Perceived susceptibility	"Since this one's more zoomed out, I feel like it's less concerned about what's happening in my area…When I look at this [graphic] it has actual counties and cities on it, so I feel like it's giving more specific warning information for this area and is advising people to be concerned about what's going on."
Different colors	Perceived severity	"Because one graphic has more detail and different colors, the severity is just much more intense."
Different color vividness	Perceived severity	"The intensity of these colors makes it more severe."
Different risk category words	Perceived susceptibility	"Compared to 'Slight', the word 'Scattered' seems more unpredictable, but also makes it feel like it's happening."
Inconsistent information within a single graphic.	Either perceived susceptibility or severity; depends on information.	"Both of them have the same [threat] information, so what's the difference? Is it the chance of it happening? Does a Moderate risk mean stronger weather?"

3.10 Figure Captions

Figure 3.1. A Convective Outlook graphic created by the Storm Prediction Center to depict the categorical and probabilistic threat of severe weather to a variety of end users.

Figure 3.2. A variety of Convective Outlook graphical designs that differ from the Storm Prediction Center's graphic by using different colors, risk language, and risk categories. The star indicates Memphis, Tennessee across all graphics for comparison purposes. All graphics were taken from the 20:00UTC run of the SPC Day 1 Convective Outlook on 04/03/18.

Figure 3.3. An example of two local news stations using different colors schemes and risk language to convey the same severe weather risk. Local news station graphics were taken from the same 8:00UTC run of the SPC's Day 3 Convective Outlook on 03/17/18.



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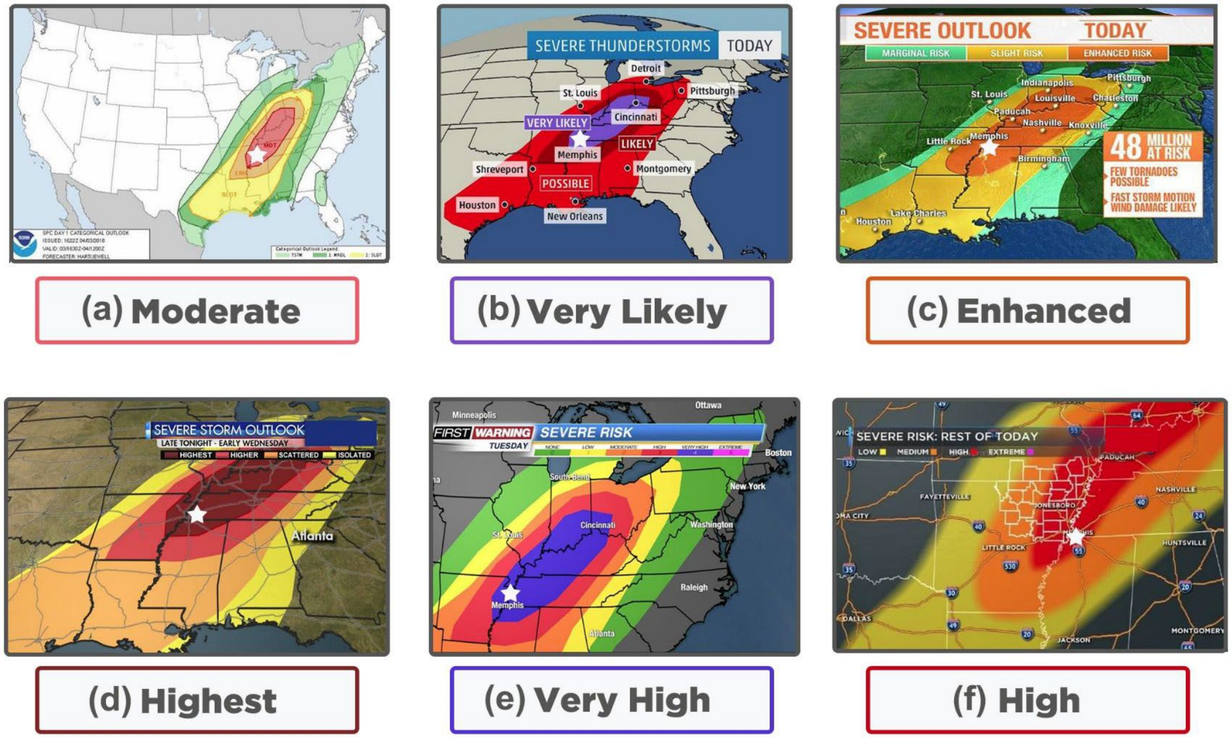

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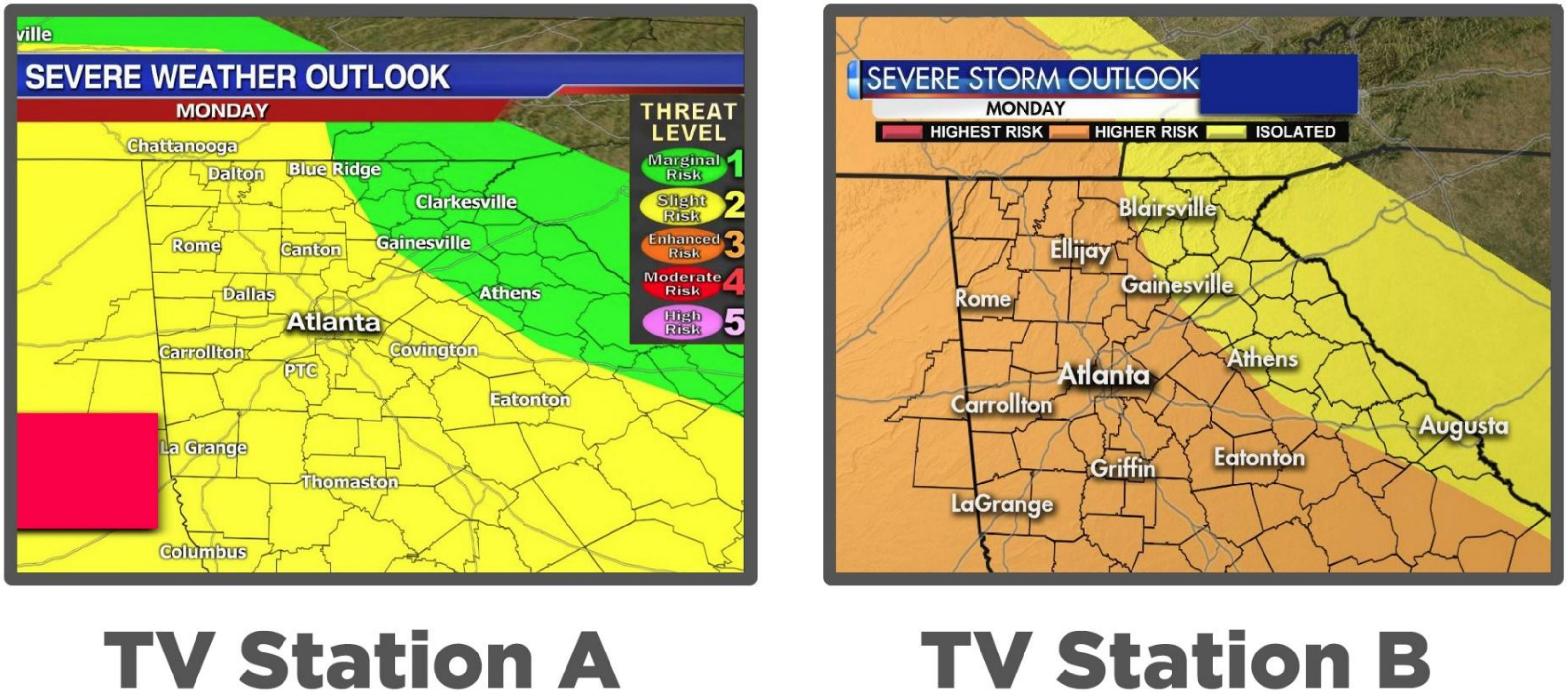

Figure 3.3. An example of two local news stations using different colors schemes and risk language to convey the same severe weather risk. Local news station graphics were taken from the same 8:00UTC run of the SPC's Day 3 Convective Outlook on 03/17/18.

CHAPTER 4

SHOULD SEVERE WEATHER GRAPHICS WEAR A UNIFORM? EXPLORING THE EFFECTS OF GRAPHICAL INCONSISTENCIES ON END USER RISK PERCEPTION, UNCERTAINTY, AND BEHAVIORAL INTENTIONS[8]

[8] Williams, C.A., So, J., and A. J. Grundstein. To be submitted to *Bulletin of the American Meteorological Society.*

Abstract

Within the last decade, the weather enterprise has become increasingly concerned that visual graphics shared with members of the public can be inconsistent, and in turn, may have a negative effect on public risk perception. In particular, meteorologists often vocalize their concerns when operational forecasters share the Storm Prediction Center's (SPC) Convective Outlook graphic and alter its risk-related content (e.g., use different colors, risk language, risk categories, etc.). But, does this visual variety have any negative consequences? In its current state, the weather enterprise lacks empirical evidence demonstrating that message consistency is a relevant operational concern and, as a result, is unequipped to offer advice on how practitioners and operational meteorologists should achieve a consistent message. To address this gap and substantiate the widely assumed effects of inconsistent graphical weather information, 1,504 college undergraduates participated in two experimental studies that manipulated graphical inconsistencies commonly associated with the Convective Outlook graphic.

The first experimental study manipulated five graphical inconsistencies (i.e., different risk categories, different colors, geographic scale, number of risk categories, and risk category language) to determine which one(s) resulted in the least perceived consistency. Two graphical variables emerged as prominent drivers of graphical inconsistency: (1) Convective Outlook graphics that depict a location in two different risk categories and (2) Convective Outlook graphics that use different color schemes. Building on these results, the second experimental study evaluated the effects of inconsistent Convective Outlook graphics on end user perceived consistency, risk perception, uncertainty, and behavioral intentions. Although behavioral

intentions to perform protective actions were not impacted by graphical inconsistencies, showing two inconsistent Convective Outlook graphics did affect participant's perceived risk, uncertainty, and information seeking intentions. Taken together, then, these findings indicate that graphical inconsistencies do matter when communicating severe weather information to end users. Therefore, when possible, it is recommended that operational meteorologists strive to maintain the same risk categories and color scheme used by the Storm Prediction Center when sharing Convective Outlook graphics with members of the public.

4.1 Introduction

With the rise of the Internet and social media platforms, people now have access to more weather information than ever before. Although this allows members of the public to receive weather information from a variety of public, private, and amateur sources, the sheer volume of available information likely contributes to a perception that weather risk messages are inconsistent. Further, members of the weather enterprise share these concerns and believe that these perceived inconsistencies may negatively affect their many audiences. The challenge, however, is that there are only a few empirical studies to-date that have explored message consistency in a weather context (Losee and Joslyn 2018; Williams and Eosco 2020; Williams et al. 2020), and only one that has evaluated the implications and/or effects of inconsistent weather messages on end user perceptions (Weyrich et al. 2019). Therefore, in its current state, the weather enterprise lacks empirical evidence demonstrating that message consistency is a relevant operational concern and, as a result, is unequipped to offer practitioners and operational meteorologists with guidance on how to achieve a more consistent message.

Although both researchers (Mileti and Sorensen 1990) and practitioners (CDC 2014; NOAA 2016) consider message consistency to be a critical component of effective risk communication, there is a lack of emphasis on how practitioners should evaluate, ensure, or even achieve a consistent message. To address this concern, a recent manuscript by Williams and Eosco (2020) sought to understand what it means to be (and not be) consistent when sharing weather risk messages. To define message consistency, these authors conducted a social science literature review based on recurring themes that emerged from previous message consistency efforts in the weather enterprise. This resulted in a definition of message consistency that captured both the needs of the operational meteorology community and incorporated relevant social science literature: “We define message consistency as two or more weather messages that must attain an optimal amount of similarity without producing any negative or adverse effects.” Although an important first step, these authors note that this definition does not quite address how to achieve message consistency and that more collaborative research is needed to further explicate this process. However, it does offer some evidence that achieving consistency likely depends on the effects, or lack thereof, that result when end users evaluate two or more weather messages.

Despite the assumption that inconsistent messages may negatively affect end users, research on the topic is quite nascent. A growing area of health communication, known as conflicting information, has conducted the most research on the topic (for review, see Nagler and LoRusso 2017). These studies show that receiving conflicting or inconsistent information: increases feelings of anxiety (Pollock et al. 2004; Hämeen-Anttila et al. 2014), alters risk perceptions (Han et al. 2006), results in public confusion and decreased trust in nutrition recommendations (Nagler 2014; Lee et al. 2017), impacts a patient’s ability to assess the reliability of sources (McIntosh and Shaw 2003), and reduces the use of and adherence to medications (Carpenter et al. 2010; Carpenter et al. 2014; Hämeen-Anttila et al. 2014). Therefore, this body of research suggests that inconsistent weather risk messages would similarly impact end users. However, only one study to-date has explored the effects of inconsistent weather risk messages on end users.

After noticing a gap in the literature, Weyrich et al. (2019) conducted a survey experiment with members of the Swiss public to determine whether receiving inconsistent textual and/or graphical weather warning information had an impact on warning quality and intended actions. According to the results, when warning messages were inconsistent (i.e., used different colors, categories, thresholds, interpretation of data, and model used) participants reported significantly lower understandability, more confusion, and lower warning quality. Not only that, but these authors also found that receiving consistent warning information resulted in a higher likelihood of performing a protective action and a lower likelihood of searching for additional information. Although this study provides initial evidence that inconsistent weather messages have negative effects on end users, more research is needed - especially studies that manipulate different types of inconsistencies in order to provide practical guidance on how to achieve a more consistent message. Therefore, building on this research, this study sought to further explore and substantiate the widely assumed effects of inconsistent graphical forecast information on end user perceptions and behavioral intentions.

Meteorologists often vocalize their concerns of inconsistent graphical forecast information during severe weather events (i.e., severe thunderstorms and tornadoes) when members of the weather enterprise visually alter the Storm Prediction Center's (SPC) Convective Outlook graphic and share it with their many audiences. The Convective Outlook graphic is a static visual display that is produced by the SPC to communicate both the categorical and probabilistic risk of severe and general thunderstorm threats across the United States (Grams et al. 2014, Figure 4.1). Although originally designed for emergency managers, operational meteorologists, and other weather enterprise partners, the increased use of Convective Outlook graphics in television broadcasts and on social media has enhanced its visibility among members of the public. Therefore, when operational meteorologists repurpose the SPC's Convective Outlook graphic by using alternative color schemes, different risk language, and/or showing a location in a different risk category, does it affect members of the public (Figure 4.2)? A recent study by Williams et al. (2020) suggests that this may be true. According to these authors, members of the public (1) identified graphical inconsistencies that are frequently mentioned by meteorologists and (2) explained that these graphical inconsistencies would likely affect their perceptions and weather-related decision-making. Therefore, this study aims to take this research inquiry one step further by manipulating the SPC's Convective Outlook graphic in two different experiments to investigate the effects of graphical inconsistencies on end users. To do this, Experiment 1 first explores five graphical inconsistency types that were mentioned in the study by Williams et al. (2020) to determine which one(s) resulted in the lowest perceived consistency. These results then informed Experiment 2, which was specifically designed to evaluate the effects of graphical inconsistencies on end user risk perception, uncertainty, and behavioral intentions. This is followed by a discussion of the results and recommendations for operational meteorologists.

4.2 Experiment #1: Perceived Consistency of Different Inconsistency Types

4.2.1 Literature Review

4.2.1.1 Perceived Consistency

When evaluating whether two Convective Outlook graphics communicated the same message, Williams et al. (2020) notes that members of the public overwhelmingly looked to see whether a location was in the same risk category or color zone. These criteria similarly emerged when participants detected inconsistent information; however, they also called attention to a variety of other reasons why the graphics conveyed different messages. For example, these authors noted that the use of different color vividness, types of information, geographical scale, risk category words, and/or the number of risk categories also affected the perceived consistency between two graphics. Based on these findings, then, we anticipate that any graphical inconsistency will lower participant's perceived consistency. However, due to the frequency with which participants mentioned both risk category and color differences in the qualitative findings by Williams et al. (2020), we hypothesize that two graphics that (1) change a location's risk category or (2) use a different color scheme will result in a significantly lower perceived consistency.

H1: Inconsistency induced by showing two Convective Outlook graphics with (a) two different risk categories and (b) two different color schemes will result in a significantly lower perceived consistency when compared against the other types of graphical inconsistencies.

4.2.2 Method

As a first step toward quantifying the effects of inconsistent or conflicting graphical forecast information, five inconsistencies associated with the Convective Outlook graphic were selected using the findings offered by Williams et al. (2020). Each inconsistency corresponded with a graphical element that members of the public frequently emphasized when asked to describe why two Convective Outlook graphics did not communicate the same message. The five graphical inconsistencies included: changes in (1) a location's risk category, (2) color scheme, (3) risk language, (4) geographic scale, and (5) number of risk categories. A PowerPoint template was then used to create hypothetical Convective Outlook graphics that feature each graphical inconsistency (Figure 4.3). This template was given to the research team by a local broadcast meteorologist, therefore, the Convective Outlook graphics used in Experiment 1 were similar to those used by other operational and broadcast meteorologists in the weather enterprise. Not only did this improve ecological validity, but it also allowed the research team to systematically manipulate the Convective Outlook graphics based on each inconsistency type. Additionally, each manipulated graphic was paired with an identical reference graphic (Figure 4.3). This design was purposeful, as it allowed for a direct comparison of perceived consistency across the five experimental conditions.

To effectively evaluate the five experimental conditions, participants were given a hypothetical severe weather scenario that was threatening their location. Scenarios or vignettes are a common research tool that enable participants to experience an issue, situation, or scenario in real-time (Barter and Renold 1999). Because vignettes have been successfully used to evaluate conflicting or inconsistent information in both a health (Elstad et al. 2012) and meteorological context (NOAA 2018; Williams et al. 2020), it was determined that a similar strategy would be advantageous for the current study. Therefore, after agreeing to participate in the online experiment for extra credit, 655 undergraduate students received a hypothetical weather scenario explaining that meteorologists were forecasting the threat of severe weather for their location on a Saturday afternoon. After reading the scenario, participants were randomly assigned to one of the five experimental conditions where they were shown both a reference and a manipulated Convective Outlook graphic based on their random assignment. This was followed by a measure of perceived consistency and demographic questions. However, because message consistency is a relatively new concept in the weather enterprise, an established scale for measuring the concept did not yet exist. Therefore, the research team developed a perceived consistency scale based on a review of interdisciplinary social science research and the definition of message consistency offered by Williams and Eosco (2020).

A total of four items were used to measure perceived message consistency. Two items were adapted from an unpublished thesis by Backhaus (2004) that asked college students to evaluate the similarity between two advertisements by comparing their (1) overall content and (2) messages. After considering the items offered by Backhaus (2004), the definition of message consistency provided by Williams and Eosco (2020), and evaluating content validity, the research team determined that two additional survey items were needed. Because the current study uses Convective Outlook graphics to explore message consistency, a survey item was created that asked participants to evaluate the visual consistency between two graphics.

However, based on exploratory and confirmatory analyses, the visual consistency item was dropped from the perceived consistency scale. Finally, as the other items ask participants about specific message features, a survey item was developed that asked participants to provide a general overview of the consistency between two messages.

To maintain internal consistency, the survey item phrasing for the newly created items mirrored the language offered by Backhaus (2004). However, Backhaus (2004) only asked participants to describe the level of *similarity* between two advertisements. After conducting the literature review, the research team noticed that other studies asked participants to judge the similarity or differences between objects using a variety of descriptive adjectives. Therefore, to improve scale validity, all items asked participants to evaluate the two forecast graphics across five different adjectives: similar, conflicting, same, contradictory, and consistent. Based on confirmatory factor analyses, the adjective 'the same' was dropped from the measure. This resulted in participants being asked to provide four different responses for each of the three items on a 7-point Likert-type scale ranging from 1 (*not at all)* to 7 (extremely; 12 items in total; see Table 4.1). For more information on the development of the perceived consistency scale, please refer to Appendix A.

4.2.3 Results

To compare the mean perceived consistency scores across the five experimental conditions, a one-way ANOVA was conducted. Recall that the five graphical inconsistency types included: changes in (1) a location's risk category, (2) color scheme, (3) risk category language, (4) geographic scale, and (5) number of risk categories (Figure 4.3). There was a significant difference in the means of the perceived consistency scores across the five inconsistency types [$F(4, 548) = 26.080$, $p < .001$]. Post hoc analyses using Tukey HSD indicated that the mean scores for risk area changes ($M = 4.813$, $SD = 0.099$, $p < .001$) and color scheme changes ($M = 4.873$, $SD = 0.098$, $p < .001$) were significantly different from changes in risk language ($M = 5.598$, $SD = 0.099$), geographic scale ($M = 5.689$, $SD = 0.101$), and number of risk categories ($M = 5.923$, $SD = 0.098$). However, the mean scores for risk area changes and color changes were not significantly different from one another ($p = 0.993$). Taken together, these results suggest that study participants perceive the lowest consistency when two Convective Outlook graphics show a location in a different risk area or use a different color scheme to convey severe weather risk.

4.2.4 Discussion of experiment 1

Out of the five graphical inconsistencies that were investigated, participants that saw two Convective Outlook graphics that depicted their location in a different risk category or used a different color scheme reported a significantly lower perceived consistency. These findings are consistent with the qualitative results offered by Williams et al. (2020), and as a result, support the hypothesis in experiment 1 (H1). Although an important first step, these findings do not yet address whether a perception of inconsistency has negative repercussions on end users. Therefore, in response to this concern, Experiment 2 aimed to study the effects of graphical inconsistencies on end user risk perception, uncertainty, and behavioral intentions.

4.3 Experiment #2: Effects of Inconsistent Graphical Forecast Information

4.3.1 Literature Review

4.3.1.1 Perceived Consistency:

Whereas the previous study investigated the perceived consistency associated with five different inconsistency types, Experiment 2 provides a more in-depth exploration of the two types that led to the lowest perceived consistency in Experiment 1. Therefore, based on the findings from Experiment 1, it is hypothesized that when two Convective Outlook graphics depict (1) different risk categories and (2) different color schemes it will result in a significantly lower perceived consistency when compared against two identical graphics. Additionally, this experiment also manipulates whether an individual received a Convective Outlook graphic that depicted a location along a risk boundary. Instead of being located in the middle of the Moderate risk category, participants in the risk boundary condition were placed on the boundary between the Moderate and High risk categories. This resulted in the risk boundary condition being 0.5 risk units higher in the overall risk continuum. Previous studies examining severe weather graphics, for example, have noted that end users often express difficulties interpreting and discerning uncertainty and risk information when their location is depicted along a risk boundary (Sherman-Morris and Brown 2012; Ash et al. 2013). Based on these findings, it was determined that exploring risk boundaries would also be an important factor to examine in Experiment 2. However, Sherman-Morris and Brown (2012) and Ash et al. (2013) did not explore the role that graphical inconsistencies may play when interpreting risk and uncertainty information along a risk boundary. Therefore, this experiment asks: what role, if any, do risk boundaries play when interpreting perceived consistency? In this regard, the following hypothesis and research question are offered to explore perceived consistency in Experiment 2:

> **H1:** Inconsistency induced by showing two Convective Outlook graphics with (a) two different risk categories and (b) two different color schemes will result in a significantly lower perceived consistency when compared against the identical graphic condition.

> **RQ1**: What role, if any, do risk boundaries play when interpreting perceived consistency?

4.3.1.2 Perceived Risk, Perceived Efficacy, and Behavioral Intentions:

Williams and Eosco (2020) consider two messages to be consistent when they do not produce any negative or adverse effects; therefore, one of the goals of Experiment 2 was to evaluate whether graphical inconsistencies affected an individual's risk perception. Recall that the Convective Outlook graphic was designed to communicate a location's overall risk for both general and severe thunderstorm threats (Grams et a. 2014). This is accomplished through the use of a risk category system that uses numbers (i.e., 4), colors (i.e., red), and risk words (i.e., Moderate) to depict both non-severe thunderstorm areas (i.e., Thunder) and five categories of increasing risk (Marginal, Slight, Enhanced, Moderate, and High). Therefore, when operational meteorologists alter a Convective Outlook graphic by changing a location's risk category from Moderate to Enhanced, for example, they inherently affect the risk information being communicated (Williams et al. 2020). As a result, when two Convective Outlook graphics show a location in different risk categories, this graphical inconsistency will likely affect an individual's risk perception. However, the findings by Williams et al. (2020) suggest that this hypothesis could be further refined. In their study, these authors propose that different inconsistency types (e.g., risk category changes, color changes, etc.) can be specifically linked to the individual elements that make up risk perception. According to the risk communication and fear appeals literature, risk perception consists of two dimensions: perceived susceptibility and perceived severity. Perceived susceptibility refers to an individual's beliefs about their likelihood of experiencing a threat, while perceived severity pertains to an individual's beliefs about the seriousness or intensity of the threat (Witte 1992). Based on these definitions, two Convective Outlook graphics depicting inconsistent risk categories would most likely affect an individual's perceived susceptibility. The results of the study by Williams et al. (2020), however, suggested that participants walked away with both susceptibility and severity information from the Convective Outlook graphic. Therefore, we hypothesize that:

> **H2:** As the risk category of the second graphic increases, a participant's (a) perceived susceptibility and (b) perceived severity will increase.

When two Convective Outlook graphics have two different color schemes, on the other hand, the relationship between perceived susceptibility and perceived severity is not as clear. Previous studies examining hazard related-graphics and meteorological displays have found that color choice can influence understanding of risk and uncertainty (Hoffman et al. 1993; Bostrom et al. 2008; Ash et al. 2013). What is missing, however, is an understanding of how color inconsistencies affect perceived risk and uncertainty. This is especially important as broadcast meteorologists and private sector companies continue to use different color schemes to distinguish themselves from other weather sources. For example, The Weather Channel's Convective Outlook graphic uses an alternative color scheme (i.e., light red, red, dark red, purple, white) that differs from the Storm Prediction Center's rainbow color scheme. This practice raises the question of whether color inconsistencies affect end user perceived susceptibility and severity. The study by Williams et al. (2020) hints at the possibility that color changes primarily affect perceived severity. During the qualitative interviews, for example, some participants mentioned that the use of different color schemes inherently changed their perceived severity of the severe weather threat. One participant explained this by stating that "because one graphic has more detail and different colors, the severity is just much more intense." Therefore, based on the qualitative findings offered by Williams et al. (2020), the following hypothesis is offered:

> **H3:** Inconsistency induced by showing two graphics with two different color schemes will result in a higher perceived severity.

Previous studies in the meteorological community have shown that when end users view weather-related graphics, they have difficulties interpreting risk and uncertainty information along risk boundaries (Sherman-Morris and Brown 2012, Ash et al. 2013). The same is likely true for the Convective Outlook graphic. In speaking with operational meteorologists, they too shared concerns that members of the public may find it difficult to interpret their severe weather risk when their location is on a risk boundary. A qualitative study by Grundstein et al. (2019)

provides empirical evidence that this is true. These authors note that some individuals struggled to interpret severe weather risk and uncertainty information when their location was on a risk boundary (e.g., between an Enhanced and Moderate risk). Not only that, but these individuals also presumed that being a risk boundary held some sort of specific meaning or significance. Other individuals, however, intuitively understood that risk boundaries were part of the overall risk category system and interpreted a risk boundary as being halfway between two risk categories. Finally, because the research team decided to place the participants on a risk boundary closer to the next highest risk category (i.e., between Moderate and High), it is likely that participants will view these graphics and walk away with a higher perceived susceptibility and severity. Keep in mind that this is only a 0.5 increase along the risk category continuum. As a result, this will likely offer additional insight into whether participants believe there is a conceptual difference in being on a risk boundary. Based on this discussion, the following research question and hypothesis are offered:

> **H4:** Inconsistency induced by showing a reference graphic with a location on a risk boundary will result in a (a) higher perceived susceptibility and (b) higher perceived severity.

> **RQ2:** Is there a conceptual difference in being on a risk boundary, such that being on a risk boundary results in a substantially different perceived susceptibility and perceived severity, and as a result, is not interpreted as a midpoint between two risk categories?

Although perceived susceptibility and severity are critical variables for determining whether graphical inconsistencies have implications on end users (Williams et al. 2020), they also play a role in assessing whether an inconsistent message affects an individual's behavioral intentions to take action. For an individual to change their behavior or consider performing a specific action, the risk communication and fear appeals literatures draw attention to the need for both perceived risk and efficacy. The dimensions of perceived risk have already been discussed in the sections above; however, the two dimensions of efficacy deserve more attention in this review. According to Witte (1992), perceived efficacy can be broken down into two dimensions: perceived self-efficacy and perceived response efficacy. Perceived self-efficacy refers to an individual's belief that they can successfully perform the action that is recommended by the message. On the other hand, perceived response efficacy refers to an individual's belief that the recommended action will successfully prevent or reduce the effects of the threat. Taken together then, an individual's perceived risk and perceived efficacy determine the likelihood that an individual will change their behavior or, in this case, perform a specific behavior. For example, according to the Extended Parallel Process Model (Witte 1992), if perceived risk and efficacy are both high, then that individual will likely perform the recommended action in an attempt to reduce their overall perceived risk. However, if perceived risk is high and perceived efficacy is low, individuals are more motivated to deny the threat and ignore the recommended action. In the context of this study, then, what effect, if any, do graphical inconsistencies have on behavioral intentions to perform an action? Although we expect perceived risk to be affected by graphical inconsistencies, the Convective Outlook graphic does not provide any efficacy information. Therefore, it is impossible to hypothesize the effects of graphical inconsistencies on behavioral intentions. As a result, the following research questions are offered:

> **RQ3:** Does inconsistency induced by showing two Convective Outlook graphics with (a) two different risk categories, (b) two different color schemes, and/or (c) two different risk boundaries affect participants perceived self-efficacy and response efficacy?

> **RQ4:** Does inconsistency induced by showing two Convective Outlook graphics with (a) two different risk categories, (b) two different color schemes, and/or (c) two different risk boundaries affect participants' behavioral intentions to perform severe weather monitoring, preparedness, and/or sheltering actions?

4.3.1.3 Perceived Uncertainty and Information Seeking:

Although previous studies investigating weather-related graphics have found that end users have trouble interpreting uncertainty information along risk boundaries (Sherman-Morris and Brown 2013; Grundstein et al. 2019), the connection between uncertainty and inconsistency is less clear. The theoretical assertions of uncertainty communication have evolved through the years: from a fixation on reducing uncertainty (i.e., Uncertainty Reduction Theory, URT; Berger and Calabrese, 1975) to a more nuanced understanding of uncertainty as something that we manage (i.e., Uncertainty Management Theory; TUM; Brashers et al. 2001). Building on these perspectives, the most recent theoretical developments suggest that a series of thresholds exist that govern the decision on how one might manage their uncertainty (i.e., increase, decrease, or maintain; Afifi and Weiner 2004). In particular, these authors conceptualize uncertainty as two different thresholds: actual uncertainty and desired uncertainty. When an individual receives a weather forecast, for example, they unconsciously designate a level of actual uncertainty. If that actual uncertainty is higher or lower than their desired level of uncertainty, then that individual will seek out information or perform other information management behaviors to equalize those thresholds (Kuang and Wilson 2017). The issue becomes more complicated when an individual encounters inconsistent or conflicting information. In this situation, instead of alleviating uncertainty through the information seeking process, we anticipate that seeking and finding an inconsistent message will increase an individual's perceived uncertainty.

According to Brashers et al. (2001), uncertainty occurs 'when details of situations are ambiguous, complex, unpredictable, or probabilistic; when information is unavailable or *inconsistent*, and when people feel insecure in their own state of knowledge or the state of knowledge in general." Therefore, like the weather forecast example mentioned above, Brashers et al. (2001)'s implies that inconsistent graphical weather information would similarly impact or affect an individual's perceived uncertainty. In the context of the Theory of Motivated Information Management, then, receiving inconsistent weather information will likely increase an individual's level of actual uncertainty - widening the gap between an individual's actual and desired levels of uncertainty. Like the findings by Weyrich et al. (2019), we anticipate that individual's will seek out even more information to reduce this discrepancy between the two levels and achieve their desired level of uncertainty. In this regard, the following hypothesis is offered:

H5: Inconsistency induced by showing two graphics with (a) two different risk categories, (b) two different color schemes, and (c) two different risk boundaries will result in increased uncertainty discrepancy and greater intentions to search for information.

4.3.1.4 The Combined Effects of Different Inconsistency Types:

With some operational meteorologists repurposing the Storm Prediction Center's Convective Outlook graphic by using both a different color scheme *and* changing a location's risk category, this experimental study also sought to explore the combined effects of different inconsistency types on end user perceptions. To our knowledge, only one study to date has explored the effects of inconsistent weather graphics (Weyrich et al. 2019). However, these authors did not isolate the different types of inconsistencies when exploring their effects on participants. As a result, there is a lack of empirical evidence indicating whether different types of graphical inconsistencies stack to have a combined effect on end users. Given that the literature outlined above suggests that introducing a single inconsistency type will have effects on end users, it is hypothesized that presenting two or more inconsistency types will result in an additive effect. Therefore, the following is offered:

H6: Inconsistency induced by showing a second Convective Outlook graphic that differs in both risk category *and* color scheme will result in the (a) lowest perceived consistency, (b) higher uncertainty discrepancy, and (c) greater intention to search for information than (1) to the risk category change only condition, (2) the color scheme change only condition, and (3) the uniform condition.

Finally, because the research team decided to place participants on a risk boundary that is closer to the next highest risk category (i.e., between Moderate and High), when combined with a second Convective Outlook graphic in a higher risk category, this condition will likely result in the highest perceived susceptibility and severity.

H7: Inconsistency induced by showing one graphic with a location on a risk boundary and a second graphic with a higher risk category will result in the (a) highest perceived susceptibility and (b) highest perceived severity.

4.3.2 Method

Whereas the previous study investigated five different inconsistency types, Experiment 2 uses a factorial experimental design to manipulate graphical inconsistency in three different ways: (1) changes in risk category, (2) changes in color scheme, and (3) whether an individual's location is on a risk boundary or not. Factorial experimental designs are a common methodological approach used by researchers who are interested in investigating the effects of several different variables and their combined effects (Collins et al. 2009). Therefore, Experiment 2 employed a 3 (*risk category*; no risk category change vs. change to lower risk category vs. change to higher risk category) x 2(*color scheme*; same color scheme vs. different color scheme) x 2(*risk boundary;* location not on a risk boundary vs. location on risk boundary) factorial experimental design. This resulted in a total of 12 experimental conditions (Figure 4.4).

Like the Convective Outlook graphics created for Experiment 1, this study used the same PowerPoint template to generate a reference graphic (Graphic A) and a manipulated graphic (Graphic B) that corresponded to each experimental condition (Figure 4.4). As inconsistent information often occurs when individuals seek out and/or receive information from different sources, two hypothetical weather sources were created for Experiment 2 (i.e., The Weather Authority and The Weather Experts). Therefore, like Experiment 1, each participant saw both a reference graphic and a manipulated graphic at the same time. It is important to note, however, that participants received different reference graphics depending on which risk boundary condition they were assigned. When a participant was assigned to the 'location on a risk boundary' condition, for example, the reference graphic showed their location on a risk boundary. Otherwise, the reference graphic did not show a participants' location on a risk boundary. This design was purposeful, as it allowed the research team to successfully manipulate whether a location was on a risk boundary while simultaneously ensuring that the risk category and color manipulations remained the same across the two risk boundary conditions.

The final two variables, risk category changes and color changes, were also manipulated for all twelve conditions. The risk category variable was manipulated in Graphic B by either moving a location into a higher risk category (i.e., Moderate to High), maintaining the same risk category (i.e., Moderate to Moderate), or shifting a location into a lower risk category (i.e., Moderate to Enhanced). Color, on the other hand, was manipulated in Graphic B by using two different color schemes. Convective Outlooks graphics, for example, either used a rainbow color scheme (i.e., green, yellow, orange, red, magenta) that has been standardized by the Storm

Prediction Center or used an alternative color scheme that has recently been developed and put into practice by The Weather Channel (i.e., orange, red, dark red, purple, white). Finally, recall that using a factorial experimental design also allows us to explore the combined effects between all three manipulated variables. Therefore, some experimental conditions manipulate a location's risk category, its color scheme, and/or the presence on a risk boundary to determine whether combining these factors affects perceived consistency, risk perception, uncertainty, or behavioral intentions.

Before conducting the experimental survey, participants were first asked to complete a pre-experiment questionnaire. After reviewing the conflicting information literature, it was determined that previous exposure to conflicting or inconsistent information may affect participants' responses (Nagler and Hornik 2012; Lee et al. 2017). However, the research team agreed that asking participants about their previous exposure after intentionally showing them inconsistent Convective Outlook graphics would likely bias their responses. As a result, 1,149 undergraduate students completed a pre-experiment questionnaire that was used to collect this exposure data and other measures associated with the study. At the end of the questionnaire, participants were redirected to a brief survey and asked to provide their contact information. Then, in three days' time, the same participants were contacted by email and asked to participate in the experimental survey. Of the original 1,149 participants, only 960 agreed to participate in the second survey. Like Experiment 1, the second questionnaire began with a hypothetical weather scenario that informed participants that they were visiting Atlanta, Georgia on a weekend in July and that meteorologists were forecasting a threat of severe weather for Saturday afternoon. After reading the scenario, participants were randomly assigned to one of the twelve experimental conditions where they were shown both a reference graphic (Graphic A) and a manipulated graphic (Graphic B) at the same time. This was followed by measures of perceived consistency, perceived susceptibility, perceived severity, uncertainty discrepancy, self-efficacy, response efficacy, and behavioral intentions to seek information and perform an action. Unless otherwise stated, all measures adopted a seven-point Likert scale. A complete list of survey items used in both questionnaires can be found in Appendix B. Finally, the responses from the two questionnaires were combined using a unique identifier code that was provided by each respondent. This code was different for each participant, and in no way allowed the research team to connect a participant's responses to their identity. After combining the responses from the two questionnaires and removing any incomplete data, this resulted in a final sample of 849 respondents.

4.3.3 Results

To evaluate the hypotheses associated with this study, a three-way (risk category changes x color scheme changes x risk boundary) analysis of covariance (ANCOVA) was first employed to examine the effects of graphical inconsistencies on end users. Three covariates were included in the analysis: Previous experience with severe weather, gender, and ambiguity aversion - a personality trait in which an individual is more tolerant of ambiguity and/or uncertainty (Han et al. 2009).

4.3.3.1 Perceived Consistency:

Based on the results from Experiment 1, the first hypothesis predicted that participants who saw inconsistent Convective Outlook graphics would report a significantly lower perceived consistency. In effect, this hypothesis acted as a manipulation check. The ANCOVA results revealed that there was a statistically significant main effect for both risk category changes ($F(2, 795) = 60.03$, $p < 0.01$) and color scheme changes ($F(1, 795) = 84.43$, $p < 0.01$). As anticipated, showing a second Convective Outlook graphic with a higher risk category (M = 4.427, SE = 0.071) or a lower risk category (M = 4.317, SE = 0.071) produced a significantly lower perceived consistency as compared to the uniform risk condition (M = 5.318, SE = 0.071). Similarly, showing a second Convective Outlook graphic with an alternative color scheme lead to a significantly lower perceived consistency (M = 4.312, SE = 0.058) when compared against two graphics that used an identical color scheme (M = 5.063, SE = 0.058). Based on these results, H1 was supported. The ANCOVA analysis also indicated a significant main effect for risk boundary. This finding suggests that when Graphic A showed a location on a risk boundary, participants perceived the two graphics as more consistent ($p = 0.01$, M = 4.792, SE = 0.058). Therefore, in regard to RQ1, it appears that participants perceived a pair of graphics as more consistent when Graphic A was on a risk boundary.

4.3.3.2 Perceived Risk, Perceived Efficacy, and Behavioral Intentions

The next set of hypotheses (H2 through H4) predicted that showing participants inconsistent Convective Outlook graphics would affect their perceived susceptibility and severity. In terms of perceived susceptibility, the ANCOVA analysis revealed a significant main effect for risk category changes ($F(2, 723) = 3.88$, $p = 0.02$) and risk boundary ($F(1,723) = 6.35$, $p = 0.01$). Post hoc analyses indicated that participants perceived a lower susceptibility when shown a second graphic depicting their area in a lower risk category (M = 5.12, SE = 0.08), in comparison to either the identical risk category condition ($p = 0.05$, M = 5.389, SE = 0.081) or the higher risk category condition ($p = 0.04$, M = 5.39, SE = 0.08). However, participants did not perceive a significant difference in susceptibility between the identical risk category condition and the higher risk category condition ($p = 1.00$). On the other hand, the results associated with the risk boundary main effect showed that participants perceived a significantly higher susceptibility when Graphic A showed their location on a risk boundary (p = 0.01, M = 5.416, SE = 0.065) compared to those who did not (M = 5.19, SE = 0.07). The ANCOVA evaluating perceived severity offered similar results. The ANCOVA analysis revealed a significant main effect for risk boundary (F(1, 720) = 4.83, $p = 0.03$), such that participants perceived a significantly higher severity when Graphic A showed their location on a risk boundary (p = 0.03, M = 5.43, SE = 0.06) compared to those who did not (M = 5.236, SE = 0.062). Changing a graphic's risk category ($p = 0.08$) or color scheme ($p = 0.59$), on the other hand, did not result in a significantly different perceived severity. Therefore, based on these ANCOVA results, H2a was supported, H2b and H3 were not supported, and H4 was supported.

To further explore the differences between pairs of graphics that showed a risk boundary in Graphic A and those that did not, various planned comparisons were used to determine whether participants perceived risk boundaries as conceptually different from their intended purpose of being a midpoint between two risk categories (RQ2). Therefore, several specific conditions were selected to determine whether being on a risk boundary resulted in a substantially larger perceived susceptibility. First, the two uniform risk category conditions were compared. This offered insight on whether increasing a risk category by 0.5 would result in a significantly larger perceived susceptibility. The planned comparison results showed that being on a risk boundary increased participants' perceived susceptibility (M = 5.57, SE = 0.16), however, it fell short of being significantly different from the no risk boundary condition (M = 5.31, SE = 0.16, $p = 0.26$). This result was further investigated by examining several other planned comparisons (Table 4.2 and Table 4.3). These planned comparisons were selected because they either shared a Graphic A or a Graphic B across the risk boundary and no risk boundary conditions. However, there were no significant results across the five planned comparisons. This suggests that in terms of perceived susceptibility, participants likely perceived being on a risk boundary as a midpoint between two risk categories.

Before evaluating the implications of inconsistent Convective Outlook graphics on participants' behavioral intentions to perform severe weather monitoring, preparedness, and/or sheltering actions, it is important to first consider the participants' perceived response efficacy and self-efficacy when looking at Convective Outlook graphics. Overall, the participants' self-efficacy (M = 4.88, SD = 1.16) was lower than their response efficacy (M = 5.42, SD = 1.18; Table 4.4). This indicates that although participants believed specific severe weather actions would reduce their severe weather risk, they were less likely to believe they could successfully perform those actions. A closer look at the individual self-efficacy items revealed that participants did not feel especially confident in being able to (1) differentiate a severe weather watch vs. warning (M = 4.50, SD = 1.69) or (2) effectively prepare for a severe weather event by creating a severe weather emergency plan (M = 4.65, SD = 1.52). In particular, this lack of confidence surrounding severe weather preparedness is noteworthy because participants indicated in the coupled response efficacy item that creating a severe weather emergency plan was important for reducing their risk (M = 5.43, SD = 1.42).

Finally, an ANCOVA analysis was used to determine whether graphical inconsistencies had any effect on perceived self-efficacy and response efficacy (RQ3). However, as predicted, there were no significant main effects. This was also true for behavioral intentions. An ANCOVA analysis indicated that there were no significant main effects for behavioral intentions to perform severe weather monitoring, preparedness, and/or sheltering actions (RQ4). This means that participants that were exposed to (a) two different risk categories, (b) two different color schemes, and/or (c) two different risk boundaries did not intend to behave any differently as a result of the graphical inconsistencies.

4.3.3.3 Uncertainty Discrepancy and Information Seeking

In a similar vein, H5a-H5c predicted that graphical inconsistencies would increase uncertainty discrepancy, and as a result, would lead to greater intentions to seek out additional weather information. An ANCOVA analysis revealed a significant main effect for color scheme changes on uncertainty discrepancy ($F(1, 718) = 4.06$, $p = 0.04$), such that using the Weather Channel's alternative color scheme resulted in a significantly larger uncertainty discrepancy (M = 4.83, SE = 0.07). Not only that, but a separate ANCOVA analysis indicated that there was a significant main effect for color scheme changes on information seeking intentions ($F(1, 721)$ =

3.61, $p = 0.05$). A closer look at this main effect suggests that using a different color scheme led to greater intentions to seek out additional weather information about the severe weather threat (M = 4.86, SE = 0.07), as opposed to two graphics that used an identical color scheme (M = 4.66). Therefore, H5b was supported, whereas H5a and H5c were not.

4.3.3.4 The Combined Effects of Different Inconsistency Types

The final set of hypotheses (H6 and H7) predicted relationships with the dependent variables based on combinations of the graphical inconsistencies. H6, for example, predicted that when a second Convective Outlook graphic differed in both color *and* risk category, this would result in a significantly (a) lower perceived consistency, (b) higher uncertainty discrepancy, and (c) greater intentions to search for additional information. When we conducted a three-way (risk category change x color change x risk boundary) ANCOVA, it revealed a significant two-way interaction effect for risk category change and color change ($F(2, 696) = 21.435$, $p < 0.01$). As a result, the effects on perceived consistency are not additive. A simple main effects analysis revealed that the effect of risk category changes on perceived consistency is much stronger when two Convective Outlook graphics had an identical color scheme ($F(2, 350) = 70.001$, $p < 0.01$, $\eta^2 = 0.29$) compared to two graphics that used different color schemes ($F(2, 349) = 3.716$, $p = 0.03$, $\eta^2 = 0.02$). These findings suggest that once a graphical inconsistency has been introduced, subsequent inconsistencies do not have much of an impact on perceived consistency (Figure 4.5).

A closer look at the simple main effects analysis indicated that changing a graphic's color scheme led to a significantly lower perceived consistency when the second graphic's risk category was identical ($F(1, 696) = 97.629$, $p < 0.01$, $\eta^2 = 0.12$) or higher ($F(1, 696) = 16.831$, p

< 0.01, $\eta^2 = 0.02$). However, when the second graphic was in a lower risk category, the perceived consistency was not significantly lower ($F(1,696) = 0.558$, $p = 0.455$, $\eta^2 = 0.00$). Therefore, instead of seeing additive effects across each of the risk category change conditions, these findings indicate that the effects of color changes on perceived consistency differ depending on the level of risk category change. As a result, H6a is only partially supported.

On the other hand, the ANCOVA analysis did not produce any significant two-way interactions for uncertainty discrepancy or information seeking intentions. Therefore, a simple contrast test was used to probe the results for an additive relationship. Although changing the color scheme and the risk category of the second graphic increased participants' (a) uncertainty discrepancy and (b) information seeking intentions, these combined conditions were not significantly different from (1) either of the risk category change only conditions, (2) the color change only condition, or (3) the uniform condition (see Table 4.5). Based on these results, then, H6b and H6c were not supported.

The final hypothesis, H7, predicted that showing one graphic with a location on a risk boundary and a second graphic in a higher risk category would result in the highest perceived risk. Since this hypothesis suggests that a single condition will possess the highest perceived susceptibility and severity, a simple contrast test was used. The results revealed that showing a single graphic on a risk boundary and a second graphic in a higher risk category did not produce the highest susceptibility or severity. Instead, showing one graphic with a location on a risk boundary and a second graphic in a higher risk category *and* with a different color scheme resulted in the highest perceived susceptibility (M = 5.65, SE = 0.16) and perceived severity (M

= 5.67, SE = 0.15). It is important to note, however, that the perceived susceptibility (Table 4.6) and severity (Table 4.7) of this condition were not significantly different from the other conditions. Therefore, H7 was not supported. For a review of all the hypotheses in Experiment 2, please see Table 4.8.

4.3.4 Discussion of experiment 2

Despite the assumption that graphical inconsistencies have negative effects on end users, there is little empirical evidence that supports this claim. Therefore, building on the results from Experiment 1, this study sought to explore the effects of inconsistent Convective Outlook graphics on end user perceived consistency, risk perception, uncertainty, and behavioral intentions. Similar to the results of Experiment 1, manipulating a Convective Outlook's risk category and color scheme significantly decreased perceived consistency. When a location was on a risk boundary, however, perceived consistency was significantly higher. At first glance, these findings may seem counterintuitive; however, recall that being on a risk boundary was operationalized as a 0.5 risk unit increase along the risk category continuum. This resulted in a 0.5 risk unit difference between the two graphics (e.g., Moderate/High vs. High), and a 1 risk unit difference when a location was not on a risk boundary (e.g., Moderate vs. High). This finding indicates that participants appropriately interpreted being on a risk boundary as more consistent. More importantly, however, it suggests that a 0.5 risk unit difference was enough to change the perceived consistency of the message.

The other perceptual variables, on the other hand, differed depending on the type of graphical inconsistency that was manipulated. Changing a graphic's risk category and/or risk boundary, for example, affected participants' perceived susceptibility and severity, while receiving two graphics with different color schemes impacted uncertainty discrepancy and information seeking intentions. Therefore, this finding suggests that there may be a qualitative difference in the two types of inconsistencies. Similar to the hypothesis posed by Williams et al. (2020), participants inherently understood that when a second Convective Outlook graphic changed a location's risk category or risk boundary it altered the susceptibility and/or severity information being conveyed by the graphic. However, using a different color scheme did not impact perceived severity as suggested by Williams et al. (2020). Instead, participants reported a higher uncertainty discrepancy and greater intentions to search for information to alleviate this uncertainty. We suspect, then, that the meaning or intention behind changing a graphic's color scheme is not as equally straightforward to end users as changing a location's risk category or risk boundary.

It appears then that uncertainty may be the distinguishing factor that differentiates these two types of inconsistencies. The findings by Williams et al. (2020) offer some evidence that this may be true. When interviewing members of the public about inconsistent Convective Outlook graphics, these authors note that a majority of participants excused the use of conflicting risk categories because they believed one of the graphics was out of date, had been updated, or was showing a forecast for a different time period. Because individuals are accustomed to the uncertainty of weather forecasts and are used to their frequent updates, it is almost expected that two weather graphics will likely depict a location in a different risk category and/or along a different risk boundary. This results in uncertainty that is familiar and easier to explain. By comparison then, changing a graphic's color scheme likely stands out as ambiguous and unusual, and as a result, increases uncertainty discrepancy and information seeking intentions.

Although changing a location's risk category did not have any significant effects on perceived uncertainty, it did impact participants' perceived susceptibility. However, this relationship was only significant when participants were shown a second graphic with a lower risk category. Otherwise, the perceived susceptibility associated with the identical and higher risk category condition were not significantly different from each other. Although these findings suggest that an individual's perceived susceptibility is more affected by a risk category downgrade than a risk category upgrade, in actuality, the high perceived susceptibility associated with the uniform risk category condition is responsible for this relationship. A closer look at the results revealed that seeing two graphics with uniform risk categories elicited a perceived susceptibility that was similar to a risk category upgrade (Table 4.3). This suggests that there may be some value in depicting uniform risk information when sharing Convective Outlook graphics across the weather enterprise. This sentiment is also shared by the warning communication literature.

According to Mileti and Sorensen (1990), after people receive a warning, they frequently seek out additional information to confirm that warning. Known as 'warning confirmation' in the warning communication literature, previous studies have shown that confirming a warning increases one's perceived susceptibility and behavioral intentions to take protective action (Perry et al. 1981; Perry and Greene 1982; Nigg 1987; Wood et al. 2018). Therefore, when an individual was exposed to two Convective Outlook graphics with uniform risk categories, it likely acted as a confirmation of the severe weather threat and increased participants' perceived susceptibility.

Although graphical inconsistencies affected risk perception, perceived uncertainty, and information seeking intentions, participants reported that they did not intend to behave any differently as a result of the graphical inconsistencies. Because the Convective Outlook graphic was solely designed to inform individuals about severe weather threats, it does not provide any efficacy or behavior-related information to end users. As a result, participant's perceived self-efficacy (i.e., an individual's belief they can successfully perform an action) and perceived response efficacy (i.e., the recommended action will reduce threat) were not significantly different across the twelve experimental conditions. A closer look at the results indicated that participants maintained a relatively high perceived risk and perceived efficacy across all of the experimental conditions. Under these circumstances, the Extended Parallel Process Model predicts that participants will likely perform protective actions to reduce their overall perceived risk (Witte 1992). Therefore, unless graphical inconsistencies can substantially alter either perceived risk and/or efficacy, the Extended Parallel Process Model explains that end user's behavioral intentions will likely remain unaffected.

On the other hand, the temporal lag between receiving the Convective Outlook graphic and needing to take protective action may have also impacted the results. Weyrich et al. (2019) reported that inconsistent graphical weather warning information impacted participants' behavioral intentions. Therefore, it is possible that the temporal difference between forecast and warning products may affect the relationship between inconsistency and behavioral intentions.

Future studies, then, should explore a range of graphical weather products along the forecast time-space continuum to determine whether inconsistencies at a specific time scale begin to negatively affect decision-making and behavioral intentions.

Operational meteorologists in the weather enterprise have been known to use a variety of different graphical inconsistencies when sharing Convective Outlook graphics among their many audiences. Therefore, this study also sought to explore the combined effects of different inconsistency types on end user perceptions. Overall, the results of this study suggest that once one graphical inconsistency had been introduced, subsequent inconsistencies did not have much of an impact on participants' perceived consistency. This finding is best demonstrated by the significant two-way interaction effect of risk category change and color change on perceived consistency (Figure 4.5). The presence of a significant interaction suggests that the combined effects of risk category changes and color changes are not additive. A closer look at the results revealed that the effect of risk category changes on perceived consistency was much stronger when two Convective Outlook graphics had an identical color scheme. Not only that, but when two graphics simply changed color schemes, the effect on perceived consistency was much stronger than the combined effects of risk category changes and color changes on perceived consistency. Having said that, changing a graphic's color scheme did result in a significantly lower perceived consistency when a risk category was upgraded to a higher risk. In a similar vein, the combined effects of some of the other perceptual variables were significantly different from their solo counterparts. However, these combined effects did not produce any large effect sizes and were not significantly different from the other experimental conditions. Given these results, there is little empirical evidence that suggests that multiple graphical inconsistencies combine to intensify the perceptions of end users.

4.3.5 Limitations of experiment 2

Finally, as with most social science research, there are several limitations that must be addressed. Because both experiments used an undergraduate student sample, the first limitation of this study is that the results lack generalizability. To overcome this limitation, researchers are encouraged to replicate this study among a more representative sample of the public. Only then, can we offer more generalizable findings about the effects of inconsistent Convective Outlook graphics on members of the public. Second, during survey development, the research team strongly considered how to best measure participants' responses and reactions to both the severe thunderstorm and tornado threat information provided by the Convective Outlook graphic. The research team decided that both severe thunderstorm and tornado threats should be combined using the phrase 'severe weather.' This decision was made because the Storm Prediction Center's public facing Convective Outlook products utilize the phrasing 'severe weather.' Therefore, the survey instrument defined 'severe weather' for participants and used that phrasing consistently throughout the survey instrument. However, there were still some concerns that participants may not read this definition or may focus on only one of the two hazards. To address this limitation, a final survey item was included that asked participants to describe the first weather hazard that comes to mind when they hear the word 'severe weather.' On average, a majority of the participants selected either severe thunderstorms (n = 525, 62%) or tornadoes (n = 184, 22%). Overall, it appeared that participants read the definition and more frequently focused on severe thunderstorms. Given that severe thunderstorms are the primary hazard being communicated by the Convective Outlook graphic, this seems like an appropriate response.

The final limitation of this study involves the order that the Convective Outlook graphics were presented to participants. During the development of the experimental design, it was determined that graphic order would not play a role when determining the consistency between two graphics. The results, on the other hand, offer some evidence that graphic order may instead affect risk perception. Consider, for example, the planned comparison between the no risk boundary/change to a higher risk category condition and the risk boundary/change to a lower risk category condition (Table 4.3). Because the no risk boundary condition involves an upgrade from a moderate risk (Graphic A) to a high risk (Graphic B), the research team expected it to have the highest perceived susceptibility. However, that was not the case. The risk boundary condition, which downgrades the risk category from Graphic A to Graphic B, had the higher risk perception. As a result, we suspect that participants may be anchoring to the first Convective Outlook graphic that they see and adjusting their risk perception based on the second graphic.

According to Tversky and Kahneman (1974), this phenomenon is commonly known as the anchoring-and-adjustment heuristic. Previous studies have shown that the anchoring-and-adjustment heuristic results in people underestimating or overestimating their potential risk - depending on the information provided by the initial anchor (Senay and Kaphingst 2009). Therefore, when an individual receives two Convective Outlook graphics with different risk categories, they will likely tailor their risk perception based on the first Convective Outlook graphic they saw. If found to be true, this might provide more insight into the value of message consistency in the weather enterprise. To explore this topic further, researchers are strongly encouraged to manipulate the order in which participants see Convective Outlook graphics. This will help determine whether the anchoring-and-adjustment heuristic occurs when inconsistent Convective Outlook graphics are presented to end users.

4.4 Conclusions and recommendations for operational meteorologists

Although operational meteorologists contend that graphical inconsistencies may negatively affect their many audiences, there is a lack of empirical literature that has explored this topic in the weather enterprise. Therefore, this study sought to determine whether graphical inconsistencies associated with the Convective Outlook graphic affect end user perceptions. Taken together, the results of Experiments 1 and 2 suggest that manipulating a Convective Outlook graphic's risk category and/or color scheme significantly lowered participant's perceived consistency. Although behavioral intentions to perform severe weather monitoring, preparedness, and sheltering actions were not impacted by graphical inconsistencies, showing two inconsistent Convective Outlook graphics did affect participant's perceived risk, uncertainty, and information seeking intentions. Based on these findings, graphical inconsistencies do matter when communicating severe weather information to end users. In fact, the results revealed that seeing two graphics with uniform risk categories and a uniform color scheme elicited a perceived susceptibility that was on par with a risk category upgrade. This suggests that there is likely value in depicting uniform risk and color information when sharing Convective Outlook graphics across the weather enterprise.

Nevertheless, this does not mean that severe weather graphics should wear a uniform. In line with the findings by Williams et al. (2020), the results of Experiments 1 and 2 suggest that operational meteorologists, broadcast meteorologists, and other weather entities can continue to customize the basic graphical design of their Convective Outlook graphic (i.e., placement of logos, legends, lower thirds, etc.). However, certain graphical elements emerged as important message features, and as a result, should remain the same when sharing Convective Outlook graphics with end users. Otherwise, the message being communicated by the Convective Outlook graphic changes, and consequently, affects end user risk perception, uncertainty, and information seeking intentions. Therefore, the findings from this study call attention to the need to eliminate the deliberate use of graphical inconsistencies when sharing Convective Outlook graphics with end users. It is recommended, then, that (when possible) operational meteorologists should strive to maintain the same (1) risk categories and (2) color scheme used by the Storm Prediction Center's Convective Outlook graphic. Having said that, more research is needed to improve the usability of the Storm Prediction Center's Convective Outlook graphic among lay public audiences (Grundstein et al. 2019). Only then can we ensure that severe weather forecast information is communicated both effectively and consistently among end users.

4.5 Acknowledgements

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4.6 Appendix A: Developing a Perceived Consistency Scale

4.6.1 Literature Review and Scale Development

To begin the scale development process, an interdisciplinary literature review was conducted to ensure a pre-established scale of message consistency did not already exist. The review process did not reveal a previously published scale; however, it did expose several similar concepts and survey items that were used to develop a measure of perceived consistency for the weather enterprise. An unpublished thesis in the field of psychology, for example, provided the most insight during scale development. In this thesis, Backhaus (2004) sought to examine college student's perceptions of and preferences for various advertisements that were aimed at reducing the consumption of alcohol on college campuses. However, in order to methodically compare the advertisements, Backhaus (2004) developed an Advertisement Comparison Questionnaire that asked participants to assess both the similarity in (1) the overall content and (2) the messages being communicated by the two advertisements. Interestingly, the two dimensions mentioned by Backhaus (2004) are similarly represented in the definition of message consistency provided by Williams and Eosco (2020). Recall that these authors define message consistency as "[two or more weather] messages [that] must convey the same overall message, even though their individual features may differ." As such, these two survey items were adapted and incorporated into the perceived consistency scale.

After considering the items offered by Backhaus (2004) and evaluating content validity, the research team determined that two additional dimensions were needed to complete the measure of perceived consistency. The current study uses Convective Outlook graphics as a vehicle to explore the implications of message consistency in the weather enterprise, therefore, a survey item was included that asked participants to evaluate the visual consistency between two Convective Outlook graphics. Finally, as the other items asked participants to evaluate the consistency of specific message features, a survey item was developed that asked participants to provide a general overview of the consistency between two messages. To maintain internal consistency, the survey item phrasing for the newly created items mirrored the language offered by Backhaus (2004). Upon further inspection, however, Backhaus (2004) only asked participants to describe the level of similarity between two advertisements. Because the item language for the perceived consistency scale was adapted from the Advertisement Comparison Questionnaire (Backhaus 2004), it seemed obvious to ask participants to evaluate the similarity between two forecast graphics. After conducting the literature review, however, the research team noticed that other studies asked participants to evaluate the similarity or differences between objects using a variety of other adjectives. Therefore, to improve scale validity, the research team decided to include a variety of adjectives in the perceived consistency scale.

With the survey item language finalized, the research team turned to drafting the adjectives that participants would use to evaluate the two forecast graphics. After examining both the literature review conducted when creating this scale and the social science literature review provided by Williams and Eosco (2020), a list of adjectives was generated based on frequency with which they appeared in the literature. After considering the generated list, the research team agreed on five adjectives: similar, conflicting, the same, contradictory, and consistent. The research team decided to incorporate both positive and negative adjectives to improve scale validity via reverse coding. This resulted in participants being asked to provide five different responses for each of the four survey items on a 7-point Likert-type scale ranging from 1 (*not at all)* to 7 (*extremely;* 20 items in total). Please see Table 4.A1 for perceived consistency scale items and adjectives used.

4.6.2 Confirmatory Factor Analyses

After developing a new questionnaire, scale, or survey item-set, it is important to first assess whether the newly developed items measure the construct in question. Therefore, before comparing perceived consistency across the five experimental conditions, the research team first evaluated the newly developed perceived consistency scale. This was accomplished by conducting a factor analysis. Social and behavioral scientists frequently use factor analyses when evaluating new or preexisting item scales (Williams et al. 2010). In terms of scale development, factor analyses provide insight on which survey items align with various constructs being measured. For this study, both an exploratory and confirmatory factor analysis were used to explore the data produced by the perceived consistency scale. The exploratory factor analysis revealed that there was an issue with the visual consistency item. In particular, the results hinted that the visual consistency item was not measuring the same construct as the other three items. Therefore, to further explore this finding, a confirmatory factor analysis was used. A confirmatory factor analyses are different from exploratory factor analyses in that they (1) prioritize evaluating dimensionality, (2) allow for a more targeted exploration of the relationships between the survey items, and (3) offer more tangible ways in which to modify or improve the scale (Brown and Moore 2012).

First, a confirmatory factor analysis was conducted using the four perceived consistency items (Figure 4.A1). Based on previous research (Hooper et al. 2008), the overall fit of the unidimensional model was borderline acceptable, χ^2 (136) = 700.26, p < .001, CFI = .89, RMSEA = .09 (.08, .09), SRMR = .09. A closer look at the factor loadings revealed that the visual consistency item did not effectively measure perceived consistency like the other three items (Figure 4.A1). Not only that, but some of the adjectives under the visual consistency item were correlated with other survey items. As a result, this item was dropped from the scale. After conducting a follow-up analysis, the overall fit was improved and within the acceptable range, χ^2 (136) = 593.73, p < .001, CFI = .91, RMSEA = .08 (.07, .09), SRMR = .08.

The five adjectives used in the perceived consistency scale were also explored via a confirmatory factor analysis (Figure 4.A2). The fit of this unidimensional model was good, χ^2 (125) = 401.35, p < .001, CFI = .95, RMSEA = .06 (.06, .07), SRMR = .08. Overall, the factor loadings were all moderately high and ranged from 0.62 to 0.92. Although not as obvious as the need to remove the visual consistency item, further inspection revealed that the factor loading for the adjective ‘the same’ was slightly lower than the factor loadings associated with the other adjectives (Figure 4.A2). This may indicate that there is a conceptual difference between two objects being perceived as ‘the same’ and ‘consistent.’ As a result, researchers might consider removing this adjective when using this scale in the future. Finally, it is interesting to note that the two negative adjectives had the highest factor loadings and were highly correlated with one another. Although likely a methodological artifact because the items were reverse coded, further research is needed to tease out of this finding.

Based on the confirmatory factor analysis, the visual consistency item and 'the same' adjective were dropped from the perceived consistency scale. This resulted in a total of 12 items (3 questions across four adjectives). Finally, the internal consistency of the measure was evaluated with a Cronbach's coefficient alpha (α). A Cronbach's alpha statistic is frequently used to evaluate the extent to which all items in a scale measure the same construct, with higher values indicating a greater degree of internal consistency. The Cronbach's alpha associated with the 12-item perceived consistency scale was 0.88. Based on previous work (Tavakol and Reg 2011), this indicates good internal reliability. Therefore, each item was summed and averaged into a perceived consistency score that ranged from 1.42 to 7 with higher scores corresponding to more perceived consistency.

4.6.3 Discussion

Surprisingly, visual consistency did not prove important when evaluating the perceived consistency of two forecast graphics. Given that the experimental stimuli were visual in nature, the research team thought visual consistency would be critical to include. However, this was not the case. Confirmatory factor analyses revealed that the visual consistency item did not measure the same construct as the other three items, suggesting that a graphic's visual design is not impactful when evaluating the perceived consistency between two forecast graphics (Figure 4.A1). This result is in line with the qualitative findings by Williams et al. (2020). After interviewing members of the public about their message consistency evaluation process, these researchers hypothesized that individuals likely do not focus on the graphical nature of the inconsistency, but rather the information that is being portrayed by that inconsistent graphical element. For example, when two Convective Outlook graphics show a location in a different risk area, that inconsistent graphical element inherently alters the susceptibility information being communicated by the graphic. Thus, for the sake of this hypothesis, it is encouraging that the visual consistency item did not properly load onto the construct of perceived consistency. On the other hand, a low factor loading could also indicate a poorly constructed survey item. In reevaluating the item language, the research team agreed that the phrasing 'visual design' may be too broad and ambiguous to effectively act as a dimension of perceived consistency. Therefore, further research is needed to determine the implications of visual design on perceived consistency. Researchers, for example, might consider various aspects of 'visual design' and develop survey items that target its different dimensions. This approach would help determine the value of visual design when evaluating the perceived consistency between two graphical messages.

When examining the adjectives associated with the perceived consistency scale, the confirmatory factor analysis revealed relatively low factor loadings for the adjective 'the same' and high factor loadings for 'conflicting' and 'contradictory' (Figure 4.A2). Like the visual consistency item, a low factor loading indicates that the adjective 'the same' may measure a different construct, and as a result, might be conceptually different from the other words used in this study. After further consideration, the research team agreed that judging sameness is likely conceptually closer to asking whether two objects are identical. For example, an individual must give a definitive yes-or-no response when asked whether two objects are the same or identical. On the other hand, when evaluating similarity, an individual would likely describe the extent to which the two objects are similar. Therefore, the other adjectives used in this study are different in that they can articulate variability. Given this conceptual difference, the adjective 'the same' was removed from the perceived consistency scale. Finally, the high factor loadings associated with the negative adjectives 'conflicting' and 'contradictory' suggest that these words correlate highly with the construct of perceived consistency. This preference for using negative adjectives when evaluating perceived consistency is similarly noted in the qualitative study by Grundstein et al. (2019). In this study, participants were asked (1) whether two forecast graphics communicate the same message and (2) whether there is anything conflicting about the two forecast graphics. Although similar themes emerged from both questions, the authors note that participants gave more targeted answers when asked about the presence of conflicting information. Together, these findings suggest that participants find it easier to identify differences over similarities. This may have implications on future studies seeking to evaluate perceived consistency, and as such, research on this topic is needed to further refine the perceived consistency scale.

Given these findings, the final perceived consistency scale consisted of twelve items on a 7-point Likert type scale ranging from 1 (*not at all*) to 7 (*extremely*). For a list of the finalized items, please see Table 4.1.

4.7 Appendix B: Experimental Survey Instruments

4.7.1 Pre-Experiment Questionnaire

The purpose of this study is to evaluate the effects or implications of inconsistent Severe Weather Outlook graphics on end user uncertainty, risk perception, behavioral intentions to seek information, and behavioral intentions to perform a protective action. In other words, this study seeks to answer the question: Do inconsistencies in Severe Weather Outlook graphics matter to members of the public? After conducting a pilot experimental study, it was revealed that two types of inconsistencies led to the highest level of perceived inconsistency: (1) changes in severe weather risk areas and (2) changes in colors. Before conducting the experimental manipulation, participants will receive this survey 3 days prior.

Participants will be provided instructions that help them create a Unique ID and this ID will allow the researchers to tie the data from the pre-experiment survey and the survey together without compromising the participants' anonymity. Using this method, no personal information would be used in connecting the two datasets. Extra credit will be provided for taking part in this study.

[INSTRUCTION] Please answer the following questions about yourself.

[*state*] Using the drop down list, please select the state where your primary residence is located.

[*how_long*] Approximately how long have you lived in that state?

- Less than 1 year
- 1 to 3 years
- 3 to 5 years
- 5 to 10 years
- More than 10 years

[*age*] How old are you?

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[INSTRUCTION] Please answer a few questions about your weather information habits.

[*wx_often*] How often do you search for weather forecast information from the sources listed below? (*Rarely or never, Once or twice a month, Once a week, Two or more times a week, Once a day, Two or more times a day)*

- Online news (such as the Washington Post website, CNN.com)
- Social Media (such as Facebook, Twitter, or blogs)
- Weather websites (such as weather.com, accuweather.com)

- Government websites (National Weather Service, weather.gov)
- Local TV Stations
- Cable TV Stations (such as The Weather Channel, WeatherNation, or AccuWeather)
- Print newspapers
- Commercial or public radio
- Weather smartphone applications
- NOAA Weather Radio
- Friends, family, coworkers, etc.

[wx_prefer] If you had to choose one, which of the following sources do you prefer when searching for weather forecast information?

- Listening to weather on the radio
- Watching weather on television
- Getting weather from a social networking site (such as Facebook or Twitter)
- Getting weather from the Internet or websites
- Getting weather from a smartphone app
- Getting weather from friends, family, or coworkers.

[*wx_consult*] When searching for weather forecast information, do you ever consult more than one source? (Yes/No)

- [wx_consult_sources] IF YES: On average, how many sources do you usually look at each time you search for weather forecast information?
- [wx_compare] IF YES: How often do you compare the weather forecast information you find at one source with the information you find at other sources? (*Never, Rarely, Sometimes, Very Often, Always)*

[*wx_search_time*] On average, how much time do you spend each time you search for weather forecast information?

- 0-1 minute
- 1-3 minutes
- 3-5 minutes
- 5-10 minutes
- More than 10 minutes

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Meteorologists often use the phrase "severe weather" to describe hazardous weather conditions produced by severe thunderstorms, such as damaging winds, tornadoes, and large hail.

[INSTRUCTION] Please answer a few questions about your weather information habits *when severe weather is in the forecast.*

[*severe_prefer*] If you had to choose one, which of the following sources do you prefer when searching for ***severe weather forecast information***?

- Listening to weather on the radio
- Watching weather on television
- Getting weather from a social networking site (such as Facebook or Twitter)
- Getting weather from the Internet or websites
- Getting weather from a smartphone app
- Getting weather from friends, family, or coworkers.

[*severe_consult*] When searching for ***severe weather forecast information***, do you ever consult more than one source? (Yes/No)

- [severe_consult_sources] IF YES: On average, how many sources do you usually look at each time you search for ***severe weather forecast information***?
- [severe_compare] IF YES: How often do you compare the ***severe weather forecast information*** you find at one source with the information you find at other sources? (*Never, Rarely, Sometimes, Very Often, Always)*

[*severe_search_time*] On average, how much time do you spend each time you search for weather forecast information ***when severe weather is in the forecast***?

- 0-1 minute
- 1-3 minutes
- 3-5 minutes
- 5-10 minutes
- More than 10 minutes

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People get weather information from a variety of sources. We are interested in your thoughts about some of those sources. *(Randomize question order)*

Remember, meteorologists often use the phrase "severe weather" to describe hazardous weather conditions produced by severe thunderstorms, such as damaging winds, tornadoes, and large hail.

[*Conflicting Information #1*] Thinking about the past 12 months, how much conflicting or contradictory information ***about the threat of severe weather*** have you heard from each of the following sources? (*None at all, a little, some, a lot)*

- Online news (such as the Washington Post website, CNN.com)

- Social Media (such as Facebook, Twitter, or blogs)
- Weather websites (such as weather.com, accuweather.com)
- Government websites (National Weather Service, weather.gov)
- Local TV Stations
- Cable TV Stations (such as The Weather Channel, WeatherNation, or AccuWeather)
- Print newspapers
- Commercial or public radio
- Weather smartphone applications
- NOAA Weather Radio
- Friends, family, coworkers, etc.

[*Conflicting Information #2*] Thinking about the past 12 months, how much conflicting or contradictory information ***about what <u>actions</u> to take during severe weather*** have you heard from each of the following sources? (*None at all, a little, some, a lot)*

- Online news (such as the Washington Post website, CNN.com)
- Social Media (such as Facebook, Twitter, or blogs)
- Weather websites (such as weather.com, accuweather.com)
- Government websites (National Weather Service, weather.gov)
- Local TV Stations
- Cable TV Stations (such as The Weather Channel, WeatherNation, or AccuWeather)
- Print newspapers
- Commercial or public radio
- Weather smartphone applications
- NOAA Weather Radio
- Friends, family, coworkers, etc.

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Remember, meteorologists often use the phrase "severe weather" to describe hazardous weather conditions produced by severe thunderstorms, such as damaging winds, tornadoes, and large hail.

[INSTRUCTION] The National Weather Service provides severe weather information to protect life and property. We are interested in your understanding of the phrases and colors that they use to convey this severe weather forecast information.

[*Severe Weather Outlook Knowledge #1*] The National Weather Service uses the following phrases to describe the risk of severe weather. We want to know what these phrases mean to you. Please rank them from one (lowest risk) to five (highest risk). (***Ripberger et al. 2019***).

- Marginal

- Slight
- Enhanced
- Moderate
- High

[*Severe Weather Outlook Knowledge #2*] The National Weather Service also uses colors to describe the risk of severe weather. We want to know what these colors mean to you. Please rank them from one (lowest risk) to five (highest risk).

- Green
- Yellow
- Orange
- Red
- Magenta

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[INSTRUCTION] The National Weather Service issues weather alerts and warnings to protect life and property. Please indicate your agreement or disagreement with each of the statements listed below. (*Randomize: 50% of sample will be asked questions about severe thunderstorms and 50% will be asked about tornadoes*.)

[*Message Fatigue #1]* There are simply too many warning messages about severe thunderstorms [tornadoes] nowadays.

[*Message Fatigue #2]* I have heard enough about how important it is to seek shelter during a severe thunderstorm [tornado] warning.

[*Message Fatigue #3]* The importance of seeking shelter during a severe thunderstorm [tornado] warning is overtaught.

[*Message Fatigue #4]* I have lost track of the amount of times I have heard that severe thunderstorms [tornadoes] are a serious threat.

[*Message Fatigue #5]* At this point, I've heard about threats related to severe thunderstorms [tornadoes] more than I ever needed to.

[*Message Fatigue #6]* Severe thunderstorm [tornado] warning messages rarely provide new information.

[*Message Fatigue #7]* After hearing about them for years, warning messages about severe thunderstorms [tornadoes] seem repetitive.

[*Message Fatigue #8]* Warning messages about severe thunderstorms [tornadoes] are all beginning to sound the same to me.

[*Message Fatigue #9]* I can predict what a severe thunderstorm [tornado] warning message is going to say.

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[INSTRUCTION] Please indicate your agreement or disagreement with each of the statements listed below.

[*Message Fatigue #10]* I am burned out from hearing that severe thunderstorms [tornadoes] are a serious threat.

[*Message Fatigue #11]* I'm sick of hearing about the negative impacts of severe thunderstorms [tornadoes].

[*Message Fatigue #12]* I'm tired of hearing about the importance of seeking shelter during a severe thunderstorm [tornado].

[*Message Fatigue #13]* Severe thunderstorm [Tornado] warning messages make me want to sigh.

[*Message Fatigue #14]* Warning messages about severe thunderstorms [tornadoes] are boring.

[*Message Fatigue #15]* Severe thunderstorm [Tornado] warning messages make me want to yawn.

[*Message Fatigue #16]* I find warning messages about severe thunderstorms [tornadoes] to be dull and monotonous.

[*Message Fatigue #17]* Severe thunderstorm [Tornado] warning messages are tedious.

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Please think about your <u>most memorable</u> severe weather experience. That experience may have happened to you personally, or you may have learned about the experience of another person (or other people). It may have been a time when a tornado actually occurred or when there was just a severe thunderstorm with the possibility that a tornado might occur.

[*Experience_Indicator #1*] Did that severe weather experience happen to you personally, or did you learn about others' experiences, or both? *Please select ONE option.*

- It happened to me personally.
- It happened to other(s), and I learned about it.
    - IF YES, who did it happen to?
    - IF YES, Approximately how far away (in miles) were you from them?
- Both - it happened to me personally, and it happened to other(s)

[*Experience_Indicator #2*] What did your severe weather experience specifically involve? *Check all that apply.*

- A tornado actually occurred. [A1]
- A severe thunderstorm actually occurred. [A2]
- There was the possibility of a tornado, but one did not occur.
- There was the possibility of a severe thunderstorm, but one did not occur.

IF YES to [A1] or [A2]: Approximately what year did that severe weather experience occur?

[*Experience_Indicator #3*] Did that severe weather experience result in....

- damage to your home or property? (*Yes/No/I don't know*)
- a family member being injured or killed? (*Yes/No/I don't know*)
- emotional impacts or personal distress? (*Yes/No/I don't know*)

[INSTRUCTION] People can have multiple experiences with severe weather over the course of their lifetime. Please think about all of your experiences with severe weather, and indicate how much experience you have had with each of the statements listed below. *Please select ONE option for each statement. (No experience, A little experience, Some experience, A great deal of experience).*

[*Multi_Experience #4*] I have feared for my life due to severe weather.
[*Multi_Experience #5*] I have feared for my loved ones due to severe weather.
[*Multi_Experience #6*] I have worried about my home due to severe weather.

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[INSTRUCTION] Please answer the following questions.

Ambiguity Aversion - Adapted from Han et al. 2009 (*Strongly disagree to Strongly agree).*

[*Ambiguity Aversion #1*] Conflicting expert opinions about a weather forecast would lower my trust in meteorologists.

[*Ambiguity Aversion #2*] I would not have confidence in a weather forecast if meteorologists had conflicting opinions about it.

[*Ambiguity Aversion #3*] Conflicting expert opinions about a weather forecast would make me upset.

[*Ambiguity Aversion #4*] I would not be afraid of using a weather forecast to make decisions even if meteorologists had conflicting opinions about it. (R)

[*Ambiguity Aversion #5*] If I received a weather forecast that experts had conflicting opinions about, I would still be willing to use it when making decisions. (R)

[*Ambiguity Aversion #6*] I would avoid making a decision using a weather forecast if experts had conflicting opinions about it.

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Please answer a few more questions about yourself.

[gender] What is your gender?

- Female
- Male
- Prefer Not to Answer
- Other? Please explain.

[latinx] Are you, yourself, of Hispanic or Latinx origin or descent, such as Mexican, Puerto Rican, Cuban, South American, or other Spanish background?

- No, I am not of Hispanic or Latinx origin or descent.
- Yes, I am of Hispanic or Latinx origin or descent.

[race] Which of the following best describes your race?

- White
- Black or African American
- American Indian or Alaska Native
- Asian
- Native Hawaiian or Pacific Islander
- Other (please explain)

[zipcode] What is your zipcode?

[severe weather check] When you hear the phrase **"severe weather"** what is the first weather hazard that comes to mind?

- Extreme Heat
- Hurricanes
- Tornadoes
- Severe Thunderstorms

- Hail
- High Winds
- Flash Flooding
- Winter Weather

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In a few days, a link to another online questionnaire will be sent to you via email. To connect your responses from this survey to the second survey, it is important that you create a Unique ID. The Unique ID that you create will be specific to you and will not allow your survey responses to be connected to your personal identity in any way.

[INSTRUCTION] Please create a Unique ID using the following 5 components:

1. **The first initial of your first name.**
2. **The first initial of your last name.**
3. **The month of your birthday (1-12)**
4. **The day of your birthday (1-31)**
5. **The year you were born (xxxx)**

For example, my name is Castle Williams and I was born on January 12, 1990. Therefore, my Unique ID would be cw1121990

[id] Please enter YOUR Unique ID:

It is important that you remember this Unique ID, because it will ensure that you are recognized for completing both surveys, and so that your responses from this survey are connected to the second survey.

[feedback] Thank you for taking the time to complete this survey on weather communication. Please share with us any constructive thoughts that you might have about the survey. Did the wording make sense? Was it too long? Please enter any comments below.

4.7.2 Experimental Survey Questionnaire

The purpose of this study is to evaluate the effects or implications of inconsistent Severe Weather Outlook graphics on end user uncertainty, risk perception, behavioral intentions to seek information, and behavioral intentions to perform a protective action. In other words, this study seeks to answer the question: Do inconsistencies in Severe Weather Outlook graphics matter to members of the public? After conducting a pilot experimental study, it was revealed that two types of inconsistencies have the most impact on end users: (1) changes in severe weather risk areas and (2) changes in colors. Therefore, those two factors, in addition to a Severe Weather Outlook's risk boundary, will be manipulated using a **3(risk area; higher change vs. lower change vs. no change) x 2(color; change vs. no change) x 2(boundary; location on a boundary vs. location not on a boundary)** factorial experimental design.

[INSTRUCTION] Please enter the Unique ID that you created at the end of the first survey. It is important that you enter this Unique ID correctly to ensure that you are recognized for completing both surveys, and so that your responses from the first survey are connected to this survey.

Remember, your Unique ID is made up of 5 different components:

1. **The first initial of your first name.**
2. **The first initial of your last name.**
3. **The month of your birthday (01-12)**
4. **The day of your birthday (01-31)**
5. **The year you were born (xxxx)**

For example, my name is Castle Williams and I was born on January 12, 1990. Therefore, my Unique ID would be cw01121990

Please enter YOUR Unique ID Here:

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Meteorologists often use the phrase "severe weather" to describe hazardous weather conditions produced by severe thunderstorms, such as damaging winds, tornadoes, and large hail.

[INSTRUCTION] Please pay attention to the forecast scenario and severe weather graphics provided in the next section, because you will be asked several questions about these graphics.

[PLEASE PAY ATTENTION TO THE FORECAST INFORMATION AND SEVERE WEATHER GRAPHICS PROVIDED IN THE NEXT SECTION, AS YOU WILL BE ASKED TO ANSWER SEVERAL QUESTIONS ABOUT THEM. SEVERE WEATHER

CAN INCLUDE HAZARDOUS CONDITIONS PRODUCED BY THUNDERSTORMS, INCLUDING DAMAGING WINDS, TORNADOES, AND LARGE HAIL.]

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Forecast Scenario: Imagine you are visiting Atlanta, Georgia on a weekend in July. When you arrive on Saturday morning, you learn that meteorologists are forecasting the threat for severe weather this afternoon. You decide to search for information about the severe weather threat and come across two forecast graphics.

[INSTRUCTION] Please pay attention to these forecast graphics because you will be asked several questions about them and will not be able to go back and look at them.

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[INSTRUCTION] We are interested in what you were thinking about during the last few minutes.

[*Thought-listing task/Manipulation Check task]* Please list any and all thoughts that you had while studying the two forecast graphics. Every thought that went through your mind is important. Do not worry about spelling, grammar, or punctuation. **(*Cacioppo et al. 1997)***

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Please answer the following questions based on the forecast graphics you saw.

[*Message consistency #1]* The two forecast graphics are…

- Not at all similar – very similar
- Not at all conflicting – very conflicting
- Not at all contradictory – very contradictory
- Not at all consistent – very consistent

[*Message consistency #2]* The overall content provided in these two forecast graphics is…

- Not at all similar – very similar
- Not at all conflicting – very conflicting
- Not at all contradictory – very contradictory
- Not at all consistent – very consistent

[*Message consistency #3]* The messages communicated by these two forecast graphics are…

- Not at all similar – very similar
- Not at all conflicting – very conflicting
- Not at all contradictory – very contradictory
- Not at all consistent – very consistent

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[INSTRUCTION] On a scale from 1 to 7, where 1 means *strongly disagree* and 7 means *strongly agree,* please indicate your agreement or disagreement with the following statements <u>based on the two severe weather forecast graphics you saw</u>.

Remember, meteorologists often use the phrase "severe weather" to describe hazardous weather conditions produced by severe thunderstorms, such as damaging winds, tornadoes, and large hail.

[*Perceived susceptibility #1]* I believe I'm at risk for severe weather. **(So et al. 2018)**

[*Perceived susceptibility #2]* It's likely that I will experience severe weather.

[*Perceived susceptibility #3]* It's possible that I will see severe weather.

[*Perceived susceptibility #4]* What is the likelihood that you will experience severe weather? Please indicate the probability as a percentage (%) using the sliding scale below.

[*Perceived severity #1]* I believe that severe weather is a serious threat.

[*Perceived severity #2]* Severe weather poses a danger to me.

[*Fear #1]* I am afraid of severe weather.

[*Fear #2]* I am frightened of severe weather.

[*Fear #3]* I am scared of severe weather.

[*Anxiety #1]* I am anxious about experiencing severe weather.

[*Anxiety #2]* I am worried about experiencing severe weather.

[*Anxiety #3]* I am upset about experiencing severe weather.

[INSTRUCTION] Please rate your agreement or disagreement with the following statements, based on the two forecast graphics you saw.

Remember, meteorologists often use the phrase "severe weather" to describe hazardous weather conditions produced by severe thunderstorms, such as damaging winds, tornadoes, and large hail.

[*Response Efficacy #1]* Knowing the difference between a weather 'watch' and 'warning' can save my life.

[*Response Efficacy #2]* It is useful to create a severe weather emergency plan, so that I know what to do when severe weather strikes.

[*Response Efficacy #3]* Closely monitoring the weather throughout the day is essential for being informed about any severe weather threats.

[*Response Efficacy #4]* Taking shelter is the best way to protect myself from severe weather.

[*Self-Efficacy #1*] It is easy for me to tell the difference between a weather 'watch' and 'warning'.

[*Self-Efficacy #2]* Creating a severe weather emergency plan is no problem for me.

[*Self-Efficacy #3*] I find it easy to stay informed and closely monitor the weather throughout the day.

[*Self-Efficacy #4*] When severe weather is approaching, I am able to take shelter easily.

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[INSTRUCTION] Please answer the following questions based on the forecast graphics you saw. Remember, meteorologists often use the phrase "severe weather" to describe hazardous weather conditions produced by severe thunderstorms, such as damaging winds, tornadoes, and large hail.

[*Uncertainty discrepancy #1]* I know less than I'd like to know about the severe weather threat. **(*So et al. 2016)***

[*Uncertainty discrepancy #2]* I want to know more than I currently know about the severe weather threat.

[*Uncertainty discrepancy #3]* I wish I knew more about the severe weather threat.

After seeing these two forecast graphics… (***Chaudhuri 2015)***

[*Behavioral intentions to search for information #1]* I would search for more information about the severe weather threat.

[*Behavioral intentions to search for information #2]* I would like to read more about the severe weather threat.

[*Behavioral intentions to take action]* Using a scale from 1 to 7, where 1 means *very unlikely* and 7 means *very likely*, how likely are you to do the following based on the two forecast graphics you saw?

- Monitor weather information closely.
- Prepare by bringing in loose outdoor items, checking your emergency supply kit, or creating a severe weather emergency plan.
- Take protective action by remaining indoors, staying away from windows, and sheltering in place.

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***Randomized order.*

[Relative Trust – Show graphics again] If you have to choose, which graphic would you trust more? Please use the sliding scale below to indicate which graphic you trust more. Remember the closer your slider is to either Graphic A or Graphic B, the more you trust it.

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[Graphical Use When Making Decisions – Show graphics again] If you have to choose, which graphic would you be more likely to use when making weather-related decisions? Please use the sliding scale below to indicate which graphic you would be more likely to use. Remember the closer your slider is to either Graphic A or Graphic B, the more likely you are to use it when making weather-related decisions.

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[severe weather check] When you hear the phrase **"severe weather"** what is the first weather hazard that comes to mind?

- Extreme Heat
- Hurricanes
- Tornadoes
- Severe Thunderstorms

- Hail
- High Winds
- Flash Flooding
- Winter Weather

Thank you for taking the time to complete this survey on weather communication. Please share with us any constructive thoughts that you might have about the survey. Did the wording make sense? Was it too long? Please enter any comments below.

4.8 References

Afifi, W. A., and J. L Weiner, 2004: Toward a theory of motivated information management. *Communication Theory,* **14**(2), 167-190.

Ash, K. D., Schumann III, R.L., and G.C. Bowser, 2013: Tornado warning tradeoffs: Evaluating choices for visually communicating risk. *Weather, climate, and society,* **6**(1), 104-118.

Backhaus, A. L., 2004: An examination of the relationship between college students' conceptual level development and their perceptions of advertisements aimed at alcohol intervention (unpublished thesis). Emporia State University, Emporia, Kansas, United States.

Barter, C., and E. Renold, 1999: The use of vignettes in qualitative research. *Social Research Update,* **25**(9), 1-6.

Berger, C. R., and R.J. Calabrese, 1975: Some explorations in initial interaction and beyond: Toward a developmental theory of interpersonal communication. *Human communication research*, **1**(2), 99-112.

Bostrom, A., L., Anselin, and J. Farris, 2008: Visualizing seismic risk and uncertainty. *Annuals of the New York Academy of Sciences,* **1128**(1), 29-40.

Brashers, D. E., 2001: Communication and uncertainty management. *Journal of communication*, **51**(3), 477-497

Brown, T. A., and M. T. Moore, 2012: Confirmatory factor analysis. *Handbook of structural equation modeling*, pp. 361-379.

Carpenter, D. M., R. F. DeVellis, E. B. Fisher, D. M. DeVellis, S. L. Hogan, and J. M. Jordan, 2010: The effect of conflicting medication information and physician support on medication adherence for chronically ill patients. *Patient education and counseling,* **81**(2), 169-176. doi: https://doi.org/10.1016/j.pec.2009.11.006

Carpenter, D. M., E. A. Elstad, S. J. Blalock, and R. F. DeVellis, 2014: Conflicting medication information: prevalence, sources, and relationship to medication adherence. *Journal of health communication,* **19**(1), 67-81. doi: https://doi.org/10.1080/10810730.2013.798380

Centers for Disease Control and Prevention, 2014: Crisis emergency and risk communication. Retrieved from: https://emergency.cdc.gov/cerc/resources/pdf/cerc_2014edition.pdf

Collins, L. M., J. J. Dziak, and R. Li, 2009: Design of experiments with multiple independent variables: A resource management perspective on complete and reduced factorial designs. *Psychological Methods,* **14**(3), 202.

Elstad, E., D.M. Carpenter, R.F. Devellis, and S. J. Blalock, 2012: Patient decision making in the face of conflicting medication information. *International journal of qualitative studies on health and well-being*, **7**(1), 18523.

Grams, J., B. Bunting, and S. Weiss, 2014: SPC Convective Outlooks. Retrieved from: www.spc.noaa.gov/misc/SPC_probotlk_info.html

Grundstein, A. J., J. So, and C. A. Williams, 2019: A qualitative look at the SPC's Day 1 Convective Outlook Among Members of the Public. *Internal Report.*

Hämeen-Anttila, K., H. Nordeng, E. Kokki, J. Jyrkkä, A. Lupattelli, K. Vainio, and H. Enlund, 2014: Multiple information sources and consequences of conflicting information about medicine use during pregnancy: a multinational Internet-based survey. *Journal of medical Internet research*, *16*(2), e60. doi: https://doi.org/10.2196/jmir.2939

Han, P. K., R. P. Moser, and W. M. Klein, 2006: Perceiving ambiguity about cancer prevention recommendations: Relationship to perceptions of cancer preventability, risk, and worry. *Journal of health communication,* **11**(S1), 51-69. doi: https://doi.org/10.1080/10810730600637541

Han, P. K., R.P. Moser, W.M. Klein, E.B. Beckjord, A.C Dunlavy, and B.W. Hesse, 2009: Predictors of perceived ambiguity about cancer prevention recommendations: Sociodemographic factors and mass media exposures. *Health communication*, **24**(8), 764-772.

Hoffman, R. R., M. Detweiler, J. A. Conway, and K. Lipton, 1993: Some considerations in using color in meteorological displays. *Weather and Forecasting,* **8**(4), 505-518.

Hooper, D., J. Coughlan, M. R. Mullen, 2008: Structural equation modelling: Guidelines for determining model fit. *Electronic journal of business research methods,* **6**(1), 53-60.

Kuang, K., and S.R Wilson, 2017: A meta-analysis of uncertainty and information management in illness contexts. *Journal of Communication*, **67**(3), 378-401.

Lee, C. J., R. H. Nagle, and N. Wang, 2017: Source-specific exposure to contradictory nutrition information: Documenting prevalence and effects on adverse cognitive and behavioral outcomes. *Health Communication*, **33**(4), 453-461. doi: https://doi.org/10.1080/10410236.2016.1278495

Losee, J. E., and S. Joslyn, 2018: The need to trust: How features of the forecasted weather influence forecast trust. *International Journal of Disaster Risk Reduction*, **30**, 95-104.

McIntosh, A., and C. F. Shaw, 2003: Barriers to patient information provision in primary care: patients' and general practitioners' experiences and expectations of information for low back pain. *Health Expectations*, **6**(1), 19-29. doi: https://doi.org/10.1046/j.1369-6513.2003.00197.x

Mileti, D. S., and J. H. Sorensen, 1990: *Communication of emergency public warnings: A social science perspective and state-of-the-art assessment* (No. ORNL-6609). Oak Ridge National Lab., TN (USA). doi: https://doi.org/10.2172/6137387

Nagler, R. H., and R. C. Hornik, 2012: Measuring media exposure to contradictory health information: a comparative analysis of four potential measures. *Communication methods and measures*, **6**(1), 56-75.

Nagler, R. H., 2014: Adverse outcomes associated with media exposure to contradictory nutrition messages. *Journal of health communication*, **19**(1), 24-40. doi: https://doi.org/10.1080/10810730.2013.798384

Nagler, R. H., and S. M. LoRusso, 2017: Conflicting information and message competition in health and risk messaging. *Encyclopedia of Health and Risk Message Design and Processing.* doi: https://doi.org/10.1093/acrefore/9780190228613.013.292

National Oceanic and Atmospheric Administration, 2014: Seven best practices for risk communication. Retrieved from: https://coast.noaa.gov/data/digitalcoast/pdf/risk-communication-best-practices.pdf

National Oceanic and Atmospheric Administration, 2016: Interpretation and use of the SPC Day 1 outlook and recommendations for increasing temporal and spatial resolution. Final Report.

National Oceanic and Atmospheric Administration, 2018: National Weather Service Hazard Simplification: Public Survey. Final Report. Retrieved from: https://www.weather.gov/media/hazardsimplification/HazSimp%20Public%20Survey%20-%20Final%20Report%20-%2006-01-18.pdf

Nigg, J. M., 1987: Communication and behavior: Organizational and individual response to warnings. In R. R. Dynes, B. DeMarchi, and C. Pelanda (Eds.), *Sociology of disasters* (pp. 103-117). Milan, Italy: Franco Angeli Libri.

Perry, R. W., M. K. Lindell, and M.R. Greene, 1981: *Evacuation planning in emergency.* Lexington, MA: Lexington Books

Perry, R. W., and M. R. Greene, 1982: The role of ethnicity in the emergency decision-making process. *Sociological Inquiry,* **52**, 306-334.

Pollock, K., J. Grime, E. Baker, and K. Mantala, 2004: Meeting the information needs of psychiatric inpatients: staff and patient perspectives. *Journal of Mental Health*, **13**(4), 389-401. doi: https://doi.org/10.1080/09638230410001729834

Senay, I., and K. A. Kaphingst, 2009: Anchoring-and-adjustment bias in communication of disease risk. *Medical Decision Making,* **29**(2), 193-201.

Sherman-Morris, K., and M. E. Brown, 2012: Experiences of Smithville, Mississippi residents with the 27 April 2011 tornado. *National Weather Digest,* **36**(2), 93-101.

Tavakol, M., and R. Dennick, 2011: Making sense of Cronbach's alpha. *International Journal of Medical Education,* **2**, 53.

Tversky, A., and D. Kahneman, 1974: Judgement under uncertainty: Heuristics and biases. *Science*, **185**(4157), 1124-1131.

Weyrich, P., A. Scolobig, and A. Patt, 2018: Dealing with inconsistent weather warnings: Effects on warning quality and intended actions. *Meteorological Applications.* doi: https://doi.org/10.1002/met.1785.

Williams, B., A. Onsman, and T. Brown, 2010: Exploratory factor analysis: A five-step guide for novices. *Australasian Journal of Paramedicine,* **8**(3).

Williams, C. A., and G.M. Eosco, 2020: Is a consistent message achievable? Defining 'message consistency' for weather enterprise researchers and practitioners. *Bulletin of the American Meteorological Society,* In publication.

Williams, C. A., A. J. Grundstein, and J. So, 2020: "Inconsistencies make me question the forecast" Using graphical weather information to understand the public's message consistency evaluation process. Manuscript in preparation.

Witte, K., 1992: Putting the fear back into fear appeals: The extended parallel process model. *Communications Monographs*, **59**(4), 329-349.

Wood, M. M., D. S. Mileti, H. Bean, B. F. Liu, J. Sutton, and S. Madden, 2018: Milling and public warnings. *Environment and Behavior,* **50**(5), 535-56

Table 4.1. The 12-item Perceived Consistency Scale.

12-item Perceived Consistency Scale
1. The two severe weather forecast graphics were… a. Similar b. Conflicting* c. Contradictory* d. Consistent
2. The overall content provided in the two severe weather forecast graphics was… a. Similar b. Conflicting* c. Contradictory* d. Consistent
3. The messages communicated by the two severe weather forecast graphics were… a. Similar b. Conflicting* c. Contradictory* d. Consistent
* indicates reverse-scored item. *Note:* The visual consistency item and the "same" adjective were removed based on confirmatory factor analysis results. See Appendix A for more information on scale development. Further, a seven-point numeric response scale was used for all items, with end points labeled "not at all" and "extremely."

Table 4.2. Adjusted marginal means of perceived susceptibility across the risk boundary conditions.

DV: Perceived Susceptibility		
	Risk Category Changes	Adjusted Marginal Means
No Risk Boundary	(1) Uniform Risk Categories	5.31
	(2) Lower Risk Category	4.92
	(3) Higher Risk Category	5.19
On Risk Boundary	(4) Uniform Risk Categories	5.57
	(5) Lower Risk Category	5.36
	(6) Higher Risk Category	5.50

Table 4.3. Summary of planned comparisons to examine perceived susceptibility differences across the risk boundary conditions.

DV: Perceived Susceptibility			
Condition	Shared graphic in same position?	Difference in Risk Categories	Adjusted marginal mean difference (Std. Error)
(4) Uniform risk, on boundary vs. (1) Uniform risk, no boundary	N/A	0.5	.26 (.23)
(6) Higher risk, on boundary vs. (1) Uniform risk, no boundary	N/A	0.75	-.12 (.23)†
(5) Lower risk, on boundary vs. (1) Uniform risk, no boundary	Yes	0.25	.05 (.22)
(5) Lower risk, on boundary vs. (2) Lower risk, no boundary	No	0.75	.44 (.22)
(6) Higher risk, on boundary vs. (3) Higher risk, no boundary	Yes	0.25	.31 (.22)
(3) Higher risk, no boundary vs. (5) Lower risk, on boundary	No	0.25	-.17 (.22)§

†A closer look at the results revealed that seeing two graphics with uniform risk categories elicited a perceived susceptibility that was higher than the risk category change to a higher risk category condition. This suggests there may be some value in depicting uniform risk category information when sharing Convective Outlook graphics.

§ Because the no risk boundary condition involves an upgrade from a moderate risk (Graphic A) to a high risk (Graphic B), the research team expected it to have the highest perceived susceptibility. However, this was not the case. The risk boundary condition, which downgrades the risk category from Graphic A (Moderate/High) to Graphic B (Moderate), had the higher risk perception. As a result, we suspect that participants may be anchoring to the first Convective Outlook graphic that they see and adjusting their risk perception based on the second graphic.

Table 4.4. Self-efficacy and response efficacy mean scores.

Self-Efficacy		**Response Efficacy**	
Question	Mean	Question	Mean
It's easy for me to tell the difference between a weather 'watch' and 'warning'	4.50	Knowing the difference between a weather 'watch' and 'warning' can save my life.	5.27
Creating a severe weather emergency plan is no problem for me.	4.65	It is useful to create a severe weather emergency plan, so that I know what to do when severe weather strikes.	5.43
I find it easy to stay informed and closely monitor the weather throughout the day.	5.16	Closely monitoring the weather throughout the day is essential for being informed about any severe weather threats.	5.33
When severe weather is approaching, I am able to take shelter easily.	5.23	Taking shelter is the best way to protect myself from severe weather.	5.65
Average Self-Efficacy	4.88	Average Response Efficacy	5.42
Note: Both perceived self-efficacy and response efficacy adopted a seven-point Likert scale, where 1 meant *strongly disagree* and 7 meant *strongly agree*.			

Table 4.5. Contrast test results that evaluate the additive relationship of risk category and color on uncertainty discrepancy and information seeking intentions.

DV: Uncertainty Discrepancy				
Condition	Adjusted Marginal Means		Difference in Adjusted Marginal Means (Std. Error)	
			(5)	(6)
(1) Uniform Risk Categories	4.54		.10 (.24)	.40 (.23)
(2) Lower Risk Category	4.62		.02 (.24)	.32 (.24)
(3) Higher Risk Category	4.72		-.09 (.24)	.21 (.23)
(4) Color Changes Only	4.93		-.29 (.23)	.01 (.23)
(5) Lower Risk Category and Color Changes	4.63		--	--
(6) Higher Risk Category and Color Changes	4.94		--	--
DV: Information Seeking Intentions				
Condition	Adjusted Marginal Means		Difference in Adjusted Marginal Means (Std. Error)	
			(5)	(6)
(1) Uniform Risk Categories	4.71		.13 (.26)	.16 (.26)
(2) Lower Risk Category	4.66		.17 (.26)	.21 (.26)
(3) Higher Risk Category	4.65		.18 (.26)	.23 (.25)
(4) Color Changes Only	4.86		-.03 (.25)	.01 (.25)
(5) Lower Risk Category and Color Changes	4.83		--	--
(6) Higher Risk Category and Color Changes	4.87		--	--

Table 4.6. Contrast test results that compare the perceived susceptibility associated with the risk boundary/change to higher risk category and color condition against the other experimental conditions.

DV: Perceived Susceptibility				
	Condition	Adjusted Marginal Means		Difference in Adjusted Marginal Means (Std. Error)
				(12)
Not on risk boundary	(1) Uniform Risk Categories	5.31		.34 (.23)
	(2) Lower Risk Category	4.92		.73 (.23)**
	(3) Higher Risk Category	5.19		.46 (.22)*
	(4) Color Changes Only	5.50		.15 (.22)
	(5) Lower Risk Category and Color Changes	4.96		.69 (.22)**
	(6) Higher Risk Category and Color Changes	5.24		.41 (.22)
On a risk boundary	(7) Uniform Risk Categories	5.57		.08 (.22)
	(8) Lower Risk Category	5.39		.29 (.22)
	(9) Higher Risk Category	5.50		.15 (.22)
	(10) Color Changes Only	5.18		.47 (.23)*
	(11) Lower Risk Category and Color Changes	5.25		.40 (.22)
	(12) Higher Risk Category and Color Changes	5.65		--

$^{*}p < .05$
$^{**}p < .01$

Table 4.7. Contrast test results that compare the perceived severity associated with the risk boundary/change to higher risk category and color condition against the other experimental conditions.

DV: Perceived Severity				
	Condition	Adjusted Marginal Means		Difference in Adjusted Marginal Means (Std. Error)
				(12)
Not on risk boundary	(1) Uniform Risk Categories	5.29		.37 (.22)
	(2) Lower Risk Category	5.13		.53 (.22)*
	(3) Higher Risk Category	5.22		.44 (.22)*
	(4) Color Changes Only	5.51		.15 (.21)
	(5) Lower Risk Category and Color Changes	4.98		.67 (.22)**
	(6) Higher Risk Category and Color Changes	5.28		.38 (.22)
On a risk boundary	(7) Uniform Risk Categories	5.49		.17 (.21)
	(8) Lower Risk Category	5.27		.39 (.21)
	(9) Higher Risk Category	5.45		.20 (.21)
	(10) Color Changes Only	5.31		.25 (.22)
	(11) Lower Risk Category and Color Changes	5.39		.27 (.21)
	(12) Higher Risk Category and Color Changes	5.66		--

*$p < .05$
**$p < .01$

Table 4.8. Hypotheses associated with Experiment #2.

Hypotheses	Result
H1: Inconsistency induced by showing two Convective Outlook graphics with (a) two different risk categories and (b) two different color schemes will result in a significantly lower perceived consistency when compared against the identical graphic condition.	H1a and H1b were supported
H2: As the risk category of the second graphic increases, a participant's (a) perceived susceptibility and (b) perceived severity will increase.	H2a was supported; H2b was not supported.
H3: Inconsistency induced by showing two graphics with two different color schemes will result in a higher perceived severity.	Not supported
H4: Inconsistency induced by showing a reference graphic with a location on a risk boundary will result in a higher (a) perceived susceptibility and (b) perceived severity.	H4a and H4b were supported
H5: Inconsistency induced by showing two graphics with (a) two different risk categories, (b) two different color schemes, and (c) two different risk boundaries will result in increased uncertainty discrepancy and greater intentions to search for information.	H5b was supported; H5a and H5c were not supported.
H6: Inconsistency induced by showing a second Convective Outlook graphic that differs in both risk category *and* color scheme will result in the (a) lowest perceived consistency, (b) higher uncertainty discrepancy, and (c) greater intention to search for information than (1) either risk category change only condition, (2) the color scheme change only condition, and (3) the uniform condition.	H6a was partially supported; H6b and H6c were not supported
H7: Inconsistency induced by showing one graphic with a location on a risk boundary and a second graphic with a higher risk category will result in the (a) highest perceived susceptibility and (b) highest perceived severity.	H7a and H7b were not supported

Table 4.9. Independent and Dependent Variables Associated with the Hypotheses in Experiment #2.

Hypotheses	Independent Variable	Dependent Variable	Result
H1	(a) Risk Category Change (b) Color Scheme Change	Decrease Perceived Consistency	H1a and H1b were supported
H2	Risk Category Increases	(a) Increase Perceived Susceptibility (b) Increase Perceived Severity	H2a was supported; H2b was not supported.
H3	Color Scheme Change	Increase Perceived Severity	Not supported
H4	Risk Boundary Changes	(a) Increase Perceived Susceptibility (b) Increase Perceived Severity	H4a and H4b were supported
H5	(a) Risk Category Change (b) Color Scheme Change (c) Risk Boundary Change	Increase Uncertainty Discrepancy Increase Information Seeking Intentions	H5b was supported; H5a and H5c were not supported.
H6	Change in Risk Category and Color Scheme	(a) Lowest Perceived Consistency (b) Highest Uncertainty Discrepancy (c) Highest Information Seeking Intentions	H6a was partially supported; H6b and H6c were not supported
H7	Change in Risk Category and Risk Boundary	(a) Highest Perceived Susceptibility (b) Highest Perceived Severity	H7a and H7b were not supported

Table 4.A1. The Perceived Consistency Scale.

The Perceived Consistency Scale
1. The two severe weather forecast graphics were… a. Similar b. Conflicting* **c. The Same** d. Contradictory* e. Consistent
2. The overall content provided in the two severe weather forecast graphics was… a. Similar b. Conflicting* **c. The Same** d. Contradictory* e. Consistent
3. The messages communicated by the two severe weather forecast graphics were… a. Similar b. Conflicting* **c. The Same** d. Contradictory* e. Consistent
4. **The visual design of the two severe weather forecast graphics was…** a. Similar b. Conflicting* **c. The Same** d. Contradictory* e. Consistent
* indicates reverse-scored item. *Note:* The bolded items (i.e. the visual consistency item and the "same" adjective) were removed based on confirmatory factor analysis results. Further, a seven-point numeric response scale was used for all items, with end points labeled "not at all" and "extremely."

4.9 Figure Captions

Figure 4.1. A Convective Outlook graphic created by the Storm Prediction Center to depict the categorical and probabilistic threat of severe weather to a variety of end users.

Figure 4.2. A variety of Convective Outlook graphical designs that differ from the Storm Prediction Center's graphic by using different *colors, risk language*, and *spatial risk contours*. The star indicates Memphis, Tennessee across all graphics for comparison purposes. All graphics were taken from the 20:00UTC run of the SPC Day 1 Convective Outlook on 04/03/18.

Figure 4.3. The five experimental conditions associated with Experiment 1.

Figure 4.4. The twelve experimental conditions associated with Experiment 2.

Figure 4.5. Interaction effect of risk category changes x color changes on perceived consistency (based on estimated marginal means).

Figure 4.A1. Confirmatory factor analysis results for the four message consistency items.

Figure 4.A2 Confirmatory factor analysis results for the five message consistency adjectives.

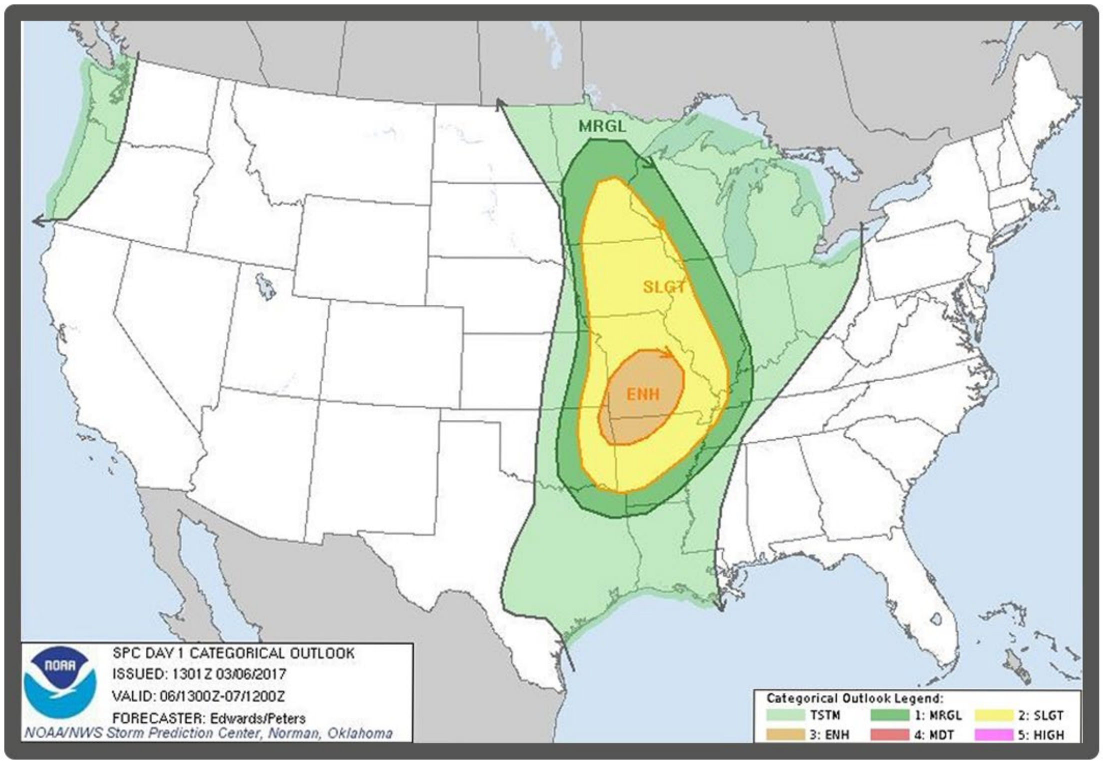


Figure 4.1. A Convective Outlook graphic created by the Storm Prediction Center to depict the categorical and probabilistic threat of severe weather to a variety end users.

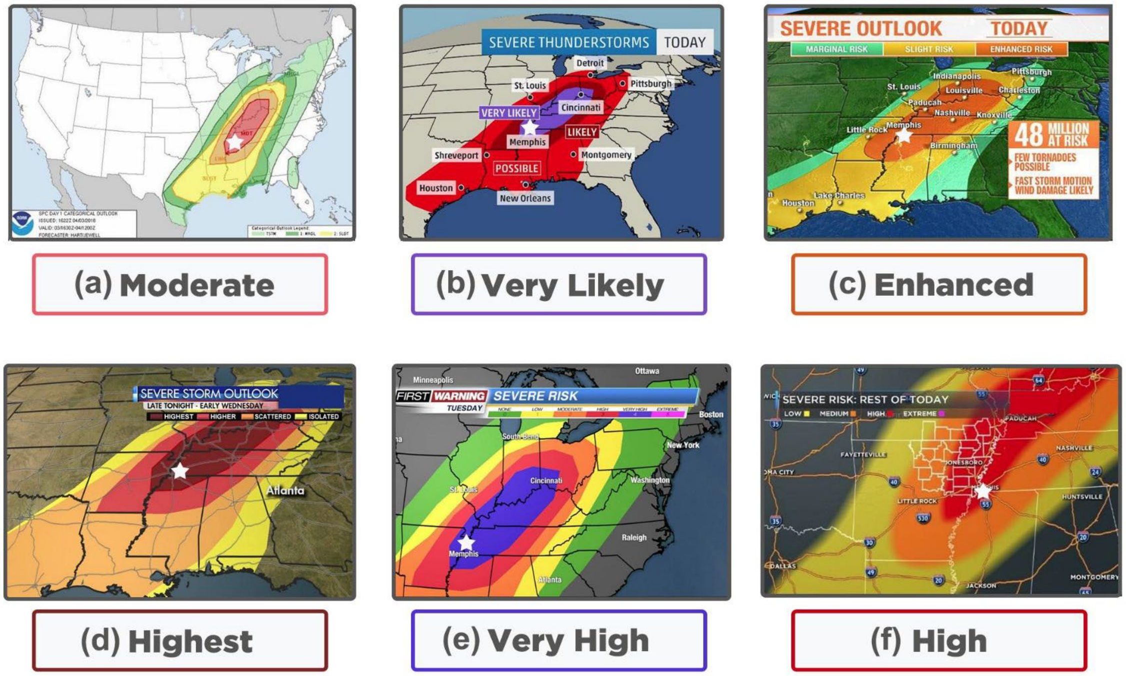


Figure 4.2. A variety of Convective Outlook graphical designs that differ from the Storm Prediction Center's graphic by using different *colors, risk language*, and *spatial risk contours*. The star indicates Memphis, Tennessee across all graphics for comparison purposes. All graphics were taken from the 20:00UTC run of the SPC Day 1 Convective Outlook on 04/03/18.

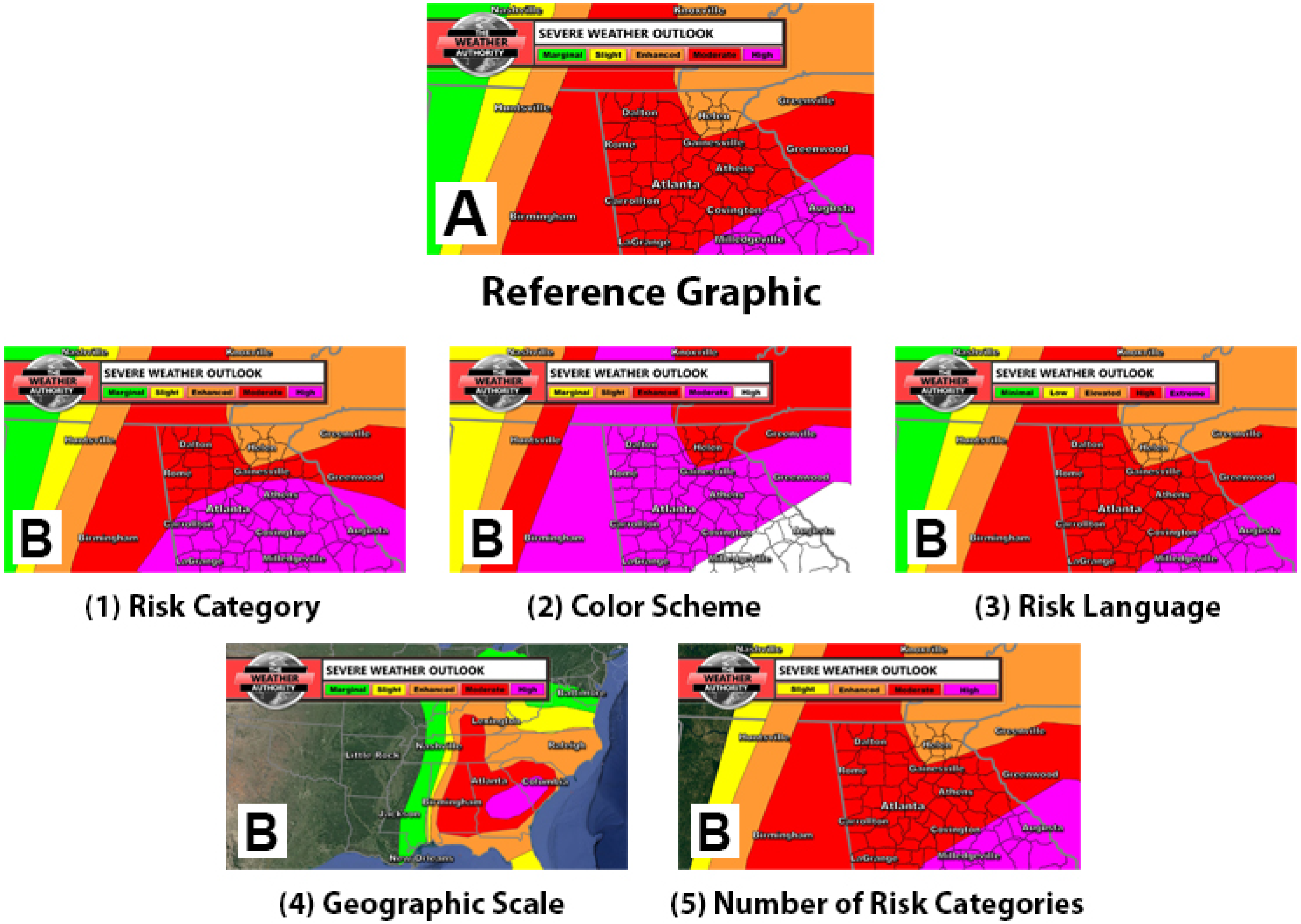


Figure 4.3. The five experimental conditions associated with Experiment 1.

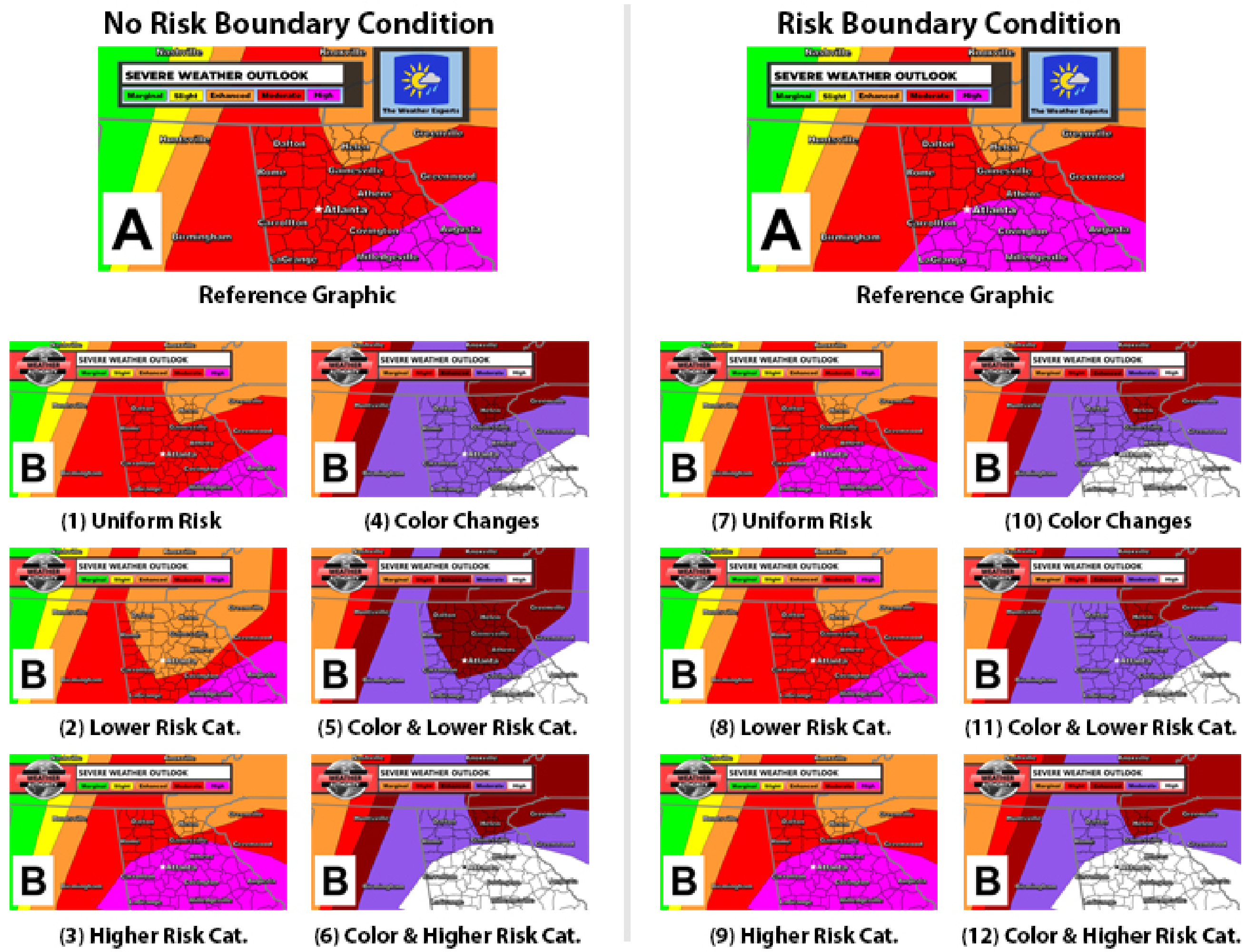


Figure 4.4. The twelve experimental conditions associated with Experiment 2.

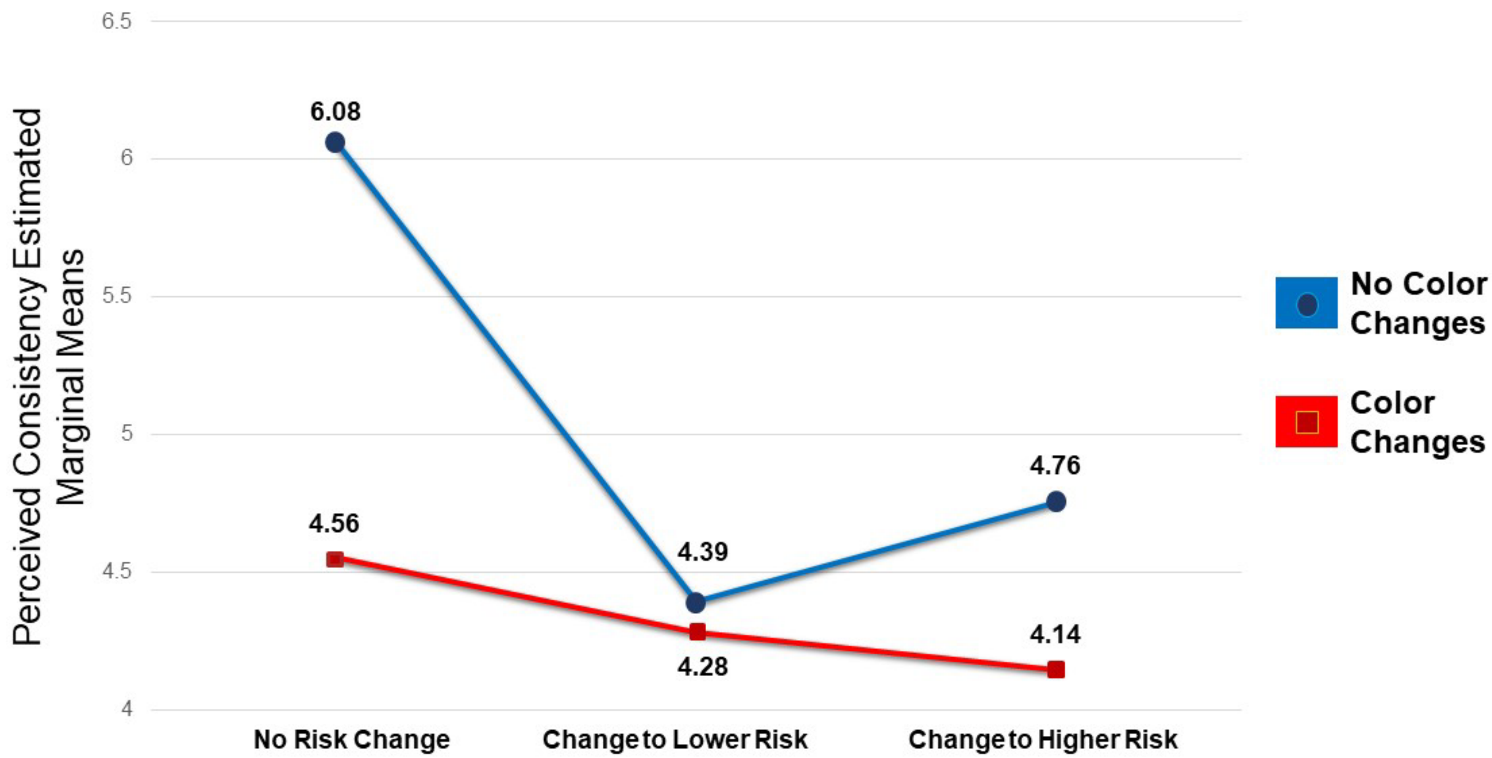


Figure 4.5. Interaction effect of risk category changes x color changes on perceived consistency (based on estimated marginal means).

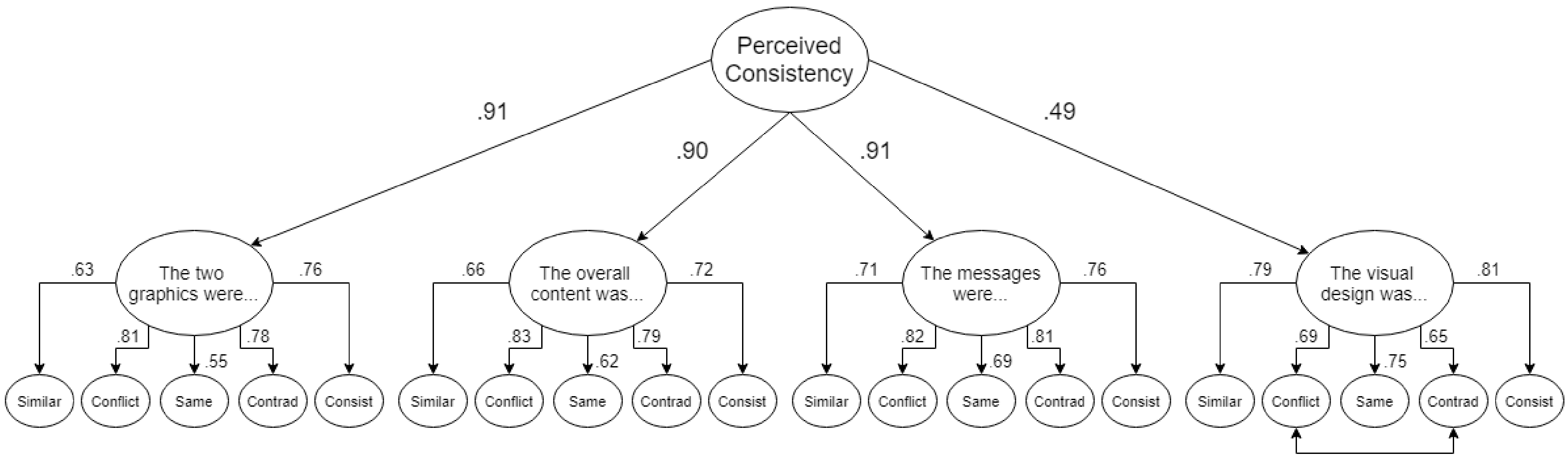
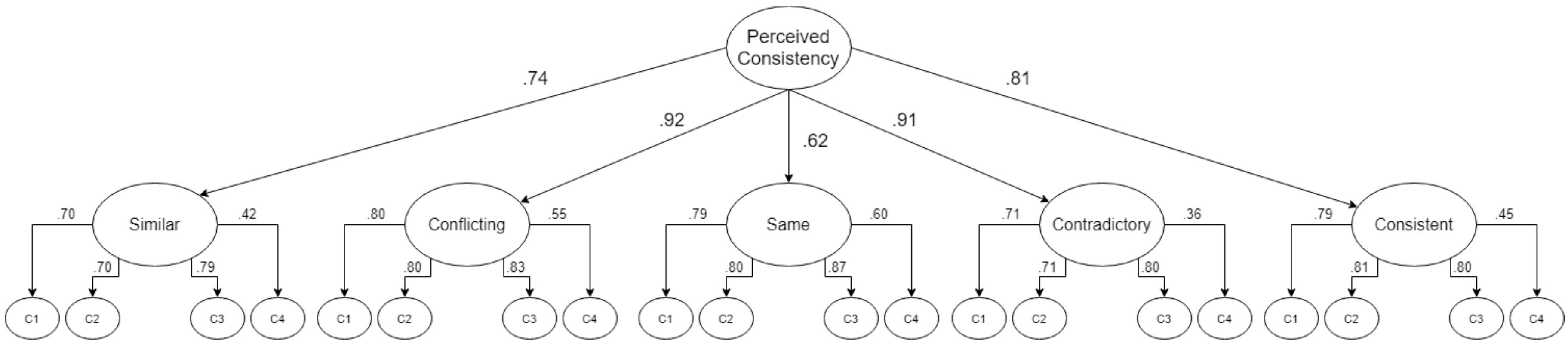


Figure 4.A1. Confirmatory factor analysis results for the four message consistency items.



Note: The following symbols are used to denote the survey items in the graphic above.

C1: The two graphics were...
C2: The overall content was...
C3: The messages communicated were...
C4: The visual design was...

Figure 4.A2. Confirmatory factor analysis results for the five message consistency adjectives.

CHAPTER 5

CONCLUSIONS AND RESEARCH-GUIDED RECOMMENDATIONS

5.1 Conclusions

With the rise of the Internet and social media platforms, people now have access to more weather information than ever before. Although this allows members of the public to receive weather information from a variety of public, private, and amateur sources, the sheer volume of available information likely contributes to a perception that weather risk messages are inconsistent. Further, members of the weather enterprise share these concerns and believe that these perceived inconsistencies may negatively affect their many audiences. The challenge, however, is that there are only a few studies to-date that have explored message consistency in a weather context. Therefore, in its current state, the weather enterprise lacks empirical evidence that (1) demonstrates that message consistency is a relevant operational concern and (2) provides research-guided recommendations to practitioners and operational meteorologists on how to achieve a more consistent message. To address this operational need, this dissertation employed a mixed-methods approach to investigate the effects of inconsistent graphical forecast information on lay public end users. Specifically, this dissertation used the Storm Prediction Center's (SPC) Convective Outlook graphic as a vehicle to explore the role of visual design in keeping a weather-related message consistent.

Before evaluating the effects of graphical inconsistencies, however, it was important to first define and conceptualize message consistency in a weather risk communication context. Over the past five years, the weather enterprise has organized conference sessions, panels, webinars, and workshops in hopes of identifying best practices for communicating a consistent message. However, without an established definition of 'message consistency,' panelists and participants found it difficult to discuss operational best practices, ground rules, and recommendations for approaching consistency in the weather enterprise. Therefore, Chapter 2 takes an important first step by combining the needs of operational meteorologists with insights from social science research to offer a definition of message consistency for weather enterprise researchers and practitioners.

To explore the language and content that meteorologists used when describing message consistency, the previously recorded organized efforts were first qualitatively analyzed. Although not an exhaustive list, five prominent themes emerged. These data showed that members of the weather enterprise frequently mentioned that:

- (1) a working definition of message consistency is needed;
- (2) inconsistencies often arise in the individual parts of a message;
- (3) specific message features likely play a role in maintaining consistency;
- (4) protective action information should remain consistent, or even uniform, across messages; and

- (5) a weather authority is needed to help facilitate message consistency within the weather enterprise.

Together, these five themes outline a problem statement relating to message consistency in the weather enterprise, and as a result, were used to inform a social science literature review. Drawing on the fields of philosophy, communication studies, and psychology, this social science literature review provided key theoretical insights that were essential in developing a definition of message consistency. Therefore, balancing the lessons learned from both theory and practice, Chapter 2 defines message consistency as "two or more weather messages that attain an optimal amount of similarity without producing any negative or adverse effects. By definition, then, the messages must convey the same overall message, even though their individual features may differ."

Although this definition offers a constructive way to conceptualize message consistency, it does not yet address how to achieve it. While it is logical to present both a definition *and* a recommendation on how to achieve message consistency, the systematic review in Chapter 2 revealed various practical constraints that call into question the feasibility of achieving it. For example, while it is ideal to assess end user perceptions prior to sharing a weather risk message, practitioners often do not have the time and/or resources to evaluate message consistency, especially in real-time as new messages become available. As such, we further pose that achieving message consistency requires a dynamic evaluation process to determine whether two or more weather messages are consistent with one another. At this time, however, this process is informal and ad hoc and needs more development. Therefore, as a next step, it is strongly recommended that both the researcher and practitioner communities work together to design, iterate, and develop a message consistency evaluation process. It is only through this blended process that both the fast-paced nature of operational meteorology, and the findings from ongoing social science research, can be combined to accommodate these practical constraints and set the stage for achieving a *more* consistent message in the weather enterprise.

While Chapter 2 provided a working definition of message consistency for weather enterprise researchers and practitioners, it lacked input from end users and individuals who receive weather messages. Obtaining input from these user groups is essential, as they ultimately determine whether a consistent message has been achieved in the weather enterprise. Therefore, to overcome this limitation, Chapter 3 used the SPC's Convective Outlook graphic to qualitatively explore the general public's message consistency evaluation process. To do this, a diverse sample of 30 community members from Athens-Clarke County, Georgia were interviewed, asked to step through four scenarios, and presented with Convective Outlook graphics with different visual designs to better understand how members of the public would hypothetically resolve situations in which they received inconsistent graphical forecast information.

According to participants, when two graphics depict a location in the same risk category and/or color zone, they inevitably communicate a consistent message. Naturally, these criteria similarly emerged when participants described why two graphics *did not* convey the same message; however, participants also mentioned other specific ways in which two Convective Outlook graphics differed (e.g., geographic scale, risk language, etc.). A closer look at these qualitative data revealed that these differences are likely tangible ways that likelihood and severity information is being unintentionally manipulated. As a result, when operational meteorologists alter specific graphical elements in a Convective Outlook (e.g., risk areas, geographic scale, risk language), they likely also unintentionally affect the likelihood and/or severity information in the process. The results of this study, then, clarify the definition offered in Chapter 2 by demonstrating that achieving "the same overall message" likely demands that end users walk away with the same feeling of risk (i.e., perceived susceptibility and perceived severity). However, this study is limited in its ability to discern the relevance of self-efficacy and/or response efficacy information in maintaining consistency, as Convective Outlook graphics only provide end users with severe weather risk information.

With previous health communication studies outlining the negative effects of conflicting information, this chapter builds on that body of literature by also exploring people's reactions to inconsistent or conflicting graphical forecast information. According to the results of this study, participants exhibited a wide range of reactions to inconsistent Convective Outlook graphics. In fact, a closer look at these data, suggest that individuals progressed through three stages when resolving conflicting information: (1) an immediate emotional response, (2) managing the conflicting information, and (3) offering recommendations to reduce conflicting information. While only some participants progressed through all three stages in sequential order, each and every participant described experiencing at least one of the stages when resolving conflicting information. More often than not, individuals reported experiencing the second stage and, for the most part, acknowledged the presence of conflicting information and offered strategies to manage and/or resolve it.

When faced with inconsistent Convective Outlook graphics, participants described a variety of strategies that they used to either engage with (e.g., seeking out additional information, consensus forecasting) or ignore the conflicting information. In particular, the benefits of trusting and relying on local sources of information emerged as a prominent theme. When exposed to inconsistent graphics in vignettes 2 and 4, for example, several individuals were more forgiving of the conflicting information and simply opted to use the graphical forecast information provided by the local meteorologist. This finding highlights the need to better understand the relationship between message consistency and geographic scale. Not only that, but it also hints at the underlying tensions that exist between achieving consistency and providing end users with a tailored forecast. Therefore, if most individuals default to local information in the face of conflict, does it matter that local WFOs alter the risk boundaries on their Convective Outlook graphics? Researchers are encouraged to partner with operational meteorologists to better understand the role of message consistency across the local, regional, and national scales, in hopes that it will determine how to best implement message consistency on a larger scale.

Although Chapter 3 provided some preliminary evidence that graphical inconsistencies may negatively affect members of the public, more generalizable social science research is needed. To address this gap and substantiate the widely assumed effects of inconsistent graphical forecast information, 1,504 college undergraduates participated in two experimental studies that manipulated graphical inconsistencies commonly associated with the Convective Outlook graphic (Chapter 4). The first experiment explored five graphical inconsistency types (i.e., different risk categories, colors, geographic scales, number of risk categories, and risk category language) that were identified in Chapter 3 to determine which one(s) resulted in the lowest perceived consistency. According to the results, two graphical variables emerged as prominent drivers of message inconsistency: (1) Convective Outlook graphics that depict a location in two different risk categories and (2) Convective Outlook graphics that use different color schemes.

Building on these results, Experiment 2 was specifically designed to evaluate the effects of graphical inconsistencies on end user perceived consistency, risk perception, uncertainty, and behavioral intentions. Like the results of Experiment 1, manipulating a Convective Outlook's risk category and color scheme significantly decreased perceived consistency. Although behavioral intentions to perform severe weather monitoring, preparedness, and sheltering actions were not impacted by graphical inconsistencies, the other perceptual variables differed depending on the type of graphical inconsistency that was manipulated. Changing a graphic's risk category and/or risk boundary, for example, affected participants' perceived susceptibility and severity, while receiving two graphics with different color schemes impacted uncertainty discrepancy and information seeking intentions. Therefore, these findings suggest that graphical inconsistencies do matter when communicating severe weather information to end users.

Although changing a location's risk category did not have any significant effects on perceived uncertainty, it did impact participants' perceived susceptibility. However, this relationship was only significant when participants were shown a second graphic with a lower risk category. Otherwise, the perceived susceptibility associated with the identical and higher risk category condition were not significantly different from each other. Although these findings suggest that an individual's perceived susceptibility is more affected by a risk category downgrade than a risk category upgrade, in actuality, the high perceived susceptibility associated with the uniform risk category condition is responsible for this relationship. A closer look at the results revealed that seeing two graphics with uniform risk categories elicited a perceived susceptibility that was similar to a risk category upgrade. This suggests that there may be more value in depicting uniform risk information when sharing Convective Outlook graphics with end users.

Nevertheless, this does not mean that severe weather graphics should wear a uniform. In line with the findings by Williams et al. (2020), the results of Experiments 1 and 2 suggest that operational meteorologists, broadcast meteorologists, and other weather entities can continue to customize the basic graphical design of their Convective Outlook graphic (i.e., placement of logos, legends, lower thirds, etc.). However, certain graphical elements emerged as important message features, and as a result, should remain the same when sharing Convective Outlook graphics with end users. Otherwise, the message being communicated by the Convective Outlook graphic changes, and consequently, affects end user risk perception, uncertainty, and information seeking intentions. Therefore, the findings from this study call attention to the need to eliminate the deliberate use of graphical inconsistencies when sharing Convective Outlook graphics with end users. It is recommended, then, that (when possible) operational meteorologists should strive to maintain the same (1) risk categories and (2) color scheme used by the Storm Prediction Center's Convective Outlook graphic. Having said that, more research is needed to improve the usability of the Storm Prediction Center's Convective Outlook graphic among lay public audiences (Grundstein et al. 2019). Only then can we ensure that severe weather forecast information is communicated both effectively and consistently among end users.

5.2 Research-guided recommendations

Finally, because this dissertation sought to strike a delicate balance between both theory and practice, a summary of the research-guided recommendations that appeared in this dissertation are provided below.

5.2.1 Chapter 2 – Defining and operationalizing 'message consistency' for weather enterprise researchers and practitioners.

- **The researcher and practitioner communities should work together to develop a message consistency evaluation process.** While it is logical to present both a definition *and* a recommendation on how to achieve message consistency, this chapter outlined various practical constraints that call into question the feasibility of achieving it. Therefore, as a next step, it is strongly recommended that both the researcher and practitioner communities work together to design, iterate, and develop a message consistency evaluation process. It is only through this blended process that both the fast-paced nature of operational meteorology, and the findings from ongoing social science research, can be combined to accommodate these practical constraints and set the stage for achieving message consistency in the weather enterprise.

- **The weather enterprise should establish and support a new research agenda.** Although previous studies offer some initial insights on message consistency, the current literature concentrates more on theory as opposed to providing practical advice on how to deliver a consistent message. However, with a working definition of message consistency, there is an opportunity for the weather enterprise to establish a new research agenda that addresses the practicality of the message consistency evaluation process and the intricacies associated with inconsistent weather messages.
- **The weather enterprise should form an ad hoc committee to develop enterprise-wide best practices.** Pulling from various committees (e.g., NWA Committee on Societal Impacts), boards (e.g., AMS Board on Enterprise Communication), organizations (e.g., Impact360 Alliance), and outside experts (e.g., risk communication experts, linguists, graphic designers), the weather enterprise could form a diverse and representative ad hoc committee to explore message consistency from an enterprise-wide perspective.

5.2.2 Chapter 3 – Understanding the public's message consistency evaluation process

- **Operational meteorologists can continue to customize the basic graphical design of their Convective Outlook graphics.** When evaluating message consistency, participants overwhelmingly thought that the two Convective Outlook graphics associated with Vignettes 1 and 3 were consistent and the two graphics associated with Vignettes 2 and 4 were inconsistent. Although the Convective Outlook graphics in vignettes 1 and 3 depicted uniform risk categories, risk language, and colors, they differed in basic graphical design. As a result, these findings suggest that basic graphical design elements (i.e., logo, placement of legend, lower-thirds, etc.) do not impact the consistency of the message being communicated by the graphics.

- **When possible, operational meteorologists should maintain the same risk areas and colors used by the Storm Prediction Center's Convective Outlook graphic.** According to participants, when two graphics depict a location in the same risk category and/or color zone, they inevitably communicate a consistent message. Naturally, these criteria similarly emerged when participants described why two graphics *did not* convey the same message. A closer look at these qualitative data revealed that these differences are likely tangible ways that likelihood and severity information is being unintentionally manipulated. As a result, when operational meteorologists alter specific graphical elements in a Convective Outlook (e.g., risk areas, geographic scale, risk language), they likely also unintentionally affect the likelihood and/or severity information in the process. Therefore, certain graphical elements act as message features and should remain the same to ensure that end users walk away with a consistent message.

- **If an operational meteorologist believes they need to shift or change the risk boundaries for their location area, it is imperative that they (1) consult and discuss the change with forecasters at the Storm Prediction Center via NWSChat and (2) be transparent with their audience about this change.** For example, this could be emphasized in a social media message, indicated somewhere on the graphic, or specifically mentioned during a weather broadcast. That way, if individuals search for more information and come across an inconsistent Convective Outlook graphic, they would be more likely to understand that the conflicting information is purposeful because a local meteorologist used their knowledge of the area to modify their severe weather risk.
- **The other graphical elements that participants mentioned less frequently (e.g., risk language, geographic scale, and number of risk categories) deserve more empirical attention before any preliminary suggestions or recommendations can be offered to the operational meteorology community.** Although various graphical inconsistencies were brought up during the interview process, risk category changes and color changes emerged as the most frequently discussed graphical inconsistencies associated with Convective Outlook graphics. This is not to say that the other graphical inconsistencies are any less important or should be intentionally used by operational meteorologists. More research is simply needed before any recommendations can be offered on the subject.

5.2.3 Chapter 4 – Exploring the effects of graphical inconsistencies on end user risk perception, uncertainty, and behavioral intentions

- **When possible, operational meteorologists should maintain the same risk areas and colors used by the Storm Prediction Center's Convective Outlook graphic.** Although behavioral intentions to perform severe weather monitoring, preparedness, and sheltering actions were not impacted by graphical inconsistencies, showing two inconsistent Convective Outlook graphics did affect participant's perceived consistency, perceived risk, uncertainty, and information seeking intentions. Not only that, but seeing two graphics with uniform risk categories and a uniform color scheme elicited a perceived susceptibility that was on par with a risk category upgrade. As a result, there is likely more value in sharing Convective Outlook graphics that replicate the same risk areas and colors used by the Storm Prediction Center.
- **Operational meteorologists should consider pairing severe weather preparedness messages alongside Convective Outlook graphics.** Although both self-efficacy and response efficacy were moderately high, participants reported a lower perceived self-efficacy. This suggests that although participants believed specific severe weather actions would reduce their overall threat, they were less likely to believe they could successfully perform those actions. In fact, participants did not feel especially confident in their ability to (1) differentiate a severe weather watch vs. warning and (2) effectively prepare for a severe weather

event by creating a severe weather emergency plan. Considering that participants also reported that severe weather preparedness is essential for reducing their severe weather threat, operational meteorologists should consider pairing severe weather preparedness messages with Convective Outlook graphics to bolster preparedness actions ahead of a severe weather threat.