PUBLIC PERCEPTION AND COMPREHENSION OF THE EXTENDED FORECAST GRAPHIC IN TELEVISION WEATHER BROADCASTS

by

JACOB RYAN REED

JASON C. SENKBEIL, COMMITTEE CHAIR
DAVID J. KEELLINGS
LAURA MYERS

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ABSTRACT

There have been multiple efforts in recent years to simplify visual weather forecast products, with the goal of more efficient risk communication for the general public. Many meteorological forecast products, such as the cone of uncertainty, storm surge graphics, warning polygons, and SPC convective outlooks, have created varying levels of public confusion resulting in revisions, modifications, and improvements. However, the perception and comprehension of private weather graphics produced by television stations has been largely overlooked. The goal of this study is to explore how the extended forecast graphic (EFG), more commonly known as the 7-day, 10-day, etc., is utilized by broadcasters and understood by the public. Data were gathered from two surveys of the general public and one survey of broadcast meteorologists.

Results suggest this graphic is a source of confusion and highlights a disconnect between the meteorologists producing the graphic and the content prioritized by their audiences. Specifically, timing and intensity of any precipitation or adverse weather events are the two most important variables to consider from the viewpoint of the public. These variables are generally absent from the extended forecast graphic, thus forcing the public to draw their own conclusions which may differ from what the meteorologist intends to convey. The placement of forecast high and low temperatures, use of probability of precipitation, icon inconsistency, and length of time the graphic is shown may also contribute to public confusion and misunderstanding. Four alternative EFGs are evaluated in this research, and it is found that showing fewer days on the

EFG and removing PoP information can increase the usefulness of the EFG and reduce confusion created by the graphic, without lessening the graphic's likeability.

LIST OF ABBREVIATIONS AND SYMBOLS

EFG(s)	Extended Forecast Graphic(s)
PoP(s)	Probability(ies) of precipitation
N	Sample size
KW	Kruskal-Wallis
$>$	Greater than
$=$	Equal to
p	Probability associated with the occurrence under the null hypothesis of a value as extreme as or more extreme than the observed value
μ	Mean
z	Computed value of a z test

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CHAPTER 1

INTRODUCTION

There is limited research concerning the efficacy and comprehension of individual television weather forecast graphics. Although smartphone weather apps are quickly overtaking television broadcasts as people's primary source of weather information (Phan, Montz, Curtis, & Rickenbach, 2018; Zabini, 2016), television remains an important staple in the suite of modalities used to consume weather information, especially among the 55 and older age demographic (Pew Research Center, 2008, 2018, 2019). Weather forecast graphics, such as hourly forecasts and future satellite and radar, are often used in local television broadcasts news station weather apps and are therefore deserving of continued study. Due to the multiple formats, types of information, and different time periods, these graphics are a potential source of confusion for viewers. Relatively little attention has been devoted to the possible misperceptions resulting from these graphics. The graphics are often only displayed for 20 seconds or less, without the presence of an on-camera meteorologist, or posted on social media with little-or-no contextual information included.

Previous research has sought to understand and close gaps in knowledge and communication between meteorologists and the public on products like tornado watches (Mason & Senkbeil, 2015), the use of different colors in radar displays (Bryant et al., 2014), and tropical cyclone track and surge graphics (Lindner et al. 2019; Bostrom et al. 2018; Saunders et al. 2017; Sherman-Morris et al. 2014). Less is known, however, about how the public perceives and understands graphics they routinely see in local television news broadcasts. The primary graphic of concern in our research is the extended or long-range forecast graphic (i.e. the 5-day, 7-day, 10-day; hereafter, EFG).

EFGs typically show between three and ten days of predicted weather. Most EFGs shown by television stations across the country are formatted similarly with vertical panels containing the day of the week, a forecast high and low temperature, weather icons, and a probability of precipitation (PoP). In some cases, single-word or single-phrase text descriptions of the day's weather are used instead of or in addition to the PoP. Information within the EFG is highly sought after online (Phan et al., 2018) and on television. This graphic is a cornerstone of local television weather broadcasts, often being used in teases on air and online to increase viewership. It is sometimes shown multiple times during a single newscast, generating revenue from advertising sponsorships. The format of local television weather broadcasts and the EFG may play an important role in the effectiveness of communicating a forecast, but this is a nascent area of research. This paper lays the groundwork for understanding more about how local television weather forecasts are formatted, what graphics are shown, what information is shown, and the length of time devoted to each graphic.

The frequent use of a PoP on EFGs is arguably the preeminent reason this particular graphic is confusing. The National Weather Service first used numerical PoPs in forecasts in 1965 (Murphy, Lichtenstein, Fischhoff, & Winkler, 1980). The use of PoPs has since become widespread and is now included in almost every weather forecast on television, smartphone weather apps, newspapers, radio (including weather radio), and the internet. The use of PoPs has become so ubiquitous, meteorologists believe the public has grown attached to them and expects to see them in weather forecasts (Stewart et al., 2015; Zabini, Grasso, Magno, Meneguzzo, & Gozzini, 2015). This is despite the conclusions of abundant previous research that demonstrates the public's poor understanding of the PoP (Kox and Thieken 2016; Abraham et al. 2015; Stewart et al. 2015; Zabini et al. 2015; Morss et al. 2010; Morss et al. 2008; Gigerenzer et al. 2005; Murphy et al. 1980). Confusion surrounding the PoP is not limited to the public. Stewart et al. 2015 found meteorologists are not in agreement with what a PoP represents or with how it should be implemented in a forecast. If the PoP is poorly understood by the public *and* meteorologists, why is it still being used? Surprisingly, over 70% of meteorologists surveyed in Stewart et al. 2015 had a different interpretation of the PoP from the National Weather Service's (NWS) definition. Broadcast meteorologists exhibited the lowest confidence in their interpretation of how a PoP should be used (Stewart et al. 2015).

The NWS defines PoP as a combination of the forecaster's confidence that precipitation will occur somewhere in the forecast area and the percent of the forecast area that will receive measurable precipitation (National Weather Service, 2008). Assuming the forecaster's confidence level is 100%, the PoP becomes strictly an expression of how much of the forecast area will receive measurable precipitation. In this case, the PoP is no longer a percent chance of rain, but rather a percent coverage of rain. There is currently no distinction on EFGs as to which of these interpretations of the PoP (Joslyn et al. 2009) should be used. Previous research (Klockow-McClain 2019; Joslyn et al. 2009) has concluded that there will be errors in interpretation of the forecast by the public without an explicit explanation of PoP in a given forecast (i.e. the reference class, timing, amount, etc.). Indeed, Morss et al. 2008 demonstrates the public's confidence in precipitation forecasts is lower than that of other forecast components, mainly temperature. It is important to minimize these errors because the misinterpretation of a forecast can erode the relationship of trust between the public and broadcast meteorologist (Joslyn et al. 2009; Sherman-Morris 2005).

Confusion surrounding the PoP continues despite the efforts of broadcast meteorologists to educate the public (Marshall, 2015; Panovich, 2013; Spann, 2017). One goal of this paper is to better understand what forecast variables the public prioritizes. If PoP information is less important than other forecast components, the PoP could be modified or removed in an effort to reduce confusion. Murphy 1993 opined that one of the aspects of creating a good forecast was to include all the information that was important to the user or users. This paper adds to existing knowledge about what forecast variables are important to a group of users, but more importantly the ways in which the public prioritizes this information. It should be the goal of meteorologists producing graphics shown in weather broadcasts to include the information the public prioritizes in a format that is easily interpretable. Previous research has shown that while the public has demonstrated a desire to see a PoP (Morss et al. 2008), it was not the most important part of the precipitation forecast (Demuth et al. 2011). Other variables, like timing, intensity, and duration of the precipitation were listed as important (Demuth et al. 2011), but these aspects of the forecast are rarely presented on the EFG. In addition to examining the role of the contribution of PoP confusion to misperception of the EFG, other factors analyzed in this research include the length of time the EFG is displayed during the television broadcast and where in the broadcast the EFG is shown relative to other graphics.

Based on feedback obtained from the first public survey and broadcaster survey, discussed in Chapters 2 and 3, four new EFGs were created. These new graphics were then evaluated using a second survey of the general public against the existing EFG format. It is hoped that the removal of PoP information, for example, will make the EFG less confusing and easier to interpret.

Seven research questions will be answered in this thesis:

1. What forecast variables are prioritized by the public and are they included on the EFG?
2. What weather graphic do broadcasters say is most important to their audience and why?
3. To what extent can the public comprehend and answer questions about a forecast after looking at an EFG?
4. For what length of time is the EFG shown during local weather broadcasts on television?
5. Does the removal of PoP information from and reduction in number of days shown in the EFG decrease the graphic's likeability or usefulness?
6. Is there an appropriate number of days that should be shown in an EFG?
7. Are the new EFGs more understandable than the current format?

Questions one through four are addressed in Chapters 2 and 3. The remaining research questions are covered in Chapters 4 and 5. Chapter 2 outlines the development and implementation of two surveys, one of the general public (N = 158) and one of broadcast meteorologists (N = 113). An additional section of Chapter 2 describes the data analysis procedures. Chapter 3 closely follows the structure of the methods. The findings regarding public demand for what variables should be most prominently featured are included, followed by a similar section showing what broadcasters reveal to be the most important elements of their weather forecast. The longest section Chapter 3 is devoted to the findings of public comprehension and perception of an EFG graphic and how long the EFG is shown. Chapter 4 outlines the development and strategy behind creating the new EFGs that are evaluated in this paper. Each graphic tested is described in its own subsection, with explanations of the hypothetical forecasts shown in each one. Another section Chapter 4 is devoted to discussing how the online survey was created and distributed through broadcast meteorologists on social media. The final section of Chapter 4 is devoted to the data analysis techniques and procedures. Chapter 5 is organized so that it closely follows that of the methods. The longest section of Chapter 5 covers the comparison between each of the new EFGs introduced in this paper against the existing format. Finally, some important topics for future research and other conclusions are discussed in Chapter 6.

CHAPTER 2

FIRST PUBLIC AND BROADCASTER SURVEYS: METHODOLOGY

a. Public Survey

A 33-question survey consisting of free-response and Likert scale questions, forecast scenarios (Sealls, 2015), and EFG interpretations was created in Qualtrics. The survey was targeted to a database of registered Qualtrics users who were at least 30-years-old and residents of Alabama, Georgia, Mississippi, or Tennessee (Figure 1). No other constraints were made. The decision was made to limit the survey to people in this age group because this represents, roughly, the demographic of people for whom television remains a popular modality to consume weather information (Pew Research Center, 2008, 2018). The survey was limited to residents in four states in the Southeast U.S. because this is a region where precipitation occurs year-round and as such, residents routinely consume precipitation forecasts. Confusion about the use of PoP seems to peak during the warm season when the precipitation regime is dominated by airmass convection or along the sea breeze front (Hill, Fitzpatrick, Corbin, Lau, & Bhate, 2010; Spann, 2017). Additionally, previous projects (Joslyn et al. 2009) have limited their study area for similar investigations to regions that are notoriously wet. The Southeast U.S. has been the subject of more recent research which suggests precipitation events are becoming more extreme in this region (Skeeter et al. 2019), which merits the need to examine the efficacy of current precipitation forecasts.

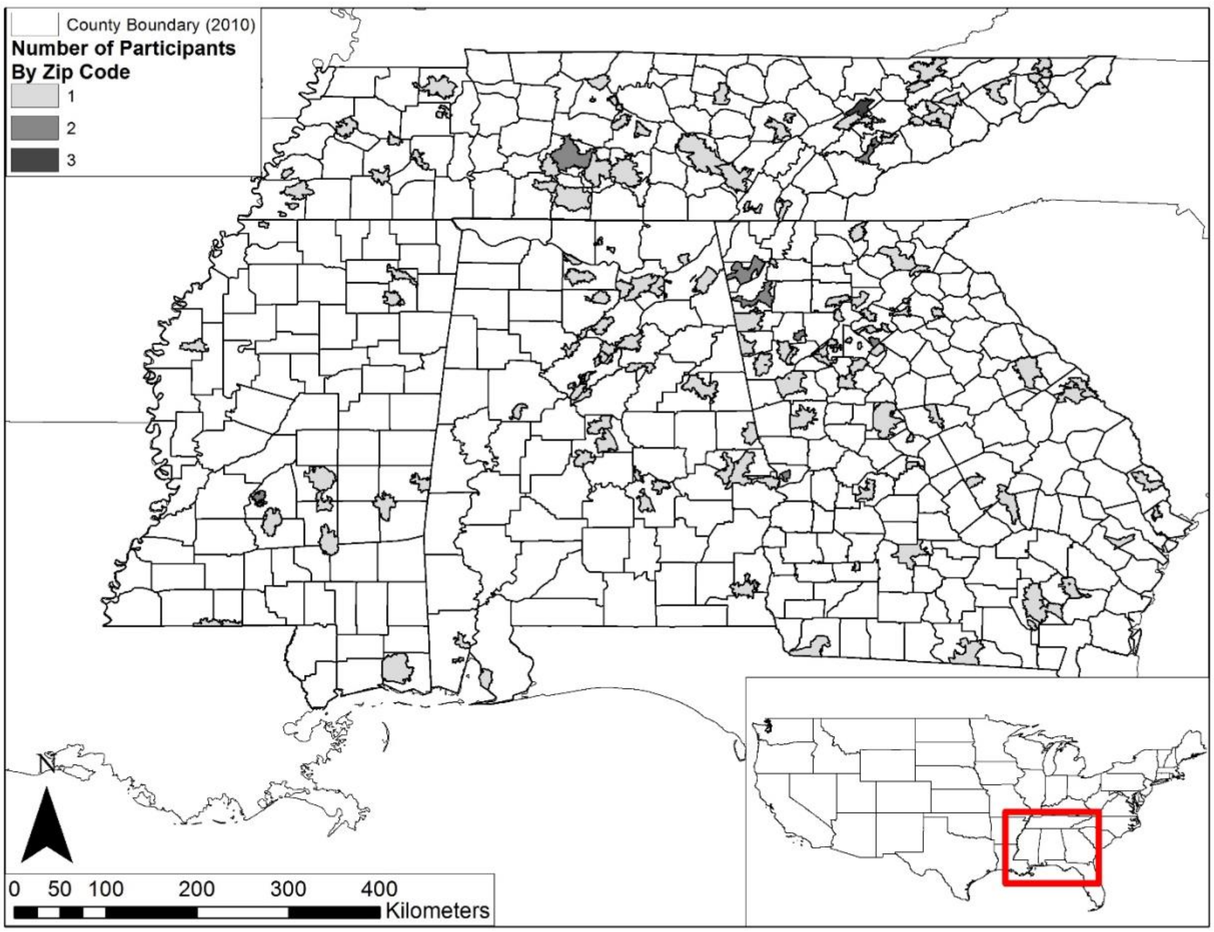

Figure 1: Study area with number of participants per zip code for the general public survey (N = 158).

Beyond the collection of background and demographic data, questions were designed to gather information on the behavior of participants related to their consumption of weather forecasts. Respondents were asked how often they check their local weather forecast and what their preferred method to check forecast information was. Participants were also asked to pick out basic forecast data, like the forecast high temperature, timing, amount, and intensity of precipitation using the EFGs shown in Figure 2. No limitations on time were made with regard to how long someone could view the EFG, as the graphic was visible on each page where there was a question related to it. Those who took the survey were prompted to comment on what they liked or disliked about each EFG. Survey participants then ranked the following precipitation forecast variables from most important to least important: timing, intensity, duration, amount, percent chance (PoP). Tied ranks were not permitted.

Figure 2: Example of a 7-day extended forecast graphic shown during a local news broadcast.

b. Broadcaster Survey

Because broadcast meteorologists are the producers and communicators of EFGs, their insight into better understanding this issue is invaluable. A 13-question survey was developed using Qualtrics and included free-response, closed-response, and Likert scale questions. This survey is the first of its kind to ask specific questions seeking information on broadcaster opinion and utilization of EFGs in their forecasts. Specific questions included how many days' worth of data is typically included in the EFG, when in the broadcast the EFG is shown, how long the EFG is shown, and what the EFG's purpose is in the forecast? Other data collected in this survey includes the typical shift the broadcaster works, state where currently employed, and opinions on the effectiveness of the PoP.

A different distribution method was used for the broadcaster survey. This survey was made available to private online groups of over 2,500 broadcast meteorologists, where participation was solicited twice. Additionally, the National Weather Association emailed their database of members requesting participation from broadcast meteorologists across the country. One hundred thirteen responses were generated. Questions in the broadcaster survey were not limited to the communication of precipitation forecasts. Rather, questions were focused on how broadcasters utilize weather graphics like the EFG, the length of time broadcasters spend creating graphics, how long they show the graphics during broadcasts, and opinions about what graphics were most important to their audiences. No geographic restrictions were made. Additionally, broadcasters of any age were allowed to participate in this survey.

c. Data Analysis

A mixture of quantitative and qualitative procedures were used to demonstrate and explain how and why the EFG is a potential source of confusion. These procedures are divided into subsections within this section to facilitate the organization and rationale for the analysis.

i. What forecast variables are most important for the public and broadcasters?

For public audiences, previous research (Demuth et al. 2011) found that the most important elements of a forecast were timing and intensity. Thus, the first objective of this research was to test how robust those findings were. In our survey, participants were asked to rank the importance of the precipitation forecast variables of percent chance, timing, amount, duration, and intensity. Participants based their importance of each variable on a Likert scale of 1-5, with 1 representing very low importance and 5 indicating the variable was extremely important. A Chi-Square test was performed to test the null hypothesis that the number of responses across the categories of precipitation forecast importance are proportional between the less important (1-3) and more important (4-5) ranks.

The broadcaster survey consisted of open-ended questions with longer responses as it was important to capture their thoughts on the EFG. Specifically, broadcasters were asked to comment on the importance of the EFG, its exact purpose, and how long they show it during the broadcast. Thus, the results for this part of the research are summarized by descriptive statistics and qualitative thematic content lists of responses. The content themes were divided into categories that say the EFG is either important or very important and other categories of responses indicating that something else was more important.

ii. EFG perception and comprehension

Similar to the broadcaster survey, open-ended questions were used and responses were categorized into themes to assess comprehension and perception of a standard EFG (Figure 2). Participants were shown the EFG and asked to answer the following questions:

1. What is the chance of rain on Sunday?
2. What time will it rain on Sunday?
3. How much rain will fall on Sunday?
4. What will be the low temperature Sunday morning?
5. How much rain will fall between Tuesday and Wednesday?
6. What did you like or dislike about the graphic?

Questions one to five have correct answers and are therefore graded and discussed as percentages correctly answered. Question six was open response about the public’s opinions of the EFG, which required the categorization of responses into themes for discussion.

An additional step in the process of evaluating the EFG feedback from broadcasters was to view features of the EFG used in television weather broadcasts. 60 television weather segments from 20 television stations across the study area shown in Figure 1 were sampled during the summer of 2018. Morning, midday, and evening weekday newscasts were observed either live or on-demand to measure the length of time the EFGs were shown in the main weather segment. Since the segment times did not follow a normal distribution, a non-parametric Kruskal-Wallis (KW) test was used to test for significant differences in the length of time the EFG was shown across the three time categories.

CHAPTER 3

FIRST PUBLIC AND BROADCASTER SURVEYS: RESULTS

a. Public Survey Characteristics

Demographic data were collected for 158 participants in the public survey (Table 1). Respondents in age groups 30-39, 40-49, 50-59, and 60+ were evenly distributed, with 41, 35, 41, and 41 members in each respective group. White females make up the overwhelming majority of respondents in the general public survey. 122 females participated and 36 males participated. A total of 76% of those who took the survey listed their ethnicity as White/Caucasian. Most participants reported themselves as having advanced education, with only 5% possessing less than a high school diploma. The sample represents a mixture of urban and suburban zip codes (Figure 1). Approximately 77% of people say they check their local weather forecast at least once per day. Local television was the most frequent method for checking weather conditions (28%), followed closely by smartphone weather apps (21%). A total of 86% of respondents reported that their source of weather information includes a PoP with 91% saying they pay attention to it.

Table 1: Descriptive statistics for study participants in the general public survey (N = 158).

Variable	N	%
Gender		
Female	122	77%
Male	36	23%
Ethnic Identification		
Caucasian	120	76%
African American	34	22%
Hispanic/Latinx	1	<1%
Other	2	1%
American Indian	1	<1%
Age		
30-39	41	26%
40-49	35	22%
50-59	41	26%
60+	41	26%
Education Level		
Less than high school	7	4%
High school graduate	34	22%
Some college	51	32%
2-year degree	17	11%
4-year degree	33	21%
Professional degree	16	10%

b. Broadcaster Characteristics

113 broadcast meteorologists from 35 states and the District of Columbia participated in the broadcaster survey (Figure 3A). The state with the highest number of respondents was Texas with 12 broadcasters. A majority of broadcasters who took this survey were between the ages of 25-34 (47%) or 35-44 (24%) (Figure 3B). There was a nearly uniform distribution of respondents across the on-air shift they say they typically work (Figure 3C). The grouping by shift was 35% for weekday evening; 26% work weekday mornings and/or midday; 28% of broadcasters surveyed work weekend evenings; and 11% work weekend mornings. Limited information was gathered about a broadcaster’s personal information. The primary goal of surveying broadcasters

was to gain more information about how they utilize the EFG, and what methods of conveying weather information they felt were or were not effective.

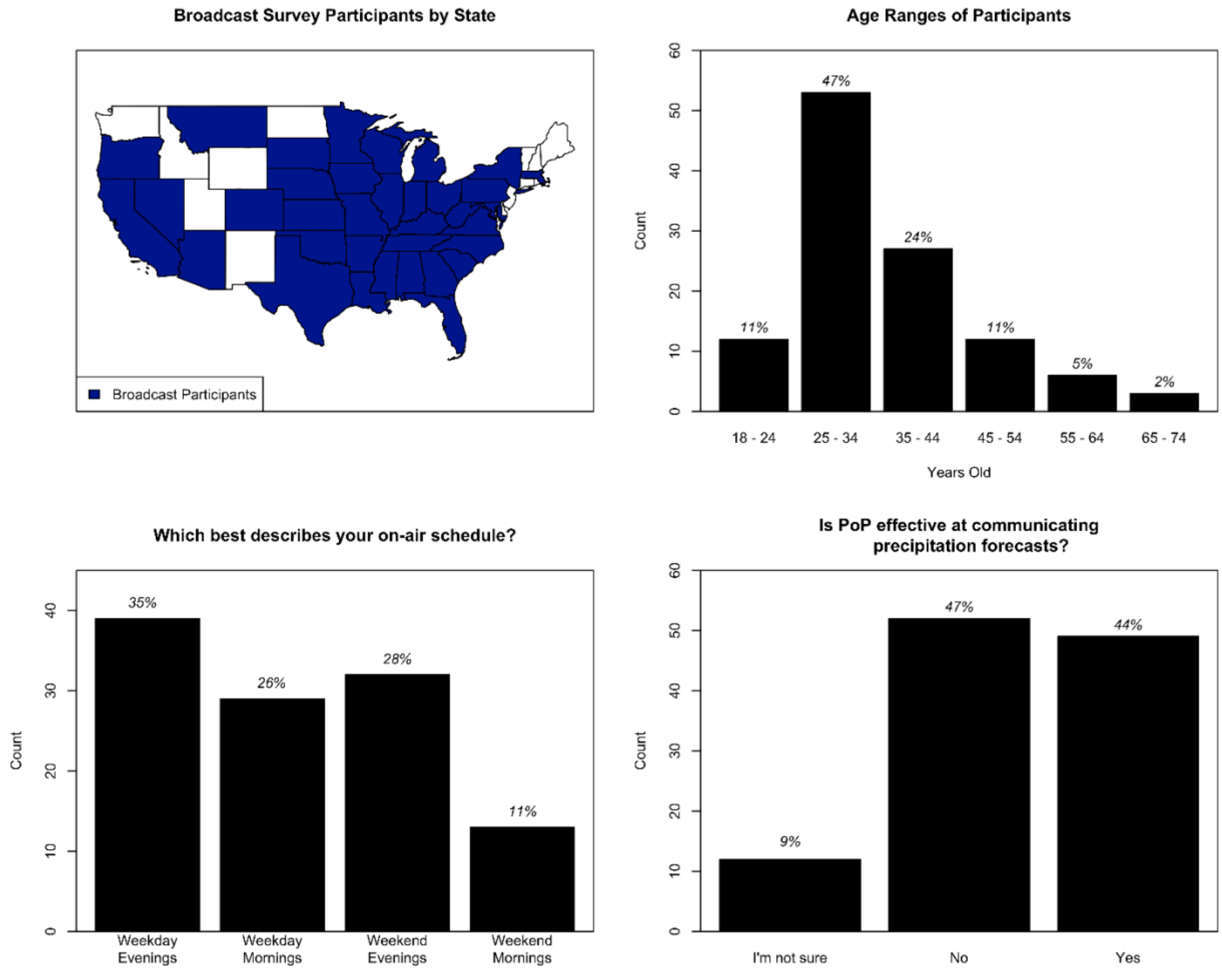

Figure 3: A.) The states in which the broadcast meteorologists who took the broadcast survey are currently employed (N = 112); B.) Age ranges of broadcasters who participated in the survey (N = 113); C.) Primary on-air shift worked by the broadcast meteorologist (N = 113); D.) Answer to the question “Is PoP effective at communicating precipitation forecasts?” (N = 113).

c. What forecast variables are most important for the public?

Results of the chi-square contingency table on ranked forecast variables are shown in Figure 4 and Table 2. The null hypothesis that the number of responses across the categories of forecast importance is proportional between the less important (ranks 1-3) and more important (ranks 4-5) categories is rejected. The disproportionality between the low and high priority rankings is statistically significant: $X^2(4, N = 152) = 27.928, p<.001$. This result is in agreement with Demuth et al. (2011): with regard to precipitation, timing and intensity are most important to the public. These two variables are absent from the EFG in Figure 2.

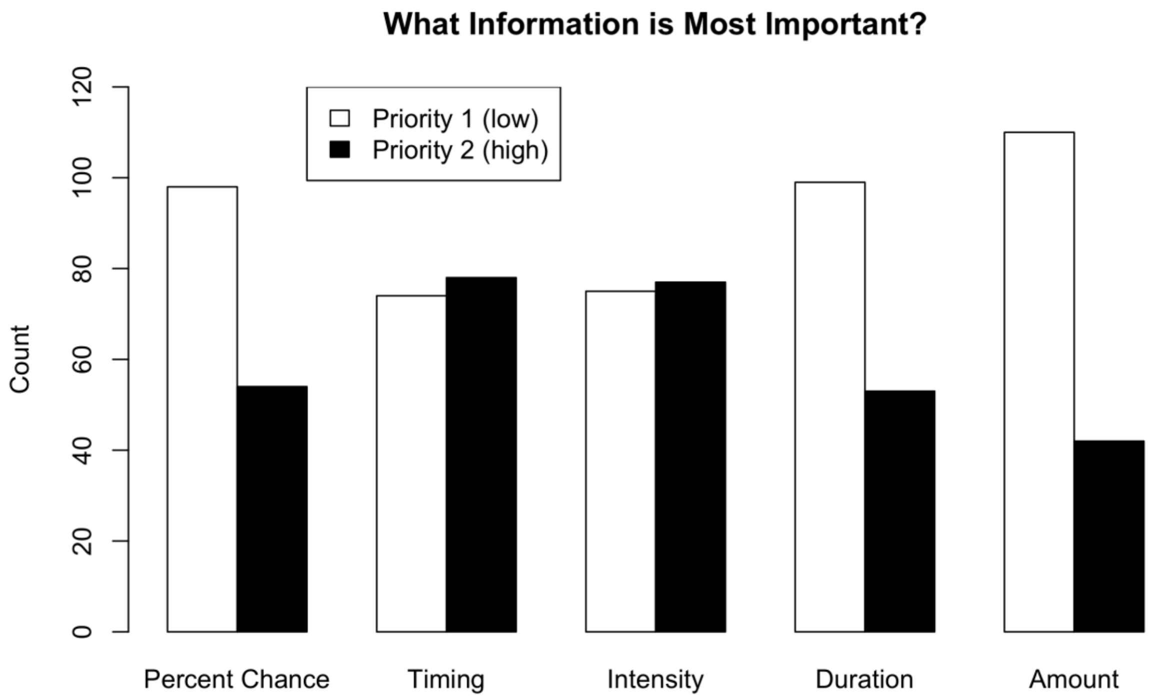

Figure 4: Chi square contingency table test results for variables the public want to see in precipitation forecasts. Responses were grouped into low priority (ranks 1-3) and high priority (ranks 4-5). The disproportionality between the groups is statistically significant (N = 152).

Table 2: Forecast importance with priority crosstabulation of ranked precipitation forecast variables. Ranks 1-3 represent low importance while ranks 4-5 are highest importance. If the ranking of the forecast variables were proportional across each forecast variable, then one would expect the number of responses to equal the value in the expected count row.

Variable			Priority 1 (Ranks 1-3)	Priority 2 (Ranks 4-5)
Forecast Importance	Percent Chance	Count	98	54
		Expected Count	91.2	60.8
		% Within Forecast Importance	64.5%	35.5%
	Timing	Count	74	78
		Expected Count	91.2	60.8
		% Within Forecast Importance	48.7%	51.3%
	Duration	Count	99	53
		Expected Count	91.2	60.8
		% Within Forecast Importance	65.1%	34.9%
	Amount	Count	110	42
		Expected Count	91.2	60.8
		% Within Forecast Importance	49.3%	27.6%
	Intensity	Count	75.0	77
		Expected Count	91.2	60.8
		% Within Forecast Importance	49.3%	50.7%

d. What forecast variables and graphics are most important for broadcasters?

Our results support the previous conclusion of Stewart et al. 2015, who found that meteorologists' definition and utilization of PoP varied from the official definition of the NWS. The disagreement about how PoP should best be used remains evident in our findings. A total of 47% of broadcasters surveyed here did not believe the PoP is an effective way of communicating precipitation forecasts, while 44% say PoP is effective (Figure 3D). In some cases, PoPs are only shown on the EFG and not on other graphics within the same broadcast, which may result in a compounding effect on confusion to the public.

Just over half (53%) of the broadcasters in our sample name the EFG as generally being the most important graphic shown to their audiences. One respondent points out that EFGs typically contain sponsorships, which underscores this graphic's importance in a weathercast. Broadcasters were asked to qualify the importance of the EFG. There is a common thread among the responses that this is "the number one reason viewers watch" because "they want to know what's coming." One broadcaster called the EFG a "one-stop shop for forecast temperatures, sky conditions, and PoPs." Other selected comments regarding the importance of the EFG reveal important insight into how broadcasters view the role of this graphic (Table 3). These beliefs seem to be in direct conflict with the findings of this paper. Because the public was unable to answer questions about precipitation timing and amounts/intensity (the variables they prioritize) after looking at an EFG, it is difficult to believe in the efficacy of this graphic as a means to plan ahead. Additionally, the lack of information present on the EFG may inhibit people from knowing how to dress for the next day, especially if atypical weather is expected, such as when the warmest part of the day does not occur in the afternoon. It would be wrong to not acknowledge the commendable effort broadcasters put into their forecasts prior to showing the EFG and the specific forecast variables that may be important in a given weather situation. The problem is that the high level of detail that may be presented earlier in the weather broadcast is lost in translation when the EFG is created. If it is true that this is the most important graphic when viewers are paying the most attention, there must be an effort to improve its efficacy.

Table 3: Categories of broadcast meteorologists' comments about what graphic they feel is most important to their audience.

Category	Value	Example Responses	N	% of total
1	EFG	"7-day forecast; It has the most information and everyone expects it in every forecast." "If I was told I could only show one graphic, that's the one I would choose." "7-day forecast as that's the number one [reason] why people watch." "This graphic's importance is underscored by the number of sponsors in markets across the country."	60	53%
2	Short-term forecast	"Hour-by-hour day planner"; "12-hour daypart"; "24-hour forecast"	15	13%
3	Futurecast Clouds/Radar	"Future radar"; "Futurecast clouds and precipitation"; "Future tracker"	10	9%
4	Radar/warnings/currents	"Radar"; "Radar and satellite as this is live and real."; "Watches and warnings"; "Current conditions"	9	8%
5	Lifestyle/impact-driven	"Travel impact"; "Lifestyle graphics like road hazards, bus stop forecast, and windshield scraping forecast"	3	3%
6	Other	"Depends on the day"; "Depends on the weather event"; "Whichever one finally makes it all click"	16	14%

e. EFG comprehension and perception

As described in the methods, six questions were asked to assess public comprehension and perception of a sample EFG. Results from each question are presented in Figure 5 where each question is labeled above its corresponding plot. Questions related to the timing and amount of expected precipitation within the EFG gave participants the most trouble. The dominant answers for each question in Figure 5 show that 72% of people were not sure what time it would rain Sunday, 86% were not sure how much rain would fall Sunday, and 79% were not sure how much rain would fall between Tuesday and Wednesday. Participants struggled to answer these questions related to the precipitation forecast, most likely because there was no information displayed on the EFG regarding timing or amount of expected precipitation. The strongest evidence of this graphic creating confusion is seen when looking at the answers to Question 2, where 72% of people said they were not sure when it would rain Sunday. This is problematic because timing was the forecast variable ranked as most important by participants we surveyed. Without the timing information, members of the public are left to guess and fill the information gaps on their own.

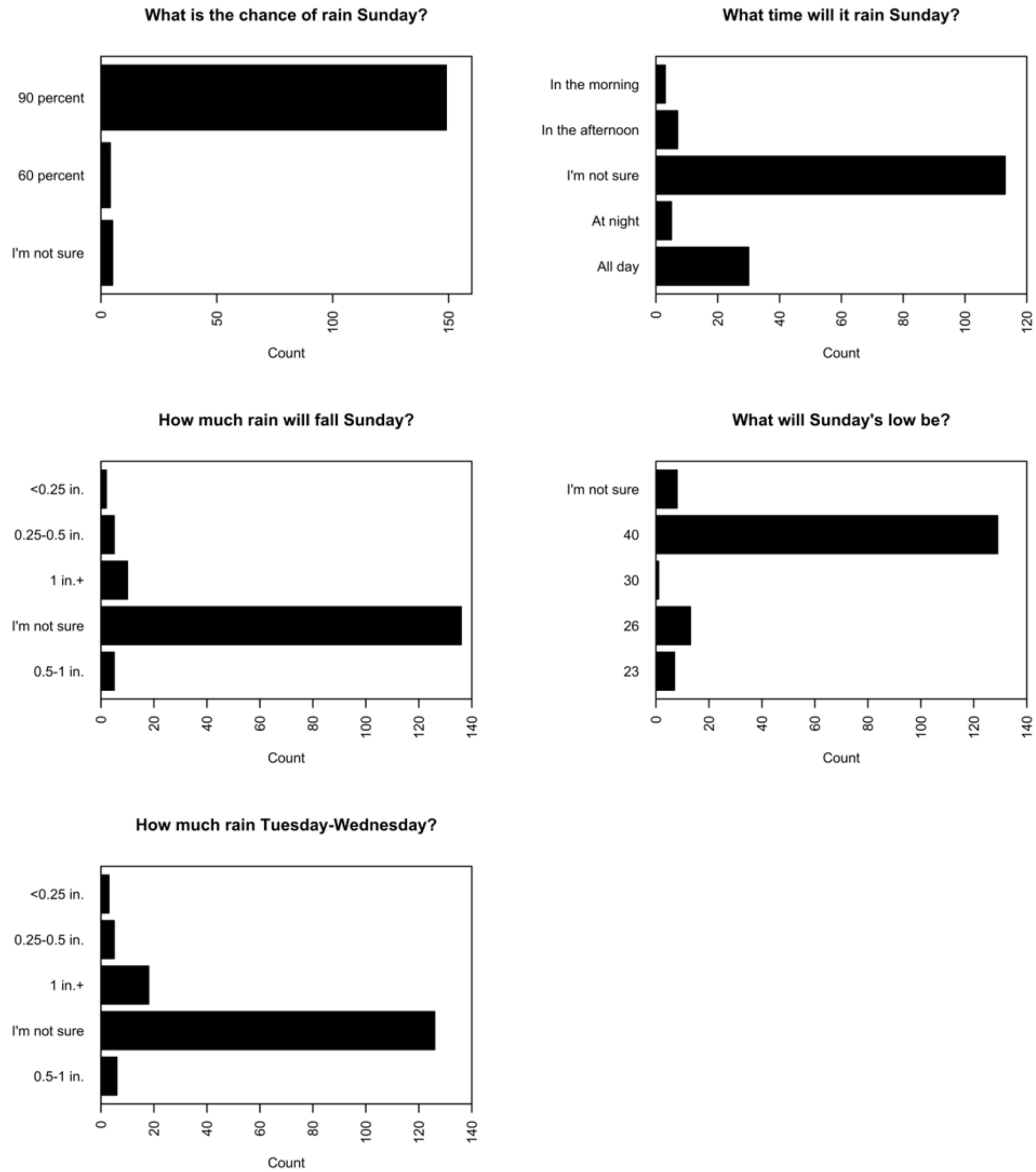

Figure 5: Answers to questions about the EFG in Figure 2. N = 158 for each question.

Results from this question are in agreement with previous studies (Zabini et al. 2015; Joslyn et al. 2009) that suggest than in search of additional information not present on the EFG, people try to infer the information they want from the weather icon present, the PoP, or any text that may be present (i.e. “isolated”, “scattered”). The second most frequently chosen answer to Question 2 was “All Day.” Previous research has shown the public has a tendency to mistakenly conflate high PoPs with either high intensity and/or high amount and/or long-duration precipitation events (Zabini et al. 2015; Joslyn et al. 2009). This can sometimes be much different from what the meteorologist intends to convey. Indeed, Sealls 2015's study of broadcast meteorologists and their audiences revealed differences in how both groups assigned PoPs to various forecast scenarios. Because Sunday's forecast shows a 90% PoP, some may have interpreted this as meaning it was going to rain all day, which may or may not have been the intent of the broadcast meteorologist.

Furthermore, the single weather icon shown on each day of the EFG is often misinterpreted (Zabini et al. 2015). When surveyed on the interpretation of weather forecast icons like the ones used in the EFG, Zabini et al. 2015 and Joslyn et al. 2009 find that the public's interpretation of the forecast icon was *almost always* different from what the forecaster intended. For example, a broadcast meteorologist may select an icon with sunshine and a small thunderstorm to indicate the chance of isolated afternoon summer storms, but this may be interpreted by the public as an assurance of precipitation. Another possible explanation of people believing it was going to rain all day Sunday (Question 2) was because of the heavy rain icon shown. This type of icon may be perceived by the public as a guarantee of rain and may lead to a false alarm if this conflicts with what the meteorologist had in mind when choosing that icon (Joslyn et al. 2009). The potential for false alarms to erode the relationship of trust has been well documented (Sherman-Morris 2005; Joslyn et al. 2009, 2012; Ripberger et al. 2015). Participants were able to identify the PoP included in Sunday's forecast (94% accuracy), as well as the low temperature forecast for Sunday morning (82% accuracy). These two elements are displayed prominently in the EFG in Figure 2, so these results are encouraging.

The open-ended responses to questions about the EFG in Figure 2 produced a variety of answers and opinions. Specifically, a question prompting participants to comment about the EFG offered perhaps the greatest insight into what people like or dislike about the EFG and how the EFG could possibly be modified to better match the demands of public audiences (Table 4). Comments were summarized into categorical themes. Some of the themes contained multiple comments that could be easily grouped together, while other themes consisted of one common phrase. Of the 157 participants that responded with comments, a total of 61 (39%) made critical comments about the deficiencies of the EFG. The most frequent comments from the Critical category (category 1) were a desire for more information, more specific information, and the timing, intensity, and amount of precipitation to be included. The lack of sub-daily timing of precipitation was the primary problem for four other participants. The Positive or Favorable Opinion category (N = 27, 17%) was characterized by general likes with less feedback than the Critical category provided. The Simple and Easy to Understand category had 11 responses. Likewise, the Status Quo category (N = 19, 12%) were participants who simply answered the EFG was “ok” or “fine”, which did not provide much feedback. A total of ten participants commented None or Nothing, while the remaining 29 provided responses that did not answer the question or were incoherent expressions. Ten of these 29 responses were likes or dislikes about the weather on the EFG, but nothing specific about the graphic itself. If the Positive, Simple, and Status Quo categories are combined, then that sum of 57 is nearly the same size as the Critical category. The categories of these responses come from a sample that is more educated than the general population. It is unclear how the categorical responses would change with a more representative sample, but it is believed that there would be slightly fewer Critical responses than the 39% found here. Thus, it can be hypothesized that roughly one third of a broadcast meteorologist’s audience critically watches and questions the details of an EFG. This number is important to consider because these viewers are more likely to remember forecast errors and raise questions.

Table 4: Categories of public comments on EFG shown in Figure 2. Respondents were prompted to write what they liked or did not like about the EFG.

Category	Value	Example Responses	N	% of total
1	EFG is deficient	"It doesn't give enough information." "Some key points are missing." "The low temperatures are a little confusing as to what day they apply." "It is not easy to understand the numbers since they are not labeled in any way." "It doesn't tell if there will be storms, or if some of the rain will change to snow." "It is not very informative."	61	39%
2	Status quo	"It is okay."; "It is fine."	19	12%
3	Simple & easy to read	"It is simple and easy to read."	11	7%
4	Positive, favorable opinion	"I like that it is self explanatory"; "I like to see several days ahead."	27	17%
5	None or nothing	"Nothing"; "N/A"	10	6%
6	Response not applicable	"Channel 2 News"; "James Spann"; "Mostly rain and below 60 degrees"; "Too cold, too much precipitation"	29	18%

Other responses not related to precipitation amounts, timing, or intensity helped explain another aspect of this graphic that may create confusion: forecast high and low temperature placement. The position of the low temperatures on the EFG in Figure 2 is staggered, meaning it is located between each day's forecast. The staggered nature of forecast highs and lows, a common EFG design scheme used by many television stations, may be the reason for the drop in number of correct responses about Sunday's forecast low temperature. Approximately 14% of people chose "26", which was located between Sunday and Monday, indicating this was the forecast low for Monday morning. One respondent commented that "it was always difficult to determine which [low temperature] numbers go with a certain day." Another said "it was not easy to understand the numbers, because they are not labeled in any way." Other comments regarding the EFG's lack of distinction between morning and afternoon weather, and the general lack of details highlight significant flaws in the design of this graphic, which are the subject of a separate manuscript. Some erroneous answers may be due to answer choice randomization and respondents clicking rapidly through the survey.

f. EFG length and timing

Factors not related to the design of the EFG may also contribute to the confusion created by this graphic. The length of time the EFG is shown during a weather broadcast and the order in which it is shown relative to other graphics are both important aspects which have not previously been studied. While the EFG is occasionally shown at times during the local newscast outside of the weather segment, it is normally reserved for a small window during the roughly three minute weathercast. The main weather segment usually happens between ten and 20 minutes after the start of the newscast, and after at least one commercial break. A total of 98% (N = 113) of those surveyed say they show the EFG at the end of their main weather segment, despite 53% saying it is the most important graphic. The reasoning behind "holding" the EFG until this point is to keep viewers watching the broadcast longer, which can lead to increase advertising revenue for the television station. In most cases, this is a decision made outside the control of the broadcast meteorologist. Where this logic breaks down is in the example of a severe weather situation when storms might be active on radar, requiring the immediate and constant attention of the meteorologist. In this case, it is reasonable to assume that radar would be the most important graphic shown, and it would be shown first and frequently, if not continuously depending on the severity of the situation. If the EFG is generally the most important graphic, it should be shown first, or at least not last in the series of graphics the broadcaster shows.

A total of 60 newscasts from 20 stations in the study area of Figure 1 were watched. An equal number of newscasts were sampled from weekday morning, midday, and evening time periods. Figure 6 (A & B) shows a comparison of the amount of time the EFG is shown versus the total time of the main weather segment. Our results reveal another dimension to the EFG problem; the public may not have enough time to digest any of the information that is present.

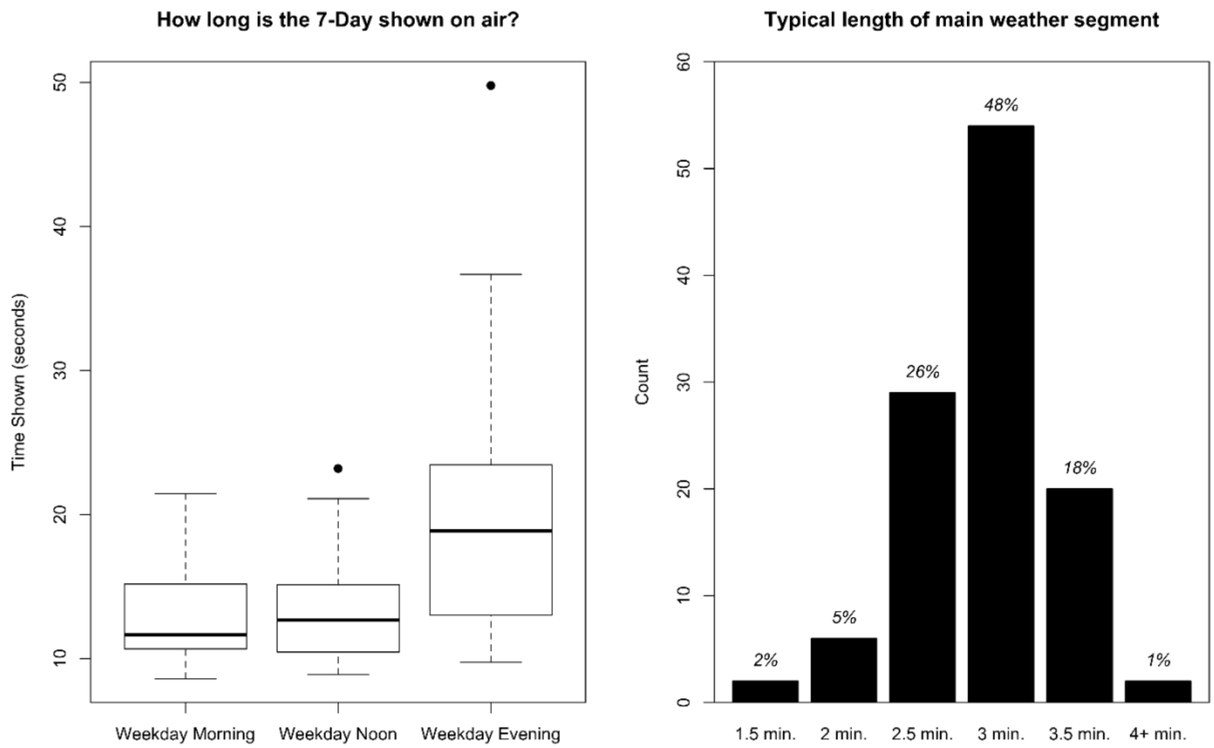

Figure 6: A.) Boxplot of length of time the EFG is shown across 60 newscasts from 20 stations, divided into three main time groups. B.) Typical length of main weather segments, according to broadcasters surveyed (N = 113).

The EFG is shown for the shortest amount of time during weekday morning newscasts (μ=12.96 seconds). The average time the EFG was shown during weekday Noon or midday newscasts was 13.51 seconds. Broadcasters working the weekday evening shift showed the EFG for an average of 20.26 seconds. The minimum time the EFG was shown was 8.6 seconds (weekday morning) and the longest time the graphic was shown was 50 seconds on a weekday evening newscast. The results of a KW test show a statistically significant difference across the three groups $X^2(2)$ =11.724, p<.001. It is important to remember that in the online survey, people were given unlimited time to view the EFG while answering the questions, and the public was still unable to identify important information. What information can be retained in 12-20 seconds? A goal of broadcasters should be to increase the amount of time the EFG is shown, and also work to keep the length of time shown consistent across all newscasts. A person watching a morning newscast should not have less time to digest the information shown on the EFG than someone watching during the evening. Based on our findings, there is room to increase the amount of time the EFG is shown in all time slots. Figure 6B shows the amount of time broadcasters say they typically have for their main weather segments. Almost half say their weathercasts are typically three minutes long. Additionally, broadcasters were asked to estimate the length of time they show the EFG, and the mean answer was 23.5 seconds. Because this is higher than any of the values observed during the 60 newscasts, broadcasters may be overestimating the time they are showing the EFG, and possibly overestimating the graphic's efficacy.

CHAPTER 4

SECOND PUBLIC SURVEY: METHODOLOGY

a. Designing New EFGs

Four new EFGs were evaluated in this research (Figure 7). While each EFG had differences in the hypothetical forecast data shown and arrangement of forecast variables, they were alike in that they attempt to overcome deficiencies in the current EFG format. These deficiencies have been described in detail earlier in the thesis. The public expressed a desire for more detailed information in the EFG. The primary goal in designing the new EFGs was to include more of the forecast information people prioritize, such as rainfall timing and intensity. Other complaints about the current EFG format targeted the lack of labels for temperatures and delineation of daytime versus nighttime weather. Each of the new EFGs was created using Baron Lynx weather graphics software version 1.03 (https://www.baronweather.com/baronlynx/).

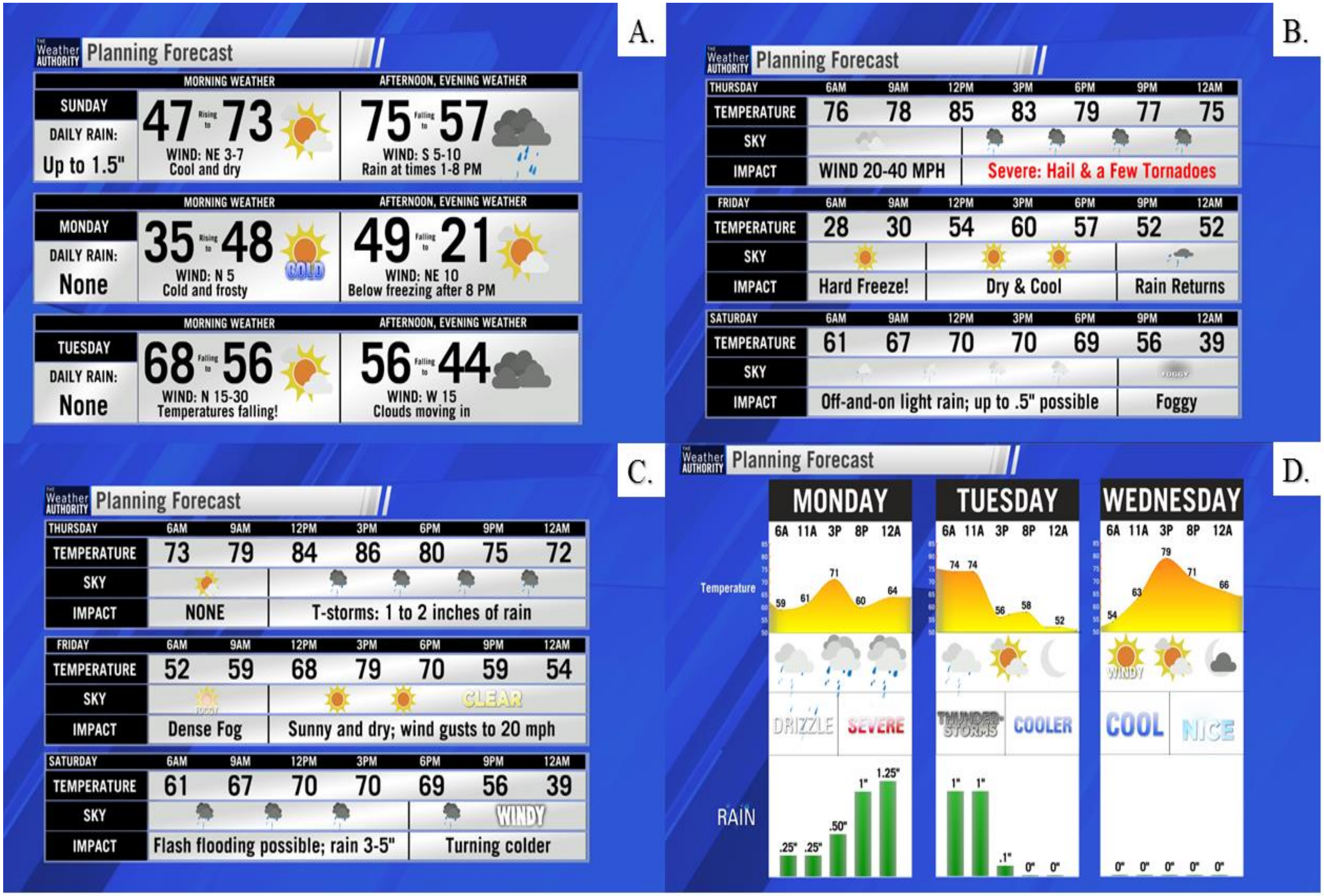

Figure 7: Four examples of new extended forecast graphics tested in this study.

The next several subsections describe the design of each new EFG shown in Figure 7, as well as the similarities and differences between each of the new graphics and the current format.

i. Figure 7A

Figure 7A shows the first new EFG used in this research. This EFG primarily differs from the current format in two ways: the new graphic contains fewer days of information and is oriented horizontally rather than vertically. Three days of forecast data are shown in this new version of the EFG. A novelty of this graphic is that instead of organizing the day hourly, there were two boxes of information, one for morning weather and another for afternoon and evening weather. The goal of breaking the day's forecast into two parts was to be able to illustrate differences in morning versus afternoon or evening weather, which cannot be done with the current EFG format (Figure 8). This utility is especially helpful for atypical weather situations, such as when the warmest part of the day is not during the afternoon. An example of how this kind of forecast is handled by the new EFG is shown on Tuesday's forecast. The graphic displays that the morning temperature will fall from 68 to 56 degrees, and then from 56 to 44 degrees through the afternoon and evening. In the current EFG format with a single high and low temperature, there is no indication of *when* the high or low will occur, and this creates the possibility of someone misinterpreting the forecast in the event of atypical weather. Because it is generally (and correctly) assumed that the warmest part of the day is the afternoon, this graphic is more functional since it should prevent someone from being surpirsed by the temperature falling during the day.

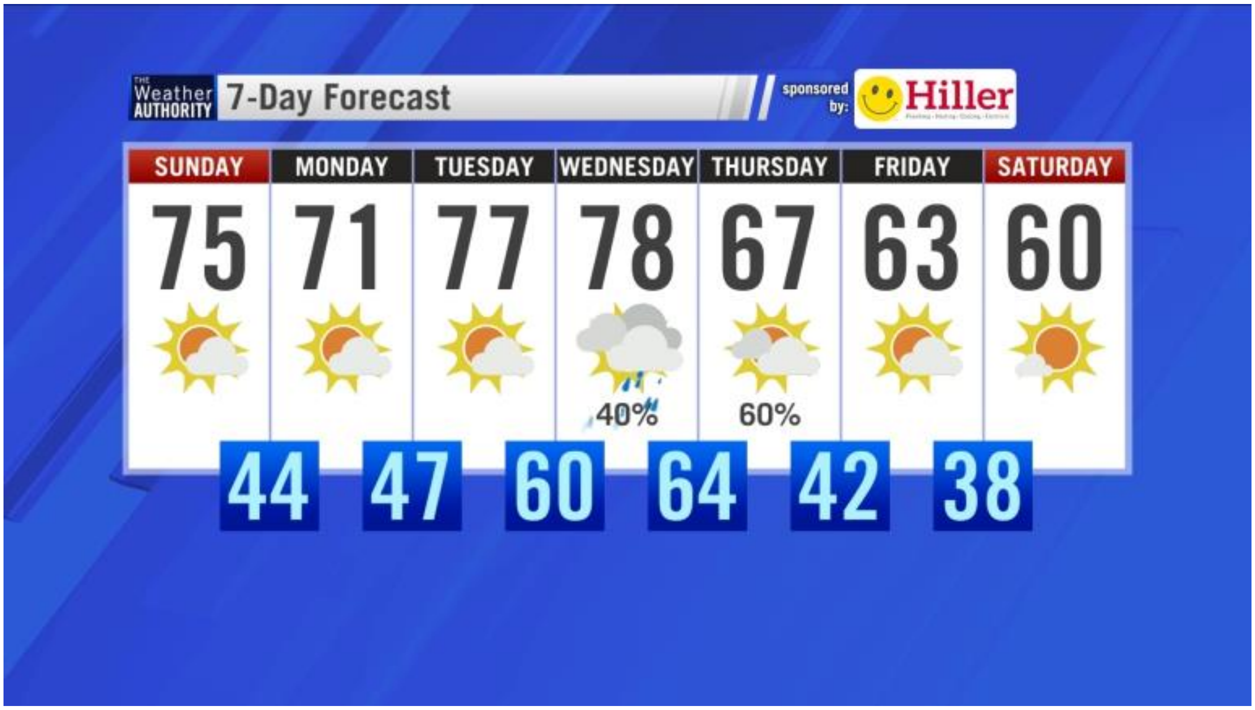

Figure 8: Example of current EFG format used at most television stations across the country.

The other two days' forecasts show the temperature on Sunday rising from the 40s to the 70s and then falling back to the 50s. The morning forecast panel shows that dry weather is expected, but rain will develop in the afternoon and evening time periods. Saturday's forecast shows a colder scenario, with temperatures rising from 35 to 49 degrees, falling to 21 in the evening. Additional forecast text on Saturday's evening forecast panel informs the viewer that temperatures will drop below freezing, an important threshold for many, by 8 p.m. One advantage of arranging the EFG horizontally rather than vertically is having the ability to include more descriptive text about impactful weather conditions.

Wind speed and wind direction are included in Figure 7A. These variables may be of importance to some, and are not usually included in the current format of the EFG. Additionally, each day in this new EFG contains a box for a daily rain total, whereas the current format of the EFG does not allow for information about rainfall amounts.

ii. Figure 7B and 7C

Figure 7B and 7C are nearly identical and thus will both be described in this subsection. Similar to Figure 7A, Figure 7B and 7C are arranged horizontally and are designed to be read across each day and then down to the next day. These EFGs are unique in that they display each day's forecast weather in hourly segments with multiple temperatures and icons for each time period. Previous research has shown the public has a tendency to misinterpret weather icons (Zabini 2016; Zabini et al. 2015; Joslyn et al. 2009) used on graphics like the EFG, but it is unclear whether or not the misinterpretation is due to the design of the icon itself, or the fact that in most cases a single icon is used to represent an entire day's worth of weather. The limitations of using a single icon to represent atypical and even routine weather were previously discussed earlier in the thesis. These two graphics also include a space for the meteorologist to include statements about the impacts of the forecast, such as severe or hazardous weather. Graphics 7B and 7C share the advantage 7A has of being able to clearly display atypical weather conditions, but in this case with a finer temporal scale.

iii. Figure 7D

Figure 7D is the most unique of the new EFGs evaluated in this paper, and it is also the most different from the current EFG format. The only similarity Figure 7D shares with the current format is that the graphic is oriented vertically rather than horizontally like the three other new EFGs. The most striking element of this EFG is that it contains meteograms to illustrate temperature patterns and bar graphs for anticipated rainfall. While it is common practice to use meteograms and bar graphs in television weather broadcasts, they are almost never a part of the EFG. The use of bar graphs and meteograms on television weather graphics has not been studied, so evaluating them as part of the EFG will provide useful insight as to whether or not these elements are effective at communicating weather forecasts in the broadcast format. The advantage of using a temperature meteogram is that it allows a chance to better visualize temperature changes over time, which is especially critical in the event of atypical weather. An example of this situation is shown on Tuesday's forecast in Figure 7D. The meteogram shows the temperature dropping from the middle 70s to the 50s from the morning to the afternoon. On the current EFG format, the meteorologist is limited in how this situation can be explained. Should the highest temperature of the day be put as the forecast high, even if it occurs at a time other than the afternoon? Should the temperature that will occur in the middle of the afternoon be shown as the high temperature? With the new EFG, there is less opportunity for confusion because the decreasing temperature trend throughout the day is clearly illustrated.

The EFG in Figure 7D has space between the temperature meteogram at the top of the graphic and the rainfall bar graph at the bottom for the meteorologist to add icons and/or text icons. This allows this graphic to be customized based on what type of weather is expected, with more room than on the current EFG format. The bar graphs at the bottom of the graphic show accumulated rainfall over each of the time periods shown on the EFG. While this is more detail than the current EFG format provides, it is possible this arrangement is not as effective or easy to understand as how forecast rainfall is communicated on EFGs A-C in Figure 7. Even so, it is hoped that feedback gathered from this EFG will aid in creating future graphics that are effective in communicating all aspects of a weather forecast.

b. Survey Design and Distribution

i. Public Survey

A 27-question online survey consisting of demographic, weather graphic opinion, interpretation and comprehension, and free-response questions was created using Qualtrics. A majority of the questions in this survey were related to each of the new EFGs described in the previous section. One screener question was included to ensure that only individuals who routinely watch television weather broadcasts participated. Of the more than 1,300 people who opened the survey, 885 passed the screener question. Therefore, the sample size is 885. Because participants could skip questions or parts of questions, occasionally the sample size for an individual question was lower than 885.

ii. Survey Distribution

Three prominent broadcast meteorologists who work in Alabama graciously agreed to distribute this survey and solicit responses through their social media platforms (i.e. Facebook, Twitter, etc.). The spatial distribution of responses mirrored each of the meteorologists' television market areas (Figure 9). The highest concentration of participants was in central and northern Alabama, overlapping with locations where two of the broadcasters work. Another grouping of responses was located closer to the Alabama Gulf Coast and Florida Panhandle, where the third broadcaster works. Other participants were located outside the state of Alabama, with some living as far west as California and others living in the Great Lakes and Northeast.

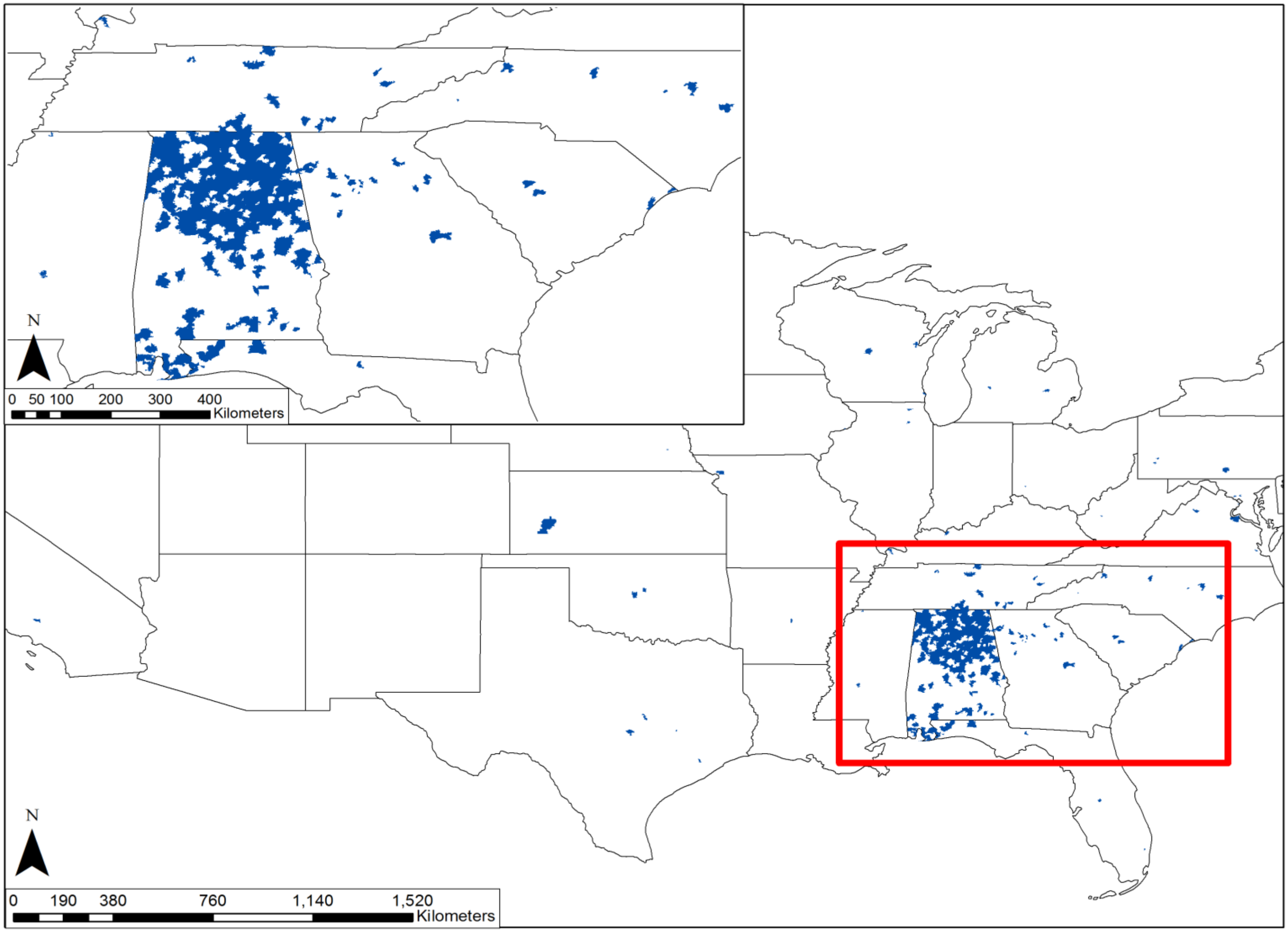

Figure 9: Footprint of participants by zip code in the general public survey posted on social media by three broadcast meteorologists in Alabama (N = 885).

c. Data Analysis

A mixture of quantitative and qualitative procedures were used to compare and contrast the likeability and usefulness of each of the new EFGs versus the current format. These procedures are divided into subsections within this section to facilitate the organization and rationale for the analysis.

i. Comparing the new EFGs against the current format

A primary goal of this paper was to create hypothetical new EFGs to better communicate weather forecasts by including more of the information people want, but without sacrificing the likeability or usefulness of the EFG. The next few sentences summarize earlier research from the thesis on this subject, but they are important to recall for this step of our analysis. Although the EFG is a hallmark of television weather broadcasts – even being named the most important graphic shown by a majority of broadcasters surveyed, there are numerous challenges which limit its effectiveness. For example, the current format of the EFG does not allow forecasters to adequately or wholly display information about hazardous or severe weather. The EFG in many cases also does not contain the information the general public prioritizes, such as precipitation intensity or timing. Furthermore, there is almost never a display for nighttime weather. In the current paper, the new EFGs we evaluated each tackle one or more of the issues listed above. The biggest difference between the current format of the EFG and the new ones put forth in this paper is that the new EFGs contain fewer days and have no probability of precipitation information anywhere on the graphic. Reducing the number of days shown on the graphics from seven to three allows us the ability to add more specific information for each day and include more information people want.

Unpublished data from the author revealed that a majority of broadcasters show seven days on their EFGs, with a handful surveyed showing more than ten. It is unclear, however, how or why this number of days was chosen. Showing seven or more days on an EFG allows the meteorologist very little space or time to include specific details on a graphic that is highly sought after. Perhaps people would be receptive to a graphic that has fewer days but contains much more specific information? Participants of the survey were asked the following question after looking at each new EFG and the current format:

1. After looking at the weather graphic above, to what extent would you agree or disagree with the following statement:

   > "This weather graphic was easy to understand and includes the information I need to plan for the next three days."

Hereafter, this question is referred to as the 'usefulness' question. Respondents were asked to rank their agreement on a Likert scale of strongly disagree to strongly agree. Values were coded from 1 (strongly disagree) to 4 (strongly agree) after the survey was closed in order to perform statistical analysis. Responses to this question were considered to be a proxy for how much people liked and understood each of the new EFGs. The analysis performed here consisted of a one-tailed z-test of each of the mean agreement values for the new EFGs against the results to the same question about the current format. A one-tailed test was used because the intent was to determine if there was a statistically higher level of likeability and usefulness in the new EFGs above the current format.

ii. Comprehension of the new EFGs

Earlier research in the thesis revealed that more than 80% of people were not able to answer basic questions about the weather forecast after looking at the EFG in its current format.

This inability to answer was largely due to the fact that the information being asked about was not contained within the EFG. The questions included identifying the forecast high and low temperatures, timing of precipitation, intensity of precipitation, and expected amounts of precipitation. Nearly identical questions were asked of participants in this survey with each new EFG, as well as with the current format. Each of these questions was closed-response with correct answers and therefore are graded and discussed as percentages of correct or incorrect answers. The next subsection outlines the questions asked about each of the new EFGs and the current format. The graphic being referred to by each question is listed in the title of each subsection.

1. EFG in Figure 7A
    a. What will the low temperature be Sunday morning?
    b. What will the high temperature be on Tuesday?
2. EFG in Figure 7B
    a. How much rain would you expect to fall on Saturday?
    b. Approximately when would you expect the rain to begin on Friday?
3. EFG in Figure 7C
    a. Approximately when would you expect the rain to begin on Tuesday?
4. EFG in Figure 7D
    a. Approximately when would the high temperature occur on Tuesday?
    b. Approximately how much rain will fall on Tuesday?
5. EFG in Figure 8 (current format)
    a. Approximately how much rain will fall on Wednesday?
    b. Which day of the week will feature the heaviest rain?

The questions listed above are referenced as 'comprehension' questions in the Results section. It is important to note that the order in which the new EFGs and current format were shown was randomized, as were the answer choices to each question.

iii. Revisiting the purpose of the EFG

In order to test the robustness of the author's findings which revealed the importance of the EFG in a weathercast, we asked respondents to rank their level of agreement with the following statement: "When I watch a weather broadcast, I pay close attention to the extended forecast." Values were coded from 1 (strongly disagree) to 4 (strongly agree) after the survey was closed and the mean values are presented in the Results section. Respondents were also asked how many days into the future did they believe forecasters could accurately predict. This question was designed to gauge how many days into the future the general public wanted to see on the EFG based on how far into the future they felt forecasts were accurate. Perhaps people only want to see data they feel is accurate and therefore would be okay with having fewer days presented on the EFG. We paired this analysis with the survey of 113 broadcast meteorologists (described earlier in the thesis) in an attempt to further justify our assertion that showing fewer days on the EFG but having more information is a viable solution to the limitations that exist in the current EFG format.

CHAPTER 5

SECOND PUBLIC SURVEY: RESULTS

a. Demographics of Public Survey

Despite our large sample (N=885), there was a lack of diversity among respondents (Table 5). Females comprised 66% of survey participants whereas 33% were male. There was a large spread in the ages of respondents, with the greatest number falling between 35 and 64 years old (approximately 68%). A total of 845 of the 885 people who took the survey identified themselves as Caucasian (95.7%). Although beyond the scope of this paper, we believe this is an unintended but critical finding related to broadcast meteorologists' social media reach that will be discussed further in the Conclusion section. More than 85% of participants reported themselves as having at least some college education; approximately 50% had at least a 4-year college degree.

Table 5: Demographic data for the general public survey.

Variable	N	% of total
Gender		
Female	587	66.6%
Male	292	33.1%
Transgender	1	0.1%
Other	2	0.2%
Age		
18-24	34	3.8%
25-34	167	18.9%
35-44	209	23.6%
45-54	202	22.8%
55-64	182	20.6%
65-74	84	9.5%
75-84	7	0.8%
Ethnic Identification		
Caucasian	845	95.7%
African American	10	1.1%
American Indian/Alaska Native	12	1.4%
Asian	3	0.3%
Native Hawaiian/Pacific Islander	1	0.1%
Hispanic/Latinx	4	0.5%
Other	8	0.9%
Education		
Less than high school	11	1.2%
High school graduate	120	13.6%
Some college	221	25.0%
2-year degree	92	10.4%
4-year degree	262	29.6%
Professional degree	179	20.2%

b. New versus old EFGs: Usefulness and comprehension

Three out of the four new EFGs (Figure 7A,7B, and 7C) evaluated in this paper had a statistically significant higher level of likeability and usefulness over the current EFG format (Table 6 and Figure 10). In order to closely follow the Methods section, this subsection will include the results of the usefulness question for each new EFG and the current format. Additionally, each of the comprehension questions for the new and old EFGs will also be presented (Table 7).

Table 6: Raw scores of the level of agreement that the new EFGs are easy to understand and are helpful. The results of the z-tests of each new EFG against the current format are shown. P-values in bold are significant at a >95% confidence interval.

EFG	Mean score	Variance	N	Z	P-value
Fig. 7A	2.787	0.6	883	3.11	**.001**
Fig. 7B	2.985	0.554	882	10.108	**<.001**
Fig. 7C	3.036	0.545	882	11.879	**<.001**
Fig. 7D	2.693	0.668	881	-0.036	0.971
Fig. 8 (Current Format)	2.695	0.652	884	--	--

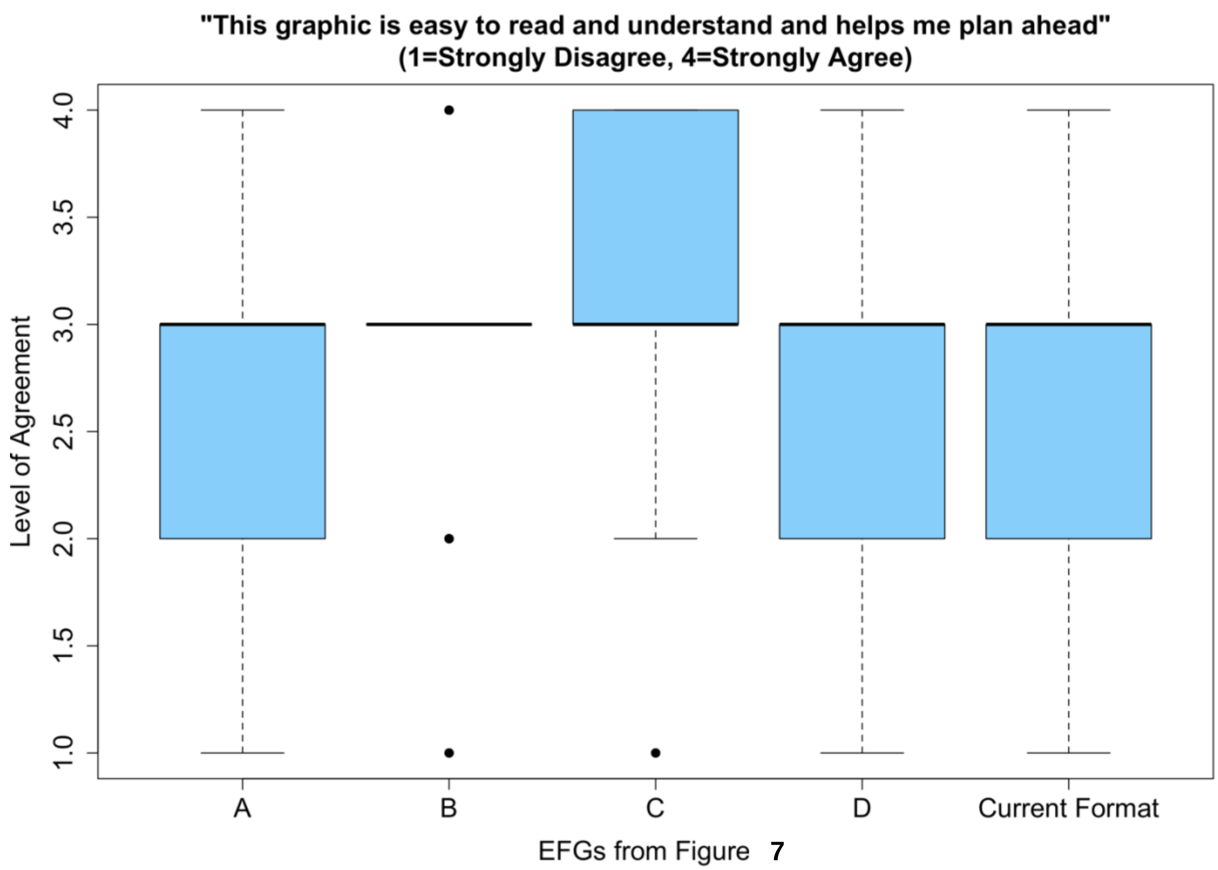

Figure 10: Boxplot showing the levels of agreement with the statement "this graphic is easy to read and understand and helps me plan ahead" for each of the EFGs in Figure 7 and the EFG in Figure 8.

Table 7: Results of the comprehension questions for each new EFG and the current format. The % correct column in Part A is left blank because the correct answer to this question was "I'm not sure," because the answer was not on the graphic.

a.) EFG	Question	% Correct	% Incorrect	% Not Sure
Fig. 7A	What will the low temperature be Sunday morning?	98%	1%	1%
	What will the high temperature be on Tuesday?	68%	31%	1%
Fig. 7B	How much rain would you expect to fall on Saturday?	93%	5%	2%
	Approximately when would you expect rain to begin on Friday?	91%	7%	2%
Fig. 7C	Approximately when would you expect rain to begin on Thursday?	17%	79%	4%
Fig. 7D	When will the high temperature on Tuesday occur?	95%	3%	2%
	Approximately how much rain will fall on Tuesday?	61%	33%	6%
Fig. 8	Approximately how much rain will fall on Wednesday?	--	20%	80%

b.)		
Fig. 8		
Which day of the week will feature the heaviest rain?	N	% of total
Tuesday	5	1%
Wednesday	247	28%
Thursday	486	55%
Friday	2	<1%
I'm not sure	143	16%

i. EFG in Figure 7A

Out of 883 responses, the EFG in Figure 7A had a mean usefulness score of 2.787 with a variance of 0.6 (Table 6). This is compared to the mean usefulness score of 2.695 (Table 6) for the EFG in Figure 8, which represents the current EFG format. The results of the one-tailed z-test (Table 6) for the EFG in Figure 7A and the EFG in Figure 8 reveal the higher usefulness score of the EFG in Figure 7A is statistically significant (Z=3.11; p=.001).

Almost every person was able to correctly identify the forecast low temperature for Sunday morning (98%; Table 7). There was, however, some confusion when asked about the high temperature expected on Tuesday. As was described in the Methods section, Tuesday's forecast featured an atypical weather day where the temperature fell throughout the day. The graphic shows the temperature falling from 68 to 56 in the morning and then from 56 to 44 in the afternoon and evening. Of the 31% of incorrect responses to this question, 29% of people chose

56 as the expected high temperature. We believe several participants chose this value because it was the first value in the afternoon weather forecast panel. Because the high temperature usually occurs during the afternoon, respondents may have instinctually glanced at only the afternoon forecast panel when looking for the high temperature. In this case, many people overlooked the temperature that was 10 degrees higher in the morning forecast panel. This suggests that people may not understand that daily meteorological highs and lows are assessed from midnight to midnight.

ii. EFG in Figure 7B

The EFG in Figure 7B has a usefulness score of 2.985 (N=882; Table 6) with a variance of 0.554. Results of the one-tailed z-test against the current format of the EFG reveal another statistically significant increase in the usefulness score of this new EFG ($Z=10.108$; $p<.001$).

The EFG in Figure 7B had more than 90% correct answers to both questions (Table 7). Participants were able to identify forecast amounts of rainfall on Saturday and timing of when rainfall would begin on Friday with a high level of accuracy.

iii. EFG in Figure 7C

This new EFG had the highest usefulness score of any of the new EFGs evaluated in this paper and likewise was much higher than the usefulness score of the current EFG format (Table 6). The usefulness score of the EFG in Figure 7C was 3.036 with a variance of 0.545 (N=882). Similar to the previous new EFGs discussed, the improvement in the usefulness score over the current format is statistically significant based on a one-tailed z-test ($Z=11.879$; $p<.001$).

Despite having the highest usefulness score, Figure 7C had the highest number of incorrect responses (Table 7) to a question than any other EFG, including the current format. Participants were asked when they thought the rain would begin on Thursday based on the graphic. Only 17% correctly answered 10 a.m.; almost 80% of the responses were incorrect. EFG 7C provides an interesting example to explore further. Thursday's forecast sky conditions and impact are clearly divided between sun and rain icons and no rain and "T-storms: 1-2 inches of rain" halfway between 9 a.m. and Noon. Of the incorrect responses, many people answered "Noon" or "12:30 – 1 p.m." which line up with where the rain icons begin. This suggests that the people looking at the graphic were paying more attention to where the icons were located rather than the dividing bar that was located between 9 a.m. and Noon. This finding suggests that future graphics that may adopt a similar format (even if not in the EFG), should carefully consider where icons are placed in relation to time, as this may influence some people's perceptions of the forecast.

iv. EFG in Figure 7D

The new EFG containing the meteograms and bar graphs was the only new EFG that did not achieve a higher usefulness score that was statistically significant over the current format. The usefulness score of this graphic was 2.693 with a variance of 0.668 (N=881). The higher variance of this EFG indicates the use of meteograms and bar graphs may have been more polarizing than the other new EFGs. When tested against the current EFG format, it was found that the usefulness decreased when compared to the current format, but it was not statistically significant (Z= -0.036; p=.971).

Almost all participants correctly answered that Tuesday's high temperature would occur in the morning (95%; Table 7). This result is encouraging because it suggests the public may not have trouble in reading and interpreting temperature meteograms. If they are understood on this graphic, they may be equally as understood when shown in other graphics or on other platforms. Fewer were sure about interpreting the bar graphs. Incorrect answers made up 33% of responses.

While more than half of responses were correct, optimism must be interpreted with caution here because the bar graphs were not labeled in a clear manner.

v. Current EFG format (Figure 8)

The usefulness score of the current EFG format was 2.695 with a variance of 0.652 (N = 884). Based on our Likert scale, the usefulness of the current format of the EFG was meager. The results of the comprehension questions relating to the current EFG format are in strong agreement with the findings described earlier in the thesis: the current EFG is a source of confusion because people cannot accurately answer questions about the forecast after looking at the graphic. In this round of questions, participants were not able to correctly identify how much rain would fall on Wednesday based on the information in the EFG (Table 7). Approximately 80% said they were not sure. The second question related to this EFG required people to identify which day would feature the heaviest rainfall. More than half selected Thursday. We believe this is because Thursday has a high probability of precipitation (60%), and there is a wealth of previous research indicating the tendency for people to mistakenly conflate high PoPs with high amounts or high intensity rainfall (Zabini 2016; Zabini et al. 2015; Joslyn et al. 2009). Interestingly, although Thursday has a higher PoP, the icon for Wednesday seems to indicate heavier precipitation, and still over half selected Thursday as the day with the heaviest rainfall potential. This may suggest that the public places more emphasis on the PoP than the weather icon when evaluating what intensity or amount of rain to expect. Still, in this case it cannot be determined from this graphic whether or not Thursday will have the heaviest rainfall and so the public may have incorrectly perceived this forecast.

c. Number of days shown in an EFG

Lazo et al. 2009 found that the public's confidence in weather forecasts is higher in the short term (Days 1-3) than in the long term, where more than half of respondents in that study had 'very low confidence' in forecasts seven to 14 days into the future. Additionally, previous research has shown the public has a tendency to begin paying attention to impending weather events and making decisions about them two to three days in advance (Myers, 2019). These studies in particular revealed a sharp difference in the usefulness of weather forecasts for the short term versus those of the long term. In other words, the general public does not view the short term forecast in the same manner as the longer term forecast. Perhaps this is why the new EFGs with fewer days into the future of forecast information were preferred over the current format. We asked participants how many days into the future they felt forecasters could accurately predict, and the results are presented in Figure 11.

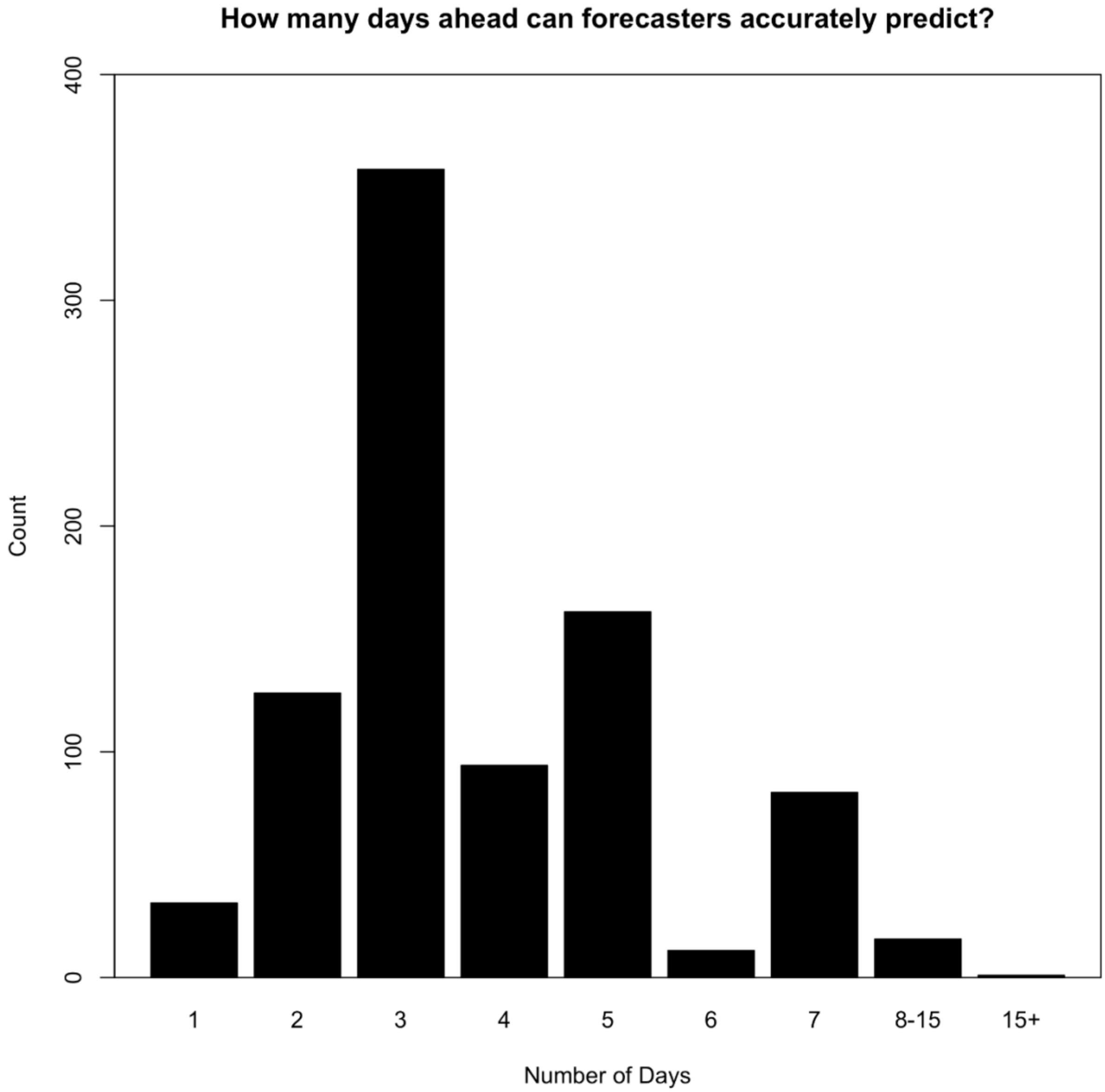

Figure 11: The number of days into the future people believe forecasters can accurately predict (N=885).

Fifty-eight percent of the public answered three days or less. These results and analyses are not intended to support the elimination of long range forecasts or discussions of future trends in weather rather than only short term specifics. Indeed, people should be alerted to potential hazardous weather, such as a severe weather outbreak, land-falling hurricane, or dangerous heat waves, as far in advance as possible. However, when evaluating the current format of the EFG, days one and seven are treated equally in that they each have a single forecast high and low temperature, single weather icon, etc. This may imply the forecaster has just as much confidence in the next day's forecast as in the forecast seven days in advance. Furthermore, in the case of the land-falling hurricane or gripping heat wave, the EFG is not designed to communicate all the hazards and necessary information that are included in those types of forecasts due to limitations described in this thesis.

CHAPTER 6

DISCUSSION AND CONCLUSION

Our results suggest that the weather graphic named as most important by broadcast meteorologists is confusing and easily misunderstood by the public. While previous studies have focused on improving tornado watches (Mason & Senkbeil, 2015), advancing comprehension of radar color schemes (Bryant et al., 2014), and more effective hurricane track and surge forecasts (Sherman-Morris et al. 2014; Radford et al. 2013), this study is one of the first to assess the public's perception and comprehension of a graphic produced by local television stations. Our results show the public's inability to answer important forecast questions, such as how much rain is expected to fall and when. Free-response comments from some participants suggest other aspects of the EFG are confusing, such as the placement of the high and low temperatures and the lack of any labels or distinctions between a.m. and p.m. weather.

Previous studies (Zabini et al. 2015; Joslyn et al. 2009) concluded that the public tends to conflate high PoPs with long duration and/or high intensity and/or high amounts of precipitation, and this misperception remained evident in our findings. Our findings about how the public prioritizes information about precipitation forecast variables are in accordance with Demuth et al. 2011, and can be used to improve the graphical communication of precipitation forecasts by including the information people want. Other factors that can make weather icons a source of confusion are similar to what makes the PoP incomprehensible: What does the icon represent? Is it the most inclement weather expected? Is it an average? Is it the weather expected during the daylight hours? Can a single icon represent 24 hours of weather conditions?

An analysis of 60 newscasts revealed the short length of time the public has to digest any information from the EFG, regardless of the time of day they consume weather information from television. Based on the feedback from the survey of broadcasters, it was conveyed that viewers expect to see the EFG during the main weather broadcast. Although the EFG is sometimes shown near the end of the newscast, this is usually dependent on the time remaining at the end of the newscast, which can be highly inconsistent. It should not be assumed that viewers remain watching beyond the main weathercast for the possibility of seeing the EFG again. And even if the EFG is shown at the end of the newscast, it is typically for less time than during the main weather broadcast, which was analyzed in this research. On rare occasions, if a broadcast meteorologist is asked to fill time at the end of the newscast, the EFG might be shown for at least 30 seconds or more. In these instances, the meteorologist is typically not on camera, and this may introduce other limitations to effective communication discussed previously. Our results pinpoint a few disconnects between the broadcast meteorologists and their audience. The responses from the broadcasters confirm the importance of the EFG, and they also suggest that it is an effective graphic to communicate routine and hazardous weather in a simple way, but our results suggest otherwise.

Other characteristics of the current EFG format which may contribute to the confusion include the vague or limited information contained within the graphic and the lack of information that the public prioritizes, such as timing and intensity information about precipitation. The EFG also suffers from not being designed to communicate hazardous or otherwise atypical weather, and the fact that the graphic rarely, if ever, shows nighttime weather.

The feedback from the surveys described in Chapter 2 of the thesis was used to create four new EFGs to be evaluated, with the goal of improving people's accuracy in interpreting the graphic. Our results suggest the usefulness and comprehension of the EFG can be improved by showing fewer days with more specific information, such as timing and intensity of precipitation. It was also found that showing fewer days of forecast information on the EFG and removing PoP information did not appear to lessen the graphic's likeableness. Three of the four new EFGs evaluated in this research (Figure 7A, 7B, and 7C) each had a statistically significant increase in usefulness when compared against the current EFG format. In addition to being ranked as more useful than the current EFG format, the new EFGs tested in this research also seemed to be easier to understand, based on the level of accuracy with which people were able to answer basic forecast questions. Some of the new EFGs tested had near 90% accuracy rates, whereas 80-90% of respondents were unsure of the correct answers after looking at the current EFG format both in this survey and the public survey described in Chapter 2 of the thesis.

The findings presented within this paper have created new research questions that should be answered with future projects. Because broadcast meteorologists were used to distribute and solicit responses for the survey on their personal social channels, the spatial distribution and demographic makeup of respondents offered insight into what groups of people these broadcast meteorologists are reaching. Minorities were underrepresented in the survey sample, and therefore may not be being reached by broadcast meteorologists on social media. Because social media is increasingly becoming a popular method for weather information (Myers, 2019; Pew Research Center, 2018, 2019; Phan et al., 2018), this underrepresentation is concerning because had this survey been life-saving information the broadcasters were pushing out, it would not have been received by some demographics.

It is not the intent of the authors to set the policies and strategic goals for private weather or government meteorological enterprise or to replace any existing weather graphics. Rather, our purpose is to address inefficiencies in television weather graphics and offer possible solutions, because this is an area where published research is lacking. Any potential changes to forecast products would require considerable discussion and careful consideration by the meteorological community and continued research before any changes are formally implemented.

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APPENDIX

INSTITUTIONAL REVIEW BOARD CERTIFICATION 1

THE UNIVERSITY OF ALABAMA | Office of the Vice President for Research & Economic Development
Office for Research Compliance

March 5, 2018

Jacob Reed
Dept. of Geography
College of Arts & Sciences
Box 870322

Re: IRB#: 18-OR-095 "Probability of Precipitation and Perceived Weather Forecast Accuracy"

Dear Jacob Reed:

The University of Alabama Institutional Review Board has granted approval for your proposed research.

Your application has been given expedited approval according to 45 CFR part 46. You have also been granted the requested waiver of written documentation of informed consent. Approval has been given under expedited review category 7 as outlined below:

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies

Your application will expire on March 4, 2019. If your research will continue beyond this date, complete the relevant portions of the IRB Renewal Application. If you wish to modify the application, complete the Modification of an Approved Protocol Form. Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants. When the study closes, complete the appropriate portions of the IRB Request for Study Closure Form.

Please use reproductions of the IRB approved stamped consent form to provide to your participants.

Should you need to submit any further correspondence regarding this proposal, please include the above application number.

Good luck with your research.

Sincerely,

Carpantato T. Myles, MSM, CIM, CIP
Director & Research Compliance Officer

358 Rose Administration Building | Box 870127 | Tuscaloosa, AL 35487-0127
205-348-8461 | Fax 205-348-7189 | Toll Free 1-877-820-3066

INSTITUTIONAL REVIEW BOARD CERTIFICATION 2

THE UNIVERSITY OF ALABAMA | Office of the Vice President for Research & Economic Development
Office for Research Compliance

February 15, 2019

Jacob Reed
Department of Geography
College of Arts & Sciences
The University of Alabama
Box 870322

Re: IRB # 18-OR-095-R1 "Probability of Precipitation and Perceived Weather Forecast Accuracy"

Dear Mr. Reed:

The University of Alabama Institutional Review Board has granted approval for your renewal application. Your renewal application has been given expedited approval according to 45 CFR part 46. You have also been granted the requested waiver of documentation of informed consent. Approval has been given under expedited review category 7 as outlined below:

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

The approval for your application will lapse on February 14. 2020. If your research will continue beyond this date, please submit the (continuing review or annual report) to the IRB as required by University policy before the lapse. Please note, any modifications made in research design, methodology, or procedures must be submitted to and approved by the IRB before implementation. Please submit a final report form when the study is complete.

Good luck with your research.

Sincerely,

Carpantato T. Myles, MSM, CIM, CIP
Director & Research Compliance Officer

358 Rose Administration Building | Box 870127 | Tuscaloosa, AL 35487-0127
205-348-8461 | Fax 205-348-7189 | Toll Free 1-877-820-3066

INSTITUTIONAL REVIEW BOARD CERTIFICATION 3

THE UNIVERSITY OF ALABAMA | Office of the Vice President for Research & Economic Development
Office for Research Compliance

December 4, 2018

Jacob Reed
Department of Geography
The University of Alabama
Box 870322

Re: IRB # EX-18-CM-109: "Improving Public Comprehension of Forecasts with New Graphics"

Dear Mr. Reed,

The University of Alabama Institutional Review Board has granted approval for your proposed research. Your application has been given exempt approval per 45 CFR part 46.101(b)(2) as outlined below:

(2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

This approval will expire on December 3, 2019. If the study continues beyond that date, please submit the Continuing Review Form within e-Protocol. If you modify the application, please submit the Amendment Form. Changes to this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants. When the study closes, please submit the Final Report Form. Please use the IRB-approved consent form.

Should you need to submit any further correspondence regarding this application, please include the assigned IRB approval number. Good luck with your research.

Sincerely,

Carpantato T. Myles, MSM, CIM, CIP
Director & Research Compliance Officer
Office for Research Compliance

cc: Dr. Jason Senkbeil

358 Rose Administration Building | Box 870127 | Tuscaloosa, AL 35487-0127
205-348-8461 | Fax 205-348-7189 | Toll Free 1-877-820-3066