WEATHER ON THE GO: AN ASSESSMENT OF SMARTPHONE MOBILE WEATHER APPLICATIONS USE AMONG COLLEGE STUDENTS

by

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Millions of people in the United States regularly acquire essential information from weather forecasts for a wide variety of reasons. A myriad of sources exists for obtaining daily weather information, and the rapid growth in mobile device technology has created a very convenient means for people to retrieve this data. Smartphone and technology use have soared in recent years, and mobile weather applications (MWAs) have also rapidly gained popularity. Research on weather sources, however, has been unable to sufficiently capture the importance of this form of information gathering. As use of these apps continues to grow and the market expands with increasing options, it is important to gain insight on which MWAs and what MWA features are most useful to consumers. To better examine MWA preferences and behaviors relating to acquired weather information, a survey of 308 undergraduate college students from three different universities throughout the southeast United States was undertaken. Analyses of the survey showed that smartphone MWAs are the primary source among college students for seeking weather forecasts. Additionally, MWA users tend to seek short-term forecast information, like the hourly forecast, from their apps and spend very little time using the app itself. Additional results provide insight on daily MWA use by college students as well as

perceptions of and preferential choices for specific MWA features, designs, and various brands in the weather enterprise.

The information gathered from this study will allow other researchers to better evaluate and understand the changing landscape of weather information acquisition and how this relates to the uses, perceptions, and values people garner from forecasts. Companies and organizations that provide weather forecasts have an ever-growing arsenal of resources to disseminate information, making research of this topic extremely valuable for future development of weather communication technology.

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CHAPTER 1: INTRODUCTION

The atmosphere is always changing, and its conditions influence our daily lives, determining what we choose to do and how we go about our day. Weather's dynamic nature, however, means that such factors as temperature, precipitation, and wind are often constantly changing. It is no wonder people want to know the individual effects forecast conditions will bring so that they can plan accordingly.

Millions of people in the United States regularly obtain essential information from weather forecasts for a wide variety of reasons (Lazo et al., 2009). With weather being perhaps the most routinely sought after type of information, it is imperative to understand the many facets of how and why people procure this information, starting with their sources and then how people use their acquired knowledge in day-to-day activities. The rapid growth in mobile device technology has created new contemporary means for people to access weather forecasts, pointing to the need to update past literature in this specific niche of weather research.

With the onset of smartphones and the increasing use of mobile weather applications (MWAs) today, this technology is rapidly becoming the public face of weather forecasting. This study evaluates and works to understand the changing landscape of weather information acquisition and how this relates to the uses, perceptions, and benefits people garner from forecasts. The thesis addresses the following research questions:

1. What specific reasons do respondents have for choosing their favorite MWA?
2. What aspects of a weather forecast are most important to respondents, and how does that relate to the MWA that they most prefer?
3. Is there a relationship between respondents' reported activities and the information they seek about weather from their MWA?

4. How do geographic and demographic factors influence MWA use?

With these research questions, the study hopes to fill the gap in the meteorological literature on our society's preferences for where they obtain weather information. This knowledge will enhance the weather enterprise's capability to accommodate a quickly changing communication landscape. Additionally, companies and organizations within the weather enterprise that provide weather forecasts have an ever-growing arsenal of resources to disseminate information, making research on this topic extremely valuable for future development in weather communication technology.

CHAPTER 2: REVIEW OF LITERATURE

To better understand how people use mobile weather applications (MWAs), it is important to review previous research on sources, use patterns, perceptions, values, and decision-making behavior relating to acquired weather information. This literature review examines various sources of weather information and discusses the evolving nature of weather communication and information access. Further, the rapid ascent of smartphone and mobile application technology is addressed, followed by considerations of perceptions relating to confidence in weather forecasts and the inclusion of probabilistic information. Finally, a presentation of conceptual models relating to the acceptance of new innovations provides a foundation for the research relating to how new technologies, like MWAs, are adopted by society.

Sources of Weather Information

Until the last 10 years, the meteorology community lacked comprehensive knowledge about where and why people obtain everyday weather information (Demuth et al., 2011). Research identified television, radio, the internet, and electronic devices as some of the many sources people turn to when they search for weather information (Lazo et al., 2009). Local television proved to be the most frequently accessed source among American adults (Lazo et al., 2009), and cable television stations, like The Weather Channel, and the internet also garnered a large proportion of source choices (Corso, 2007; Grotticelli, 2011).

Of interest is the fact that, at the time of these studies, cell phones and electronic devices appeared to be a less common source for obtaining weather information with most Americans, either registering as second least used (Lazo et al., 2009) or completely omitted as a possible option in other surveys (Corso, 2007; Grotticelli, 2011). Because of how rapidly information-seeking and consumption behavior are changing as a result of continually evolving technology (Handmark, 2010; Zickuhr, 2011), previous research, even from the past 5-10 years, has become obsolete (Demuth et al., 2011).

The results of three surveys, undertaken at different times, indicate the varying preferences for where people like to gather weather information (Table 2.1). With mobile devices absent from two of the three reports, local news and internet sources appear to be most popular.

Table 2.1: Results from Surveys on Weather Information Sources

Sources	Corso (2007)	Grotticelli (2011)	Hickey (2015)
Mobile Applications	---	---	23.2%*
Specific Website or Application	---	---	19.1%
Local News	44%	54%	20.6%
Internet	23%**	20%	14.2%
The Weather Channel/Cable	17%	19%	15.2%
Radio	8%	5%	3.4%
Newspaper	3%	2%	3.5%
Other/Not Sure	5%	---	0.9%
*Default weather app on device ** Includes both local television/newspaper website and national weather websites			

These studies do not adequately account for smartphones and mobile applications. More recent research, however, captured smartphone use for retrieving weather information. For example, a Canadian study surveyed residents in Ontario and found that the use of cell phone apps for weather information was not as popular as other modes, including talking with family and friends, local radio, and The Weather Network, a Canadian cable weather television channel (Silver, 2015). A separate survey in 2015, however, revealed that MWAs are the preferred source for weather information, surpassing the more traditional source of television (Hickey, 2015), illustrating the importance of the research undertaken here.

In addition to the choice preference in weather sources, Americans have come to depend on multiple ways for acquiring weather data as opposed to using only one primary source. Of the 1461 respondents to the survey, some 83.5% of respondents reported that they use three or more sources a week, while 43.6% use five or more different sources a week (Demuth et al., 2011). The authors, however, could not find any distinct pattern relating to how people choose their sources of information nor could they connect how the multiple sources used on a weekly basis relate to one another.

There have been several studies that have assessed patterns in news consumption (Henke, 1985; Althaus and Tewksbury, 2000; Didi and LaRose, 2006), with one in particular highlighting the importance of weather information through perspectives on news programming (Pew Research Center, 2008). Because weather forecasts are often an important part of local and regional newscasts and news programming, there is a connection between news and weather information-seeking.

Diddi and LaRose (2006) analyzed how undergraduate college students look for and consume news information through a variety of outlets. College students' news consumption was dependent on the strength of the developed preference for a specific news outlet. Individuals who tune into the local news every morning will continue to do so, as long as they are satisfied with the content they are receiving. Additionally, nearly half of all Americans follow news concerning weather very closely, making weather-related headlines the most important of any type of news story (followed by content relating to crime and public safety) (Pew Research Center, 2008).

Other research relating to weather sources reveals that those who are younger tend to look less at local television for weather information and more at the internet and websites compared to older generations (Corso, 2007) (Table 2.2). Overall, newspaper, local television websites, and the radio were found to be unpopular for most people today. It is important to recognize that the survey data was collected nearly 10 years ago, suggesting that the generational weather-source preferences will have shifted over time.

Table 2.2: Weather Sources Stratified by Generational Age Groups (Corso, 2007)

	Total	Echo (18-30)	GenX (31-42)	Boomer (43-61)	Mature (62+)
Local TV	44%	30%	45%	49%	51%
The Weather Channel	17%	21%	13%	17%	17%
NWS or national website	17%	25%	21%	12%	11%
Radio	8%	7%	9%	8%	7%
Local Website	6%	5%	5%	5%	9%
Newspaper	3%	2%	2%	4%	4%
Other	3%	4%	2%	4%	2%
None	2%	4%	2%	1%	---

In addition to analyzing the source preference for individuals seeking weather data, it is also important to understand the time of the day and how often people acquire the information. On average, people look for weather data about four times daily (Lazo et al., 2009). One of the peak times for accessing weather information is in the early morning (6:00AM-8:00AM), as people prepare for their daily activities; the second peak occurs in the early to late evening (4:00PM-7:00PM and 7:00PM-12:00AM), as people are planning for the day ahead.

Smartphones

i. The Trend in Mobile Technology

Americans, especially younger generations, constantly seek information and expect to have immediate results. The added value of convenience is certainly a motivating factor in what options and sources they choose (Oblinger and Oblinger, 2005). Students value convenience over many other factors and therefore turn to their smartphones and mobile devices to quickly access information (Bomhold, 2013).

Cellular phones and mobile devices are ubiquitous in modern society, and their day-to-day functions are becoming increasingly important for cell-phone owners and consumers of information. A 2011 Pew Research Center study found that 95% of the “millennial” generation (ages 18-34) and 85% of all American adults own cellular phones. College students, who align mostly with the millennial generation, have the highest rate of cell phone use compared to any other generation. In terms of how cell phone owners use their phone, 76% take photos, and 72% use text messaging capabilities (Zickuhr, 2011). For mobile internet use, only 38% of all adults have accessed the internet on their mobile devices, while the number of millennials who use the internet on their phones was much higher at 63% (Zickuhr, 2011). Many Americans who use the internet on their phones are seeking weather information as well (Handmark, 2010).

Cellular devices currently consist of smartphones, defined as “a cellphone that includes additional software functions as email or an internet browser” (smartphone, 2016). Smartphone use has soared in recent years (Zickuhr, 2011; Dahlstrom et al., 2012; Smith, 2015) with research in 2012 indicating that 62% of undergraduate college students own a smartphone, up from 55% in the previous year (Dahlstrom et al., 2012). A more recent study of smartphone use in the United States found that 64% of American adults own a smartphone, much higher than the 35% of adults reported in 2011 (Smith, 2015). Across all age spectrums, the use of smartphones for text messaging, internet access, calling, and emailing ranked highest as reasons people use their devices. Smartphones are often used for many other practical purposes too, including online banking and real estate searches (Smith, 2015).

With the rise in smartphone use, applications on these devices are also soaring in popularity. An application (abbreviated as app) is defined as a program downloaded onto mobile devices that serves a specific purpose for the user (app, 2016). Between 2009 and 2011, surveys of the American public found that nearly twice as many adults were downloading apps to their phones, increasing from 22% to 38% (Purcell, 2011). Adults are most likely to download apps that provide continuous information on news, weather, sports, and finance (Purcell, 2011). While most popular mobile apps revolve around games and entertainment, apps for weather come in a close second followed by social media apps and those used for travel and navigation (Purcell, 2011).

In terms of how people use their different mobile apps throughout the day, news applications are most popular in the morning as are weather applications, suggesting that people seek information to plan their day based on weather conditions (Böhmer et al., 2011). Overall use of mobile devices is at its lowest around 5:00AM and peaks around 6:00PM. Further, the average amount of time spent on any particular app was less than one minute for all users at all times (Böhmer et al., 2011).

MWAs like other smartphone apps, have rapidly gained popularity (Hickey, 2015). As use of these apps continues to grow and the market continues to expand with increasing options, it is important to gain insight on the consumption of MWA information and on MWA features that are most useful to consumers.

ii. The Weather Enterprise and Smartphone Technology

The private sector of the weather enterprise has taken advantage of the growing use of mobile apps. Various companies and organizations have introduced some of the most well-known weather apps used by Americans today (Nagle, 2014). In 2007, The Weather Channel became the first major weather corporation to launch its own app aimed at consumers who sought to easily retrieve forecasts in the palm of their hand (The Weather Channel, 2013). Since then, a multitude of companies has joined the mobile technology market, creating their own MWAs. Accuweather launched its app in 2008 (Accuweather, no date), and Weather Underground released its mobile app in 2011 (Weather Underground, 2011). While there are many MWAs available to consumers, each with its own unique offerings, some apps use data that is sourced from the same organization. For instance, The Weather Company, provides information for many MWAs available to consumers, including The Weather Channel MWA, Apple Weather, and some local television station MWAs.

The National Weather Service (NWS) in conjunction with other government entities has also taken advantage of the increase in mobile phone usage. The mission of the NWS is to "provide weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy (National Weather Service, 2003). Thus, the core focus of the NWS is on more immediate, life-threatening weather events. The Department of Homeland Security (DHS) use the Commercial Mobile Alert Service (CMAS) to reach as many members of the general public as possible during times of imminent threat and time-sensitive crises (National Research Council, 2011). CMAS was transitioned over to the Wireless Emergency Alert (WEA) service in 2012, with an added dimension of severe weather alerts. The NWS along with partner government agencies like the Federal Emergency Management Agency (FEMA) and the Federal Communications Commission (FCC) have the capability to send out geographically relevant notifications to cell phone users for extreme severe weather, America's Missing: Broadcast Emergency Response (AMBER) alerts, and both local and national emergencies ("NWS, no date a). Additionally, in 2016, the NWS began offering a service to smartphone users that allows easy access to its mobile website with a single touch of a button. The product has similar functions as an app, but instead of using data from within the application, users are transferred to a mobile version of the NWS website that carries out the user's requests for location-specific forecasts (NWS, no date b).

In addition to disseminating weather forecasts and emergency weather alerts to the public, meteorologists are capitalizing on smartphone technology in a creative way, developing an application that crowdsources data that is then ingested into weather technology. The mPING weather app allows citizen meteorologists to provide real-time surface observations of winter time precipitation events. The interface of the application was designed to facilitate the reporting of winter weather events, and the information is intended to ground-truth and verify radar data (Elmore et al., 2014).

Weather Forecasts and Perception

i. How do people use weather forecasts?

While it is important to understand where people turn to for weather information, the reasons behind why they collect this information is equally as important (Demuth et al., 2011). The acquisition, use, and understanding of weather information are all interrelated and affect one another. The landmark study on sources and personal interpretation of weather data by Lazo et al., (2009) looked at the locations for which people obtain forecasts, individual perception of the important characteristics of a forecast, and the decisions made from the gathered information. Most people use weather forecasts for the city or area in which they live (87% usually or always). Respondents most often looked at forecasts for areas within close proximity to their own residence (cities in their region rather than in other states, territories and countries). Location, timing, probability, and type of precipitation along with forecast temperatures are seen as most valuable to users (Lazo et al., 2009). This study also found that people use weather forecasts mostly to stay informed about the weather (72% usually or always), but other popular uses include how to dress and how to plan activities that could be affected by the weather (Lazo et al., 2009).

ii. Uncertainty Information in Weather Forecasts

Several studies on perception of weather forecasts focus on public confidence in the information and how far in advance forecasts were made (Corso, 2007; Lazo et al., 2009; Joslyn and Savelli, 2010; Grotticelli, 2011). One study found that 75% of respondents were satisfied or very satisfied with weather forecasts that they receive on a regular basis (Lazo et al., 2009). For short-term forecasts (less than one day in advance), most people reported having high or very high confidence in the information, with only a handful of people showing low or very low confidence (Table 2.3). However, user confidence in the forecast decreased with an increase in the forecast lead time.

Table 2.3: Public Confidence in Forecasts Dependent on Lead Time, (Adapted from Lazo et al., 2009)

Amount of Lead Time for a Forecast	Very High Confidence	High Confidence	Medium Confidence	Low Confidence	Very Low Confidence
Less than 1 Day	43%	42%	13%	1%	1%
1 Day	25%	48%	22%	3%	1%
2 Days	11%	38%	39%	10%	2%
3 Days	5%	21%	49%	20%	6%
5 Days	2%	8%	34%	40%	16%
7-14 Days	2%	3%	16%	31%	47%

In a survey of residents in Washington and Oregon, Joslyn and Savelli (2010) found that the public understands uncertainty information in deterministic weather forecasts. The participants also understood that an increase in lead time for a forecast would have more error and forecast uncertainty. Interestingly, participants were able to gauge that high wind forecasts were often overestimated with the actual wind speeds verifying much lower. Forecasts for snowfall were met with much more skepticism than a forecast for "no snow," and forecasts that call for rain are trusted more than a forecast that indicates no rain.

MWAs often use percentages in their forecast products to represent probabilities of a certain phenomenon happening (probability of precipitation (PoP), for example). It is therefore essential to understand how the public perceives probabilistic weather information, as it is a common feature on MWAs. Discussion in recent years over the value of adding uncertainty information to deterministic forecasts has led to an increase in research that investigates how to better convey details of doubt or unpredictability. Studies have addressed uncertainty in general (Nicholls, 1999) and uncertainty in terms of weather forecasts (Morss et al., 2008; Joslyn and Nichols, 2009; Lazo et al., 2009). Deterministic weather forecasts that highlight only one potential scenario are being phased out in favor of forecasts that express uncertainty through probabilities or ranges.

Studies in both the United States and Italy found that an overwhelming majority of people automatically infer probabilistic ideas of uncertainty when they are exposed to a single-scenario deterministic forecast (Morss et al., 2008; Zabini et al., 2015). Even with a forecast that only offered a specific high and low temperature, respondents expected variability in the actual verified values. People preferred uncertainty information in their forecasts (i.e., a range of temperatures) rather than a single specific outlook, supporting the trend to add uncertainty information into public weather forecasts (Zabini et al., 2015).

While people may expect uncertainty and prefer to have uncertainty information included in a forecast, the public must be able to correctly interpret and understand the information provided to them. In several studies analyzing PoP, researchers found that there was an incongruent understanding of what the PoP actually means among the general public (Murphy et al., 1980) and among some operational meteorologists and forecasters (Stewart et al., 2015. Other studies, however, have found probabilities to be quite useful in helping people make decisions based on forecasts (Roulston et al., 2006; Nadav-Greenberg and Joslyn, 2009; Marimo et al., 2015).

Using an experimental economic laboratory activity, Roulston et al. (2006) simulated a road maintenance situation involving a hypothetical winter weather scenario. Participants were told they were responsible for deciding whether their company should salt roadways given specific weather conditions. The study found that those given uncertainty information about the weather forecast were likely to make a better applied decision as compared to those who were not given this information. In a different study providing uncertainty information with temperature forecasts, results showed that the inclusion of the uncertainty with both tables and graphs helped participants better gauge the most likely outcome for a temperature forecast compared to those who did not have the same uncertainty information (Marimo et al., 2015). The inclusion of supplemental uncertainty information was useful in helping participants interpret and choose the most probable temperature forecast outcomes. People understand the importance of having uncertainty information in the forecast and have the capacity to use this information to make better, more informed decisions.

With studies showing that uncertainty information could provide added-value in weather forecasts, a new conundrum unfolds in terms of whether uncertainty should be expressed as a probability or in terms of frequency. (Information as a probability would be 90%, while the same idea expressed as frequency would be 9 out of 10). One study found that the public struggles with probabilistic information and how to interpret and understand it (Nicholls, 1999). However, a more recent study addresses various ways to express wind speed forecast information and found that participants actually preferred to have probabilistic information over frequency (Joslyn and Nichols, 2009).

Suggestions have been made on how to improve the communication of weather forecast information to reduce the confusion people have over uncertainty information, often referred to as second-order uncertainty. The wording and language of weather forecasts could be standardized to create uniformity across all platforms (Kox et al., 2015). Stewart et al. (2015)

found that operational forecasters in broadcasting, at the National Weather Service, and in other sectors are not harmonious in their understanding of the probability of precipitation (PoP). Perhaps to better convey uncertainty information, it is essential that communicators of this information coordinate and conform in their definitions and understanding of the terminology that they are responsible for expressing and interpreting for the general public.

Different Models of Information Gathering and Decision Making

While the use of mobile phones, especially smartphone devices, is relatively new, the explosive growth of this technology has provided a new way for people to access weather information. Chan-Olmsted et al. (2013) identify the diffusion of innovations theory (DIT) and the technology acceptance model (TAM), two important theoretical models that could potentially determine the success of a mobile application or use of a smartphone to access information.

DIT is a conceptual model that explains how people perceive an innovation, defined as any entity that is seen as new, unique, or different (Rogers, 1995). DIT helps to shed light on the beginnings of smartphone use and acquisition of weather information through mobile websites and apps. DIT is comprised of five major concepts: relative advantage, compatibility, complexity, trialability, and observability, some of which tie directly into TAM (Rogers, 1995). Relative advantage, observability, complexity, and compatibility are especially relevant to the study of weather applications. Relative advantage gauges the improvements of the new technology compared to its predecessor. Users are more likely to adopt the innovation if the new additions are more useful or favorable than what preceded it (Rogers, 1995). In the case of MWAs, if the apps are seen to be more valuable than a traditional source like television or newspaper, then the app will likely become the preferred choice.

Observability relates to how easy it is for someone to visualize or tangibly understand the results of what they are using. A weather application would have high observability because users can clearly see if the weather forecast was correct or incorrect (Rogers, 1995). Complexity pertains to how simple or difficult the innovation is expected to be in terms of use and comprehension of the product or idea. If the innovation seems to be difficult to use or understand, adoption is less likely than if it is perceived to be simple to use (Rogers, 1995). Lastly, compatibility deals with how the innovation adapts to social norms and practices. If the new technology resonates well with individual lifestyles and can offer benefits without being inconsistent with day-to-day activities, it is likely to be adopted.

TAM, similar to DIT, was originally developed to understand the use and subsequent acceptance of computers (Davis et al., 1989). TAM emphasizes ideas of relative usefulness and ease of use, both of which are strong points for why mobile news apps are widely used by the public. While the adoption of new technology, like a news or weather app, would begin with deciding on how simple it is to use, if the user does not believe the product offers much utility, the new technology will not likely be successful (Chan-Olmsted et al., 2013). Additionally, the perception that a technology or product is easy to use and provides an added benefit to the user strongly correlates not only with current usage rates but also with predicted future use (Davis 1989). Both DIT and TAM help guide the understanding of the popularity, use, and perception of mobile news applications.

CHAPTER 3: METHODOLOGY

To gather the data needed to address the research questions, a survey of students at three universities was undertaken, following approval by the Institutional Review Board (IRB) at East Carolina University (Appendix A). Survey responses were analyzed statistically and through content coding for the open-ended responses.

Data Sources

i. Survey Sample

A 28-item survey was administered to college students from three different universities: East Carolina University, the University of Georgia, and the University of South Carolina (Appendix B). The three schools were chosen after contacting faculty members who agreed to assist in the research. The schools were also chosen because of their location in the southeast, limiting the potential effects of varying climate conditions that could factor into how respondents answer the questions (Figure 3.1).

College students were surveyed because they have a high rate of smartphone usage (Zickuhr, 2011). Previous research has successfully gathered information from college students for studies on cell phone use (Didi and LaRose, 2006; Bomhold, 2013) and weather perception (Roulston et al., 2006; Marimo et al., 2015). Additionally, because the undergraduate college student generation will continue using smartphones and other new technologies that arise in the future, it is important to document their use of smartphones and apps because it will be their uses and demands that are most likely to shape future products

Figure 3.1: Locations of the Three Schools from Which the Survey was Administered.

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Introductory college classes were sampled to ensure that those completing the survey had diverse academic interests rather than sampling from upper-level courses with students who have already declared specific majors. The survey used in this study was administered using the Qualtrics survey software. Emails with a survey link and brief message were sent to professors at each of the three schools, who agreed to assist in the study. They then forwarded the emails to undergraduate students in the introductory Geography courses.

Before the survey was distributed, it was pre-tested with a small group of non-meteorologists at East Carolina University. Feedback was solicited on the content, syntax, and understandability of the survey using methods described by Presser et al. (2004). The survey was then modified and finalized based on the results of the pretest.

Survey Structure

A total of 308 complete responses were collected between October, 2016 and January, 2017, with 135 from East Carolina University, 75 from the University of Georgia, and 98 from the University of South Carolina. Most questions consisted of multiple-choice options where respondents chose one answer from a list. Some questions specified "other" as a choice, which allowed participants to supply an answer that was not listed. Strategies from Smyth et al. (2009) were implemented to seek thorough open-ended responses from participants. Other survey questions featured a 5-point Likert scale (1 = not at all important, 5 = extremely important) to gauge the level of agreement with the statements provided and for questions involving confidence in MWA forecasts and the level of satisfaction with the MWAs.

To build on past studies regarding sources of weather information (Lazo et al. 2009; Morss et al. 2011), the survey employed similar questions. While a direct comparison between studies is not possible, using similar questions serves to build our knowledge on using MWAs.

The survey begins with questions on demographic information, including age, gender, race, education, family income, and the zip code of the location where respondents identify as home. Following these questions, participants were asked about how they spend their time to evaluate how they may be affected by weather conditions. They were asked about weather forecasts in general, specifically about where they acquire forecast information, the importance of different elements or aspects of a weather forecast, and their level of confidence in forecasts overall. The next set of questions shifted to mobile devices and MWAs, asking respondents about their ownership of cell phones and smartphones, after which they were prompted to select answers that best describe their daily smartphone habits, preferences for MWAs, and their perception of and confidence in specific MWA features. For the purposes of this study, the use of "MWA features" and "MWA components" refers to different characteristics of MWAs that provide users with information on forecast aspects or elements. For instance, the 5-day forecast feature on a MWA can provide information on the temperature and precipitation aspects from a forecast for the next 5 days. Table 3.1 presents the research questions in the study and the corresponding survey items that address the study's main ideas.

Table 3.1: Research Questions and Corresponding Survey Items

Research Questions	Survey Question
What specific reasons do respondents have for choosing their favorite MWA?	Which mobile weather application is your favorite?
	What is the primary reason that you prefer this weather app?
	Are there other reasons why you prefer this weather app?
What aspects of a weather forecast are most important to respondents, and how does that relate to the MWA that they most prefer?	Which mobile weather application is your favorite?
	A weather forecast can provide several types of information about temperature, cloudiness, wind, and precipitation (such as rain, snow, hail, or sleet). How important is it to you to have the information listed below as part of a weather forecast?
	A weather forecast can provide several types of information about temperature, cloudiness, wind, and precipitation (such as rain, snow, hail, or sleet). How important is it to you to have the information listed below as part of a weather forecast?

Is there a relationship between respondents' reported activities and the information they seek about weather from their MWA?	On average, year-round, how many hours per week do you spend on the following activities?
	What time(s) of the day do you access weather information from your mobile weather application? Choose all that apply:
	On average, how much time do you spend looking at information on your mobile weather application for each individual session?
	On average, how much time do you spend looking at information on your mobile weather application on a daily basis?
	How important are each of the following mobile weather application components to you?
How do geographic and demographic factors influence MWA use?	Which school do you attend?
	What is your age?
	To what racial or ethnic group do you most identify?
	What is your gender?
	What is your highest level of education so far?
	In what zip code do you consider your home to be located?
	What time(s) of the day do you access weather information from your mobile weather application? Choose all that apply:
	On average, how much time do you spend looking at information on your mobile weather application for each individual session?
	On average, how much time do you spend looking at information on your mobile weather application on a daily basis?
	How important are each of the following mobile weather application components to you?

The final survey question asked respondents if they had any suggestions or recommendations for how their MWAs or MWAs in general could be improved.

To limit the number of incomplete survey responses, respondents were not required to answer any question before proceeding in the survey. Therefore, survey items have varying numbers of responses.

Statistical Analyses

Descriptive statistical methods were used to analyze the data and draw conclusions about MWA use among respondents. Data from the survey was exported into Microsoft Excel format from Qualtrics to format the information and remove unnecessary variables. The data was then imported into IBM SPSS format for further analysis.

Both quantitative and qualitative statistical analyses were employed to analyze the survey data. For the purposes of this research, Likert-scale questions were designated as continuous variables, because while these questions have a specific number of items (categories) from which respondents choose, past research indicates that opposite ends of the Likert spectrum ("not important at all" and "very important," for example) are understood by respondents to be a continuum similar to interval-based questions (Willits et al., 2016). Additionally, Likert-scale answers were classified into a number scale from their qualitative descriptions for easier analysis (Table 3.2).

Table 3.2: Reclassification of Likert Answers into Numeric Values for Analysis

Not at all important	Not important	Neutral	Important	Extremely Important
1	2	3	4	5

Not confident at all	Not confident	Neutral	Confident	Very Confident	Not on my app
1	2	3	4	5	0

To better understand the association between different factors pertaining to the respondents, Chi square tests and (independent sample) one-way analysis of variance (ANOVA) tests were applied to variables. The Chi square test was used when survey answers were categorical; ANOVA was used when these answers were continuous. Additionally, cross tabulation analyses comparing two sets of data were used to uncover relationships between variables and answers from respondents.

Responses to some questions were consolidated and recoded in SPSS to allow for simpler analyses of cross tabulation descriptive statistics and to meet the assumptions of a Chi square analysis (Table 3.3). Chi Square assumes that expected values in a contingency table are at least five. Therefore, some survey answers were combined into groups to meet the assumption. Survey responses that included "not on my app" were not considered in the statistical analysis process because the study will only consider respondents who have the relevant experience with specific MWA features.

Table 3.3: Example of Consolidation of Likert Answers for Simplified Cross-Tabulations

	Not at all important	Not important	Neutral	Important	Very Important	Not on my app
Previous Numerical Value	1	2	3	4	5	0
New Numerical Value	1	1	2	3	3	Null

If the assumption of at least 5 expected values for each cell is still not met after combining categories, the Chi Square output can still be used but with some limitation. If the *p* value is not significant, the likelihood ratio value can be used in conjunction with the *p* value to justify that there is no association between the two variables analyzed. If the *p* value returns as significant and the assumption is violated, the information is unreliable and cannot be used.

One-way ANOVA tests were employed when analyzing continuous Likert-scale variables and universities and gender as independent variables. Before conducting one-way ANOVA tests on the data to see if any differences exist between specific groups, a Levene's Test was undertaken because the amount of respondents from each school is not the same. Levene's Test examines one of the assumptions of a one-way ANOVA test (homogeneity of variances) to see if this requirement has been violated. Because the number within each variable group is dissimilar, there is a chance that this assumption is not met. When conducting the Levene's Test for the different groups, if the variances are not statistically significant, the ANOVA tests and their results are valid. If the Levene's Test statistic returns as significant, the ANOVA test results cannot be reported because the statistical computation may be unreliable.

The one-way ANOVA test can signal a significant difference between groups, but it does not explicitly state the relationship of the statistical difference between specific groups. Therefore, the Tukey HSD (honest significant difference) test is used. The Tukey HSD test is a post hoc ANOVA test that explicitly identifies a difference between specific groups.

For questions that allowed for multiple responses, the Qualtrics program does not export the answers into separate columns for analysis. Therefore, answers were manually sorted and coded with a binary 1 or 0 classification in order to analyze responses. A "0" designation was given for options that were not selected by the respondent, while a "1" was used to represent an option that was chosen for an example, as shown in Table 3.4.

Table 3.4: Example of Reclassifying Multiple-Response Items with Binary System

Example of Possible Answers	12AM–6AM	6AM-8AM	8AM-11AM	11AM-1PM	1PM-4PM	4PM - 7PM	7PM-12AM
12AM-6AM, 11AM-1PM, 7PM-12AM	1	0	0	1	0	0	1
6:00AM – 8:00AM	0	1	0	0	0	0	0
8AM – 11AM, 4PM-7PM, 7PM-12AM	0	0	1	0	0	1	1

Content-Coding

With open-ended survey responses where participants were free to provide their own answers, a content analysis was performed by two researchers, who coded the answers into categories to gain a clearer picture of main ideas and themes. Categories were determined through directed content coding strategies, where one identified important themes and concepts that were prevalent on respondent answers (Hsieh and Shannon, 2005). Initial categories were created, with classes with overlapping ideas consolidated. After both coders separated responses on their own, a Cohen's Kappa test was used to verify the reliability of the content coding to ensure valid results and inter-rater agreement (Cohen, 1960). The analyses of survey responses both with quantitative statistical tests and qualitative content-coding of open-ended suggestions from responses address the research questions for this study.

CHAPTER 4: DATA AND ANALYSIS

This chapter presents information provided by the 308 respondents to the survey. Demographic information reported by respondents, including age, race, and gender, is introduced, followed by information from survey items that helps to establish an understanding of how people use their MWAs. Details on smartphone ownership, use, and amount of MWAs on a device set a foundation for which to answer the research questions posed in the study.

The first research question examines reasons why people prefer their favorite MWA. The second research question is intertwined with the first and explores how the perceived importance of weather forecasts relates to MWA choice. The third research question delves more deeply into reported weekly activities (commuting, leisure outdoor enjoyment, and jobs or occupations that are primarily outside). These activities are explored in conjunction with MWA habits and patterns, including the times of day people access their MWA for weather information, the duration for which they view this information, and the features that are most valuable to them. The final research question explores possible relationships between how different universities and gender may be associated with MWA choice and how the MWA is used to retrieve weather information. Following specific consideration of the research questions, information from open-ended suggestions for how to improve MWAs is presented.

Characteristics of the Respondents

Students from East Carolina made up 44% of the total respondents surveyed, with the rest of the respondents from the University of South Carolina (32%) and the University of Georgia (24%). Most of the student respondents are between the ages of 17 and 22 (Table 4.1). The predominant race represented is white at nearly 80%, with Black and Asian rounding out the top three. There were more females than males who answered the survey (51.9%) compared to 47.4% men. Because most of the respondents are undergraduate students, a large majority had some college credit with no degrees (88.3%), followed by less than a tenth with an associate's degrees (6.5%) or a Bachelor's degree (4.2%).

Table 4.1: Demographic Information of Respondents by School (n=308)

Demographic Variable	School			
	ECU	USC	UGA	TOTAL
AGE				
Under 17	0	0	1	1
17-19	75	38	43	156
20-22	51	52	26	129
23-25	5	3	3	11
26 or older	4	5	2	11
RACE				
White	103	83	58	244
Black or African American	15	8	5	28
Hispanic or Latino	6	4	3	13
Native American or American Indian	2	0	1	3
Asian or Pacific Islander	5	2	7	14
Other	4	1	1	6
GENDER				
Male	69	55	22	146
Female	65	42	53	160
Transgender	0	1	0	1
Prefer not to answer	1	0	0	1
EDUCATION				
Some college credit, no degree	120	83	69	272
Associate's degree	12	6	2	20
Bachelor's degree	2	7	4	13
Master's degree	1	2	0	3
Professional degree	0	0	0	0
Doctorate degree	0	0	0	0

To affirm the high rates of smartphone use for acquiring weather information among the student participants, the survey asked about cell phone and smartphone ownership along with sources of weather information and how frequently these sources are used. Of the 308 people surveyed, only 1 person did not own a cell phone and 2 others did not own a smartphone. Most respondents have owned a cell phone for at least 4 years (92.8%), while over 96% of respondents have owned a smartphone for at least 2 years (Figure 4.1).

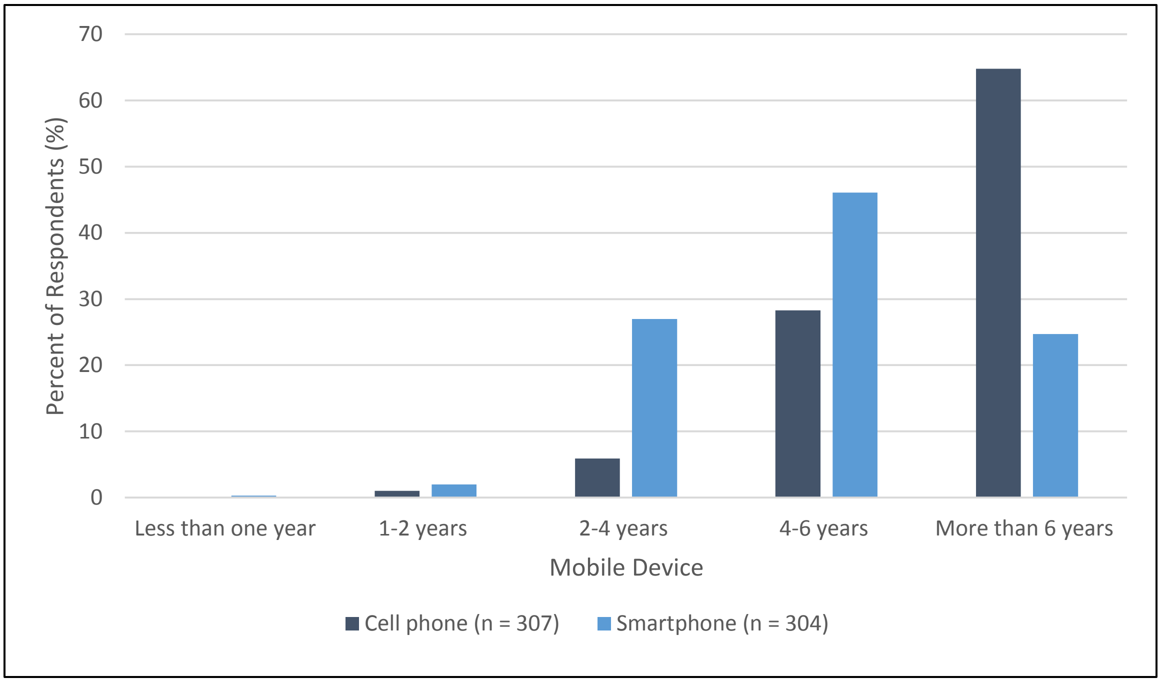

Figure 4.1: Duration of Mobile Device Ownership

In previous studies, local television was the top source for the United States public (Lazo et al., 2009). However, among the college students surveyed, MWAs were overwhelmingly the most frequently used choice to access forecast information, with over 80% checking their MWA at least once a day (Table 4.2). The second most favored option was gathering information on weather forecasts from friends and family. Most respondents seldom use the newspaper or the NOAA Weather Radio to retrieve weather forecasts.

Table 4.2: Frequency of Weather Sources Accessed by Respondents (%)

Source for Weather Information (n)	Frequency of which source is used		
	At Least Once a Day	At Least Once a Week	Rarely or Never
Mobile Phone (Smartphone App) (308)	80.8	16.6	2.6
Friends/Family (306)	17.3	65.4	17.3
Other Internet Sites (307)	9.4	29.6	60.9
Local Television (307)	6.8	31.3	61.9
National Weather Service Website (306)	6.5	29.1	64.4
Commercial/Public Radio (306)	5.6	30.7	63.7
Cable Television (306)	4.9	24.5	70.6
NOAA Weather Radio (307)	1.3	7.5	91.2
Newspaper (304)	1.3	5.6	93.1

Before addressing favorite MWAs, it is necessary to know the number of MWAs an individual has on his/her device and if respondents use free MWAs or apps that require a fee. Including default MWAs that are oftentimes pre-loaded onto a smartphone, more than half of students have only one MWA, while more than 35% have two MWAs (Figure 4.2). Of those surveyed, 91.8% have never paid for a MWA, and the 25 people who have paid often do not pay more than $3.00.

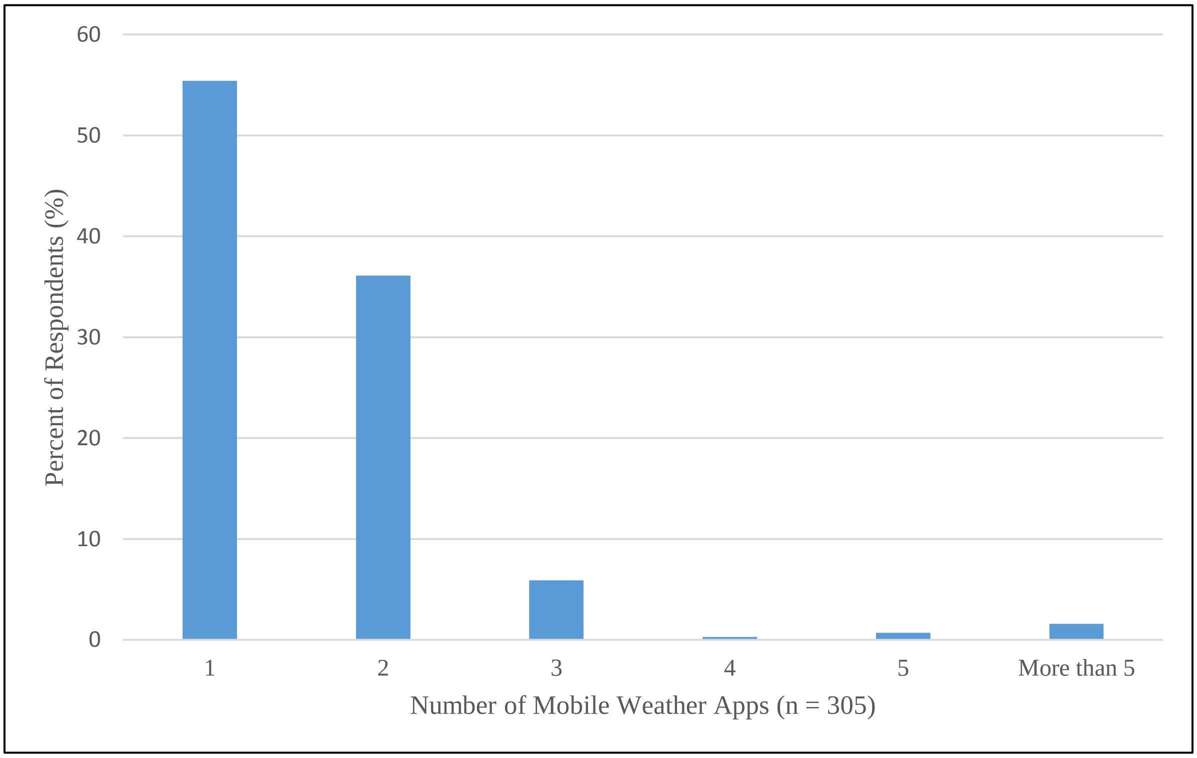

Figure 4.2: Number of MWAs on a Respondents' Mobile Device

Research Question 1: What specific reasons do respondents have for choosing their favorite MWA?

Three items from the survey address this research question, asking students to identify their favorite MWA and the reasoning behind their MWA preference (Table 3.1). The Weather Channel (42.9%) and Apple Weather (27.6%) MWAs were overwhelmingly the most popular among respondents. As previously noted, the forecast information from both apps come from The Weather Company (Apple, 2017), so users are receiving the same forecast information. AccuWeather, "Other" MWAs and WeatherBug round out the top 5 choices (Table 4.3). For the "Other" category, respondents had a variety of different apps used, including Sunshine, MyRadar, and Dark Sky. Additionally, some respondents did not use the MWA on their smartphone, opting to use their internet browser to “google” the forecast or navigate to websites with weather information.

Table 4.3: Respondents’ Favorite MWA

Mobile Weather Application	Number of Respondents	Percent of Respondents (%)	Percent whose favorite MWA is the Default
The Weather Channel	132	42.9	52.3
Apple Weather	85	27.6	89.3
AccuWeather	30	9.7	73.3
WeatherBug	17	5.5	17.6
Wunderground	15	4.9	20.0
Yahoo Weather	6	2.0	83.3
Local Television Station App	5	1.6	60.0
Other	18	5.8	33.3
TOTAL	308	100.0	

Some MWAs are pre-loaded onto smartphones for consumers, which will be referred to as “default” MWAs. Over 50% of those who most prefer The Weather Channel MWA reported that it was their default app, and nearly 90% of respondents who find Apple Weather to be their favorite MWA acknowledge that it was the default on their device. Most respondents who prefer WeatherBug and Wunderground switch to these MWAs from the default MWA.

Participants were asked to identify both the primary reason and additional secondary reasons for choosing their preferred MWA. Nearly 32% chose their favorite MWA because it is easy to use, while about 23% of people prefer their MWA because it came as the default MWA when they acquired their smartphone (Figure 4.3). The design and graphics on a MWA seemed to be less important to respondents, with only 3.6% picking this as their primary reason.

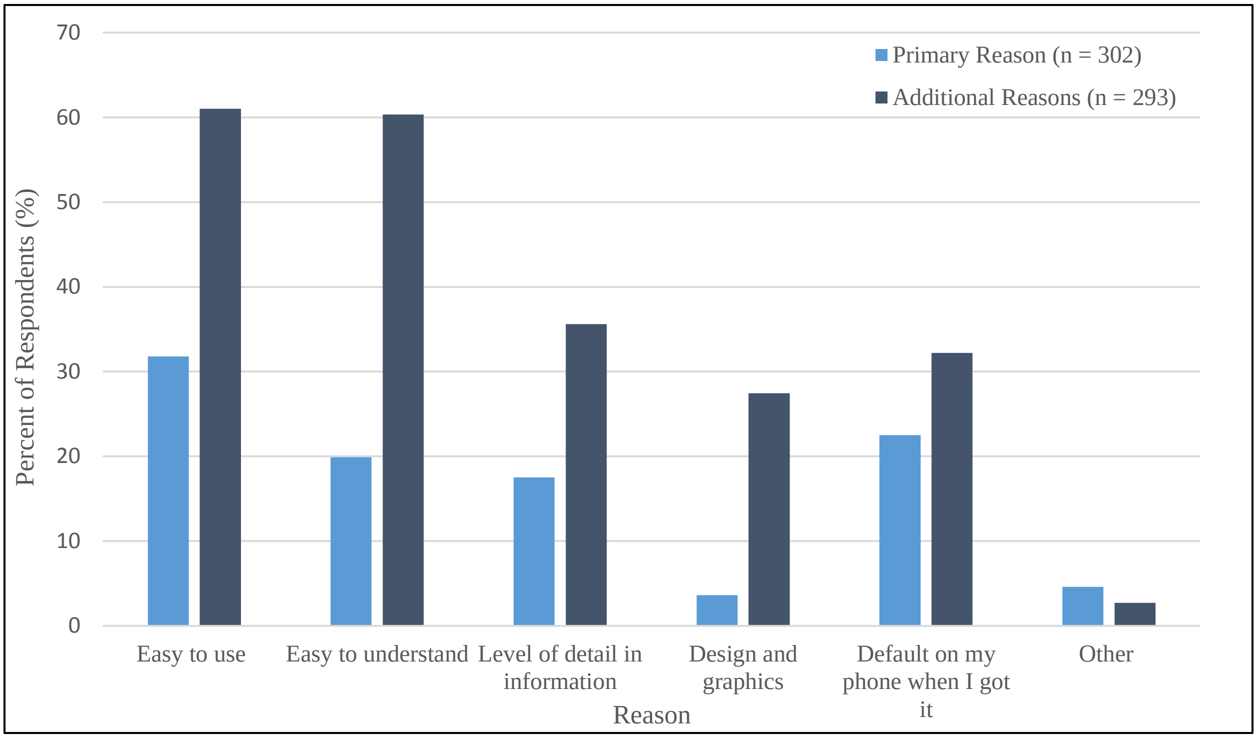

Figure 4.3: Primary and Additional Reasons Why Respondents Chose Their Favorite MWA

In a follow-up question, respondents were allowed to select all the options seen in Figure 4.3 that were additional reasons for selecting their MWA of choice. While about 37% chose only one additional reason, approximately 59% surveyed had more than one reason, and over one third chose three or more reasons. Ease of use was the most common answer (61.0%), and easy to understand was very close behind (60.3%) (Figure 4.3). Other answers respondents provided that were not listed as options in the survey included accuracy and reliability as well as the use or preference for specific features on the MWA.

A cross tabulation analysis comparing respondents' MWA choice to their most important reason they chose their app shows some distinctions between specific MWAs (Table 4.4). For

The Weather Channel, users most cited ease of use and easy comprehension of information on their app, while respondents who prefer Wunderground and Weatherbug like that their MWAs provide a sufficient level of detail in the information that is accessed. AccuWeather and Apple Weather users most prefer their apps because it is the default app pre-loaded onto their device. Overall, except for Wunderground, most respondents do not see the design and graphics of their MWA to be the most important rationale for the MWA they chose as their favorite.

Table 4.4: Favorite MWA Based on Specific Primary Reason (%)

MWA (n)	Primary Reason for MWA Preference					
	Easy to Use	Easy to Understand	Level of detail in information	Design and Graphics	Default	Other
The Weather Channel (129)	40.3	24.0	18.6	2.3	11.6	3.1
AccuWeather (30)	33.3	20.0	13.3	0.0	30.0	3.3
Wunderground (14)	14.3	14.3	42.9	14.3	0.0	14.3
WeatherBug (17)	23.5	23.5	35.3	5.9	0.0	11.8
Apple Weather (83)	24.1	14.5	4.8	4.8	49.4	2.4
Yahoo Weather (6)	50.0	0.0	0.0	0.0	50.0	0.0
Local television station app (5)	20.0	20.0	60.0	0.0	0.0	0.0
Other (18)	22.2	22.2	33.3	5.6	0.0	16.7

Data from the follow up survey item allowed respondents to select all additional reasons why they chose their favorite MWA, and 58.5% of respondents chose more than one reason for why they prefer their MWA, resulting in a higher frequency in nearly every category (Table 4.5). MWAs that are easy to use and easy to understand remain important to MWA users. Additionally, while most respondents did not choose design and graphics as a primary reason, this category had sufficient representation as an important additional consideration for students.

Table 4.5: Favorite MWA Based on Additional Reasons other than Primary Reason (%)

MWA (n)	Primary Reason for MWA Preference					
	Easy to Use	Easy to Understand	Level of detail in information	Design and Graphics	Default	Other
The Weather Channel (130)	59.2	61.5	39.2	25.4	26.9	0.8
AccuWeather (30)	40.0	46.7	23.3	40.0	33.3	3.3
Wunderground (15)	46.7	66.7	33.3	33.3	6.7	6.7
WeatherBug (17)	58.8	52.9	35.3	29.4	5.9	5.9
Apple Weather (84)	64.3	53.6	25.0	26.2	46.4	0.0
Yahoo Weather (6)	66.7	50.0	33.3	0.0	33.3	0.0
Local television station app (5)	60.0	40.0	60.0	0.0	40.0	0.0
Other (18)	72.2	61.1	55.6	16.7	16.7	22.2

A critical component of understanding why people choose their favorite MWA is whether or not they switch from the default MWA that is pre-loaded on the smartphone. Survey items that correspond to this include questions on whether or not a switch was made from the default to another MWA and, if so, what reasons are given for this switch. Of the 305 people who answered this particular question, 39.3% switched to a different MWA, with 75% of those respondents citing only one reason. Nearly 70% those of respondents liked their new MWA more because it offered more information and details, while ease of use, understandability, and graphics were cited as reasons among at least 15% of those who switched (Figure 4.4).

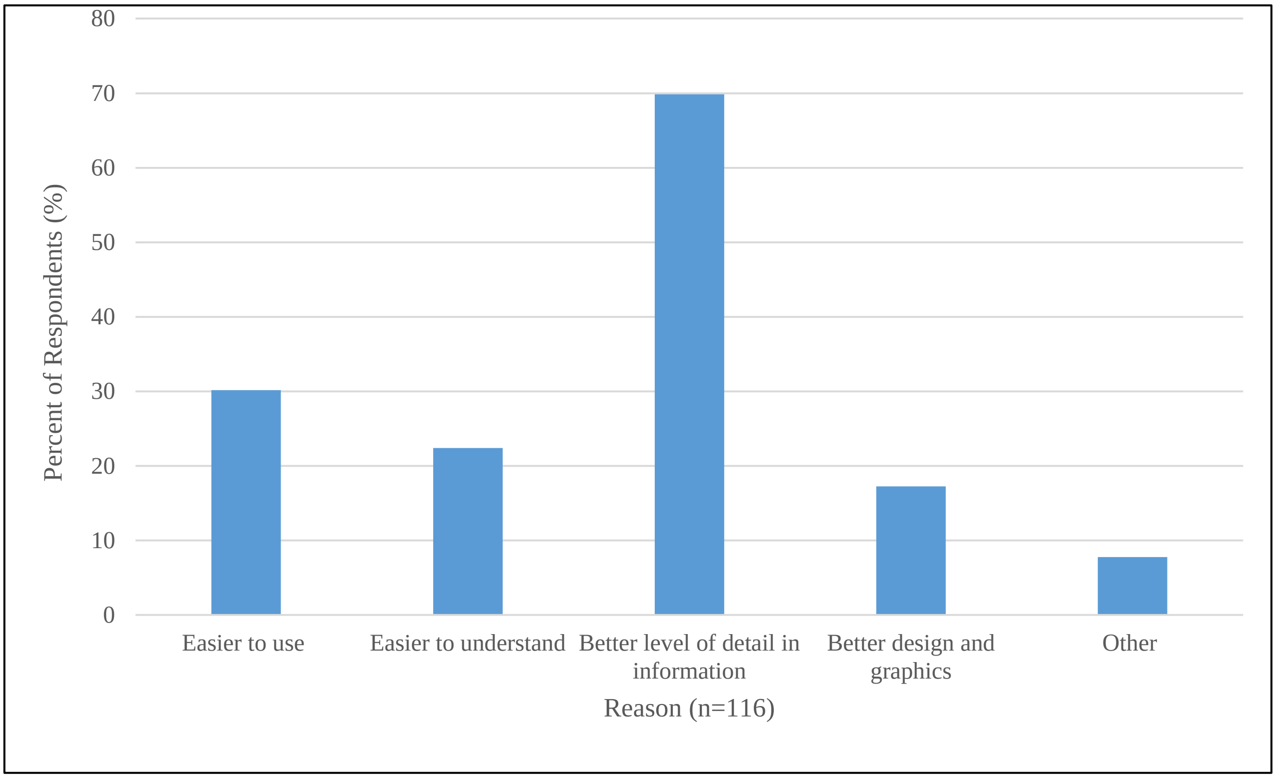

Figure 4.4: Respondents' Specific Reasons for Switching from Default MWA (%)

There are specific features on MWAs that may affect people's choices for which app they most prefer. A majority of MWAs used by respondents provides a short-term hourly forecast, a 5-day forecast, and precipitation chances, all of which were perceived as important features (Table 4.6). Pollen count and airport delay features were seen as less important, along with miscellaneous elements like advertisements and weather-related videos and news headlines.

Table 4.6: Respondents Identifying Importance of Specific MWA Components (%)

MWA Feature (n)	Level of Importance		
	Important/Very Important	Neutral	Not at all important/Not important
Hourly forecast (294)	87.4	8.2	4.4
Chance of precipitation (306)	87.3	9.8	2.9
Current information (303)	85.5	9.6	5.0
Severe weather alert (302)	84.8	10.9	4.3
5-Day forecast (302)	81.1	13.9	5.0
10-Day forecast (286)	50.0	25.2	24.8
Satellite and radar (281)	43.8	29.9	26.3
Pollen count (267)	34.8	35.6	29.6
Lightning detection alert (273)	26.0	33.3	40.7
Airport delays (253)	25.7	32.4	41.9
UV index (273)	25.6	36.3	38.1
News headlines about weather (259)	25.5	35.1	39.4
10+ Day forecast (267)	19.9	40.4	39.7
Weather videos (249)	13.7	34.5	51.8
Advertisements (207)	8.2	17.9	73.9

To further understand the importance people place on specific components available on MWAs, the survey sought to shed light on how confident respondents are in forecasts overall from all sources and confidence in some of the same elements available on MWAs (Table 4.7). Most respondents report that they are confident in a weather forecast, regardless of where they retrieve the information (69.2%), while 21.4% are neutral. For specific MWA features, respondents trust the hourly forecast, with over 85% being confident or extremely confident. For 5-day forecasts, 65.8% of those surveyed were confident or extremely confident in the information accessed, but for forecasts with longer lead times (10-day forecasts, 10+ day forecasts), the decay in confidence for MWA users increases, mirroring the findings from previous research (Lazo et al., 2009). Many respondents were neutral in their sentiment on MWA features like the maritime forecasts, lightning detection alert, rain notification, and pollen count features. However, some of these features are not available on all MWAs.

Table 4.7: Respondents' Confidence in Specific MWA Forecast Features (%)

MWA Feature (n)	Level of Confidence		
	Confident/Very Confident	Neutral	Not confident at all/Not confident
Hourly forecast (304)	85.2	12.2	2.6
Severe weather alert (286)	73.8	19.9	6.3
Rain notification alert (267)	70.4	27.7	1.9
5-Day Forecast (303)	66.0	26.7	7.3
Lightning detection alert (255)	49.8	40.4	9.8
Pollen count (258)	35.3	51.9	12.8
Lakes, rivers, oceans forecast (239)	33.9	56.5	2.5
10-Day forecast (284)	26.1	42.3	31.7
10+ Day forecast (266)	18.4	34.2	47.4

The Weather Channel, Apple Weather, and AccuWeather MWAs are the most popular among respondents, with many citing that these apps are easy to use, easy to understand, or pre-loaded as a default on their smartphones. Most of the students surveyed do not switch from their default MWA, but those who make the change to a different MWA do so because their new preferred app has the desired level of detail in the information provided. Additionally, when it comes to MWA features, short-term forecasts, like the hourly and 5-day components, are perceived to be important or very important. Severe weather alerts and current conditions are also seen as crucial for MWA users.

Research Question 2: What aspects of a weather forecast are most important to respondents, and how does that relate to the MWA that they most prefer?

The second research question explores how the perceived importance of certain aspects of a weather forecast, regardless of where the respondent retrieves the information, may relate to which MWA they ultimately choose. Similar to the personal importance placed on specific MWA features, those surveyed wanted detailed information on the chance, location, and timing of expected precipitation (Table 4.8). The type of precipitation was less important, along with specific details on precipitation amounts.

Table 4.8: Respondents' Perceived Importance of Aspects of Forecasts (%)

Forecast Aspect (n)	Level of Importance		
	Important/Very important	Neutral	Not at all important/Not important
Chance of precip (308)	92.4	4.2	3.3
When precip occurs (307)	90.0	6.7	3.4
Low temperature (308)	86.7	9.7	3.6
Where precip occurs (307)	84.5	11.5	3.9
High temperature (307)	83.4	10.0	3.6
Type of precip (307)	78.5	14.9	6.7
Time of day of high temperature (307)	65.8	19.4	14.8
Time of day of low temperature (308)	63.0	21.8	15.2
Humidity (306)	60.2	21.3	18.5
Amount of precip (308)	59.4	23.9	16.7
Chance of different amounts of precip (306)	43.5	36.2	20.4
Wind speed (307)	38.5	31.5	30.0
Pollen count (307)	34.8	30.0	35.2
Cloud cover (307)	25.2	34.6	40.3
Wind direction (307)	13.6	31.8	54.6

For temperature-related information, forecast high and low temperatures were reported to be important but not so much the timing of these daily events. Additionally, over 60% of respondents found humidity to be important or very important. Cloud cover and wind direction was less of a concern.

When comparing the importance respondents’ place on certain aspects of a weather forecast and their favorite MWAs, there are some notable similarities and differences between users who prefer The Weather Channel, Apple Weather, AccuWeather, and “Other” MWAs (Table 4.9). Precipitation chance and timing are important for users regardless of MWA preference. Respondents who favor “Other” MWAs find more value in information on high temperature and wind direction compared to users of the top three most popular MWAs, but these same respondents find the least value in the timing of the high and low temperatures. Additionally, Apple Weather users find wind speed to be less important than do users of other MWAs, and those whose top MWA is AccuWeather find precipitation type to be less important.

Table 4.9: Respondents Who Use Specific MWAs and Find Specific Forecast Aspects to be Important/Very Important (%)

Forecast Aspect	MWA (n)			
	The Weather Channel (129)	Apple Weather (83)	AccuWeather (30)	Other (60)
Precip Chance	92.2	92.8	93.3	92.1
Precip When	90.7	96.3	86.7	82.5
High temperature	88.4	81.9	80.0	95.2
Low temperature	89.9	79.5	83.3	93.7
Precip Where	84.5	86.7	80.0	85.5
Precip Type	83.7	81.9	66.7	77.4
Time of high	68.2	69.9	70.0	60.3
Time of low	68.2	67.5	66.6	50.8
Humidity	65.9	56.6	62.1	57.1
Precip Amount	62.8	53.0	56.7	61.9
Different Chance of Different Amounts of Precip	48.0	42.2	33.3	47.6
Wind speed	40.3	25.3	53.3	46.0
Pollen count	40.3	31.3	33.3	34.9
Cloud cover	24.0	22.9	20.0	34.9
Wind direction	10.9	6.0	13.3	27.0

Research Question 3: Is there a relationship between respondents' reported activities and the information they seek about weather from their MWA?

The third research question explores the relationship between different weather-dependent activities in which respondents engage on a weekly basis and their use of MWAs. Overall, the students surveyed do not spend a considerable amount of time commuting to work or school, nor do they often work outside as part of their occupation. There are however more students who partake in outdoor leisurely activities (Figure 4.5).

When looking at the time people spend on a variety of activities and comparing this to their favorite MWA, results show that the overwhelming favorites, not surprisingly, are The

Weather Channel and Apple Weather regardless of the amount of time spent on each activity. This is likely because these two MWAs tallied the highest rates of use.

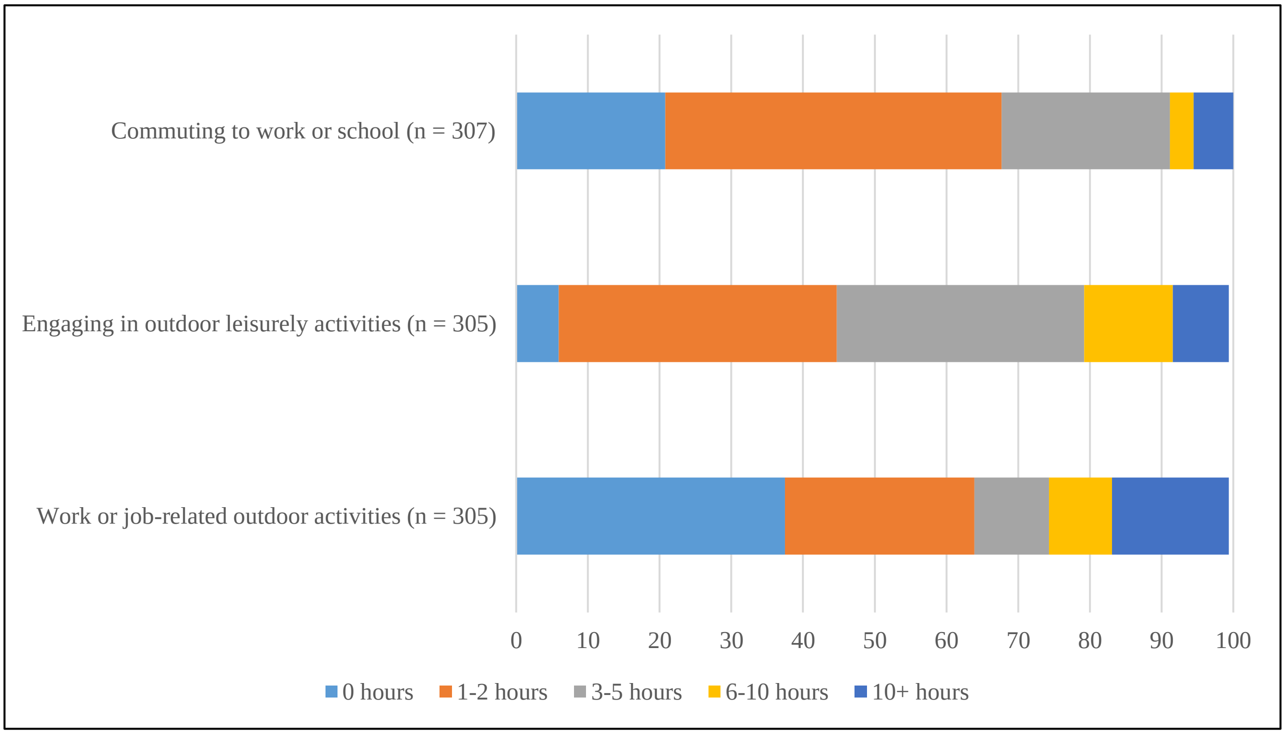

Figure 4.5: Average Time Respondents Spend on Activities Weekly (%)

Comparing the same activities to MWA features respondents find to be important or very important, data suggests that the amount of time spent commuting, in outdoor recreation, or in outdoor work has no effect on the perceived importance of various MWA components. For instance, 80.8% of respondents commuting two hours or less weekly find the 5-day forecast to be important or very important compared to 82.5% of those who commute 3 or more hours a week. The data also indicates that the different types of activities do not appear to affect perceived importance of MWA forecasts and other characteristics. The percentage of respondents who find severe weather alerts important or very important, for example, does not change drastically for those who engage in 0-2 hours of commuting (84.1%), outdoor activities (86.4%), and outdoor work (85.7%). The absence of any major pattern is repeated for all of the MWA features when analyzed in relation to activities (Table 4.10).

Table 4.10: Time Spent on Weekly Activities and Respondents Who Find Specific MWA Features to be Important/Very Important (%)

MWA feature	Commute Time		Outdoor Rec Time		Outdoor Work Time	
	0-2 hours	3+ hours	0-2 hours	3+ hours	0-2 hours	3+ hours
5-day forecast (n)	80.8 (164)	82.5 (80)	82.8 (111)	79.9 (131)	81.2 (155)	81.3 (87)
10-day forecast (n)	48.7 (93)	52.1 (49)	50.8 (64)	49.7 (78)	47.8 (88)	54.5 (54)
10+ day forecast (n)	19.7 (35)	19.3 (17)	21.0 (25)	18.6 (27)	18.4 (32)	22.2 (20)
Hourly forecast (n)	88.0 (176)	86.0 (80)	87.1 (115)	87.4 (139)	86.6 (162)	88.5 (92)
Current information (n)	86.6 (175)	83.8 (83)	85.8 (115)	85.5 (141)	86.4 (165)	84.3 (91)
Severe weather alert (n)	84.1 (169)	82.8 (82)	86.4 (114)	83.1 (138)	85.7 (162)	82.6 (90)
Satellite and radar (n)	42.6 (80)	45.7 (42)	43.0 (52)	43.9 (69)	43.5 (77)	43.6 (44)
Chance of precipitation (n)	89.8 (184)	82.8 (82)	89.7 (122)	85.5 (142)	87.6 (169)	87.2 (95)
Pollen count (n)	33.5 (59)	38.9 (35)	33.6 (39)	36.5 (54)	34.7 (58)	36.1 (35)
UV index (n)	24.0 (46)	25.6 (23)	24.2 (29)	26.7 (40)	25.6 (44)	25.5 (25)
Lightning detection alert (n)	26.3 (47)	25.8 (24)	22.4 (26)	28.6 (44)	24.7 (42)	28.0 (28)
Airport delays (n)	25.4 (43)	25.3 (21)	24.8 (26)	24.8 (36)	23.4 (37)	27.2 (25)
Weather videos (n)	14.5 (24)	12.2 (10)	12.4 (13)	14.9 (21)	12.3 (19)	16.3 (15)
News headlines (n)	22.8 (39)	29.9 (26)	21.1 (23)	27.2 (40)	20.6 (33)	31.3 (30)
Advertisements (n)	8.2 (11)	6.9 (5)	8.0 (7)	7.6 (9)	6.4 (8)	10.0 (8)

In conjunction with understanding what features respondents like to use on their MWA, analyzing the amount of time spent looking at smartphone weather information is crucial as well. Survey items inquired about the average duration of how long students look at their MWA and the different times throughout an entire day spent accessing weather information from an MWA. Nearly 90% of respondents spend less than 3 minutes on their MWA for each individual session (Figure 4.6). When looking at how much time is spent daily, most are on their app between 1-5 minutes, while less than 20% spend more than 5 minutes a day.

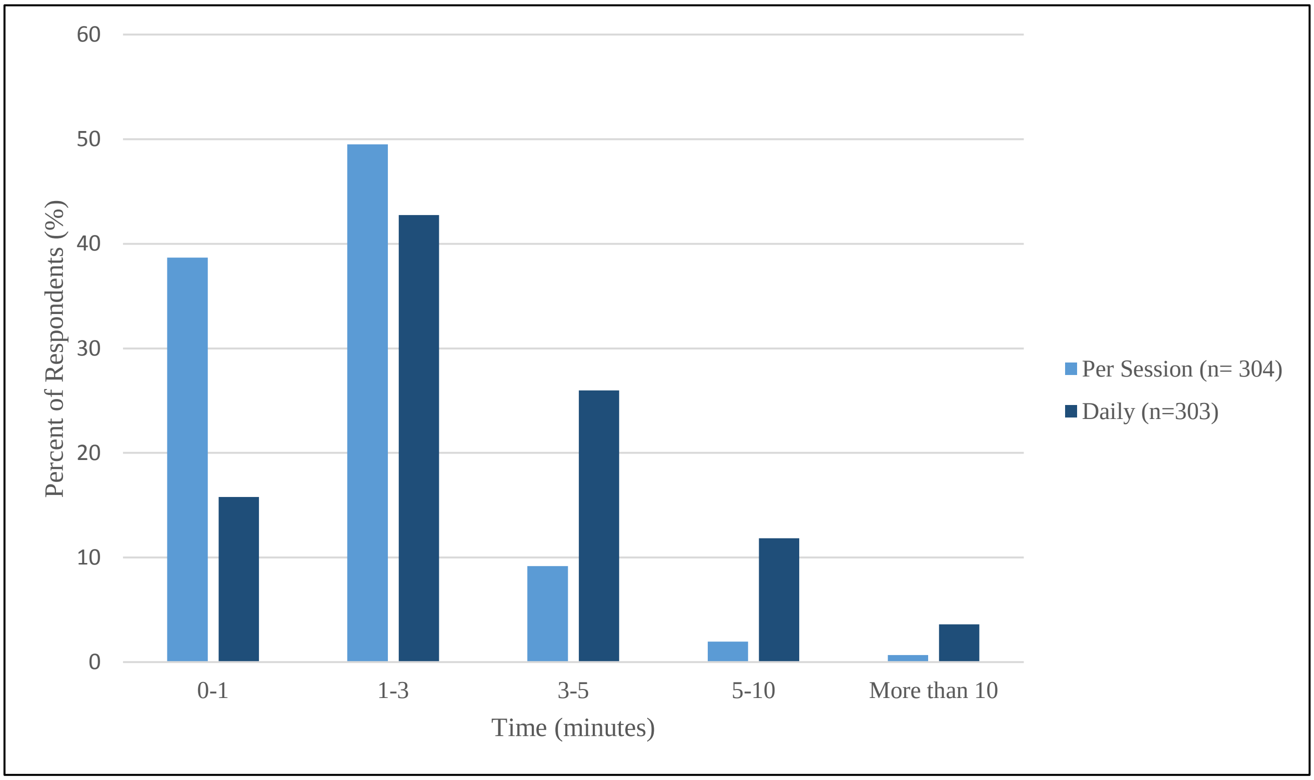

Figure 4.6: Respondents Who Report MWA Use for Specific Durations per Session and Daily (%)

In comparing commute, outdoor recreation, and outdoor work with the amount of time respondents spend on their MWA both per session and on a daily basis, there were subtle differences observed within activities. More respondents spend more time per session looking at weather on their phone if they engage in three or more hours of outdoor work compared to those who work outside for fewer than three hours weekly (Tables 4.11, 4.12). Additionally, a Chi square analysis revealed no significant association between the amount of any specific activity and the duration of MWA use both per session and per day.

Table 4.11: Respondents who Spend Time Weekly on Specific Activities and also Spend Specific Intervals of Time on a MWA per Session (%)

		0-1 minute	1-3 minutes	3-5 minutes	More than 5 minutes
Commute	0-2 hours (n)	39.5 (81)	47.3 (97)	9.8 (20)	3.4 (7)
	3 + hours (n)	36.7 (36)	54.1 (53)	8.2 (8)	1.0 (1)
Outdoor Rec	0-2 hours (n)	42.2 (57)	45.9 (62)	9.6 (13)	2.2 (3)
	3 + hours (n)	36.1 (60)	51.8 (86)	9.0 (15)	3.0 (5)
Outdoor Work	0-2 hours (n)	42.5 (82)	47.4 (92)	8.3 (16)	1.6 (3)
	3 + hours (n)	32.4 (35)	51.9 (56)	11.1 (12)	4.6 (5)

Table 4.12: Respondents who Spend Time Weekly on Specific Activities and also Spend Specific Intervals of Time on a MWA Daily (%)

		0-1 minute	1-3 minutes	3-5 minutes	More than 5 minutes
Commute	0-2 hours (n)	17.6 (36)	42.6 (87)	24.5 (50)	15.2 (31)
	3 + hours (n)	12.2 (12)	42.9 (42)	28.6 (28)	16.3 (16)
Outdoor Rec	0-2 hours (n)	18.7 (25)	44.0 (59)	24.6 (33)	12.7 (17)
	3 + hours (n)	13.9 (23)	42.2 (70)	25.9 (43)	18.1 (30)
Outdoor Work	0-2 hours (n)	16.1 (31)	45.8 (88)	26.6 (51)	11.5 (22)
	3 + hours (n)	15.7 (17)	38.0 (41)	23.1 (25)	23.1 (25)

In terms of what times of the day are most popular for students to check their MWA, the morning hours between 6:00AM and 11:00AM see the most MWA activity compared to the rest of the day (Figure 4.7). Activity quickly diminishes from the late morning through the early evening, with a gradual increase between 7:00PM and midnight. Approximately 10% check their MWAs during the late overnight hours of 12:00AM to 6:00AM.

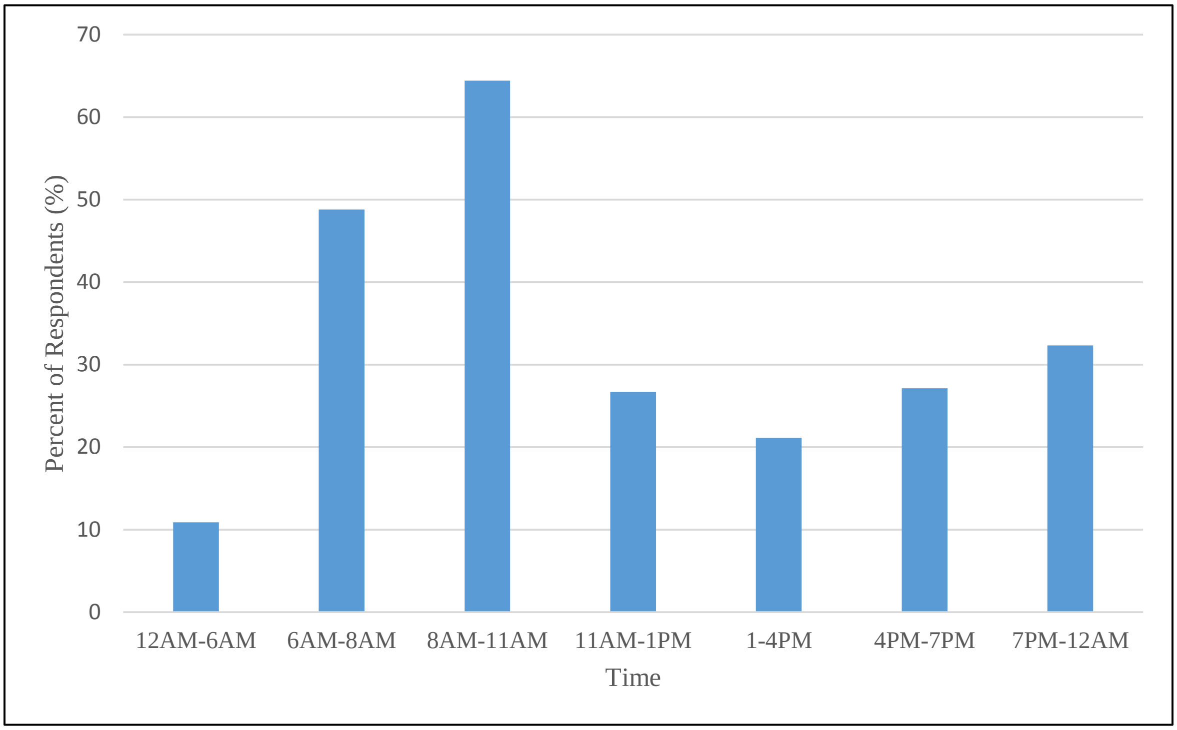

Figure 4.7: Respondents Who Report MWA Use during Specific Time Intervals (%)

Comparing the reported weekly activities to the times of day MWA are accessed by respondents, the most popular time interval was 8:00AM to 11:00AM regardless of the activity or the hours spent on the activity (Table 4.13). A Chi square test determined that there is a statistically significant association between respondents who work outside and the use of MWAs between midnight and 6:00 in the morning. In looking specifically at the cross tabulation, more students who work outside for a longer duration (more than 3 hours) check their MWA during the early overnight hours compared to students who work between 0-3 hours outside weekly.

Table 4.13: Amount of Time Spent Weekly on Specific Activities and the Time of Day Respondents Check Their MWA

		12AM-6AM	6AM-8AM	8AM-11AM	11AM-1PM	1PM-4PM	4PM-7PM	7PM-12AM
Commute	0-2 hours	10.8 (22)	46.6 (95)	64.7 (132)	26.5 (54)	20.6 (42)	25.5 (52)	33.3 (68)
	3 + hours	11.2 (11)	53.1 (52)	64.3 (63)	27.6 (27)	22.4 (22)	30.6 (30)	30.6 (30)
Outdoor Rec	0-2 hours	11.2 (15)	49.3 (66)	62.7 (84)	25.4 (34)	16.4 (22)	23.9 (32)	34.3 (46)
	3 + hours	10.8 (18)	47.6 (79)	66.9 (111)	28.3 (47)	25.3 (42)	29.5 (49)	30.7 (51)
Outdoor Work	0-2 hours	7.8* (15)	46.9 (90)	66.1 (127)	25.0 (48)	19.3 (37)	24.0 (46)	32.8 (63)
	3 + hours	16.7* (18)	50.9 (55)	63.0 (68)	30.6 (33)	25.0 (27)	32.4 (35)	31.5 (34)
*statistically significant association at 0.05 significance level								

Research Question 4: How do geographic and demographic factors influence MWA use?

The final research question investigates the connection between respondents' demographics and how this information relates to MWA preferences and usage patterns. Chi square and ANOVA tests were conducted to compare respondent information between schools and between gender. Because age, race, and education level were all relatively uniform in the sample, they were not analyzed. For gender-related analyses in this section, the "transgender" and "prefer not to answer" options were omitted, as both categories together garnered only two total responses.

In comparing students' responses from East Carolina University (ECU), the University of South Carolina (USC), and the University of Georgia (UGA), several categories showed significance. For aspects of a weather forecast, a statistically significant difference between the three schools existed for how respondents view information regarding how much precipitation is forecast (Table 4.14). A post-hoc analysis found that the perceived importance of precipitation amount by UGA students was lower compared to both ECU and USC, meaning students at UGA do not find this piece of information as critical. Another statistically significant results between schools was found with the perceived importance of the weather video feature (UGA had lower perceived importance in this feature).

Table 4.14: Statistically Significant ANOVA Test Differences in MWA Preference and Use by University

Importance of Weather Forecast Elements				
Survey Item	ANOVA Test Result	Degrees of Freedom	ANOVA significance	Tukey HSD Test
Amount of Precipitation	F = 9.768	2	0.000*	ECU-UGA: $p = 0.000$* UGA-USC: $p = 0.003$*
Importance of MWA Features				
Survey Item	ANOVA Test Result	Degrees of Freedom	ANOVA significance	Tukey HSD Test
Weather videos	F = 3.726	2	0.025*	ECU – UGA $p = 0.026$*
Confidence in MWA Features				
Survey Item	ANOVA Test Result	Degrees of Freedom	ANOVA significance	Tukey HSD Test
None	N/A	N/A	N/A	N/A
*statistically significant association at 0.05 significance level				

In comparing gender differences, statistically significant results were found where men perceived wind speed and wind direction to be more important compared to women (Table 4.15). Additionally, more men than women find the satellite and radar feature important on a MWA.

Table 4.15: Statistically Significant ANOVA Test Differences in MWA Preference and Use by Gender

Importance of Weather Forecast Elements			
Survey Item (Importance of Forecast Elements)	ANOVA Test Result	Degrees of Freedom	ANOVA significance
Wind speed	F = 4.387	1	0.037*
Wind direction	F = 8.021	1	0.005*
Importance of MWA Features			
Survey Item (Importance of MWA Features)	ANOVA Test Result	Degrees of Freedom	ANOVA significance
Satellite and radar	F = 28.992	1	0.000*
Confidence in MWA Features			
Survey Item (Importance of MWA Features)	ANOVA Test Result	Degrees of Freedom	ANOVA significance
None	N/A	N/A	N/A
* significant at 0.05 level			

With Chi square tests on categorical variables between schools, some categories were consolidated to meet test assumptions of having no more than 20% of cells with less than five expected values. For the amount of time spent on MWAs per session, three time intervals were combined to form two distinct intervals of 0-3 minutes and 3+ minutes. A statistically significant association exists for time respondents spend on their MWA per session, where more students at USC used their MWA for a longer time period per session than did students at UGA and ECU (Table 4.16).

For the primary reason respondents chose their favorite MWA, the "design and graphics" option was eliminated because only 11 students chose this option and because a previous Chi square analysis including this variable failed to meet the expected value assumption. Two Chi square tests returned as statistically significant with regard to the three universities. One included the primary reason why respondents choose their favorite MWA. A lower percentage of students at USC chose "easy to use" as their most important reason for choosing their MWA compared to UGA and ECU. Additionally, the number of students who chose "easy to understand" at UGA and "default" at ECU were less compared to the two other schools. However, with a Cramer's V value of 0.174, this post hoc result reveals schools have a minimal effect on respondents' primary reason for choosing their favorite MWA. The other statistically significant Chi square result was for the amount of time spent on a MWA per session by respondents, such that more students at UGA spent 0-1 minutes on their MWA compared to students at USC and ECU who spent more (or less?) time on their MWAs.

Table 4.16: Chi Square Analyses on MWA Preference and Use by University

Feature	Result	Degrees of Freedom	Significance	Cramer's V Association
Favorite Weather App	$\chi^2 = 6.545$	6	0.365	
Primary Reason for MWA	$\chi^2 = 15.448$	8	0.051*	0.174
Default Switch?	$\chi^2 = 0.105$	2	0.949	
Time of Day for MWA Use				
12-6AM	$\chi^2 = 0.798$	2	0.671	
6-8AM	$\chi^2 = 1.101$	2	0.577	
8-11AM	$\chi^2 = 0.518$	2	0.772	
11-1PM	$\chi^2 = 0.337$	2	0.845	
1-4PM	$\chi^2 = 2.275$	2	0.321	
4-7PM	$\chi^2 = 3.704$	2	0.157	
7PM-12AM	$\chi^2 = 0.948$	2	0.623	
MWA Use				
Per Session	$\chi^2 = 13.052$	6	0.042*	0.147
Daily	$\chi^2 = 5.258$	6	0.511	
Pay for App?	$\chi^2 = 0.922$	1	0.631	
Number of MWAs on Phone	$\chi^2 = 1.436$	4	0.838	
* significant at 0.05 level				

For gender, statistically significant associations were found for respondents who use their MWAs between midnight and six in the morning, where women were more likely to use their phones during the early overnight hours compared to men (Table 4.17). Additionally, an association was found with gender and the amount of MWAs a respondent reported having on their device, where men reported having more MWAs than women.

Table 4.17: Chi Square Analyses on MWA Preference and Use by Gender

Feature	Result	Degrees of Freedom	Significance	Cramer's V Association
Favorite Weather App	$\chi^2 = 3.738$	1	0.291	
Primary Reason for MWA	$\chi^2 = 3.057$	5	0.691	
Default Switch?	$\chi^2 = 0.422$	1	0.516	
Time of Day for MWA Use				
12-6AM	$\chi^2 = 4.786$	1	0.034*	0.122
6-8AM	$\chi^2 = 0.063$	1	0.801	
8-11AM	$\chi^2 = 1.439$	1	0.230	
11-1PM	$\chi^2 = 0.178$	1	0.673	
1-4PM	$\chi^2 = 0.175$	1	0.676	
4-7PM	$\chi^2 = 1.128$	1	0.288	
7PM-12AM	$\chi^2 = 0.004$	1	0.947	
MWA Use				
Per Session	$\chi^2 = 1.704$	3	0.636	
Daily	$\chi^2 = 2.920$	4	0.571	
Pay for App?	$\chi^2 = 2.344$	1	0.126	
Number of MWAs on Phone	$\chi^2 = 11.429$	2	0.003*	0.194
* significant at 0.05 level				

Geographical Consideration

To determine if there are any geographically relevant connections to how respondents answered the survey, the zip codes provided were mapped using ArcGIS ArcMap. The majority of students who attend East Carolina University live in North Carolina. The same was found for University of South Carolina students living in South Carolina and University of Georgia students living in Georgia. A few students from all three schools live in coastal areas, while a majority live in inland locations (Figure 4.8). Additionally, a small number of students consider their home to be located outside of the southeast, some of which include New Jersey, New York, Maryland, and California.

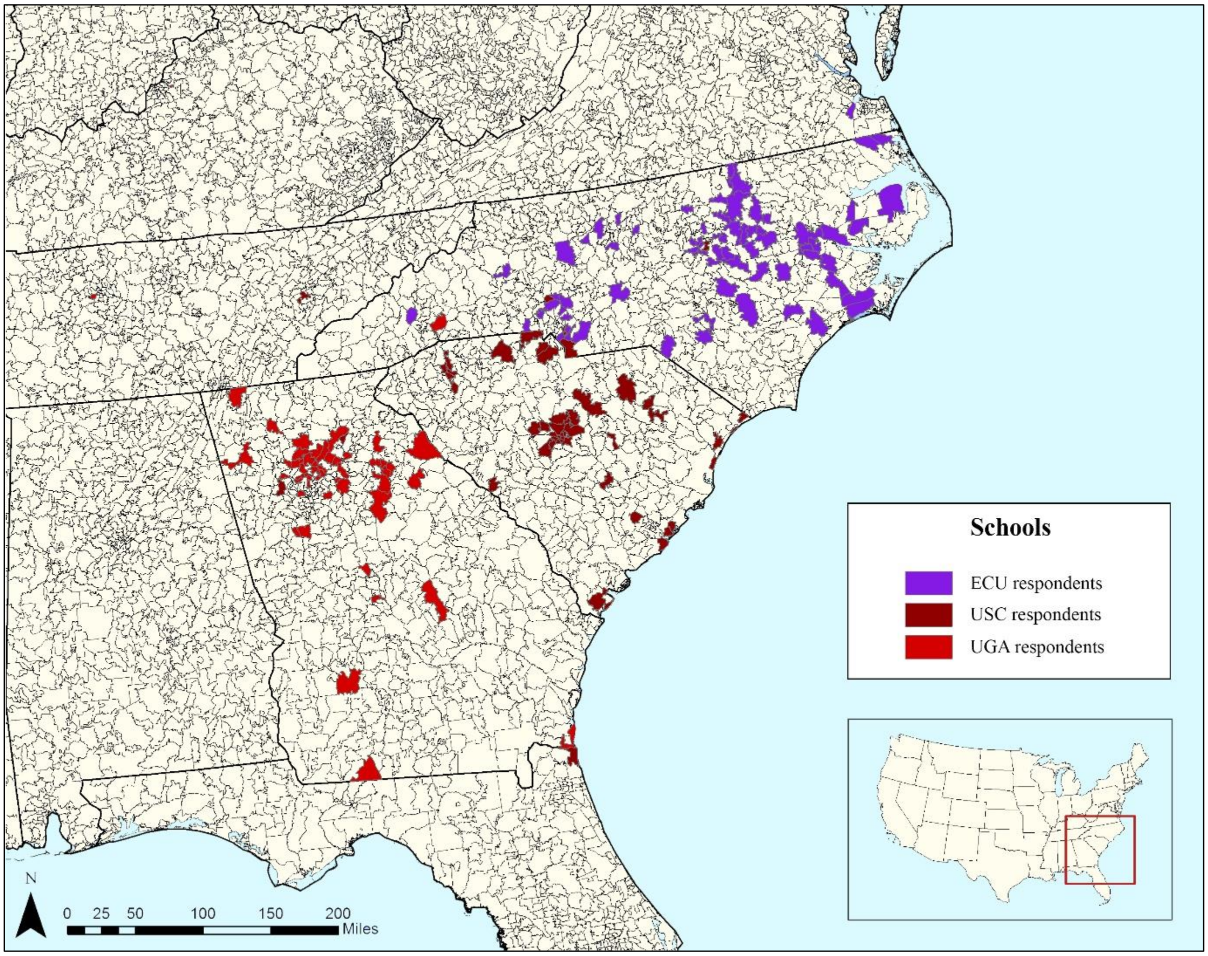

Figure 4.8: Zip Codes for Where Respondents Considered Their Home to be Located

Suggested changes from respondents to improve MWAs

As the final item on the survey, respondents were prompted to provide suggestions for how they think MWAs could be improved. Of the 308 total surveyed, 256 contributed information on what they believe would enhance MWAs, with 280 total suggestions counted (some respondents provided multiple suggestions). Because the question was open-ended, the information from respondents was content-coded by two coders trained in the methods described by Hsieh and Shannon (2005). One coder analyzed the responses to extract key themes and patterns in order to construct categories in which feedback was sorted (Table 4.18). Both coders then sorted responses into the established categories.

Table 4.18: Content Coding Categories and Corresponding Examples

Category	Value	Example	Number of responses
1	No changes suggested	"I wouldn't make any changes."	46
2	Accuracy	"Better accuracy."	50
3	Information and Features	"Provide a suggestion for articles of clothing to wear."	68
4	Design/More User-Friendly/Customization	"Simple to understand picture representation of the upcoming weather."	53
5	Radar	"Having an easier local radar to see what is going occur without difficulties."	21
6	Location	"If the app could update your location's weather while traveling."	13
7	Notifications (Severe weather and other alerts)	"I think notifications for change in predicted weather would be convenient to have."	16
8	Advertisements	"No advertisements."	8
9	Miscellaneous	"I would like humor to be added into a forecast, as it seems often they are somewhat bland."	5

A Cohen's Kappa coefficient inter-coder reliability test was performed to measure the level of agreement between the two coders and to ensure that the content-coding yielded reportable results. For Cohen's Kappa 1.00 represents perfect reliability and 0.00 no reliability. The agreement (α) was calculated to be 0.955, which shows near perfect reliability for the dataset.

Respondent suggestions centered on better information or features (24.3%), overall MWA design (18.9%), and improved accuracy (17.9%). While the categories for radar and notifications could have been consolidated with the information and features category, there were a number of responses that targeted these separate items directly. One of the suggestions for radar and notifications included having an enhanced radar that scans the atmosphere more frequently, while a suggestion for the notifications category included having a setting that alerts users when the forecast changes unexpectedly. Also, 16.4% of respondents explicitly stated that they are satisfied with MWAs and offer no ideas for improvement.

CHAPTER 5: DISCUSSION/ANALYSIS

Weather will always be a force to contend with on a day-to-day basis, and understanding the source from which people access weather information is essential. Past research has established the foundation to further explore where people gain information on weather forecasts, but with the rapid growth in mobile device technology that affords much convenience for users, even the most recent studies have been unable to adequately capture the use of MWAs to obtain weather information. This research is aimed at filling the gap in the areas of mobile smartphone technology and its role as a dominant weather source among college students, while also updating existing literature on sources of weather information.

Summary of Results

Demographic information about respondents revealed a rather homogenous sample. A majority of participants were white, young college students. An overwhelming majority of those surveyed use smartphones regularly for forecasts, while the second most popular choice was conferring with friends and family. Over 90% do not use newspapers or NOAA Weather Radios for forecasts.

The first research question uncovered information on which MWAs available to consumers were the most popular and the reasons behind respondents' choices. The Weather Channel and Apple Weather MWAs were by far the most commonly used apps, followed by AccuWeather, WeatherBug, and Wunderground. When respondents were asked for the single reason they prefer their favorite MWA, ease of use, understandability, and being the pre-loaded default on the device were the top choices. When allowed to expand their reasoning with all applicable answers, the level of detail in a MWA along with the design and graphics of an app were viewed as important reasons. While most do not switch from their default MWA, approximately 39% have moved to another app because they were not satisfied with factors like the depth of information or they reported that their current MWA is too complicated.

It is important to note that while the research did identify which MWAs are most popular among respondents, the specific MWA does not matter as much as the perceived importance and user confidence in MWA features, which is addressed by research question two. Most respondents found the hourly and 5-day forecast to be most useful, as well as severe weather alerts and current conditions. Most were also confident in the same features. Two complementary questions under the initial research question provides additional information to address MWA preference. Results from a cross-tabulation analysis indicate that perceived importance of weather forecast aspects did not affect which apps participants chose.

The third research question focuses on reported activities in which respondents engage in weekly and how personal lifestyles may affect how individuals use MWAs. Data suggests that activities and the length of participation in the activities has very little influence over which MWA features are used more. Reported activities also have little effect on how long individuals spend looking at weather information on their app(s). However, a statistically significant association was found for outdoor work and those who use their phones between 12:00AM and 6:00AM.

The final research question sought to analyze gender and university with the many variables analyzed in the survey. Although most analyses using Chi square and ANOVA were not statistically significant, there is a statistically significant relationship between schools and some MWA use. An ANOVA test revealed that students at both ECU and USC placed more importance on information about the amount of precipitation in a forecast than did students at

UGA. Additionally, students at ECU were more confident in the pollen count feature on a MWA than UGA students and believed that weather videos were more important than UGA students. A statistically significant, but weak, association was also found for universities and both the amount of time respondents spend on their MWA for each session and the number one reason they use their preferred MWA.

For gender, men believed that wind speed and wind direction were more important to have in a forecast than women. Additionally, the satellite and radar feature is less important to women than to men. Chi Square results indicate that women tend to check their MWAs in the overnight hours of 12AM to 6AM more so than men, and men tend to have more MWAs on their smartphone than women.

Qualitative answers relating to what respondents believe will further improve MWAs revealed that many would like weather apps to be more accurate, provide additional features, and be more user-friendly and customizable to individual preferences. Additionally, many were happy with their phones as is.

Implications

The data collected from the analyses of the survey highlights a wealth of information about college students and their use of smartphones and MWAs for acquiring weather forecast information. Additionally, this study updates the findings from previous studies by Lazo et al. (2009) and Demuth et al. (2011) on sources of weather forecast information and how respondents use the information daily. Lazo et al., (2009) found that local television and other media were the most common mode for retrieving daily weather information; this study, however, brings to light a younger generation's habits and the implications that will change the paradigm of communication weather information well into the future.

The popularity of The Weather Channel and Apple Weather apps (both of which are default apps on many phones) combined with the fact that most respondents do not switch from their default MWAs signifies that most students are satisfied with the quality of their default MWA and therefore do not feel compelled to switch. Corporations and organizations in the weather enterprise that are able to forge relationships with cell phone service providers or technology companies will likely have the most success with their products, as they are most likely to be used by consumers.

The use of MWAs and MWA choice are important, but information about how people use MWAs helps paint a more complete picture. Respondents want to know about precipitation and temperature. Nearly every aspect of precipitation (chance, timing, location, and type) was perceived as important aspects of a forecast, while the forecast high and low temperature and the timing of these temperatures were valuable for those surveyed, which was the case in Lazo et al. (2009).

A majority of students use their MWAs in the early morning and in the late evening, times that are often associated with when people wake up and start their day and when they are winding down and preparing for the next day. The peak in MWA use in the morning hours between 6:00AM and 11:00AM is similar to findings by Lazo et al. (2009), where a majority of people report seeking weather information between these hours. This suggests that respondents are accessing their MWA and actively seeking forecast information right as they begin their day. While there was a considerable percentage of respondents who looked at their MWAs between 4:00PM-12:00AM, Lazo et al. (2009) found a much higher rate of weather information seeking between the same hours. However, these authors captured information from an older population sample, while this study focuses on college students, so it is not surprising to see some differences in times of use.

Most respondents spend as little as seconds on their MWA, suggesting that they only glance at their phone just long enough to retrieve the information they need to plan their day. Also, current conditions, the hourly forecast, and severe weather notifications were among the most popular MWA features. These are all tools that help in the near-term, bolstering the idea that respondents are most concerned with the present and the immediate future. The 5-day forecast was also perceived as important along with the precipitation chance feature. This indicates that MWAs need to show this desired information up front.

There were some statistically significant differences with gender in this study, where women looked at their MWAs more than men during the overnight hours and men have more MWAs on a device than women. Past research by Demuth et al. (2011) found some statistically significant differences in gender as well, including that women more often than men use weather forecasts for such purposes as planning what to wear, planning leisurely activities, and for simply just knowing weather conditions.

Valuable information was gathered from the many suggestions offered by respondents in the open-ended portion of the survey. Some advocated for the addition of new MWA features tailored to active lifestyles that could better pinpoint how the weather would impact them throughout the day. Others proposed features would provide advice on what to wear and how to prepare based on the forecast. Increased accuracy was another common theme, as well as improved design and the ability to customize a MWA to an individual’s own liking.

The results from this study suggest that students understand the benefits of using a MWA over other sources for acquiring weather forecast information, which corresponds with several aspects from the Diffusion of Innovations Theory (DIT) (complexity, compatibility, and relative advantage) (Rogers 1995) and the Technology Acceptance Model (TAM) (relative usefulness and ease of use) (Davis et al., 1989). Two primary reasons for why respondents chose their favorite app included ease of use and understandability. Both of these ideas relate to TAM and the complexity component of the DIT, indicating that simpler technologies are more readily adopted and accepted than ones that are perceived to be difficult to use.

With students' on-the-go lifestyles and their demand for information that allows for them to plan for the near future, a MWA offers a compatible, convenient, and useful alternative to local television, radio, and other weather forecast sources. MWAs provide the information that respondents find important in a forecast, and the portable nature of smartphones and MWAs allows students to take the forecasts with them wherever they go without having to wait for information that is delivered at specific times on other sources. The high smartphone usage rates among a majority of respondents makes MWAs highly accessible. With weather information only a few taps away, little effort is required to obtain valuable forecast details that students can use to plan. MWAs are also often pre-loaded onto consumers' phones at the time of purchase, making weather information available to almost everyone with a smartphone who chooses to use a weather app.

Convenience, utility, and compatibility are some of the important elements of both DIT and TAM, culminating as reasons why MWAs are widely embraced by students in this study. MWAs provide many improvements over other sources, and DIT's relative advantage characteristic indicates that because many respondents are satisfied with their weather apps and see that MWAs as valuable, this positive impression will lead to further acceptance and continued use of this technology into the future.

While the NWS provides forecasts for the public, its core focus centers on more immediate, life-threatening weather events. Because the NWS does not currently have an MWA that can be accessed by the public, there are no direct benefits from this research to any of their products. However, for the weather enterprise’s private sector companies, this study highlights the potential improvements that can be made to MWAs to garner even more favorability among a young demographic. From the most liked and disliked MWA features to the many suggestions provided by respondents, organizations that want to continually improve their product have new information they can consider when updating their MWAs. Public sector agencies like the NWS may consider using MWA technology to reach a changing demographic that clearly uses mobile technology on a regular basis.

Limitations of Research

While the study presents important information, there are several limitations that should be addressed. The information from the research, while valuable, is not generalizable. The study only assesses the use of MWAs by college students who were chosen from specific classes in Geography programs in the Southeast. Respondents were similar demographically and geographically, which does not allow for broad conclusions of the American public as a whole. Additionally, the survey was disseminated in the Fall and Winter months. This could impact survey results as the presence or lack of significant weather events may have affected respondents’ answers to questions.

Finally, the intent of allowing respondents to skip questions rather forcing them to answer every question was to increase the number of completed surveys. However, the analyses of responses were more difficult because of the differing number of people answering each question. For example, for some cross tabulation analyses with two variables being analyzed, some respondents would answer one of the questions while failing to answer the second question, resulting in the inability to calculate some respondent answers.

Because the study was limited in its geographic and demographic scope, the study can be expanded to include more participants encompassing a larger study area. Additionally, while surveys are effective tools for social science research, other methods, including qualitative interviews and focus groups should be considered to extract deeper richer information from MWA users. With new technology and methods for smartphone research, there are mechanisms that can directly extract information on MWA user habits and patterns. This form of information acquisition allows for researchers to obtain information more reliable than information relayed by respondents about their own activities.

Contributions to Future Knowledge

This original research extends the knowledge and capabilities of the atmospheric science world to millions of people who rely on their mobile devices for weather information. With the dynamic technological world of portable devices and smartphone applications, it is critical to understand the connection between the weather enterprise and the general public. Sources of weather information have changed drastically within the last decade, and it is imperative to remain cognizant of how consumers of weather information perceive and use the many resources available to them. Building on existing literature, this study sheds light on the popularity and use of MWAs on smartphone devices for acquiring weather information. This study also reassesses the many documented sources of weather forecast information to determine how the growth of MWAs has affected the sources that people choose for weather. While the focus for this research is on commonplace everyday weather situations, connections can be drawn and applied to severe weather scenarios that pose a more significant threat to life and property.

This integrative study incorporates ideas and facets from a multitude of disciplines, including geography, atmospheric sciences, communication, and psychology, making this research endeavor valuable to many fields. It is hoped that further investigations into this area can fill gaps in the literature and provide comprehensive knowledge of weather source use and preference that will allow future researchers and academics in the weather enterprise and beyond to better accommodate the people who use products to stay informed about the weather.

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APPENDIX A: IRB APPROVAL

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
4N-70 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** · www.ecu.edu/irb

Notification of Amendment Approval

From: Social/Behavioral IRB
To: Minh Phan
CC:
Burrell Montz Covey
Date: 10/18/2016
Re: Ame1_UMCIRB 16-001651
UMCIRB 16-001651
Weather on the Go: An Assessment of Smartphone Mobile Weather Applications Use among College Students

Your Amendment has been reviewed and approved using expedited review for the period of 10/18/2016 to 10/4/2017 . It was the determination of the UMCIRB Chairperson (or designee) that this revision does not impact the overall risk/benefit ratio of the study and is appropriate for the population and procedures proposed.

Please note that any further changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. A continuing or final review must be submitted to the UMCIRB prior to the date of study expiration.The investigator must adhere to all reporting requirements for this study.

Approved consent documents with the IRB approval date stamped on the document should be used to consent participants (consent documents with the IRB approval date stamp are found under the Documents tab in the study workspace).

The approval includes the following items:

Document	Description
Survey_Minh(0.02)	Surveys and Questionnaires

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

IRB00000705 East Carolina U IRB #1 (Biomedical) IORG0000418
IRB00003781 East Carolina U IRB #2 (Behavioral/SS) IORG0000418

APPENDIX B: THE SURVEY

Q1 Which school do you attend?

- East Carolina University (1)
- University of Georgia (2)
- University of South Carolina (3)
- University of Florida (4)
- University of South Florida (5)
- Other School (6) ____________________

Q2 What is your age?

- Under 17 (1)
- 17-19 (2)
- 20-22 (3)
- 23-25 (4)
- 26 or older (5)

Q3 To what racial or ethnic group do you most closely identify?

- White (1)
- Black or African American (2)
- Hispanic or Latino (3)
- Native American or American Indian (4)
- Asian or Pacific Islander (5)
- Other (6)

Q4 What is your gender?

- Male (1)
- Female (2)
- Transgender (3)
- Prefer not to answer (4)

Q5 What is your highest level of education so far?

- ❍ Some college credit, no degree (1)
- ❍ Associate’s degree (2)
- ❍ Bachelor's degree (3)
- ❍ Master's degree (4)
- ❍ Professional degree (5)
- ❍ Doctorate degree (6)

Q6 In what zip code do you consider your home to be located?

Q7 On average, year-round, how many hours per week do you spend on the following activities?

	0 hours (1)	1-2 hours (2)	3-5 hours (3)	6-10 hours (4)	10 + hours (5)
Commuting to work or school (1)	❍	❍	❍	❍	❍
Engaging in outdoor leisurely activities (2)	❍	❍	❍	❍	❍
Work or job-related outdoor activities (3)	❍	❍	❍	❍	❍

Q8 A weather forecast can provide several types of information about temperature, cloudiness, wind, and precipitation (such as rain, snow, hail, or sleet). How important is it to you to have the information listed below as part of a weather forecast?

	Not at all important (1)	Not important (1)	Neutral (2)	Important (3)	Extremely Important (3)
Chance of precipitation (1)	❍	❍	❍	❍	❍
Amount of precipitation (2)	❍	❍	❍	❍	❍

Type of precipitation (3)	❍	❍	❍	❍	❍
When precipitation occurs (4)	❍	❍	❍	❍	❍
Where precipitation occurs (5)	❍	❍	❍	❍	❍
Chance of different amounts of precipitation (6)	❍	❍	❍	❍	❍
Low temperature (7)	❍	❍	❍	❍	❍
High temperature (8)	❍	❍	❍	❍	❍
Time of day of low temperature (9)	❍	❍	❍	❍	❍
Time of day of high temperature (10)	❍	❍	❍	❍	❍
Cloud cover (11)	❍	❍	❍	❍	❍
Wind speed (12)	❍	❍	❍	❍	❍
Wind direction (13)	❍	❍	❍	❍	❍
Humidity (14)	❍	❍	❍	❍	❍
Pollen count (15)	❍	❍	❍	❍	❍

Q9 How often do you get weather forecasts from the sources listed below?

	Rarely or never (1)	Once or twice a week (2)	Once a week (2)	Two or more times a week (2)	Once a day (3)	Two or more times a day (3)
Local television channel (1)	❍	❍	❍	❍	❍	❍
Cable television channel (2)	❍	❍	❍	❍	❍	❍
Mobile Phone (Smartphone App) (3)	❍	❍	❍	❍	❍	❍
Newspaper (4)	❍	❍	❍	❍	❍	❍
Commercial/Public radio station (5)	❍	❍	❍	❍	❍	❍
NOAA weather radio (6)	❍	❍	❍	❍	❍	❍
National Weather Service website (7)	❍	❍	❍	❍	❍	❍
Other internet sites (8)	❍	❍	❍	❍	❍	❍
Friends/Family (9)	❍	❍	❍	❍	❍	❍

Q10 Considering weather forecasts from any source, how confident are you in the overall accuracy of the information in a forecast?

❍ Not at all confident (1)
❍ Not really confident (2)
❍ Neutral (3)
❍ Confident (4)
❍ Extremely confident (5)

Q11 Do you own a cell phone?

❍ Yes (1)
❍ No (2)

If No Is Selected, Then Skip To End of Survey

Q12 For how many years overall have you owned a cell phone?

- Less than one year (1)
- 1-2 years (2)
- 2-4 years (3)
- 4-6 years (4)
- More than 6 years (5)

Q13 A smartphone is a cell phone with enhanced capabilities and software that allows for specific functions. Do you own a smart phone?

- Yes (1)
- No (2)

If No Is Selected, Then Skip To End of Survey

Q14 For how many years overall have you owned a smartphone?

- Less than one year (1)
- 1-2 years (2)
- 2-4 (3)
- 4-6 years (4)
- More than 6 years (5)

Q15 How many different mobile weather applications do you have, including the default mobile weather application that came on your phone?

- 1 (1)
- 2 (2)
- 3 (3)
- 4 (4)
- 5 (5)
- More than 5 (6)

Q16 Which mobile weather application is your favorite?

- ❍ The Weather Channel (1)
- ❍ AccuWeather (2)
- ❍ Wunderground (3)
- ❍ WeatherBug (4)
- ❍ Apple Weather (5)
- ❍ Yahoo Weather (6)
- ❍ Local Television Station App (7)
- ❍ Other (please specify) (8) ____________________

Q17 What is the primary reason that you prefer this weather app?

- ❍ Easy to use (1)
- ❍ Easy to understand (2)
- ❍ Level of detail in information (3)
- ❍ Design and graphics (4)
- ❍ Default on my phone when I got it (5)
- ❍ Other (please specify) (6) ____________________

Q18 Are there other reasons why you prefer this weather app? Choose all that apply:

- ❑ Easy to use (1)
- ❑ Easy to understand (2)
- ❑ Level of detail in information (3)
- ❑ Design and graphics (4)
- ❑ Default on my phone when I got it (5)
- ❑ Other (please specify) (6) ____________________

Q19 Have you switched from the default weather app that came on your phone?

- ❍ Yes (1)
- ❍ No (2)

If No Is Selected, Then Skip To What time(s) of the day do you access...

Q20 If yes, why did you switch to the new app?

- ❑ Easier to use (1)
- ❑ Easier to understand (2)
- ❑ Better level of detail in information (3)
- ❑ Better design and graphics (4)
- ❑ Other (please specify) (5) ____________________

Q21 What time(s) of the day do you access weather information from your mobile weather application? Choose all that apply:

- ❑ 12:00AM-6:00AM (1)
- ❑ 6:00AM-8:00AM (2)
- ❑ 8:00AM-11:00AM (3)
- ❑ 11:00AM-1:00PM (4)
- ❑ 1:00PM-4:00PM (5)
- ❑ 4:00PM-7:00PM (6)
- ❑ 7:00PM-12:00AM (7)

Q22 On average, how much time do you spend looking at information on your mobile weather application for each individual session?

- ❍ 0-1 minute (1)
- ❍ 1-3 minutes (2)
- ❍ 3-5 minutes (3)
- ❍ 5-10 minutes (4)
- ❍ More than 10 minutes (5)

Q23 On average, how much time do you spend looking at information on your mobile weather application on a daily basis?

- ❍ 0-1 minute (1)
- ❍ 1-3 minutes (2)
- ❍ 3-5 minutes (3)
- ❍ 5-10 minutes (4)
- ❍ More than 10 minutes (5)

Q24 How important are each of the following mobile weather application components to you?

	Not on my app (0)	Not at all important (1)	Not important (1)	Neutral (2)	Important (3)	Very Important (3)
5-day forecast (1)	❍	❍	❍	❍	❍	❍
10-day forecast (2)	❍	❍	❍	❍	❍	❍
10 + day forecast (3)	❍	❍	❍	❍	❍	❍
Hourly forecast (4)	❍	❍	❍	❍	❍	❍
Current information (temperature, wind, humidity) (5)	❍	❍	❍	❍	❍	❍
Severe weather alert (tornado, hurricane, flood, etc.) (6)	❍	❍	❍	❍	❍	❍
Satellite and radar (7)	❍	❍	❍	❍	❍	❍
Chance of precipitation (8)	❍	❍	❍	❍	❍	❍
Pollen count (9)	❍	❍	❍	❍	❍	❍
UV index (10)	❍	❍	❍	❍	❍	❍
Lightning detection alert (11)	❍	❍	❍	❍	❍	❍
Airport delays (12)	❍	❍	❍	❍	❍	❍
Weather videos (13)	❍	❍	❍	❍	❍	❍
News headlines about weather (14)	❍	❍	❍	❍	❍	❍
Advertisements (15)	❍	❍	❍	❍	❍	❍

Q25 How confident are you in the accuracy of the following features of your mobile weather application?

	Not on my app (0)	Not confident at all (1)	Not confident (1)	Neutral (2)	Confident (3)	Very Confident (3)
Hourly forecast (1)	❍	❍	❍	❍	❍	❍
5-day forecast (2)	❍	❍	❍	❍	❍	❍
10-day forecast (3)	❍	❍	❍	❍	❍	❍
10 + day forecast (4)	❍	❍	❍	❍	❍	❍
Lakes, rivers, oceans forecast (5)	❍	❍	❍	❍	❍	❍
Rain notification alert (6)	❍	❍	❍	❍	❍	❍
Lightning detection alert (7)	❍	❍	❍	❍	❍	❍
Severe weather alert (tornado, hurricane, flood, etc.) (8)	❍	❍	❍	❍	❍	❍
Pollen count (9)	❍	❍	❍	❍	❍	❍

Q26 Have you ever paid for a mobile weather application?

- ❍ Yes (1)
- ❍ No (2)

If No Is Selected, Then Skip To One last question! What kinds of chan...

Q27 If yes, how much did you pay for your weather app?

- ❍ Less than $1.00 (1)
- ❍ $1.00-$3.00 (2)
- ❍ $3.01-$5.00 (3)
- ❍ More than $5.00 (4)

Q28 One last question! What kinds of changes do you think would improve mobile weather applications?