A Survey of the Public Understanding of Doppler Radar

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ABSTRACT

Doppler radar is an important tool used by meteorologists. As opportunities for the public to view radar information increase, it is crucial that they are able to understand the information that they are viewing in order to make informed decisions. 318 students in three large lecture courses at Iowa State University (ISU) were surveyed about their knowledge of Doppler radar and represented the public in this study. 32 junior and senior meteorology students were also surveyed and used as the expert or control group. The results show that while the public understands basic concepts related to Doppler radar, there are misunderstandings or confusion about the application of it.

1. Introduction

Doppler radar is an essential tool used by meteorologists to gain insight on what is arguably one of the most complicated dynamical systems that exists – the atmosphere. From guiding a National Weather Service (NWS) forecaster to issue a tornado warning to showing a broadcast meteorologist where the strongest winds will most likely occur, the benefits of Doppler radar are apparent.

Since the initial realization over a half century ago that radar can be used to sense and predict weather, more and more people are acknowledging the ability of radar to protect and save lives and property. In fact, estimates show that the NWS Doppler radar system prevented over 330 fatalities and 7800 injuries from tornadoes between 1992 and 2004. This saved over $3 billion, almost twice as much as it cost to implement the system (Sutter and Simons 2006).

In the past, only professional meteorologists had access to radar information. Nowadays, many people have the opportunity to access a wealth of radar information due to internet and cell phone capabilities. In addition, private weather companies now cater to a growing customer base driven by need and education regarding weather information. (J. Johnson, 2007, Weather Decision Technologies Inc., personal communication). Some of this information plays a vital role in the health and well-being of U.S. citizens, especially during severe and hazardous weather such as lightning, floods, hurricanes, and tornadoes.

Meteorologists have a reasonable understanding of Doppler radar images and their meanings, but what the public understands about Doppler radar images is unknown. The goal of this study is to find out the current state of knowledge about Doppler radar in the general public and how detailed their understanding is about these images. The ability of the public to interpret radar images available over the Internet is necessary for the awareness during situations of possible danger. As technology advances, it is important to assess how the public views radar technology now and how they access this information.

2. Background

Doppler radar benefits Americans in many ways. As opportunities to access radar information increase, it is important that people understand the images that they are viewing. For this to happen, proper education must occur for people to view these radar images accurately. An examination of several disciplines is necessary to determine the best way to communicate weather radar information to the public. Prior to educating people about radar, which involves scientific and mathematic principles, the educator should be aware of the history of weather radar him or herself. The educator must also understand the pre-existing knowledge and attitudes that the public has regarding scientific issues, determine how the public learns scientific information, and know how to communicate his or her message effectively.

a. History of weather radar and its societal benefits

Although the use of radar began with the military around the beginning of World War II, it was not officially used for weather purposes until 1945. Even then, the primary user of weather radar was the military. People began to realize the benefits of weather radar when the first tornado warning solely based on radar data was issued on April 5, 1956 (Whiton et al. 1998). Not long after, devastating hurricanes led the Weather Bureau (now known as the National Weather Service) to propose a budget to Congress for the installation of a new network of radars called the Weather Surveillance Radar-1957 (WSR-57). The first WSR-57 was in place by 1959. The ability to detect storms behind intervening rainfall and to observe hurricanes at great distances was improved. Development of the network of Weather Surveillance Radar-1988 Doppler (WSR-88D) radars began in 1988, and the first Doppler weather radar was in place by 1990. The network of 161 WSR-88D's boasted color displays, velocity and interactive capabilities (Whiton et al. 1998). In addition, Simons and Sutter (2005) found that after the installation of the WSR-88D's, tornado fatalities dropped by 45% and injuries by 40%. Furthermore, the mean lead warning time on a tornado increased from 5.3 to 9.3 minutes.

There has been much advancement in weather radar technology in the past 60 years and society has greatly benefited from it. However, many improvements can and will be made in the future. Hurricanes, floods, and tornadoes kill about 150 people each year in the United States alone (NCAR). Some of these deaths may be preventable with more education and advancement in radar technology.

b. Public knowledge and attitudes about science

Although Americans strongly support government funding for basic scientific research, many Americans do not fully understand the scientific process. In fact, in a 2004 National Science Foundation survey, only 23% gave responses indicating that they knew what it meant to study something scientifically (Science and Engineering Indicators 2006).

Despite the lack of scientific knowledge among the public, many people have a high regard for the scientific community. In a 2004 Virginia Commonwealth University Life Sciences survey, 92% of the respondents agreed with the statement that "scientific research is essential for improving the quality of human lives" (VCU 2004). It is clear that while Americans have a high regard for the scientific community, there is a large scientific knowledge gap. If people are to make informed decisions that may aide in protecting themselves and their families, more knowledge is necessary to close the scientific gap.

c. How the public learns scientific information

It is difficult to define only one or two ways that the public learns scientific information. Diverse populations (e.g. gender, age, ethnicity, etc.) and a multitude of delivery mechanisms (e.g. paper, video, web-based, etc.) yield for challenging work for those trying to understand informal learning processes. Survey articles on scientific literacy (Laugksch 2000), models of pedagogy and epistemology (Matthews 2007), and instructional technology (Hew et al. 2007) indicate that there are as many models and approaches as there are educators. In addition, research shows that the same instructor can teach the same material in the same way to a multitude of classes, and experience different learning outcomes (Shulman 1999).

While some literature exists pertaining to how learning processes are studied, there is a lack of literature relevant to how people actually learn scientific information in an informal setting. As pointed out in Matthews (2007), "good teachers have long followed Aristotle's pedagogical lead—they start instruction with what is familiar and known, and build to what is unknown." Alternatively, as suggested by Ausubel (1968), "to teach a child, find out first what they know and then build upon it."

d. Effective communication

Television is currently the main source of information for the public, but the growth of the Internet continues to change the way material presents itself. In 2004, 63% of American adults and 81% of teens were online, and those numbers continue to grow today (Rainie et al. 2005). The Internet was also the number one source of information regarding specific scientific issues in the same year (Science and Engineering Indicators 2006). While the Internet allows for more access to scientific information, most Americans are not in contact with a scientist on a regular basis. In fact, TV weathercasters are often the most visible representatives of scientists in U.S. households (NIST 2002).

In addition, criticism is portrayed toward television media for being more interested in covering sensationalism than pure science, and for fostering negative opinions of science and technology. Nonetheless, the media also frequently portrays scientists as authoritative figures (Nisbet et al. 2002), perhaps giving the public a reason to continue viewing such programs.

Modern media is also visual, so any scientific presentation should contain colorful graphics and visual stimulants. Scientific information often contains jargon. Thus, Hoppen et al. (1996) suggests that scientific information be clearly presented and words or acronyms that may be confusing to the public be clearly explained.

3. Data

In order to understand how to better educate the public to make more informed decisions using weather radar during severe and hazardous weather events, one must first find out what the public does and does not already understand. A survey about Doppler radar was distributed to three large lecture courses at Iowa State University (ISU). The survey consisted of three types of questions including questions on the most basic radar concepts, radar application, and demographics.

The survey was distributed to a 200-level introductory meteorology class, a 100-level introductory psychology class, and a 200-level advertising class. Altogether, the survey was dispersed to 901 students. However, since the survey was voluntary and not all students attend class every day, 318 students completed the survey. Fifty-five surveys were received from the students in the psychology class, 141 from the meteorology class, and 122 from the advertising class.

Surveys were also distributed to meteorology majors in two upper-level meteorology classes at ISU. Thirty-two junior and senior students completed the survey, and they were treated as the experts in the study and were used as the control group.

4. Methodology

a) Survey distribution

The survey was designed using guidelines received from a radar expert at the University of Oklahoma (P. Heinselman, 2007, personal communication) and information from Gall et al. (1996).

The ISU Institutional Review Board (IRB), a group charged with protecting the safety and well-being of human research participants in university settings, approved the study. In the case of this and all IRB-approved studies, survey participation was voluntary and participants were permitted to skip any question they did not wish to answer.

The study collected demographic information from each survey participant including his or her gender, age group, highest academic completion, and area of study. The actual male to female ratio was also collected from the Office of the Registrar to determine whether the sample was representative of the class.

The author would like to distribute this or a similar survey to a wider demographic in the future; however, due to time constraints she was only able to survey people within the university. Thus, the author is aware that the results from this study are not representative of the entire American public. However, for this study, the term *public* will be used to describe the survey participants who completed the survey in one of three large lecture courses. The three courses were chosen because they are taken by a wide variety of ISU students and are considered as representative of the liberal arts and science curriculum and university as a whole.

While distributing a radar survey to an introductory meteorology class may seem biased, this assumption is not necessarily correct. In fact, the students in the introductory meteorology class learn the fundamentals of meteorology but do not learn specifically about radar. In addition, non-science or engineering students in need of science credits commonly take this course. As a result, it is probable that most of the students taking the class already have *some* interest in the weather, and perhaps may even have a greater working knowledge of Doppler radar than other university students. Surveys were distributed in the meteorology class at the beginning of the class period and handed in at the end.

The students in the psychology class who chose to participate were not given class time to complete the survey. Those who chose to participate stayed after class. This is probably the reason for the given number of participants. As a result, the sample from the students in the psychology class may include those who already have an interest in weather.

Instead of completing the survey on paper, the students in the advertising class had the opportunity to take the survey on the Internet. They were also given two extra credit points by their professor as an incentive for completing the survey.

Despite these distribution differences, the author does not believe that they had any substantial effects on the results of the study.

The junior and senior meteorology students were chosen to represent the experts in this study because they possess the greatest knowledge of meteorology (and radar) out of all the undergraduates at ISU. It is important to note, however, that while the upper-level meteorology students have had significant contact with radar data and some instruction on the topic, none of them has taken a course specifically geared towards radar research. Although considered experts in this study, their expertise is not the same as someone with a PhD in radar meteorology.

b) Statistical analysis

P-Values were computed to see if there were any statistically significant differences between either two of the three classes, or the public compared to the experts. A P-Value represents the probability of getting a sample statistic or more extreme sample statistic in the direction of the alternative hypothesis, H_A, when the null hypothesis, H_o, is true. P-Values were computed by first comparing two different proportions, P_1 and P_2, where for e.g.

$$P_1 = x_1/n_1$$

and x_1 is the observed count and n_1 is the sample size. In this study P_1 represented a proportion of one class and P_2 represented a proportion of another class (i.e. 2.17% of the meteorology students vs. 18.03% of the advertising students said they have poor knowledge of the weather, noted in Table 5). Next, H_A and H_o were determined. H_A was represented by $P_1 \neq P_2$ and H_o by $P_1 = P_2$. The combined proportion, P_c, combined the observed counts x_1 and x_2, with the sample sizes n_1 and n_2, where

$$P_c = \frac{x_1 + x_2}{n_1 + n_2}$$

The test statistic, Z, was then computed where

$$Z = \frac{P_1 - P_2}{\sqrt{\left[\frac{P_c(1 - P_c)}{n_1} + \frac{P_c(1 - P_c)}{n_2}\right]}}$$

and corresponded to a P-Value in a normal distribution table. A P-Value closest to zero means the proportion is more significant. Typically, a P-Value $< .05$ means the proportion is statistically significant.

5. Results

Note: In each figure and table, M represents the meteorology class, P represents the psychology class, A represents the advertising class, O represents the overall average of the three large lecture classes, and E represents the expert group.

The demographic of the survey participants was as follows:

Table 1 shows the percentage of male and female participants as well as the *actual* percentage of male and female students in each class. Overall, there was a female participation bias. There were more female participants in the survey, but there were actually more male students in the classes. However, the overall number of male and female participants was fairly even.

In addition, the ratio of male to female participants in the meteorology class was about 3:2. More females participated in the survey in the psychology class than did males, and the same was true for the students in the advertising class where the ratio of male to female students was about 5:11. Males dominated the expert group by a factor of about 3.5, a statistic that is not uncommon in the meteorological field.

Although Liberal Arts were the most common area of study (Table 2), almost all areas of study were well represented except for Engineering and Veterinary Medicine. This distribution shows the sample represents a diverse student population. The most common areas of study for the students in the meteorology class were Liberal Arts and Agriculture and Life Science. In the psychology class, the most common areas of study were Liberal Arts and Business. Liberal Arts, Business, and Design were the most common areas of study in the advertising class.

TABLE 1. Percentage of (a) male and female survey participants and (b) actual male and female students in each class.

(a)

Gender	M (%)	P (%)	A (%)	**O (%)**	E (%)
Male	59.85	44.23	31.15	**45.98**	77.42
Female	40.15	55.77	68.85	**54.02**	22.58

(b)

Gender	M (%)	P (%)	A (%)	**O (%)**	E (%)
Male	79.00	51.00	38.00	**56.00**	80.00
Female	21.00	49.00	62.00	**44.00**	20.00

TABLE 2. Percentage of survey participants studying Agriculture and Life Science, Business, Design, Engineering, Human Science, Liberal Arts, Natural and Physical Science, or Veterinary Medicine.

Area of Study	M (%)	P (%)	A (%)	**O (%)**	E (%)
Ag./Life Sci	29.23	10.20	3.31	**15.67**	0.00
Business	9.23	24.49	26.45	**18.67**	0.00
Design	2.31	8.16	22.31	**11.33**	0.00
Engineering	4.62	4.08	0.00	**2.67**	0.00
Human Sci	10.77	14.29	8.26	**10.33**	0.00
Liberal Arts	26.92	34.69	39.67	**33.33**	100
Nat/Phys Sci	16.92	4.08	0.00	**8.00**	0.00
Vet Med	0.00	0.00	0.00	**0.00**	0.00

Since the survey participants were students at a university it was not surprising that 98.71% of them were between the ages of 18 and 29 (Table 3).

TABLE 3. Age of survey participants.

Age	M (%)	P (%)	A (%)	**O (%)**	E (%)
18-29	98.53	98.11	99.18	**98.71**	93.55
30-49	1.47	1.89	0.00	**0.96**	6.45
50-64	0.00	0.00	0.82	**0.32**	0.00
65+	0.00	0.00	0.00	**0.00**	0.00

The majority (58.06%) had completed at least *some* undergraduate coursework, and 33.87% said their highest academic level completed was high school (Table 4).

TABLE 4. Highest academic level completed, including high school, the General Education Development test, some undergraduate coursework, an undergraduate degree, graduate degree, or Ph.D.

Level	M (%)	P (%)	A (%)	**O (%)**	E (%)
High School	42.65	46.15	18.85	**33.87**	0.00
GED	1.47	0.00	1.64	**1.29**	0.00
Some UGrad	50.00	46.15	72.13	**58.06**	100
UGrad Deg.	4.41	1.92	6.56	**4.84**	0.00
Grad Deg.	0.74	1.92	0.00	**0.65**	0.00
PhD	0.74	3.85	0.82	**1.29**	0.00

The participants were also asked about their opinion of their knowledge-level regarding the weather (Table 5). From the public participants, those in the meteorology class said they possess the greatest knowledge, as 52.17% of them said they have a good understanding of the weather. Those in the psychology class said they possess the least amount of knowledge, as 80.77% said their knowledge-level was either fair or poor.

TABLE 5. Percentage of participants who said they have poor, fair, good, or exceptional knowledge about the weather.

Knowledge -Level	M (%)	P (%)	A (%)	**O (%)**	E (%)
Poor	2.17	13.46	18.03	**10.26**	0.00
Fair	40.58	67.31	48.36	**48.08**	3.23
Good	52.17	15.38	33.61	**38.78**	38.71
Exceptional	5.07	3.85	0.00	**2.88**	58.06

a) Basic knowledge

It is clear from the results that the public has heard of Doppler radar and has seen radar images. In total, 95.57% of those surveyed said that they have heard of it (Figure 1) and 95.27% said they have seen an image before (Figure 2).

Of those who said they had *heard* of Doppler radar, 98.69% said they had heard about it on television. About 2/3 also said they had heard about it at school and/or on the Internet. In fact, the number of responses from the public indicating that they had heard about Doppler radar on TV or the Internet was about the same as the experts.

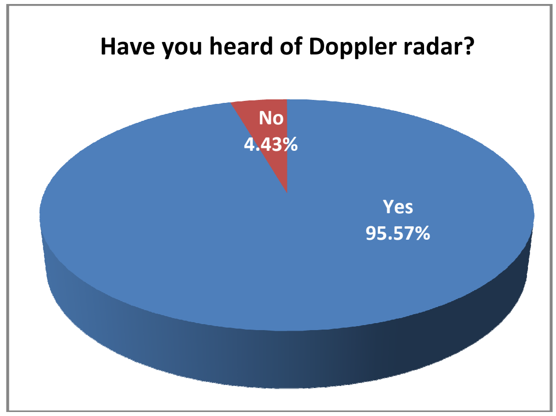

FIG. 1. Percent of the public who said they had or had not heard of Doppler radar prior to the survey.

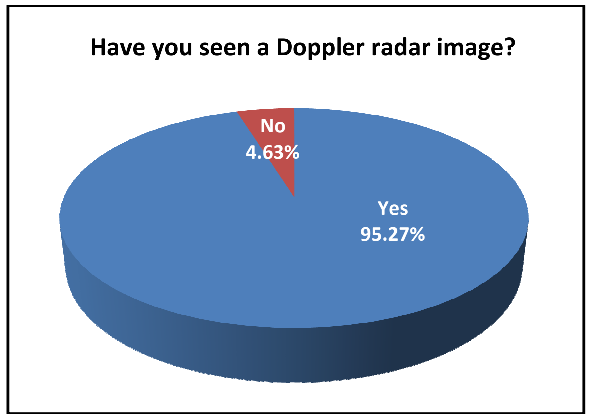

FIG. 2. Percent of the public who said they had or had not seen a Doppler radar image prior to the survey.

Table 6 shows that almost all of the participants said they have *seen* a Doppler radar image on a local TV news station (97.38%). Many have also seen an image on a cable TV news station (85.25%).

TABLE 6. Percentage of participants who have seen a Doppler radar image on a local TV news station, cable TV news station, on a cell phone, on the NWS website, or on a different website.

Option	M(%)	P(%)	A(%)	**O(%)**	E(%)
Local	97.84	98.08	96.49	**97.38**	96.88
Cable	93.53	80.77	77.19	**85.25**	96.88
Cell Ph.	25.90	25.00	10.53	**20.00**	46.88
NWS site	76.26	63.46	59.65	**67.87**	100.00
Other site	22.30	30.77	11.40	**19.67**	40.63

About 2/3 have seen a radar image on the NWS website (www.weather.gov). Not surprisingly, the positive response rate from the meteorology class was higher than the psychology and advertising classes. The P-Value comparing the responses of the meteorology class to the psychology class regarding the NWS website was .0770 and the P-Value comparing the meteorology class to the advertising class was .0046 (recall that a P-Value .05 typically means the proportion is statistically significant). This means that the number of students in the meteorology class who access radar data on the NWS website is significantly more than the other two classes. All the experts said that they have seen an image on the NWS website.

Of those who said they have seen an image on a website *other* than the National Weather Service, the most common response was a local TV news website or The Weather Channel website (www.weather.com).

Figure 3 shows that the participants understood the color red usually indicates the highest amount of activity measured on Doppler radar. However, the participants' responses were somewhat split when they answered the question about the color that usually indicates the lowest measured amount. Figure 4 shows that just over half (55.21%) knew that the color blue indicates the lowest measured amount of activity, and 36.91% chose green. There was a statistically significant difference between the number of correct responses in the advertising class compared to the number of correct responses in the meteorology class. Those in the advertising class answered the question more correctly, and the P-Value corresponding to the two proportions was .0325.

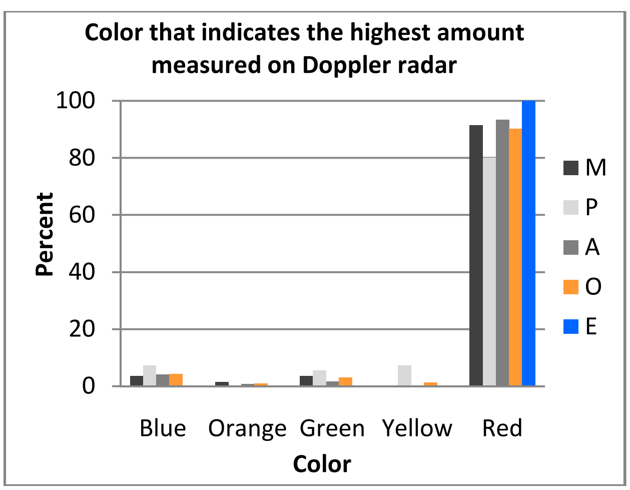

FIG. 3. Responses to the question, "Of the colors listed, which is usually indicative of the *highest* measured amount on Doppler weather radar?"

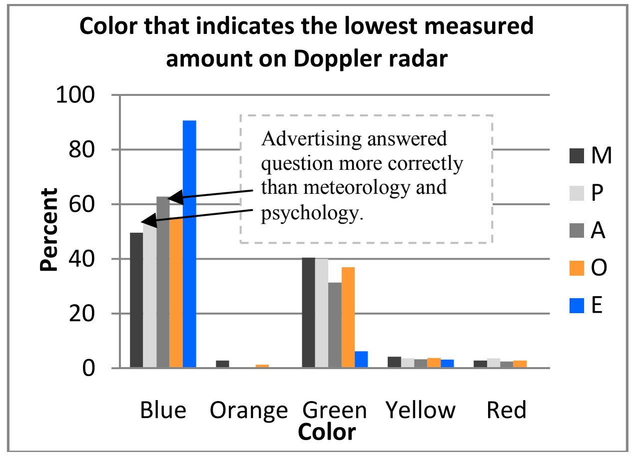

FIG. 4. Responses to the question, "Of the colors listed, which is usually indicative of the *lowest* measured amount on Doppler weather radar?"

The participants were also asked whether they would prefer to view an animated radar image, still image, or had no preference, should they be given the opportunity. The responses favored viewing an animated image instead of a still image 18:1 and viewing an animated image over having no preference 5:1 (Figure 5). These results may indicate that people understand the ability of weather systems to move in all directions. With that understanding, they need to know the direction that the weather system is moving in order to determine the best action to take by viewing an animation. The public did not realize that an animated radar image is more useful than a still image as well as the experts did, however. In the expert group, 96.88% said they would view an animated image. The resulting P-Value comparing the proportion of the public who would rather view an animated image to the experts was .0184.

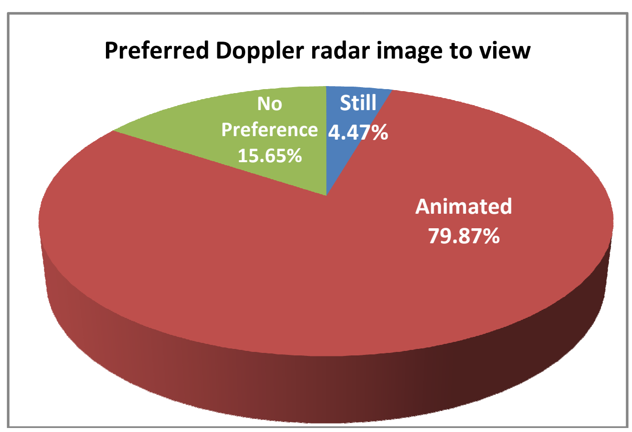

FIG. 5. Those who preferred an animated image, still image or had no preference to the kind of Doppler radar image to view, should they be given the opportunity.

b) Application

1) DOPPLER RADAR USES

The survey results showed that people are familiar with Doppler radar and generally know what the colors represent. However, they were unable to apply their knowledge correctly.

Participants were given nine examples of ways Doppler radar can be used, some correct and some incorrect. Figure 6 shows the responses to the *incorrect* answers: finding clouds, measuring aerosols, measuring CO_2, and locating radiation. While not many participants selected measuring aerosols, measuring CO_2 and locating radiation, over half (52.55%) of them selected finding clouds. It is not known whether the participants *actually* think meteorologists turn to radar in order to locate clouds (versus looking at satellite data), or if participants assumed that if precipitation is seen on radar then there must be clouds there as well. Clouds can be sensed on radar, especially if the radar is on clear air mode, however cloud detection is not a primary reason for the use of Doppler radar. Some of the experts may have over analyzed the question or found it confusing since about 20% of those participants responded that Doppler radar is used to find clouds as well (Figure 6). Table 7 shows that the P-Value corresponding to the differences in answers between the public and the experts was .0003, meaning that even though some of the experts answered incorrectly, the expert group answered the question significantly better the public participants.

The highest percentage of the public participants that said meteorologists use radar to find clouds came from the meteorology class. This also supports the idea that survey participants over analyzed the question since they may be more aware of the tools that can be used to sense and predict weather. (*Note: The survey only asked questions related to Doppler radar. There was no mention of satellite or other meteorological instruments.)*

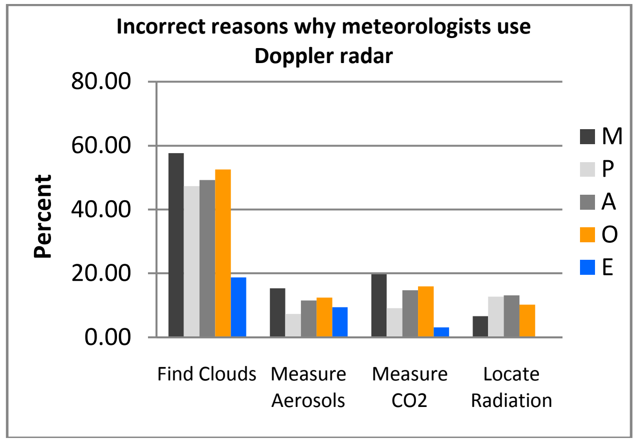

FIG. 6. Responses to the *incorrect* examples for why meteorologists use Doppler radar including finding clouds, measuring aerosols, measuring CO_2, and locating radiation.

TABLE 7. P-Values comparing the public to the experts regarding the incorrect choices of why meteorologists use Doppler radar.

Choice	P-Value, O vs. E
Finding Clouds	.0003
Measuring Aerosols	.6153
Measuring CO_2	.0517
Locating Radiation	.0580

Among the *correct* reasons for why meteorologists use Doppler radar (Table 8), one would expect the most common answer to be *measuring precipitation*. Almost all (90.63%) of the experts chose this answer. However, only 57.64% of the public participants answered this way. As seen in Table 9, the difference in these two proportions is statistically significant. Another statistically significant difference was between the public and the experts for using Doppler radar to forecast weather and locate tornadoes (Table 9).

TABLE 8. Responses to the *correct* choices for why meteorologists use Doppler radar including measuring precipitation, forecasting weather, tracking hurricanes, locating tornadoes, and locating severe and damaging winds.

Choice	M (%)	P (%)	A (%)	**O (%)**	E (%)
Meas Precip	64.23	52.73	52.46	**57.64**	90.63
Forecast Wx	87.59	85.45	91.80	**88.85**	75.00
Track Hurr	67.15	63.64	72.95	**68.79**	65.63
Loc Tors	75.91	58.18	77.05	**73.25**	90.63
Loc Svr Winds	62.77	41.82	69.67	**61.78**	68.75

TABLE 9. P-Values comparing the responses of the public to the experts for the correct reasons why meteorologists use Doppler radar.

Choice	P-Value, O vs. E
Measuring Precipitation	.0003
Forecasting Weather	.0236
Tracking Hurricanes	.7135
Locating Tornadoes	.0309
Locating Severe/Damaging Winds	.4382

While 57.64% of the public said Doppler radar was used to measure precipitation, 88.85% said Doppler radar was used to forecast weather. While forecasting weather is not *incorrect*, measuring precipitation is more correct than forecasting weather. Perhaps forecasting weather was the most common response because it was the broadest choice.

Actually, Table 8 shows that measuring precipitation was the *least* common answer among all of the correct choices. One would think that measuring precipitation would be the *most* common response since it is the main reason why meteorologists use Doppler radar. No statistical data explains reasoning for the answers that were given.

Table 8 also shows that a higher number of the public participants chose forecasting weather and tracking hurricanes than the experts did. It is possible that the experts who did *not* choose forecasting weather did so because they were thinking about a longer time-scale and assumed computer models and other maps would be used to forecast the weather. In addition, it is possible that the experts who did *not* choose tracking hurricanes did so because they again were thinking about a longer time-scale. While radar *can* be used to track hurricanes as they near the coast, satellite is used to track hurricanes at distances very far away from land. Nevertheless, meteorologists use radar to track hurricanes on a short time-scale.

The experts also realized the potential to locate tornadoes on radar significantly more than the public did (Table 9). In addition, more experts knew that radar can be used to locate severe and damaging winds than the public. However, the difference was not statistically significant. These results show the public did not fully understand the ability of Doppler radar to warn people of dangerous weather, and they may not be using the data to their full advantage during severe weather events.

Overall, no particular class performed overwhelmingly better than the other two classes on this question (Table 8). For example, more people in the meteorology class said that Doppler radar is used to measure precipitation, but more people in the advertising class said that radar is used to track hurricanes. Furthermore, the number of responses saying that Doppler radar is used to locate tornadoes was equal in the meteorology and advertising classes but significantly lower in the psychology class.

Table 10 shows P-Values that represent the quasi-random results for this particular question. For example, those in the psychology class answered significantly worse than those in the meteorology and advertising classes in regards to radar being used to locate tornadoes as well as severe and damaging winds. However, those in the advertising class answered significantly worse than the meteorology students in regards to radar being used to measure precipitation.

TABLE 10. P-Values comparing the responses of each of the three classes for the correct reasons for why meteorologists use Doppler radar.

Choice	M vs. P	M vs. A	P vs. A
Meas. Precip.	.1396	.0547	.9736
Forecast Weather	.6908	.2682	.1959
Track Hurricanes	.6415	.3100	.2105
Loc. Tornadoes	.0145	.8296	.0103
Loc. Svr Winds	.0081	.2420	.0004

2) ACTIONS TAKEN

In an attempt to understand what actions the public would take during a severe weather event, participants were asked what they would do in a situation where they knew there was a risk of severe weather for the day and suddenly heard a rumble of thunder.

Figure 7 shows that some people (34.38%) would continue to do whatever they were doing and take no action whatsoever (e.g. ignore the rumble of thunder). However, many said that they would go to the Internet to look at radar images and/or would turn on the TV to see if any broadcast meteorologists were reporting anything. Not surprisingly, the experts were slightly less dependent on TV than the public and most (87.50%) of them said that they would seek out radar information on the Internet (Figure 7).

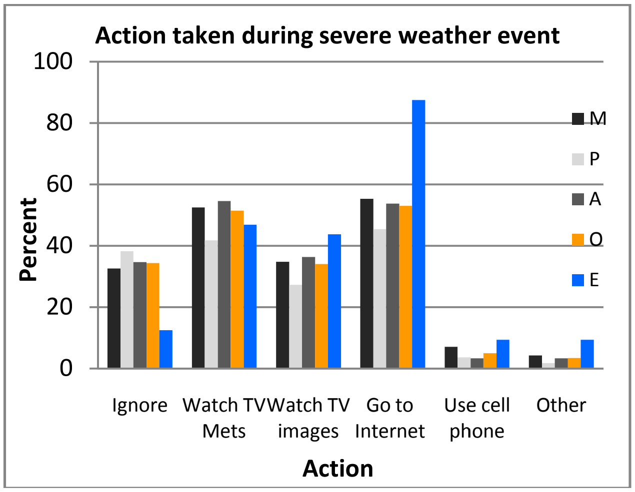

FIG. 7. Actions taken by participants if they knew there was a potential for severe weather and heard a rumble of thunder. Choosing more than one answer was permissible. The choices were to continue doing whatever they were doing (e.g. ignore), turn on the TV and see if any TV meteorologists are reporting, turn on the TV to see radar images, go to the Internet to look at radar images, use a cell phone to look at radar images, or take some action other than what was listed.

3) IMAGE INTERPRETATION

Previously it was mentioned that most of the participants knew that red is the color that indicates the highest measured amount on Doppler radar (among the choices given). Table 11 shows that their logic followed suit when 94.62% of them said the most likely place for hail to fall would be location C in Figure 8.

TABLE 11. The most likely place for hail to fall in Figure 8.

Location	M (%)	P (%)	A (%)	**O (%)**	E (%)
A	0.72	3.64	3.28	**2.22**	3.12
B	0.72	0.00	0.00	**0.32**	0.00
C	97.12	87.27	95.08	**94.62**	96.88
D	1.44	9.09	1.64	**2.85**	0.00

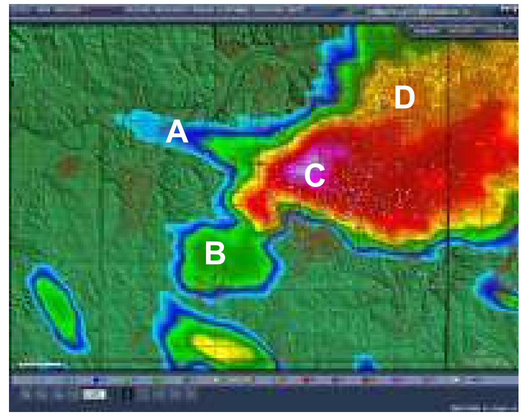

FIG. 8. Base reflectivity from Kansas City, MO on 22 May 2003 (Coash 2003). Participants were asked which location, A, B, C, or D would be the most likely place for hail to fall.

However, their logic did not follow suit when they had to determine what was shown in the image in Figure 9. While it was not expected that they would choose the correct answers [ground clutter and non-precipitating echoes (e.g. insects, birds, bats, dust particles)], *heavy rain* was actually the most common answer as seen in Table 12.

This response shows that the participants did not apply what they had chosen in an earlier question where 55.21% chose the color blue (36.91% said green) as indicating the lowest measured amount on Doppler radar. Figure 9 shows a blue area with a small amount of green on it. Thus, it was expected that the majority would have responded by saying the image shows light rain. However, that was not the case because the plurality (about 43%) said the image shows heavy rain.

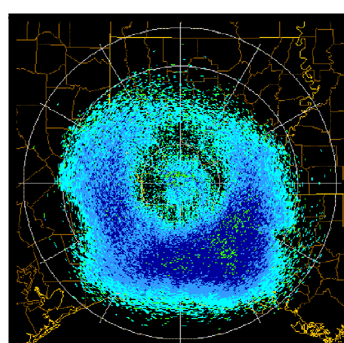

FIG. 9. Ground clutter and non-precipitating echoes in Ft. Polk, LA (Gauthreaux et al. 1999).

TABLE 12. Responses to what is shown in the image in Figure 9 including light rain, heavy rain, ground clutter, non-precipitating echoes such as insects, birds, bats, and dust, and nothing; the radar is malfunctioning.

Choice	M (%)	P (%)	A (%)	**O (%)**	E (%)
Light rain	36.96	40.74	33.61	**36.31**	6.25
Heavy rain	30.43	38.89	59.02	**42.99**	0.00
Grnd clutter	32.61	11.11	8.20	**19.43**	81.25
Non-pre ech	14.49	12.96	6.56	**11.15**	43.75
Malfunction	2.90	3.70	5.74	**4.14**	3.13

TABLE 13. Corresponding P-Values between the classes for the image shown in Figure 9.

Choice	M vs. P	M vs. A	P vs. A	O vs. E
Light Rain	.6242	.5729	.3626	.0006
Heavy Rain	.2620	.0000	.0136	.0000
Grnd Clutter	.0024	.0000	.5351	.0000
Non-pre ech	.7840	.0394	.1604	.0000
Malfunction	.7731	.2564	.5721	.7813

Moreover, 59.02% of the students in the advertising class said that the image in Figure 9 shows heavy rain compared to 30.43% of those in meteorology and 38.89% in psychology (Table 12). On the other hand, 32.61% of the meteorology students said that the image shows ground clutter compared to 11.11% of students in psychology and 8.2% in advertising. Neither class did well on the question, but the advertising class had the least number of participants answer the question correctly. The corresponding P-Values are listed in Table 13.

Perhaps the responses from the advertising class mirror a true representation of the public because the fewest number of non-technical majors were represented in the class compared to the other two classes. Almost 60% of them said the image shows heavy rain. This could be problematic for someone who is afraid to drive in heavy rain at night (when radars often operate in clear air mode, which is more sensitive to false returns).

Furthermore, Table 13 shows that the differences in responses between the public and the experts were significant in all of the cases *except* for those who said the image was showing a malfunctioning radar. However, the percentage of people who said the radar was malfunctioning was such a small number that the result was insignificant.

Participants were also asked whether heavy rain and heavy snow look the same on radar. Over half of the public chose the incorrect answer and said the two types of precipitation look the same (Table 14). In addition, 12.50% of the experts also thought this to be true. Table 15 shows this result is statistically significant because the corresponding P-Value to the two percentages above is .0000. Despite the differences between the meteorology, psychology, and advertising classes regarding the ground clutter image, Table 15 also shows that there was no statistically significant difference among the three classes for this question.

The inability of the public to recognize the fact that snow and rain do not look the same on radar may be problematic. What often looks like light precipitation in the winter can actually be heavy snow. Motorists may often underestimate the snowfall rate and end up putting themselves and their families in dangerous situations while driving.

TABLE 14. Results for whether or not heavy snow and heavy rain look the same on Doppler radar.

Choice	M (%)	P (%)	A (%)	**O (%)**	E (%)
True	50.72	58.49	55.83	**54.02**	12.50
False	49.28	41.51	44.17	**45.98**	87.50

TABLE 15. P-Values for those who believe heavy rain and heavy snow look the same on Doppler radar.

Choice	M vs. P	M vs. A	P vs. A	O vs. E
True	.3357	.4121	.7451	.0000
False	.6643	.5879	.2549	1

6. Conclusions

It is clear that the public had heard of Doppler radar and had seen radar images. For the most part, they understood simple concepts such as the colors that indicate the highest and lowest amount measured. Most people also understood the implications of viewing an animated image versus a stationary image. They are probably aware that storms move in different directions and that they must view an animated image to see in which direction a storm is headed.

However, the public was not always able to apply their knowledge about Doppler radar.

Just over half knew radar is used to measure precipitation, which was significantly less than the experts. Although the participants knew where hail would most likely be located on an image, they believed an image showing ground clutter and non-precipitating echoes showed heavy rain. In addition, the majority thought that heavy rain and heavy snow look the same on radar.

The need for people to be able to interpret radar images themselves was demonstrated in the fact that about the same number of people would seek out radar information from a broadcast meteorologist as would seek out radar information on the Internet. Furthermore, the public did not realize the benefits of using Doppler radar to sense and predict severe and hazardous weather. The number of people who knew tornadoes can often be detected by Doppler radar was significantly less than the experts.

There was not one specific class that performed better than another. For example, the students in the advertising class answered the most correctly by saying that blue is the color that represents the lowest measured amount of activity on Doppler radar. However, the same students answered the most *incorrectly* on the question regarding the ground clutter image since the highest number of them said the image showed heavy rain (the students in the meteorology class answered most correctly). Additionally, more of the students in the advertising and meteorology classes were aware that meteorologists could use radar to tornadoes and severe and damaging winds.

However, the students in the psychology class performed slightly worse than the students in the other two classes. This was consistent with their acknowledgement of their level of understanding of weather presented in Table 5.

The results show that although the public has heard of Doppler radar and is familiar with the multiple ways to access it, people have many misconceptions about radar images. Public education is needed, especially as technology advances and radar information becomes more complex.

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