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Corresponding author mail id : robinson.bellmon@gmail.com

Use and Access in the New Ecology of Public Messaging

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Abstract

The use of social media and other communication technologies have created a new ecology of public messaging. As it is a core task of government to inform its residents about risks, public managers, and emergency managers, specifically, must understand this new ecology if they are to effectively communicate with the public. A challenge of this new media environment is the differential access of members of the community to various technologies. Partial proportional odds regression (PPO) provides a strategy that is useful to separate effects of access from effects of use. This article illustrates the use of PPO regression to separate access and use effects based on a survey which followed a series of severe weather events in the spring of 2016. The survey includes an address-based sample of residents in the state of Oklahoma to ask about the use of various communication technologies to share information about the weather system (among other subjects). We find that age and work status are related to access while income, gender, race, and exposure to extreme weather are related to use of various communication media. This information provides emergency managers with a stronger foundation for developing a portfolio of information options for their communities.

1 Introduction: The Need for a New Ecological Understanding of Public Information

When extreme weather events bear down on communities across the United

States, most residents look to official sources, such public emergency managers or local media, for reliable information (Hammer and Schmidlin, 2002; Brotzge and Donner, 2013). In Florida, people may look for official declarations of evacuations. In Texas, people may look for changes to traffic patterns to ease evacuation. In Kansas, residents may look for information on sheltering from tornadoes. These same members of the community often redistribute that message through their personal use of a variety of technologies (Reuter and Kaufhold, 2017).

Despite the centrality of the government in providing information in these contexts, this role of the government as a provider of information is not the most common subject for research. There has been a great deal of research on how government provides services or oversees contracts to provide services. This informational role, however, has been subject to less attention. Fundamental questions remain as changes in our communication technologies change the incentives and capabilities related to the sharing of information. While there has been research into the use and adoption of social media and new media technologies in emergency management, many questions remain. A recent review in the specific risk communication case (Reuter & Kaufhold, 2017) described a robust literature – but one populated almost entirely by demonstrations of the feasibility of these technologies or case studies of their use. Little of the research has assessed the mechanisms by which these technologies work to spread (or segregate) public safety information.

In this paper, we analyze data collected following a series of tornadoes in Oklahoma to assess behaviors related to sending information about the storms across various technologies and media platforms. In particular, we assess whether certain demographic factors make people more or less likely to send information across different platforms. This assessment requires the use of a relatively uncommon regression technique – partial proportional odds regression (PPO) – in a manner that allows us to distinguish factors related to access to a media technology from factors related to the greater use of those technologies. We conclude with a discussion of how public managers seeking to disseminate information can successfully design their information campaigns.

1.1 Traditional Views of Public Information

The traditional view of public safety information focuses on an authority to-citizen (A2C) model of communication (Reuter & Kaufhold, 2017). In this approach, public information is sent from a single, official source and is received by a defined audience. In the case of weather information, the audience may be all potentially-affected residents subject to an incoming weather front. One version of this is Reverse 9-1-1 or Wireless Emergency Alert systems which send a recorded telephone message or text message to landlines and registered cellphones in a particular geographic area (Kim, Martel, Eisenman, Prelip, Arevian, Johnson & Glik 2019). In the public safety realm, especially weather safety, the audience is generally defined by geography. In other areas of policy, the audience for specific information may be related to use of a particular policy (e.g. people considering visiting a specific park) or clients of a specific service (e.g. parents of children attending a specific school). For this reason, we will move away from the "citizen"-based language in the literature to the term "residents" for our discussion (see Roberts (2020) for an in-depth criticism of using the term citizen imprecisely). We will refer to the A2C model as the authority-to-resident (A2R) model.

One challenge for public managers in the context of communicating with the public, especially through online methods, is the preservation of trust (Morgeson III, VanAmburg, & Mithas, 2010; Wang & Kapucu, 2007). However, research suggests that the use of effective communication strategies, including the use of symbols, can increase trust in government (Alon-Barkat, 2019; Liu, Horsley, & Yang, 2012) or decrease feelings of being distrusted by the public (Appleby-Arnold, Brockdorff, Fallou, & Bossu 2019).

Another challenge for public managers in this model is to employ a dissemination strategy that reaches all or most of the intended audience (accounting for costs). Zhao, Zhan, and Liu (2019) emphasize the different uses of social media, in particular, by different segments of the public in the aftermath of the 2017 bombing at an Ariana Grande concert. Relatedly, researchers found that while there was some channel switching in information seeking behavior during Hurricane Harvey in 2017, many Texans in the study stayed with their preferred traditional or new media sources (Petrun Sayers, Parker, Seelam, & Finucane, 2021). As a result, emergency mangers needed to reach across several media formats to disseminate critical information. This may mean employing traditional marketing techniques to get information out to audiences in the same way that products are advertised. Public information may appear on billboards or television commercials. Each of these approaches has different costs and reaches different audiences – likely with varying levels of success.

1.2 The New Ecology of Information

The traditional model of disseminating information is giving way to newer approaches based on new technologies and social media. One of the largest revolutions in the spread of information is the abandonment of the simple authority-to-resident approach to spreading information in favor of one that incorporates citizen-to-citizen (C2C) communication (Reuter & Kaufhold, 2017). The spread of public information may depend more on the active redistribution of information among the audience than on the initial exposure of members of the audience to direct messages from the government source. We will refer to this as the resident-to-resident model (R2R).

The differences in this approach are profound but not always obvious.

The diversification of media has made it difficult to reach a large segment of society through any one channel of communication. The days are long past when a majority of adults would watch one of a small number of evening news channels, for example. Getting information out via radio is limited by the reduced importance of local radio stations as well as a general drop in radio listenership. Now more people are seeking information through a broad array of sources ranging from text messaging services to fragmented webpages to Facebook to Twitter to emerging social media platforms. Robinson, Pudlo, and Wehde (2019) refer to this as a new ecology for public information.

In this diverse environment, it is simply not possible to target a large majority of the audience with a single media. Instead, one must rely on the sharing of information between members of the audiences to disseminate the information well past its initial audience. This environment necessitates a move from the one-to-many communication model to a many-to-many communication model (or a one-to-many-to-many model). The official source can release information, but most recipients will receive the information not directly from that source but, rather, from other members of the initial audience.

The key shift in the move from authority-to-resident (A2R) to resident-to-resident (R2R) models of information sharing signifies the recognition that people who are at one time a receiver of information will also be a potential sender of information to others. The empirical component of this paper will focus on these novel sharing (sending) activities rather than the more traditional questions of receiving and media choice.

1.3 The Spread of Public Safety Information in the New Ecology of Information

The discussion hereto has treated the dissemination of information in a generic sense. The movement from A2R models to R2R (or authority-to-resident-to-resident - A2R2R) models affects everything from information about hurricane tracks to the latest Hollywood movie release. It may be the case that public safety information does not disseminate in the same ways as other sources of information. Advertisements about movies may create different incentives for people to redistribute the information either to provide entertainment for their friends or to seem well-informed about popular topics. This may not be a good model for the spread of public safety information. Despite the efforts of cartoon bears, public safety information does not have the cultural gravity of other entertainment information. Even political information may not be a good model for public safety information. Partisan political information may be more likely to spread within political networks rather than across political divides (Bennett & Iyengar, 2008; Huckfeldt & Sprague, 1987). This creates specific incentives for spreading partisan political information that may not apply to public safety information. The result for political information may be redistribution channels that bifurcate information within separate political networks and place a ceiling on the breadth of sharing.

Scholars of emergency management have devoted significant attention to the networked nature of disaster governance, information sharing, communication, and collaboration (Berthod, Grothe-Hammer, Muëller-Seitz, Raab, & Sydow, 2017; Martin, Nolte, & Vitolo, 2016; Nowell & Steelman, 2014). Most of this work considers the networks that develop between various organizations and communication between them. Echoing calls in public administration more broadly (Jakobsen, James, Moynihan, & Nabatchi, 2016), scholars have argued that these communications are embedded in a social context and should also consider communication with the public (EL Khaled & Mcheick, 2019; Thompson-Dyck, Mayer, Anderson, & Galaskiewicz, 2016).

The specific dynamics of public safety information accentuate a challenge for public managers: a variation on the classic digital divide. When originally coined, the digital divide referred to the gap in access to internet service – particularly hi-speed internet access (Norris, 2001). A lack of access was common in rural communities or in older populations where adoption rates were low. Decades later, the nature of the digital divide has transformed but remains a problem. The focus now is on usage rather than access to infrastructure (van Deursen & van Dijk, 2014). However, differences in usage grow all the more important as more information (in our case, public safety information) moves online and through various internet platforms. It is not enough to have access to high-speed internet or a smart phone. Now, access to information requires relatively frequent use of a web browser, Twitter, or Facebook.

More broadly, scholars of e-government initiatives have demonstrated the relevance of the digital divide across different governmental jurisdictions such as municipalities in South Korea (Lim, 2010; Lim & Tang, 2007) as well as among citizens and their use of e-government (Thomas & Streib, 2003). Thomas and Streib (2003) find that racially minoritized, lower income, older, and less educated individuals are less likely to be visitors to government websites than their counterparts.

This leaves us with an appreciation of the importance of the new ecology of public safety information. Public managers, generally, and emergency managers, as a subset thereof, have fewer direct tools to contact a large portion of the population. Instead, they have more tools that reach smaller and smaller subsets of the population. As such, they must increasingly rely on the indirect spread of information through personal communication networks – often mediated through various electronic and social media. For example, tornado warnings from government officials or weather experts have a limited direct reach on Twitter, but, the information has substantial secondary spread due to sharing by the initial audience (Silver & Andrey, 2019). Successful and efficient dissemination of public safety information within this new ecosystem will call for a detailed understanding of who is listening and who is talking within the ecosystem. The next section elaborates a simple, preliminary model of information sending behavior within the new ecology of public safety information.

2 A Demographic Model of the Redistribution of Public Safety Information

Improvements in our understanding of the dissemination of public safety information will require a return to the fundamentals of communication design. At the most fundamental level, we can expect the dissemination of any message to be a function of three categories of characteristics: sender characteristics, message characteristics (including the medium of the message), and receiver characteristics.

Sender These characteristics represent qualities of the message sender (in our case, likely a public safety manager) that may influence the uptake, comprehension, and redistribution of the message.

Messenger These characteristics represent elements of the message itself – including the media through which the message travels – that may influence uptake, comprehension, and redistribution of the message.

Receiver These characteristics represent qualities of the receiving population that may influence uptake, comprehension, and redistribution of the message.

It is unlikely that any one study will consider the effects of all of these categories of characteristics (See Kim et al 2019 for a rare exception). The complexity within each category is sufficient to prevent the careful control or manipulation of all categories simultaneously. Instead, research designs will emphasize specific elements – an approach we adopt here. Our research design focuses on receiver characteristics, so this section will elaborate on how receiver characteristics can influence their subsequent dissemination behaviors within the new ecology of public safety information.

The study of receiver characteristics within the public safety information literature has largely limited itself to the traditional one-to-many model of communication. In these studies, researchers have investigated the factors related to the likelihood that a person receives official information about a particular threat, such as a hurricane path (see Brotzge and Donner, 2013 for a review of these factors and tornado warnings). For the most part, this research has reported how demographic differences create disparities in the reception of public safety information (Brotzge and Donner, 2013; Wehde, Pudlo and Robinson, 2019).

In simple terms, the probability of respondent i receiving information ($P_R(i)$) about a threat is modeled as a function of basic demographic factors for that respondent(Ψ_i).

$$P_R(i) = f(\Psi_i) \quad (1)$$

The bulk of the literature on message reception has been about demographics, the components of Ψ (with two notable exceptions we will discuss below). The most common elements of a demographic model of public safety communication include gender, race, income, and education (Brotzge & Donner, 2013; Cutter, Boruff, & Shirley, 2003; Procopio & Procopio, 2007; Wehde, Pudlo, & Robinson, 2019; Ripberger, Krocak, Wehde, Allan, Silva, & Jenkins-Smith 2019; Petrun Sayers, Parker, Seelam, & Finucane, 2021). These elements are so common in models of risk communication and risk perception as to be non-controversial inclusions. In fact, the evidence is sufficiently strong that the omission of any of these could be deeply problematic.

We will transition this model (and use the existing literature as a baseline) to instead explore the propensity to share information (P_S) – rather than the probability of receiving information. Recall that the discussion of the digital divide focuses on questions of access and use. We will use these two considerations as a filter for potential additions to the demographic model of public safety communication.

For each element of the demographic model (Ψ_i) we will consider both use and access hypotheses. A use hypothesis ($H_{use}X$) is one where an independent variable is expected to be related to the frequency of use across all values (from no use, to a single use, to multiple use, etc.). An access hypothesis ($H_{access}X$) is one where the independent variable is expected only to be correlated with the probability of a zero vs. non-zero frequency of use but not between different non-zero categories of use.

The traditional literature on the digital divide has focused on two components: location and age (Norris, 2001). The focus on location involved the slow extension of infrastructure into rural communities. While almost all communities have access to some form of high-speed internet access or access to cellular phones, access is still more difficult in rural areas (Townsend, Sathiaseelan, Fairhurst, & Wallace, 2013). We include rural status (as distinguished from urban and suburban) for respondents in our model.

Age is also a significant factor in digital media usage more generally (Friemel, 2016) and seems easy to justify for inclusion in a model of public safety communication that increasingly relies on new platforms like personal electronic devices and social media.

This literature provides a strong foundation for our initial access hypotheses:

- $H_{access}1$: Older respondents are less likely to have a non-zero frequency of sending information.

- $H_{access}2$: Respondents in rural areas are less likely to have a non-zero frequency of sending information.

We also include hypotheses related to use for these primary components of the digital divide literature.

- H_{use}1: Older respondents are less likely to have higher frequencies of sending information – across the range of levels of information sharing.

- H_{use}2: Respondents in rural areas are less likely to have higher frequencies of sending information – across the range of levels of information sharing.

In this exploratory study, we are also interested in whether the work status of a respondent may affect his or her behaviors related to public safety information. It may be that the reduced time constraints on part-time, unemployed, and retired people makes greater usage of media technologies possible. Alternatively, these statuses may bring with them social isolation that suppresses usage of communication tools generally. In the specific case of retirement, age may compound the suppressing effect on usage – so we include retirement as a special category of "not working full time".

This leads to another set of hypotheses:

- H_{access}3: Respondents who are not working full-time are less likely to have non-zero frequencies of sending information – across the range of levels of information sharing.

- H_{use}3: Respondents who are not working full-time are less likely to have higher frequencies of sending information – across the range of levels of information sharing.

It is worth noting that the most notable exceptions to the focus on demographic factors have been assessments of the role of disaster experience and geographic location – the latter of which is treated as a demographic factor in some literatures. Extensive research has shown that disaster experience is an important part of protective actions and preparedness – including evacuations (Dash & Gladwin, 2007; Sattler, Kaiser, & Hittner, 2000). To represent disaster experience, we include indicators of whether the respondent reported experiencing a tornado at their residence following the then recent series of storms. Previous research suggests level of threat or experience is associated with warning reception and response to threats (Ripberger, Krocak, Wehde, Allan, Silva, & Jenkins-Smith 2019; Robinson, Wehde and Pudlo 2019; see also Symons, Amlôt, Carter, and Rubin 2021 and Robinson et al. ND for recent non-tornado examples). We also include several demographic variables as control variables – allowing each to operate as both use and access factors. The specific control variables are discussed below in terms of measurement and research design.

3 Research Design

To investigate how demographic characteristics influence the dynamics of public safety information, we conducted a survey of residents of the US state of Oklahoma in the late Spring of 2016. In late April and early May of 2016, two major storm fronts spawned tornadoes throughout Oklahoma. Shortly after these storms (early to mid-June of 2016) we fielded a large internet survey through the Meso-Scale Integrated Socio-geographic Network (MSIS-Net), a series of panel surveys administered quarterly to an address-based random sample (ABS) of approximately 2,500 Oklahoma residents (Jenkins-Smith et al., 2017). This project uses data that were collected from 2,528 residents[1].

3.1 Survey Design

The survey included questions related to climate change, extreme weather, and energy development. The survey also included a module related to the series of storms that passed through the state in late April and early May prior to survey fielding (hopefully ensuring strong recall of behavior during the storms). The survey asked each respondent if they recalled the particular storm. Only if they said yes, was the respondent asked how he or she was affected by the randomly selected storm (if at all). Respondents reported potential effects including rain, winds, flooding, hail, and tornadoes (each reported independently) or that they were unaffected. This analysis only includes people who reported that they were affected by rain, wind, flooding, hail, or tornadoes. This sample represents almost 1,000 residents of Oklahoma (approximately half of the respondents to the panel).

The survey instrument asked each respondent about whether they received a tornado warning and, if so, through what media. The survey followed with questions related to whether respondents had sent or

[1] Further information on survey design (including response and cooperation rates) is available at http://crcm.ou.edu/epscor/codebooks/MSISNet-TechnicalOverview.pdf

received information through a variety of media including personal conversation, phone, e-mail, text message, Facebook, and others. We use the survey responses related to reported disaster experience along with the questions on communication behaviors and demographic characteristics to build a model of the demographic drivers of public safety information behaviors.

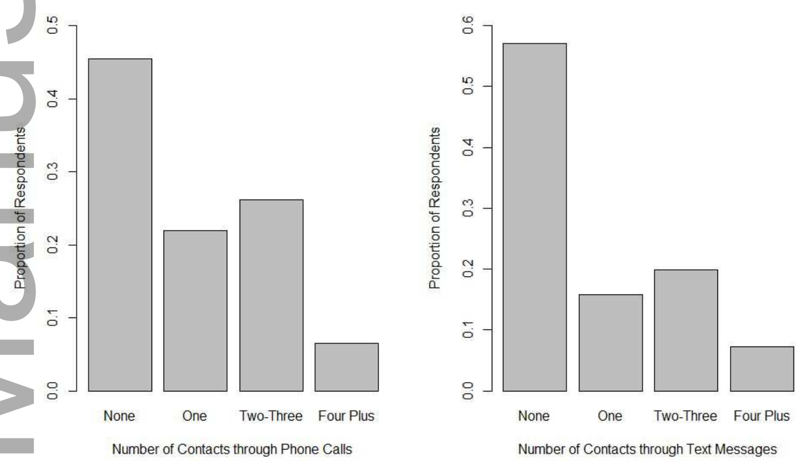


Figure 1: The Distribution of Public Safety Information Contacts

3.2 Measurement

The key measurement choice for this analysis is for the dependent variable – public safety information contact. The survey instrument divides usage based on sending and receiving information across various platforms. For this article, we will focus on sending information about the storms using two technologies: traditional phone calls and text messaging. Traditional phone calls represent a comparison case wherein access issues should not complicate assessments of frequency of use. Text messaging (sending) is our example of a contemporary new media format that is potentially subject to access challenges calling for special attention.

For each of these technologies, respondents reported that they contacted the following number of people to either send or receive information about the recent storm: none, one, two or three, or four or more. Figure 1 illustrates the distribution of these dependent variables.

We elected not to directly ask respondents their number of contacts to avoid heroic expectations of recall (even in the short time frame between the storms and the survey). Our expectation was that the ordered categories would allow us to identify the highly active respondents without the risk of overly influential (and unreliable) observations possible with an open response count. Future investigations can adopt less conservative measurement strategies, but this approach was appropriate for an exploratory study.

The demographic control variables are traditional in their measurement strategy.

Tornado This item indicates whether a respondent reported being affected by a tornado – an extremely potent disaster exposure. For the purposes of this study, the effect of tornado exposure serves as a benchmark for comparison to other effects.

Age Respondent age is measured in years.

Race The model includes dummy variables for African Americans, Native Americans, and other races with Caucasian as the baseline category.

Education The model includes dummy variables for some college, college graduate, and graduate education. High school or less education is the baseline category.

Work Status The model includes dummy variables for not-working, part-time work, disabled, and retirement with employed full-time as the baseline category.

Location The model includes dummy variables for suburban and rural respondents (based on self-reports) with urban as the baseline category.

Gender The model includes a dummy variable for gender with female as the baseline category.

Income The model includes logged income in dollars.

Table 1 presents summary statistics for these independent variables.

Table 1: Summary Statistics, n = 991

Statistic	N	Mean	St. Dev.	Min	Max
Tornado Experience	991	0.38	0.49	0	1
Age	991	58.3	14.1	19	98
Logged Income	991	10.9	0.72	9.21	13.7
Rural	991	0.39	0.49	0	1
Urban	991	0.19	0.39	0	1
Suburban	991	0.42	0.49	0	1
White	991	0.88	0.32	0	1
African American	991	0.03	0.17	0	1
Native American	991	0.05	0.22	0	1

Other Race	991	0.04	0.20	0	1
Working Part-time	991	0.11	0.32	0	1
Working Full-time	991	0.43	0.50	0	1
Retired	991	0.31	0.46	0	1
Disabled	991	0.07	0.26	0	1
Not Working	991	0.07	0.26	0	1
Some College	991	0.33	0.47	0	1
Bachelor's Degree	991	0.29	0.46	0	1
Graduate School	991	0.25	0.43	0	1
Male	991	0.41	0.49	0	1

3.3 Regression Analysis

The dependent variable only takes on positive integers which represent categories of number of contacts and therefore necessitates a careful approach to statistical analysis. We employed a modified version of proportional odds (PO) linear regression to assess the relationship between the independent variables and the communication technology usage dependent variable. An alternative name for PO regression is ordered logistic regression with partial proportional odds (PPO) regression also known as generalized ordered logistic regression (GOLOGIT).

In a simple PO linear regression, the regression model assesses a series of parallel regressions of the probability of one (or a set of values) on the dependent variable and all greater values of the dependent variables. For example, one component of proportional odds regression estimates the correlation of the independent variables and a dependent variable where those that answered “none” (no contacts) are compared to those that responded with all categories greater than none. In a second component of the regression, the model estimates the correlation of the independent variables and a dependent variable where those that answered “none” or “one” to those who responded with the higher value categories (“two to three” or “four or more”). This is done for all potential ordered comparisons. The proportional odds model assumes that the coefficients for the independent variables in all of the component models are equal (hence the term “proportional odds”). This approach serves to test “use” hypotheses but cannot distinguish between the effect of a variable on zero/all-non-zero distinctions needed to test “access” hypotheses because the coefficients are constrained to be equal across zero/non-zero comparisons along with all lesser/greater comparisons.

The proportional odds assumption is violated less often than one might imagine - but it can be problematic. We assess whether the proportional odds assumption holds for the model as a whole, as well as for each independent variable, using a Brant test. We can then selectively relax the proportional odds assumption for those variables that fail the Brant test of proportional odds using a partial proportional odds (PPO) model. We estimate the PO model using the MASS and VGAM packages in R while the PPO model is estimated only using the vglm function in the VGAM package (Ripley et al., 2013; Yee, 2010). Variables for which the proportional odds assumption holds are direct tests of the corresponding "use" hypothesis – and evidence that no "access'' hypothesis is needed for that variable. Test of the distinctive coefficient separating zero from non-zero integer values tests the "access" hypotheses – as this is only possible once we relax the proportional odds assumption and allow the coefficients for the zero/non-zero equation to vary from the coefficients for the higher levels of use. That is to say, variables that "pass" the Brant test do not exhibit differential coefficients across component regression models and, thus, do not exhibit evidence of an "access" differential.

4 Results

Table 2 presents results from PO models for both dependent variables: phone calls and text messaging. Brant tests of the proportional odds assumption were conducted for both models. All variables in Model 1 passed the test; therefore, Model 1 (Phone Contacts) in Table 2 represents the final and most appropriate model for ordered categorical number of contacts through phone calls. Note that this indicates that use and access operate similarly which implies the absence of a notable gap in access to phones – consistent with our expectations. In Model 2 (Text Contacts), variables representing age and retired status failed the Brant test. Therefore, we relaxed the proportional odds assumptions for these variables (allowing the coefficients for these variables to vary across the component regressions at each level of the dependent variable). The results from the partial proportional odds model for sending texts is presented in Table 3.

Table 2 suggests some results are robust across use of both communication types: phone call and text messaging. Specifically, we see that being male has a negative and statistically significant coefficient in both models.

Table 2: Proportional Odds Regression Coefficients

	Number of Phone Contacts (Model 1)	Number of Text Contacts (Model 2)
Experienced Tornado	0.39∗∗∗	0.48∗∗∗
	(0.12)	(0.13)
Age	−0.01	−0.04∗∗∗
	(0.01)	(0.01)
African American	0.95∗∗∗	0.60∗
	(0.33)	(0.34)
Native American	0.38	0.73∗∗
	(0.28)	(0.28)
Other Race	0.14	−0.36
	(0.31)	(0.35)
Some College	0.22	0.26
	(0.20)	(0.22)
Bachelors	−0.06	0.09
	(0.21)	(0.23)
More than Bachelors	−0.10	−0.32
	(0.22)	(0.24)

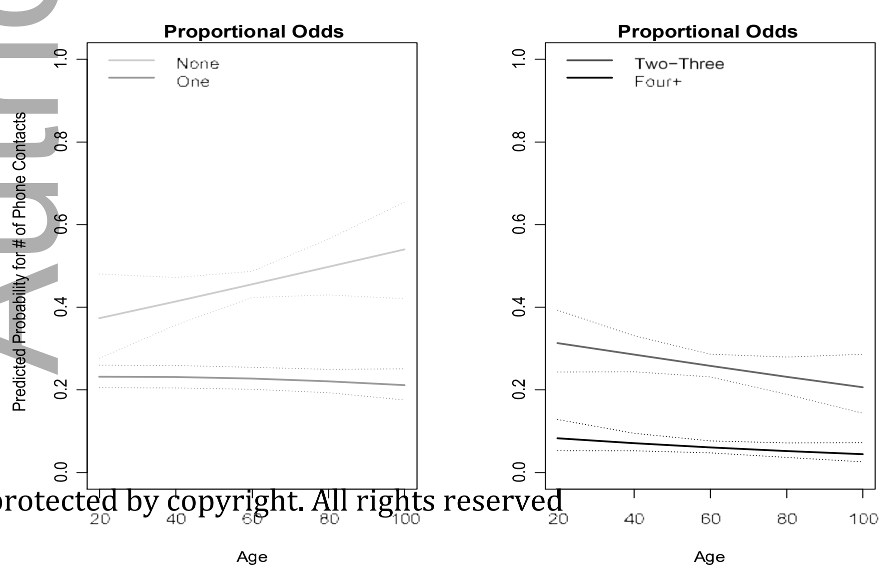
Not Working	0.33	−0.19
	(0.24)	(0.25)
Working part time	−0.21	−0.29
	(0.21)	(0.22)
Retired	0.24	−0.46**
	(0.19)	(0.21)
Disabled	0.14	0.08
	(0.25)	(0.27)
Suburban	−0.22	−0.18
	(0.16)	(0.18)
Rural	0.14	−0.07
	(0.17)	(0.18)
Male	−0.23*	−0.35**
	(0.13)	(0.14)
Logged Income	0.01	0.42***
	(0.09)	(0.10)
Constant:1	−0.37	2.64**
	(1.07)	(1.17)
Constant:2	0.58	3.44***
	(1.07)	(1.17)
Constant:3	2.56**	5.21***
	(1.08)	(1.18)

*p < .1; **p < .05; ***p < .01. Standard errors in parentheses.

Table 2 demonstrates that African American respondents are more likely to report communication across both models. Finally, tornado experience, representing storm severity, is positive and significant across both models. This suggests that both being African American and experiencing the tornado are associated with increased sending of information across these media (rejection of a null "use" hypothesis).

However, mode of communication seems to create some differing patterns. Comparing Model 1 and Model 2 reveals a number of interesting differences. For age, we see distinguishing patterns. The relationship between age and the likelihood of communicating by phone is null as visualized in Figure 2. The overlapping confidence intervals for "none" suggests that age has a positive but very slight relationship with the probability of contacting no individuals by phone call. Figure 2 also demonstrates the null relationships between age and each of the different categorical levels of phone call contacts. On the other hand, as age increases the likelihood of communicating by text decreases. This pattern suggests a technological trade-off (or, rather, the lack of adoption of the new technology) among older respondents – as expected.

Figure



2: Predicted Probabilities by Age for Phone Contact Across All Categories

For work status we see different patterns. Specifically, all patterns of non-work, or part-time work, are unrelated to number of contacts through phone calls. Being retired, however, has a distinct negative association with communication through text messages. Given the correlation between age and retired status, and the relationship of both with possible access or knowledge of text-messaging technologies, these findings are consistent with our expectations of the digital divide. Income has a positive and significant relationship with text communications but no relationship with phone communications. Finally, suburban and rural respondents were no different from their urban counterparts for their use of both technologies. However, as noted, the Brant test suggested age and retirement status do not have proportional effects across categories. Therefore, we model the number of texted contacts using partial proportional odds models, also called generalized ordinal logit models, in Table 3.

Table 3: Partial Proportional Odds Models for Number of Texted Contacts

Variable	Coefficient	Std. Err.
Experienced Tornado	-0.49***	0.13
Age:1	0.038***	0.007
Age:2	0.027***	0.007
Age:3	0.056***	0.01

African American	-0.62*	0.35
Native American	-0.73**	0.29
Other Race	0.39	0.35
Not Working	0.18	0.25
Working part-time	0.29	0.22
Retired:1	0.49**	0.21
Retired:2	0.53**	0.24
Retired:3	-0.63	0.39
Disabled	-0.079	0.27
Rural	-0.12	0.14
Urban	-0.18	0.18
Some College	-0.27	0.22
Bachelors Degree	-0.10	0.23
More than Bachelors	0.31	0.24
Male	0.35***	0.14
Logged Income	-0.42***	0.11
Constant:1	2.68*	1.19
Constant:2	4.08***	1.20
Constant:3	4.46***	1.26
Residual Deviance	2054 on 2950 df	
Log-likelihood	-1027 on 2950 df	
N	991	

*p < .1; **p < .05; ***p < .01.

Reference categories: white, working full-time, suburban, high school or less, and female.

Hauck-Donner effects present for Age:3.

Likelihood ratio tests used to calculate stat. sig.

The PPO models allow us to relax the assumption that all variables have the same effect across all levels of the dependent variable. An observant reader will notice the coefficients, for proportional variables, are of the same or similar magnitudes but opposite signs as those found in the PO models – which is due to how the different packages estimate the constant terms (the cut-points) in the various models. The substantive relationships reported above hold when estimating predictions from both models. Thus, we can interpret the coefficients in Table 3 as the opposite sign of those reported. We will report the results in terms of the predicted probability in the figures wherein the different packages report comparable results. In particular we are interested in how variables where the proportional odds assumption is relaxed performed. In Table 3 we see that the proportionality assumption for both age and retired work status are relaxed as recommended by the Brant Test. For all other demographics and tornado experience, we find similar results as in our PO model, Model 2, in Table 2. To best evaluate the non-proportional effects of age and retired status, we plot the predicted probabilities for both variables for both proportional and partial proportional odds models. For age, these results are plotted in Figure 3.

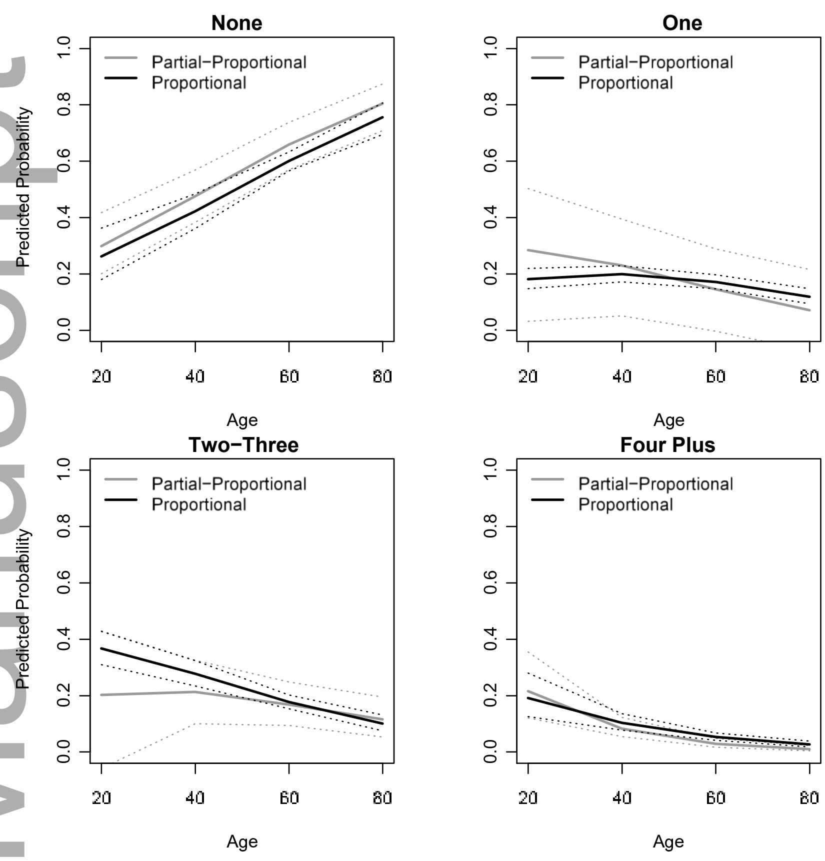


Figure 3: Results from Partial Proportional and Proportional Odds Models

Figure 3 compares the predicted probabilities for each category by age for both modeling strategies in the top four panels[2]. These various panels allow for a nuanced comparison of the estimation strategies and their effects on the relationship between age and number of texted contacts.

[2] All other variables are held at their respective means (continuous variables) or modes (categorical variables)

Using the PPO model allows us to better test the access and use relationships for age. In particular, the results in the top left and right panels suggest that age has a strong access effect. When modeled using the PPO strategy, the positive relationship between age and non-use becomes stronger as does the negative relationship between age and contacting a single person through text message. However, allowing for partial proportional odds flattens the relationship between age and contacting two-three individuals through text, further supporting the primary effect of age through access, as opposed to use, when modeled appropriately.

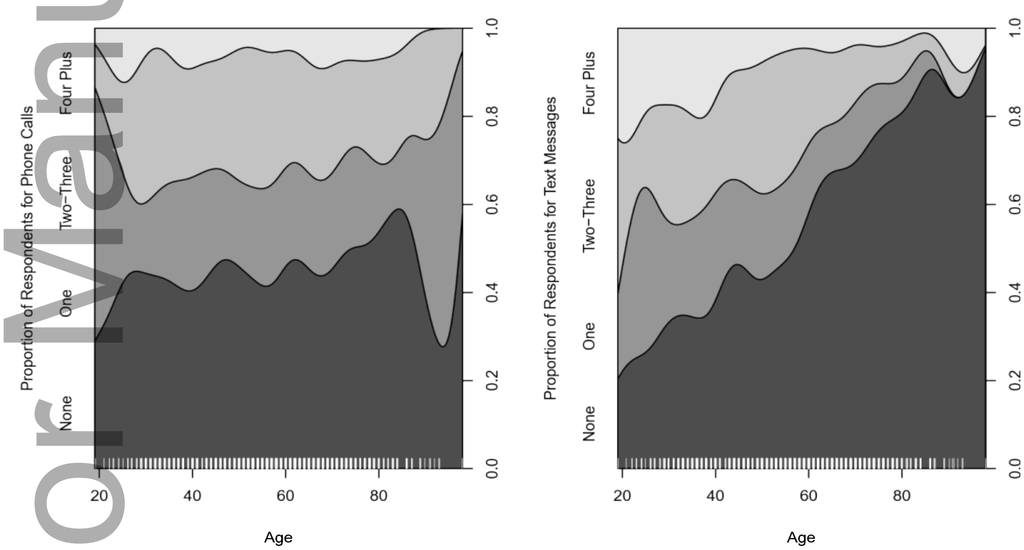


Figure 4: Bivariate Cumulative Distribution Plots of Age and Number of Contacts

Figure 4 plots the distribution of responses as a continuous function of age. This plot helps illuminate the relationship found in the models. The panel on the right of Figure 4 shows that after about age 83 respondents either contact no one through text or two or more. This further explicates the relationship between age and text usage as one of access. Those older individuals who do have access to texting use it, but there is a certain proportion who likely don't have access and therefore report no use. On the other hand, for phone calls, at the oldest ages of our respondents we see the largest proportion are contacting one individual in the panel on the left of Figure 4. This suggests that age does not affect access to phone calls, but only use as we see that no individuals over 84 years old report contacting four or more people through a phone call.

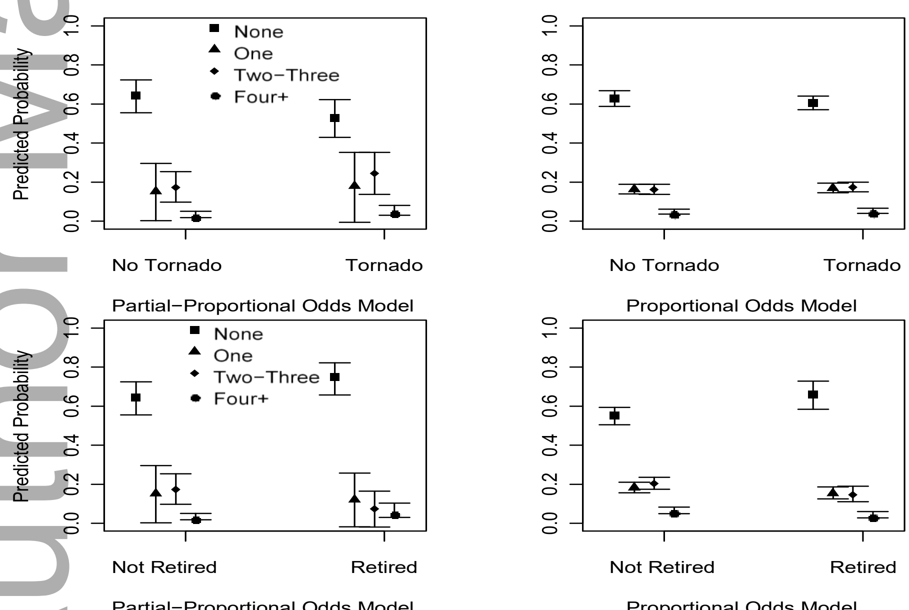


Figure 5: Results from Partial Proportional and Proportional Odds Models

Figure 5 plots predicted probabilities for tornado experience in the top two panels and the effect of retirement in the bottom two panels, for both proportional and partial proportional odds models[3]. These figures suggest retired status primarily has an access effect as the largest change across working statuses is for a single text contact. The nonproportional odds model suggests, relative to the proportional odds model, that this effect occurs at higher predicted probabilities; that is, when modeled appropriately, retirement increases an already very high predicted probability. Additionally, comparing the top and bottom panels, we can see that the effect of retirement is generally larger than the effect of experiencing a tornado, especially on the predicted probability of contacting no-one through text.

5 Discussion

Our exploratory investigation into the demographic drivers of information behaviors has revealed patterns distinguishing various populations. Of course, as an exploratory investigation, our results must be interpreted cautiously.

We find evidence of increased use of both technologies for sending information when a respondent reports that he or she was in a community affected by a tornado. The significance and magnitude of the tornado experience variable is not surprising and in line with previous research

[3] All covariates held at respective means or modes.

(Robinson, Pudlo and Wehde 2019; Ripberger et al 2019). However, this provides a useful baseline for comparison of the various demographic factors.

Demographic factors were important components of information sharing behaviors - but in various ways. Most notably, age was a consistently important factor depressing the use of text messaging (the more recent technology) while having no effect on phone-based behaviors. Importantly, we find support for both of our age-related hypotheses, $H_{access}1$ and $H_{use}1$. Age both significantly increases the probability of texting no-one and decreases the probability of texting more people. Importantly, we find this is primarily driven through access effects as age has the strongest negative relationship with contacting one person through text, compared to the other higher contact categories. These results suggest there exists a strong age-based communication divide, which is even stronger for newer technologies, in line with prior work on the digital divide, e-government, and tornado warning reception(Thomas & Streib, 2003; Ripberger et al 2019).

We also found that components often omitted from models of government public and R2R communication were important parts of the information behaviors. Interestingly, we did not find support for either of our location-based hypotheses ($H_{access}2$ and $H_{use}2$). Being located in a rural area had no significant relationship with either access or use of either communication method. These results suggest the communication and digital divides based on home location may be less evident in post-crisis communication. However, employment status, especially retirement, has a strong relationship with the probability a respondent reported contacting others through text. We, therefore, find mixed support for our hypotheses related to work-status ($H_{access}3$ and $H_{use}3$), as other categories of not-working, relative to working full-time, have no relationship with communication behaviors. The effect of retirement is especially strong for access, as opposed to use, of text communication providing further evidence of a digital divide. On the other hand, work status had no relationship with number of contacts through phone calls. These findings are in line with the recommendations of Reilly, Atanasova, and Criel (2015) who emphasize understanding the information seeking behaviors of the audience to guide communication platform choice during crises.

One limitation of our work is that we are unable to make conclusions about the ordering or timing of R2R information sending. Respondents who report using text messages to send information may have already exhausted their use of phone calls or vice versa respondents may be texting first and calling later. Additionally, we do not know if these information channels are used within minutes, hours, or possibly even days after the event. Future research should consider examining the timing of information sending and ordering of information channels as implications for emergency manager immediate use of communication channels also hinge upon knowledge of these factors. Research into timing could also consider distinctions between pre-event, during event, immediately post-event, and long-term communication related to any disaster. Such research would require a long time frame for data collection and would likely have to collect specific messages rather than the recall-based approach taken here.

These patterns of responses are particularly important for the practice of emergency management and the dissemination of public safety information. The goal being contact with all (or as high a proportion as is feasible), it is essential to understand how information spreads through the community once released from official sources. This is especially important given the significant economic investment in and value of improvements in improved information technologies (Wehde, Ripberger, Jenkins-Smith, Jones, Allan, and Silva 2021). For these investments to reach their fullest value to society, the information they improve must be widely distributed to and amongst the public. Patterns in redistribution are particularly important for understanding how community members who are vulnerable to social isolation may still get important safety information. The factors related to information behaviors (age, work status, racial minority status, etc.) are also related to general disaster vulnerability. An effective and socially conscious informational plan on the part of public managers must account for the differences in information reception and redistribution.

To this end, our results imply that emergency managers prioritize the consideration of two populations who may lack access to important communication channels for emergency management – older and retired residents. Emergency managers should consider these populations when developing an outreach and communication strategy – likely layering communication strategies to create redundant communication channels to reach these less-connected populations. Our research emphasizes the importance of the prevailing approach among many emergency managers which is to communicate with residents using a broad package of tools. Most importantly, emergency managers in communities with large numbers of older or retired residents should not emphasize the use of new media strategies like text messaging without a compensatory strategy to reach the populations least likely to be engaged through new media channels. New media, such as texting or social media, are simply one tool in this varied package. Tools such as Reverse 9-1-1 systems which can send a prerecorded voicemail to both landlines and cellphones may deserve special consideration as combining the strengths of both new and older media. These results emphasize the importance of a portfolio strategy for public safety information and the thoughtful balancing of the access of various residents to different communication channels.

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