Connected Communications: Network Structures of Official Communications in a Technological Disaster

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ABSTRACT

Informal online communication channels are being utilized for official communications in disaster contexts. Channels such as networked microblogging enable public officials to broadcast messages as well as engage in direct communication exchange with individuals. Here we investigate online information exchange behaviors of a set of state and federal organizations during the Deepwater Horizon 2010 oil spill disaster. Using data from the popular microblogging service Twitter, we analyze the roles individual organizations play in the dissemination of information to the general public online, and the conversational microstructure of official posts. We discuss characteristics and features of following networks, centrality, and conversational dynamics that may affect information exchange in disaster. This research provides insight into the use of networked communications during an event of heightened public concern, describes implications of conversational features, and suggests directions for future research.

Keywords

Disaster research, social media, online informal communication, social networks

INTRODUCTION

The utilization of informal online communication technologies is emerging as a useful strategy for public officials to engage persons at risk, to convey warning information, and to relay informational updates over the course of a disaster event. Traditional communication mechanisms, such as television and radio broadcast media, remain key media for at risk information seekers, but are directed and managed by major media outlets. Online communications enable organizations to manage their own communications activities and engage with stakeholders and constituents directly and in real time. As members of the public increase their information seeking in disasters, it has become vital that public officials make use of new communication channels that enable direct interaction with the public online in order to monitor online milling activity (including local organizing and information exchange), directly engage in conversation with constituents, and adapt their messaging strategy to increase public protective action response.

While many government organizations are actively engaging informal communication mechanisms online, research has shown that governmental adoption has been slow (Sutton, 2009; Sutton, 2010) or not made a priority (Sutton, Hansard, and Hewitt, 2011). Public safety organizations that do engage social media have tended to utilize it as an additional channel to broadcast public information (Heverin and Zack, 2010), with little interaction online between the organization and its constituents. Prior research has included field studies, surveys, and online data collection

activities. Missing is the systematic study of the structural properties of public officials' communication networks and how these networks affect communication and engagement in disaster response . In this paper we conduct exploratory research on the networks and conversational microstructures of Twitter accounts held by public officials and governmental organizations. We focus on Twitter posts made during the Deepwater Horizon oil spill disaster,[1] in order to show the networks, roles, and conversation dynamics of official accounts during a significant disaster event. This research will lead to greater understanding of potentially influential organizations and conversation structures during a disaster response, helping to affect future policy for disaster communication dissemination through informal online networks.

BACKGROUND

Online Communication and Extreme Events

Twitter represents an important online venue for social interaction and information exchange in disaster. Outside of the disaster context, it has been studied primarily by computer scientists and modelers interested in systems and online social networks (Huberman, Romero, and Wu, 2008; Krishnamurthy, Gill,and Arlitt, 2008; Kwak, Lee, Park, and Moon, 2010; Cha, Haddadi, Benevenuto, and Gummadi, 2010) and the spread of specified information, such as rumors and political ideology (Mendoza, Poblete, and Castillo, 2010; Tumasjan, Springer, Sandner, and Welpe, 2010). As a social medium in disaster it is of immediate interest to social scientists as well. Work in this area has been limited, however, because principled data collection and management of the resulting materials require novel techniques. Within the disaster context, Twitter has been identified as a mechanism for resource mobilization and collaboration as well as a platform for sharing life-safety information (Starbird and Palen, 2010). Research on disaster response has indicated that rapid exchange of up-to-date information about a given situation is a vital information resource in this context (Sutton, Palen and Shklovski, 2009).

Studies of online communication in disasters have shown that the public often utilizes social media to fill the information gap that occurs when emergency responders follow a traditional model for public information release (Sutton, et al 2010). Disaster-specific Twitter research include descriptive studies that focus on Twitter adoption and use in mass convergence events (Hughes and Palen, 2009), mechanisms of information production, distribution and organization (Starbird,and Palen, 2010; Vieweg, Hughes, Starbird, and Palen 2010; Chew and Eysenbach, 2010), and public participation and citizen reporting across a variety of hazard types (Sutton, 2010).

Government Use of Social Media

Government engagement in social media is one strategy of E-Government, or the use of tools to communicate and collaborate with the public seeking services online. Empirical studies on the use of Twitter by government communicators in crisis response and management have included, for instance, investigations of communications following a technological disaster (Sutton, 2010), where there was little online engagement by public officials; following the shooting of a local police officer (Heverin and Zack, 2010), where Twitter was used to relay informational updates during the investigative process; and a largescale slow moving natural disaster (Bruns, 2011), where official communicators obtained a large following and served as "mythbusters." An additional study conducted by Heverin and Zack (2011) determined that most law enforcement Twitterers use their accounts primarily as a channel for public information, rather than public engagement. While event-driven research has revealed communication patterns and their potential effect on disaster-affected populations, little is known about the networked relationships of governmental organizations using Twitter and how such relationships may affect communication patterns in disasters.

DATA

Government Twitter Account Enumeration

[1] The 2010 Deepwater Horizon oil spill (DWH) was one of the largest accidental marine oil spills in the history of the petroleum industry, resulting in an estimated release of more than 206 million gallons of crude oil into the Gulf of Mexico.

The data for this project come from the popular microblogging service, Twitter, as collected by Butts et al. (2011). Data was collected on a set of pre-identified official government entities holding Twitter user accounts. Data consists of the history of activity for each of these entities, as well as covariates about each user specified in their online profile. Twitter allows each of its users to specify subscription relationships; as such social ties constitute pathways for information exchange. In this section we briefly describe the enumeration procedure for obtaining our set of government accounts as well as detailed information about the specific data used in this research.

Enumerating all official government Twitter accounts is a difficult task due to the rapidly changing environment and the lack of centralized information about which government entities have accounts and which do not. We began by listing all federal and state government entities that would be key to the alert and warning process for all hazards and threats (this initial step does not take Twitter presence into account). This is a very general criterion, not limited to specific types of disasters nor a specific region of the United States. Once a set of government entities was identified, we looked at the websites of these federal agencies, State Governors, offices of Homeland Security and Emergency Management to find and identify active Twitter accounts. We also used GovTwit as an additional (but limited) database of Twitter accounts.[2] This enumeration procedure ensured that the same types of government entities were considered across states and the country. In addition it prevented random searching on Twitter itself and false identification of non-official accounts. The result of this process is 216 uniquely identified government Twitter accounts, ranging from FEMA to the Michigan State Police.

In addition to general participation in hazards related conversations online, we are specifically interested in those government entities active in response to the Deepwater Horizon disaster. Thus we augmented the initial large-scale, diverse set of government accounts with some event-specific targets. Some of these accounts may have been set up specifically for the Deepwater Horizon response or represent government agencies more specifically involved in a disaster of this type. We focused on agencies that would represent official sources of information about the event response, in particular those that addressed environmental impacts (including fish and wildlife), health impacts, and economic impacts of the disaster. Thirty additional accounts were added to our final list via this search. From this set of accounts eight were dropped after data collection because the user had been suspended or no longer existed. Therefore our analysis is conducted on a set of 238 official government Twitter accounts. All of these accounts represent state and federal level government agencies, or the offices of a government administrator of some type. We did not collect accounts that represent for-profits, such as the oil industry, or not-for-profit agencies, such as the American Red Cross. Our search procedure was based on the advertised existence of Twitter accounts on an agency's website, therefore we do not capture unpublished accounts.

Once the set of government accounts and their corresponding agencies were determined, we classified these organizations by sphere and sector. Each account was coded across two dimensions, organizational sphere (federal, state, or regional) and organizational sector (public safety, health, defense and law enforcement, environment and wildlife, government officials, and economy or industry).

Account Information and Posting Activity

An individual's posting activity is available (up to 3200 posts) from the Twitter API. One may obtain the history of timestamped posts for each user, including a number of covariates about each tweet, such as the number of times it was re-posted by other users. We are interested in posting activity of each of the identified state, regional, and federal accounts during the initial disaster response and subsequent recovery, therefore we collected posts from each user from the beginning of May 2010.[3] In addition to user histories, we obtained the "following" network of social relationships among users.[4] Finally, we were able to obtain a set of actor level covariates about each user account. This includes the date the account was created, the number of others following them as well as the number of other

[2] GovTwit was the world largest government social media directory until it shut down on November 8, 2011. (see: http://www.blog.govtwit.com/2011/11/08/bittersweet-end-govtwit-directory-turns-three-but-forced-to-shut-down/)

[3] Our interest is in the network and microstructures of posted content from official organizations, not the entire content stream pertaining to the DWH event. Therefore, this post-event data collection start remains relevant to our research aims.

[4] Social tie data was obtained at the beginning of April, 2011. Though this does not correspond with the event period it allows us to test hypotheses about how posting behaviors during DWH are associated with subsequent positions in the following network.

accounts they follow.

METHODS

Tweet Topic Coding

One of our interests is to understand if government accounts on Twitter have distinct patterns of posting behavior. To better understand how these officials disseminate information and engage with the public during the Deepwater Horizon disaster, we performed a content analysis of messages posted by these users. To begin, we distinguished between posts that are oil spill related and those that are not. We performed a two step procedure to code individual posts as being on topic or off topic.

First, we identified a set of keywords likely to be used in conversation about the event. This includes words and phrases such as "oil spill," "BP," "wildlife impact," etc. Using automated text matching routines we searched for instances of these keywords in each of the posted tweets. We separated user accounts into two groups, those whose posts contain no oil spill relevant language and those that contain at least one mention of oil spill relevant language. For each of the accounts whose posts contain oil spill relevant language, all tweets were manually coded as on topic and off topic. On topic tweets are defined as including any mention of the oil spill, responses to the oil spill, or its impacts on health, environment and wildlife, economy, etc. For all accounts, we coded a sample of twenty-four posts for each user. Each tweet was coded by at least two coders. Inter-rater reliability was calculated with Cohen's Kappa and 90% on average indicating very high coding reliability.

Accounts that included oil spill related language underwent additional content analysis to identify emergent themes related to key issues discussed by accounts representing each sphere and across all sectors. Coding was inductive and continually updated as additional themes were identified to create broad, cross-cutting categories. Coding each individual tweet as on topic or off topic allows one to obtain an estimated proportion of each user's stream of activity that was directly related to the oil spill. We will use this estimate in subsequent analysis.

Relational Microstructure Coding

In this work we are interested in differentiating patterns of communication behavior by government entities on Twitter. In this context there are a number of different features of posted messages that are of interest. First, there are many different roles an actor could occupy vis a vis a single post, signifying conversation and collaboration online (Honeycutt and Herring, 2009). For instance, an actor may be the sender of a message; a receiver of the message; a third party mentioned in the message; or an unreferenced audience member (who nonetheless is party to the communication). On Twitter, messages are often directed at specific audience members via the convention @username somewhere in the body of the conversation.

Another feature of information exchange on Twitter is the re-distribution of messages obtained from other users. Called "retweeting", this serial transmission of information is especially important for information diffusion and visibility -- a vital concern in disseminating hazard alerts and warnings. The process of copying and retweeting content is easily distinguished on Twitter because of the user convention to add an "RT @username:" before the copied content. In this case the RT stand for retweet and the flagged user typically denotes the source of the information.

We used automated text coding routines to code each individual tweet for what we call the relational microstructure. This includes whether the tweet was directed at specific others, and whether it was a retweet or original content. This typology allows us to further distinguish between different posting patterns.

RESULTS

Patterns of Posting

To begin our analysis we consider which organizations post content related to the oil spill response and recovery. Only 26% of government accounts posted at least one tweet related to the Deepwater Horizon oil spill. For those

accounts that posted oil spill relevant content, there is great variability in the attention paid to the event. Unsurprisingly, some organizations, such as those in geographically distant areas or not directly involved in the disaster response, posted only one on topic tweet while others, such as states most heavily affected by the oilspill, have a posting history where more than 95% of tweets are event-related. Tweets related to the oil spill centered on two primary issues; disaster response activities and attempts to cap the well, and the effects of the oil flow on humans, animals, and environment. There were differences in the tweet content based on both the sphere in which the tweeting organization resides and their sector. State Twitter accounts tended to comment on locally relevant information such as claims processes, applying for aid, and local water conditions including water closures, as well as updates on State disaster response activities. Federal Twitter accounts provided information and updates that were relevant to a larger audience including information on the health effects of the oil flow and cleanup (i.e. @CDCemergency); response activities undertaken by organizations and organizational administrators (i.e. @usgs; @coastiechris); and open access to fact sheets, testing and analysis activities, and data (i.e. @epagov; @usnoaagov).

Relational Microstructure

Next, we considered the four-category classification of posts according to the presence/absence of directedness and the presence/absence of retweeted content. That is, we classified each post into one of four categories: (1) not directed and not a retweet, (2) not directed and a retweet, (3) directed and not a retweet, and (4) a directed retweet. Directedness in messages is a particularly interesting feature because is signals publicly-visible, direct engagement with another user. When this user is a member of the general public directedness is a possible demonstration of attempts to engage with the public, by answering questions or providing specific information, and potentially increasing trust between officials and the public (Peters, Covello, and McCallum, 1997).

41.6% of government accounts have posted at least one directed tweet. However, only 5.8% of government accounts have a posting history where at least 10% of posts are directed. There is a very small set of users who regularly post directed messages. Those accounts that have a high portion of directed messages cross both state and federal spheres but primarily represent government executives and the public safety sector. Perhaps unsurprisingly, the personal accounts of individual government executives have the highest portion of directed messages, with many of the messages focusing on their political activities. At the federal level, the TSA has a high portion of directed messages in response to questions posed by individual to clarify issues of allowed carry-on items for commercial airline travel. Of the accounts that posted directed messages in response to oil spill related items, @GOHSEP, the Louisiana state account for the Governor's Office of Homeland Security and Emergency Preparedness, demonstrated significant interactions via directed texts . @GOHSEP also engaged in recommender system activities by posting recommendations to follow individual user accounts on Fridays. [5]

Next we consider the proportion of retweets in an organization's posting history. Since the use of directed messages within this population is very infrequent, government accounts are primarily distinguished based on the proportion of retweets in their posting history. Accounts with a high proportion of retweets demonstrate that they are obtaining information from other users and reposting it. This behavior could be contrasted with an account that simply posts its own content and does not use Twitter itself to gather information.

Most organizations have very low rates of retweeting. Only a few organizations have high proportions of retweeting in their posting history. Accounts that do retweet tend to include tweets from an affiliated organization or government executive. For instance @epagov retweets the content of @lisapjackson (the Environmental Protection Agency administrator) and @oil_spill_2010 (a members-only, official account for the response operation), and @coastiechris, the Public Affairs Officer for the US Coast Guard, retweet content from the USCG.

From this analysis, we find that there is a high number of organizations that use Twitter primarily as a broadcast mechanism of internally sourced information; in other words, they do not direct messages to others, nor do they retweet information. This is seen most consistently in federal accounts, where evidence suggests that Twitter adoption and use is an additional, or perhaps even redundant, information channel to reach users in the microblog sphere.

Following Network

[5] #Followfriday is a convention, or game, used to recommend new accounts to follow on Twitter.

As the previous discussion indicates, official government accounts on Twitter show different patterns of posting behavior. The variability in the microstructure of tweets demonstrates that these accounts share information in different ways. To better understand how the underlying structure of the information exchange network effects the diffusion of information we explore the structure of the following network among these accounts. In Figure 1 we show the observed following network among government accounts on Twitter. There are many plausible explanations for why government entities on Twitter choose to follow other governmental accounts. Following relationships may signal organizational affiliation, be an additional mechanism through which they can direct their own followers to other information sources of interest, be a way in which they can monitor the activities of others to learn about norms of behavior and posting practices, or serve as a professional community of practice. Characterizing the structure of the following network offers insight into how information exchange may operate. In this section we consider basic properties of the following network and their implications for information exchange.

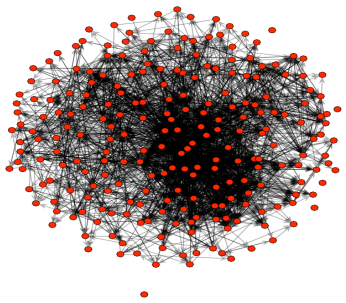

Figure 1: Following network among government accounts

Sparsity, Reciprocity and Hierarchy

Following relationships within the set of government accounts tend to be sparse. The probability that any two government accounts follow each other is only 0.059. However, while following relationships may be sparse, they do tend to be reciprocal (if user A is following user B, it is likely that user B is also following user A). 42.8% of following relationships among the government accounts are reciprocated, making such relationships over 7 times as common as would be expected by chance. Reciprocity indicates existence of a follower-follow back relationship that, given the lack of following relationships by government accounts, represents an informed decision to be in connection online.

Following relationships can be thought about as "paths" for potential information flow. These pathways, allow information to flow back and forth in a "directed" manner. It is important to consider how these pathways affect potential information exchange in both direct relationships (i.e. between any two actors) as well as via indirect relationship (i.e. more global pathways that require a series of exchanges). Reciprocity captures the tendency for directed relationships to be bidirectional. Locally reciprocated relationships may point towards a more mutual information-sharing norm between pairs of organizations. However, hierarchy in social networks refers to the tendency for direct or indirect relationships to be asymmetric. In our context, hierarchy is observed as the fraction of pairs where user A can pass along information to user B, but B cannot direct information to A. To measure global hierarchy we use the measure proposed by Krackhardt (1994) and find that the observed Krackhardt hierarchy is 0.16. In other words, 16% of pairs of nodes connected by some directed path, are connected by an asymmetric path. This observed value is significantly higher than expected by chance (p-value < 0.01). This implies that while actor A may direct a piece of information along a path of social contacts to actor B, the reverse is not true – actor B does not have the same access to actor A.

Combined with the previous results on reciprocity, we see that the following network has local reciprocity but global hierarchy. This suggests that there may be a mutually connected core set of actors who share information and then serve as agents to disseminate information towards more peripheral actors. These peripheral actors, however, may not be able to pass information back towards the core. This type of core/periphery structure in the following network has important consequences for the direction in which information can flow, as well as the ability for one organization to communicate directly to another via Twitter. In the absence of reciprocal relationships on Twitter, other paths or channels may need to exist for direct communication to occur between governmental organizations.

Tweet Exposure

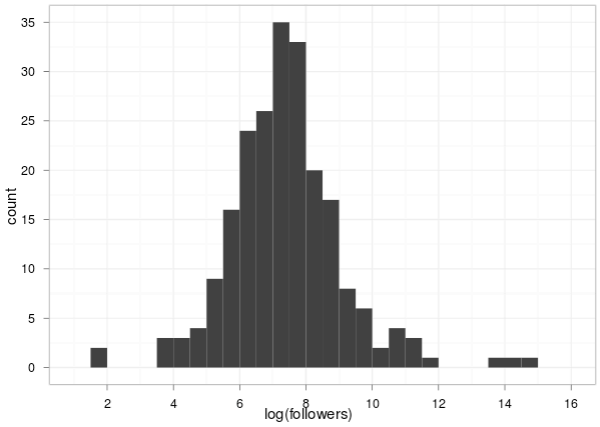

Figure 2: Follower distribution

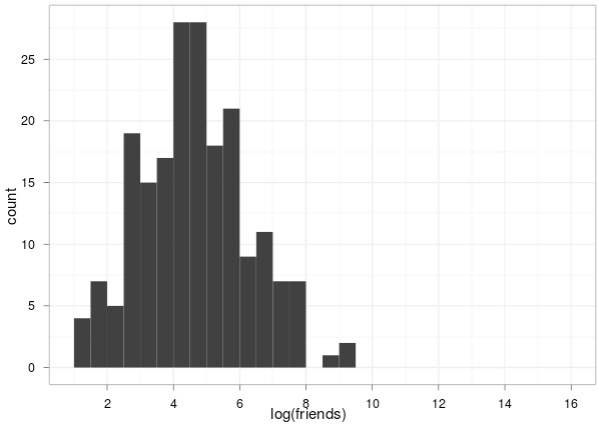

Figure 3: Friend distribution

Turning to a consideration of ties beyond the set of government accounts, we observe that government accounts in our sample tend to have many more followers than contacts whom they follow back. When we consider the distributions of followers compared with the distribution of organizations they follow back (i.e. 'friends') in Figures 2 and 3 (distributions of followers and friends are shown on log scale for readability), we find an asymmetry in organizational relationship. Government accounts demonstrate non-reciprocal relationships between their followers and their decision to follow back, indicating that these public officials are contributing to the Twitter atmosphere largely by producing content rather than engaging with others through directed communication or content consumption. Therefore, while messages posted by government accounts are received by large numbers of Twitter users on average, the government accounts we examined do not have many contacts from which they directly receive information.

Prominence, Power and Influence

Information sharing potential is also a function of one's position within a networked environment. Positions have differential access to others - some are more central or prominent, and some are isolated. An actor's position has important consequences for information access, power, influence, etc. (Freeman, 1979; Burt, 1992; Wasserman and Faust, 1994). Degree is one measure of prominence within a network; it is demonstrated by the number of connections to others. As previously discussed, the number of connections an individual has is important because it determines direct access to others, in contrast with mediated access, and it also determines the exposure of ones' tweets. The accounts @FEMA, @dhsjournal, @craigatfema, and @readydotgov have the highest numbers of followers within the government following network. Then also tend to be embedded within the core of the network. Because many others follow their activity, these organizational actors are potentially influential in terms of broadcasting information, exchanging information, or establishing norms for posting.

Another important measure of centrality examines the extent to which an actor lies on short paths between others. Known as betweenness, this measure of centrality captures the idea that if one lies on many shortest paths between other pairs, one may have an advantage in control the flow of information or resources between these third parties. @FEMA, @dhsjournal, @craigatfema, and @readydotgov also have high betweenness, as do @whitehouse and @usagov accounts. These organizations are thus in a better position to act as information brokers than low-betweenness accounts because they have the potential to aid in passing information between organizations that cannot reach each other directly via shortest paths.

Differential Mixing

We next consider the mixing rates between actors across organizational sphere and sector. Mixing rates capture the differential propensity to be tied to others based on covariate similarity. One common example of this is homophily, which has been observed in many real-world social networks (McPherson, Smith-Lovin, and Cook, 2001). This has implications for information sharing and collaborations. If organizations are not paying attention to each other's activity there is a higher potential for redundant or contradictory information to be released. In our analysis, this is most visible among following relationships across different organizational sectors. Perhaps unsurprisingly, we find that each sector has high inter-group following relationships, however highly prevalent cross-groups ties exists

primarily between environmental organizations and elected officials. In generally, we find a lack of connection between organizations across different sectors. While this may signify that organizations are linked via common interests or tasks, it has implications for information sharing, inter-organizational collaboration, and resolving response task dependencies.

DISCUSSION AND CONCLUSIONS

Governmental organizations are adopting Twitter as an additional channel to communicate with other organizations and members of the public during routine times and times of crisis. In this research we have investigated network structural properties, and microstructures of individual tweets produced by governmental organizations in relation to a large scale disaster. We found that more on topic tweets tend to be contributed from those organizations located within the proximity of the disaster event and that tweet content varied based upon the sphere and sector in which the organization resides. Most instances of government Twitter use followed similar patterns as those found in Heverin and Zack (2010) who observed a lack of emphasis on public engagement, as well as Starbird and Palen (2010) who noted that locally relevant content is supplied by local/state actors.

Analysis of the follower network among governmental accounts reveals that federal organizations are more central, with respect to several measures, than most other government organizations, as are health and public safety organizations. Most peripheral to the network are elected officials and political actors. While these three sectors show differing results in their network centrality measures, all three had greater numbers of directed conversations with individuals on average. Analysis of the relational microstructure of Twitter accounts revealed low numbers of directed tweets, and retweeted content. However, of those accounts that did make use of these conventions, we note that they tend to increase conversation with their followers rather than just broadcasting press releases or providing online links to daily updates. This raises a number of questions about the use of relational conventions for future response, particularly in the context of increasing trust and developing a greater network of followers through this informal communication medium, which we discuss next.

In crises and disasters, the ways in which content and informational flow are managed is vital. Organizations must optimize posted content to reach large specified audiences, in many cases across vast geographical spaces. Understanding how governmental organizations are utilizing Twitter can aid disaster responders in their efforts to disseminate real-time public information in a system of complicated networks in more efficacious and efficient ways.

In disaster response, message dissemination and distribution is of great concern. The goal is to widely distribute accurate, yet simple, messages to the public to keep populations informed and safe. Examining relational microstructure allows one to quantify different behavioral tendencies and make predictions of the impact of these approaches on message trustworthiness and credibility by populations at risk. For example, information believability may increase if there is evidence of a trusted relationship between an organization and its followers. Yet follow back activity between official organizations and members of the public seldom occurs. In future work it will be important to examine the effects of relational microstructure on public protective action response. For instance, does evidence of directed communications increase trust in information? Government decisions to follow back individual accounts must also be examined in order to understand how follow back activity provides a pathway to additional information sources as well as its effectiveness for enabling directed communications. For instance future investigations might examine the decisions made by government agencies with high numbers of followers that choose not to follow back, asking if is this due to the fear that too many followers may "clog channels," even though in disaster it has the potential to open doors for backchannel, directed messages. Investigators might additionally ask if a lack of follow back activity indicates an absence of active Twitter monitoring, or if it might signify that other strategies are in place, such as keyword searches, to follow trending information during a disaster response.

In addition to the implications of behavioral tendencies in the use of social media, we also gain a new understanding of the systems of social relations by analyzing network structure. Basic measures, such as centrality indices, allow us to identify prominent organizations that have the potential to broker information, effect "community of practice" posting behaviors, and influence the flow of information via the network. Our results indicate that health and public safety organizations tend to be more central, making them vital communication partners to reach the public. In the

case of disaster response, these organizations could play a central leadership role. Understanding the current posting behavior of government accounts is important for making policy recommendations. In disaster situations, responders can no longer ignore the medium; they must understand how to best utilize it to further enhance disaster response and recovery efforts. Knowing how tweets are structured, observing the function of organizational centrality, and understanding the effects of follow back activity will lead to more direct and efficient messaging, to inform the public at risk, leading to a more effective disaster response.

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REFERENCES

1. Bruns, A. J. Burgess, K. Crawford, and F. Shaw. (2012). #qldfloods and @QPSMedia: Crisis Communication on Twitter in the 2011 South East Queensland Floods. Brisbane: ARC Centre of Excellence for Creative Industries and Innovation.

2. Burt, Ron S. (1992). Structural Holes: The Social Structure of Competition. Cambridge, MA: Harvard University Press.

3. Butts, Carter T., Jeannette Sutton, Emma S. Spiro, Matt Greczek, Sean Fitzhugh, and Britta Johnson . (2011). Hazards, Emergency Response, and Online Informal Communication Project Data. University of California, Irvine and University of Colorado, Colorado Springs.

4. Cha, M., Haddadi, H., Benevenuto, F., and Gummad, K.P. (2010). Measuring User Influence on Twitter: The Million Follower Fallacy. *Proceedings of the 4th International AAAI Conference on Weblogs and Social Media.* Washington, D.C.

5. Chew, C., and Eysenbach, G. (2010). Pandemics in the Age of Twitter: Content Analysis of Tweets during the 2009 H1N1 Outbreak. *PLoS ONE 5(11): e14118.* doi:10.1371/journal.pone.0014118

6. Crowe, A. (2010). The elephant in the JIC: The fundamental flaw of emergency public information within the NIMS framework. *Journal of Homeland Security and Emergency Management.* 7(1).

7. Freeman, Linton C. (1979). Centrality in Social Networks: Conceptual Clarification. *Social Networks* 1:223-258.

8. Heverin, T. and Zach, L. (2010). Twitter for City Police Department Information Sharing. *Proceedings of the Seventy-Third American Society for Information Science and Technology Conference*, Pittsburgh, Pennsylvania.

9. Heverin, T., & Zach, L. (in press). City Police Department Adoption and Use of Twitter as a Crisis Communication Tool. In C. Hagar (Ed.), *Crisis Information Management: Communication and Technologies* Oxford, UK: Woodhead Publishing Limited.

10. Honeycutt, C., and Herring, S.C. (2009). Beyond Microblogging: Conversation and Collaboration via Twitter. *Proceedings of the 42nd Hawaii International Conference on System Sciences.* Los Alamitos, California.

11. Huberman, B.A., Romero, D.M., and Wu, F. (2008). Social Networks that Matter: Twitter under the Microscope. arXiv:0812.1045v1

12. Hughes, A.L., and Palen, L. (2009). Twitter Adoption and Use in Mass Convergence and Emergency Events. *Proceedings of the 6th International ISCRAM Conference.* Gothenburg, Sweden.

13. Katz, Leo. (1953). A new status index derived from sociometric analysis. *Psychometrika* 18:39-43.

14. Krackhardt, David. (1994). "Graph Theoretical Dimensions of Informal Organizations." In K. M. Carley and M. J. Prietula (Eds.), Computational Organization Theory, 89-111. Hillsdale, NJ: Lawrence Erlbaum and Associates.

15. Krishnamurthy, B., Gill, P., and Arlitt, M. (2008). A Few Chirps about Twitter. *Proceedings of the 1st Workshop on Online Social Networks.* New York, New York.

16. Kwak, H., Lee, C., Park, H., and Moon, S. (2010). What is Twitter, a Social Network or a News Media? *Proceedings of the World Wide Web Conference Committee*. Raleigh, North Carolina.

17. Latane, B., J. H. Liu, a. Nowak, M. Bonevento, and L. Zheng. (1995). Distance Matters: Physical Space and Social Impact. *Personality and Social Psychology Bulletin* 21:795-805.

18. McPherson, M., L. Smith-Lovin, and J.M. Cook. (2001). Birds of a feather: Homophily in social networks. *Annual review of sociology* 27:415-444.

19. Mendoza, M., B. Poblete, and C. Castillo. (2010). Twitter Under Crisis: Can we trust what we RT? *1st Workshop on Social Media Analytics SOMA '10,* July 25, 2010, Washington, DC, USA.

20. Peters, R.G., V.T. Covello, and D.B. McCallum. (1997). The Determinants of Trust and Credibility in Environmental Risk Communication: An Empirical Study. *Risk Analysis*. 17(1): 43-54.

21. Starbird, K., and Palen, L. (2010). Pass it on?: Retweeting in Mass Emergency. *Proceedings of the 7th International ISCRAM Conference.* Seattle, Washington.

22. Sutton, J.N. (2009). Social media Monitoring and the Democratic National Convention: New Tasks and Emergent Processes, *Journal of Homeland Security and Emergency Management*: Vol. 6 : Iss. 1, Article 67.

23. Sutton, J.N., (2010). Twittering Tennessee: Distributed Networks and Collaboration Following a Technological Disaster. *Proceedings of the 7th International ISCRAM Conference.* Seattle, Washington.

24. Sutton, J.N., Hansard, B., and Hewett, P. (2011). Changing Channels: Communicating Tsunami Warning Information in Hawaii, *Proceedings of the 3rd International Joint Topical Meeting on Emergency Preparedness and Response, Robotics, and Remote Systems.* Knoxville, Tennessee.

25. Sutton, J.N., Palen, L., and Shklovski, I. (2008). Backchannels on the Front Lines: Emergent Uses of Social Media in the 2007 Southern California Wildfires. *Proceedings of the 5th International ISCRAM Conference.* Washington, D.C.

26. Tumasjan, A, T.O.Sprenger, P.G. Sandner, and I.M. Welpe. (2010) Predicting Elections with Twitter: What 140 Characters Reveal about Political Sentiment. *Association for the Advancement of Artificial Intelligence.*

27. Vieweg, S., Hughes, A.L., Starbird, K., and Palen, L. (2010). Microblogging During Two Natural Hazards Events: What Twitter may Contribute to Situational Awareness. *CHI 2010 Crisis Informants.* Atlanta, Georgia.

28. Wasserman, Stanley and Katherine Faust. (1994). Social Network Analysis: Methods and Applications. Cambridge: Cambridge University Press.