Tweeting the Spill:
Online Informal Communications, Social Networks, and Conversational Microstructures during the Deepwater Horizon Oilspill

Jeannette Sutton, Trauma Health and Hazards Center, University of Colorado Colorado Springs, Colorado Springs, CO, USA

Emma S. Spiro, Department of Sociology, University of California Irvine, Irvine, CA, USA

Carter T. Butts, Departments of Sociology and Statistics and the Institute for Mathematical Behavioral Sciences, University of California Irvine, Irvine, CA, USA

Sean Fitzhugh, Department of Sociology, University of California Irvine, Irvine, CA, USA

Britta Johnson, Trauma Health and Hazards Center, University of Colorado Colorado Springs, Colorado Springs, CO, USA

Matt Greczek, Trauma Health and Hazards Center, University of Colorado Colorado Springs, Colorado Springs, CO, USA

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 the authors 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, they analyze the roles individual organizations play in the dissemination of information to the general public online, and the conversational aspects of official posts. The authors discuss characteristics and features of the following networks including actor centrality and differential mixing, as well as how structural features may affect information exchange in disasters. 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: *Actor Centrality, Differential Mixing, Disaster Research, Microblogging, Online Informal Communication, Social Media, Social Networks*

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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 broadcast television and radio, remain key dissemination channels for persons at risk in disaster, but are directed and managed by a small number of major media corporations. Online communications enable organizations to manage their own communication 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.

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. It began on April 20, 2010 with an explosion on the Deepwater Horizon drilling rig, stationed in the Gulf of Mexico approximately 400km southeast of Houston, TX. The oil well was capped on July 15, 2010, ending almost three months of constant oil flow. During this time, international attention was directed toward the Gulf of Mexico and the impact of the oil spill on local coastlines, including animal habitats and the resulting environmental destruction, economic effects on fisheries and tourism, and long term health effects on coastal populations.

Online communications regarding the oil spill became one of the primary strategies of federal response agencies that established a single website (www.deepwaterhorizonresponse.com) to consolidate information dissemination and create a unified voice that linked to a number of social media technologies including Facebook, Twitter, YouTube, Flickr, and RSS feeds. This public facing website was just one strategy for online communications. Other agencies at the state and local level also utilized networked technologies to broadcast updates and interact with concerned individuals. The extent to which these organizations utilized social media technology, specifically the microblogging service Twitter, is the focus of this research.

While many government organizations actively engage in informal communication mechanisms online, research has shown that governmental adoption of social media channels has been slow (Sutton, 2009; Sutton, 2010) or non-prioritized (Sutton, Hansard, & Hewitt, 2011). Public safety organizations that do engage social media have tended to utilize it as an additional channel to broadcast public information (Heverin & Zack, 2010), with little interaction online between the organization and its public constituent-followers. 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 microstructure of Twitter accounts held by public officials and governmental organizations. We focus on Twitter posts made during the Deepwater Horizon oil spill disaster, 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.

We begin by discussing online communication and extreme events, governmental disaster response, and organizational networks following disasters before turning our attention to the data collection and analysis activities.

BACKGROUND

Online Communication and Extreme Events

Twitter represents an important online venue for social interaction and information exchange in disasters. Outside of the disaster context, it has been studied primarily by computer scientists and modelers interested in systems and online social networks (Cha, Haddadi, Benevenuto, & Gummadi, 2010; Huberman, Romero, & Wu, 2008; Krishnamurthy, Gill, & Arlitt, 2008; Kwak, Lee, Park, & Moon, 2010;) and the spread of specified information, such as rumors and political ideology (Mendoza, Poblete, & Castillo, 2010; Tumasjan, Springer, Sandner, & 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 & 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, & 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 includes descriptive studies that focus on Twitter adoption and use in mass convergence events (Hughes & Palen, 2009), mechanisms of information production, distribution and organization (Chew & Eysenbach, 2010 Starbird & Palen, 2010; Vieweg, Hughes, Starbird, & Palen, 2010), and public participation and citizen reporting across a variety of hazard types (Sutton, 2010).

Additional studies of what we call "microstructure elements," such as markers of retweeted or directed content between friends-followers have also been conducted. These include examinations of the retweet function as an informal recommender system (Boyd et al., 2010; Starbird & Palen, 2010), as a strategy to propagate information (Hui et al., 2012), and thematic analyses of individual tweets that received significant attention during a disaster event (Starbird & Palen). Honeycutt and Herring (2009) examined the function of "@" within a tweet, finding that most routinely (91% of the time) this is used to direct a message to another person, followed by making a reference to another person (5.4%).

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. Practices and policies for online engagement and crisis communications among government actors have received considerable attention as they parse out strategies to work effectively within existing infrastructure and legal restrictions (see for instance the www.socialmediagovernance.com for a database of policies). Empirical studies on the use of Twitter by government communicators in crisis response and management have included: investigations of emergent procedures for social media monitoring developed by public information officers during a national special security event (Sutton, 2009); communications following a technological disaster (Sutton, 2010), where online engagement by public officials was observed very infrequently; following the shooting of a local police officer (Heverin & Zack, 2010), where Twitter was used to relay informational updates during the investigative process; a large-scale, slow-moving natural disaster (Bruns, 2011), where official communicators obtained a large following and served as "mythbusters"; and the

development of social media communication strategies and procedures in the immediate hours following a large scale disaster event with long-term power outages (Sutton, 2012). 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.

Social Networks in Disaster

Social networks play an important role in the transmission of information in disaster contexts. Effective disaster response relies on effective organizational communication in order to solve tasks and disseminate relevant information (Auf der Heide, 1989). Organizations must maintain an undisrupted flow of communication, whether within organizations, between organizations, or to the broader public. While organizations are typically accustomed to information flow within the organization, inter-agency communication and communication to the public may be diminished in disruptive disaster settings (Auf der Heide, 1989). This has important implications for the effectiveness of disaster response. How efficiently information flows through a network plays a large role in determining whether or not disaster response is successful (Comfort et al., 2004). Accordingly, network analysis of communication channels is a fruitful endeavor as we seek to understand information flows among governmental organizations.

The importance of information flow has long encouraged researchers to study social networks in the context of disasters. Previous studies have examined rumors surrounding toxic, cancer-causing foods in Europe (Kapferer, 1989), misinformation about casualties following a windstorm (Scanlon, 1977), effects of population size on information transmission in two post-disaster communities (Richardson et al.,1979), differences in viscosity of information flow through formal and informal personal channels of communication (Lai & Wong, 2002), and countless other cases. By giving us tools for systematic analysis of information transmission and connections between individuals, social network analysis informs our understanding of communication patterns in a variety of contexts. Our case study with Twitter gives us the opportunity to examine these organizational communication patterns via online, informal message transmission.

DATA

Government Twitter Account Enumeration

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 available 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 or 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.[1] This enumeration procedure ensured that the same types of government entities were considered across states and the country (see Figure 1). 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.

Figure 1. Spatially embedded following relationships among enumerated government organizations. Node size is scaled based on activity (number of statuses posted) and node color represents number of followers (red nodes have high numbers of followers).

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 time-stamped 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.[2] In addition to user histories, we obtained the "following" network of social relationships among users.[3] 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 accounts they follow. This set shows variability in the number of followers and friends they have, as well as their level of activity since the account was created. We show descriptive statistics for the accounts in Table 1.

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. Using the results of this automated process, 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. The automated process of identifying accounts with on topic content is only as accurate as the predefined keywords used in the matching process and there is potential for content to be

Table 1. Descriptive statistics on the government Twitter accounts

	Minimum	Mean	Median	Maximum
Followers	0	25,169	1,687	2,073,292
Friends	0	446	86	15,168
Tweets	0	1,064	555	11655

on topic without using these specific keywords. Therefore, to prevent missing on topic content for the accounts not coded, we coded a sample of twenty-four posts for all users. 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 identified as having posted content 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 & 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 stands 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. Additionally, we also code for the presence of external links, mentions of users elsewhere in the content (excluding directed message markers) and for hashtags. Hashtags are metadata added to the tweet to specify content or channels of interest. For example, one might add the tag #oilspill to mark the content as related to the oil spill.

We consider the four-category classification that results from the directed message and retweet coding. These categories are of direct interest because they relate to behaviors that involve production of content versus serial transmission. We also consider directed message to be indicative of conversational engagement with other Twitter users; this behavior is contrasted with broadcasting (undirected) content. The four-category classification is seen below in Table 2.

Table 2. Four-category classification for elements of conversational microstructure in tweets

	Undirected Content	Directed Content
Original Content		@ (user name)
Retweeted Content	RT	@ (user name) RT

RESULTS

Patterns of Posting

To begin our analysis we consider which organizations posted 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 oil spill, 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 resided and their sector. State Twitter accounts (such as Alabama, below) 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:

(@alabamaema) ADEM increases monitoring of water quality at local beaches. http://bit.ly/92tBBK

(@alabamaema) More info on the change in Federal fishing areas closed to fishing. http://bit.ly/9RT4CD

Federal Twitter accounts provided information and updates that were relevant to broad audiences including information on the health effects of the oil flow and cleanup (i.e. @CDCemergency) for instance:

(@CDCemergency) Health surveillance data: Learn how CDC is tracking potential health effects related to the #oilspill http://is.gd/cKd2o

The CDC also posted information directed to those personally affected by the health effects of oil and tar on the beach:

(@CDCemergency) Wash skin ASAP if contact w/ oil or tar balls from #oilspill occurs. If you develop a rash, see a health care provider. http://is.gd/cHsMV.

Other federal agencies posted information about the response activities undertaken by their organizations and organizational administrators (i.e. @usgs; @coastiechris); and some, such as @epagov, posted links to fact sheets, information about testing and analysis activities, and data such as:

(@epagov) We're publishing data on BP oil spill in open formats, following open gov principles #opengov #gov20 http://epa.gov/bpspill/data

The variation in type of content posted by the different governmental spheres indicates the possibility that agencies have identified variation in goals and strategies for public facing communications online.

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 it 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, & 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 whose accounts have a high proportion 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 proportion of directed messages, with many of the messages focusing on their political activities. At the federal level, the TSA has a high proportion of directed messages in response to questions posed by individuals 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. Primarily, @GOHSEP posted direct messages to individuals, who posted inquiries or suggestions:

(@gohsep) @UBUIBIOK Great DM tweets of alternative tech ideas -- please call and share at: 281.366-5511 or http://bit.ly/aLZwCY

In addition, this account engaged others by publicly thanking them for retweeting @gohsep posts:

(@gohsep) Thanks for the RTs @ellepiari @IBRRC @BPOilNews @hcreel381 @sarahlee310 @webmiss007 @averydav @Catballou @dbro113 @surflightroy

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):

(@epagov) RT @lisapjackson: Just posted the latest air monitoring data from the Gulf. Continue to check www.epa.gov/bpspill for air and water updates

From this analysis, we find that there are 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.

We also consider how the behaviors described above compare with members of the general public. Part of the data collection from Butts et al. (2011), includes a random sample of users who post content containing keywords chosen at random from Ogden's English Word List. This set of users can be considered a comparison group of average behaviors on Twitter. We compare the proportion of tweets containing each of our microstructure elements between

these two populations, as seen in Figure 2. In this figure, we see that government accounts have a much higher proportion of posts containing external links. They have very low number of directed or retweeted messages, compared with general public users. These results reinforce the previous results, demonstrating that these organizations use Twitter primarily as a broadcasting mechanism to share information.

Following Network

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 affects the diffusion of information, we explore the structure of the following network among these accounts. In Figure 3 we show the observed following network among government accounts on Twitter. We note a dense lobe in the lower right portion of the network, indicating reciprocal relationships among these organizations (discussed next) and outliers with fewer connections on the edges of the network graph.

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 2. Comparison of presence of microstructure elements between government accounts and random sample of other users

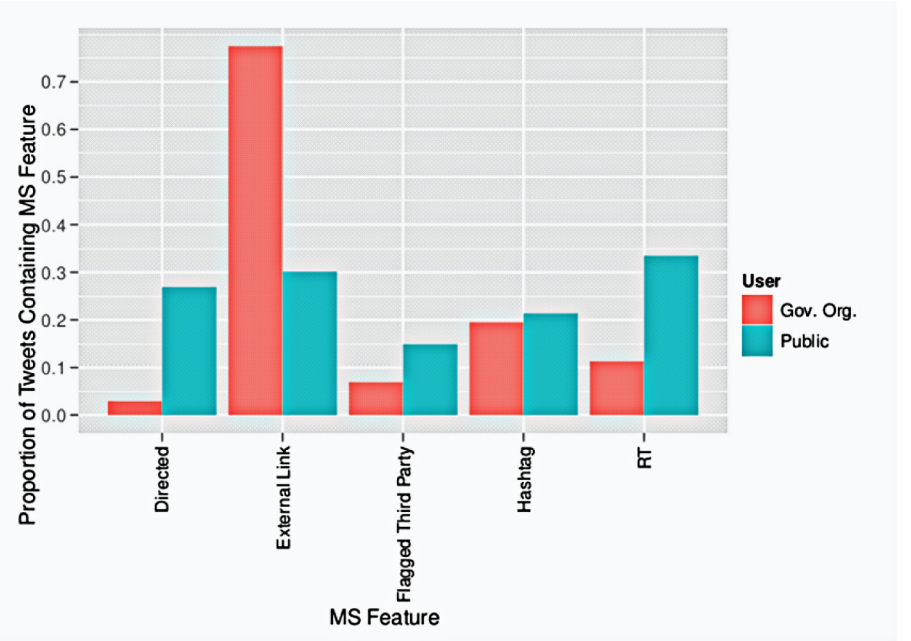
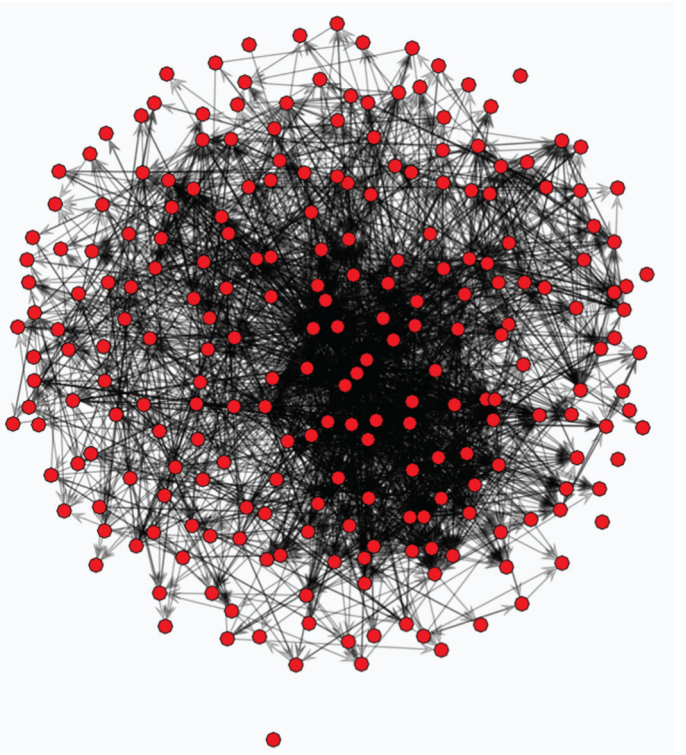


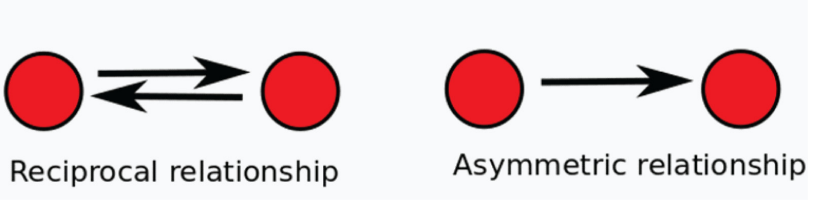
Figure 3. Directed following relationships among government organizations on Twitter



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). Reciprocal or mutual relationships are different from asymmetric relationships, as seen in Figure 4. 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.

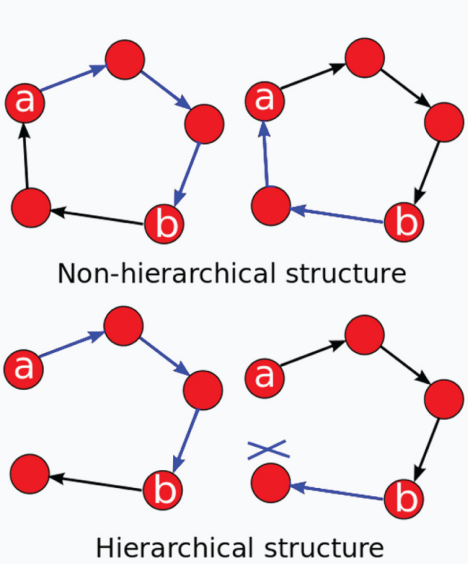
Figure 4. Example of reciprocal and asymmetric relationships



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 relationships (i.e. more global pathways that require a series of exchanges). Reciprocity captures the tendency for directed relationships to be bi-directional. 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). For example, consider the two different structures illustrated in Figure 5. In the top structure node a can reach (perhaps to pass information or a message) node b through a directed path, shown in blue on the top left. Likewise, node b can reach node a through a directed path, shown in blue on the top right. In fact any node in this network can reach any other through a directed path. Therefore the structure has zero global, Krackhardt hierarchy. In the network illustrated in the bottom two panels we have removed one relationship. The result is that node b can no longer reach node a through a directed path. This illustrates a globally, hierarchical structure. Note that reciprocity and hierarchy are two different notions. Though the top panel in Figure 5 has no global hierarchy each of the relationships shown are asymmetric, not reciprocal.

We compute the Krackhardt hierarchy for the following networks among government organizations on Twitter. The observed 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) given a conditional uniform graph test conditioned on size and density. 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.

Figure 5. Example of global hierarchy. In the top, a can pass information to b through the blue path. Likewise, b can pass information to a through the blue path. In the bottom, b can no longer reach a through a directed path.



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

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 6 and 7 (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 & 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. They 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 controlling 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. In Figure 8, we show the most highly connected individuals, those in this dense central core. 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.

Figure 7. Distribution of friends for government organizations (log scale)

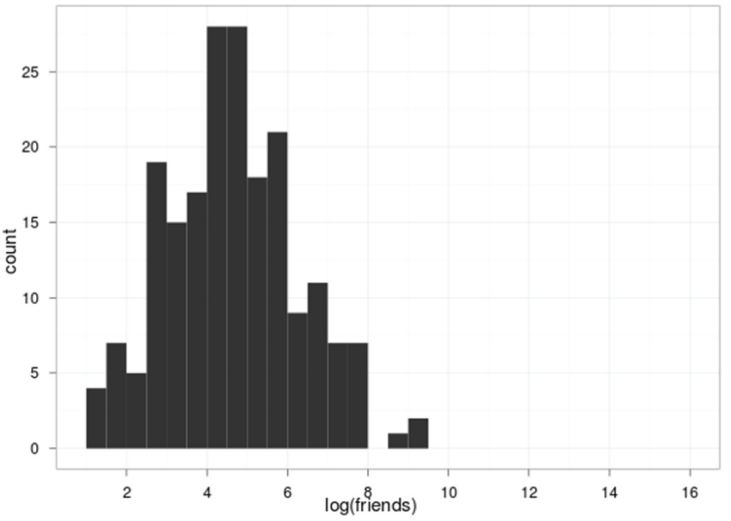
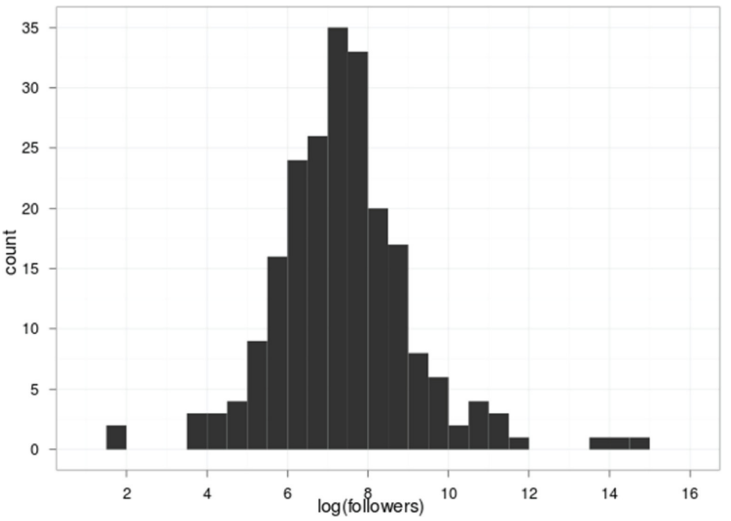
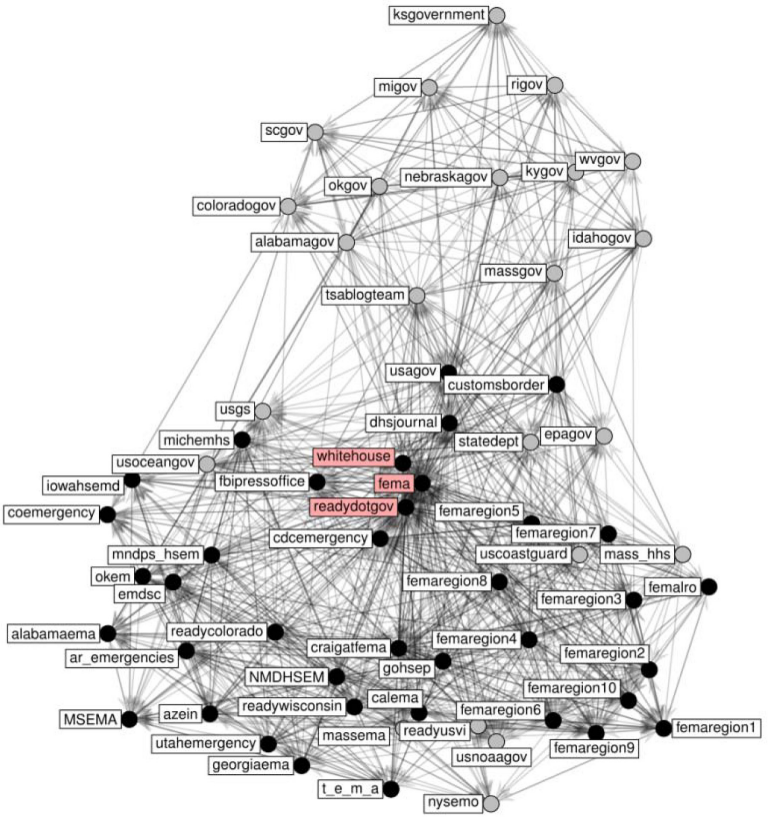


Figure 6. Distribution of followers for government organizations (log scale)



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, & 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 environ-

Figure 8. Core of the Twitter following network among government organizations



mental organizations and elected officials. In general, 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

Governmental organizations are adopting Twitter as an additional channel to communicate with other organizations and members of the public during both routine times and times of crisis. In this research we have investigated network structural properties and microstructure 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, health, public safety, and elected officials or political actors, show differing results in their network centrality measures, all three had greater numbers of directed conversations with individuals on average. The peripheral position of elected officials may be most interesting because these actors tend to also have the highest number of friends that they follow back in comparison with other accounts in our sample. So they may have a greater reach and ability to connect to a broader public through directed communications, suggesting that connecting with these accounts may lead to a wider audience to disseminate key messages.

Analysis of the relational microstructure of Twitter accounts revealed low numbers of directed tweets, and retweeted content on average. 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. The network aspects among organizations and conversational microstructures identified within tweet content leads to 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.

CONCLUSION

In crises and disasters, management of content and informational flow 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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ENDNOTES

1. 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/)
2. Our interest is in the network and microstructure 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.
3. 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.

Jeannette Sutton, PhD, is a Senior Research Scientist in the Trauma Health and Hazards Center at the University of Colorado Colorado Springs. She specializes in disaster sociology with a primary focus is on the evolving role of Information and Communication Technology, and online informal communications in disaster. Additional areas of research include the socio-behavioral aspects of disaster warning systems, outreach and service provision to vulnerable populations via online communications, and Volunteer Technical Communities in disaster. Sutton received her doctoral degree from University of Colorado, Boulder.

Emma Spiro is currently a doctoral candidate in the Department of Sociology at the University of California, Irvine. Her research is focused on communication dynamics in online environments during disaster response and recovery, social network analysis, and data collection methods from online sources. In addition to an MA in Mathematical Behavioral Sciences from UCI, Spiro holds a BA in Applied Mathematics and a BA in Science, Technology, and Society from Pomona College.

Carter T. Butts is Professor in the Departments of Sociology and Statistics and the Institute for Mathematical Behavioral Sciences at the University of California, Irvine, and director of the UCI Center for Networks and Relational Analysis. His research focuses on the development and application of mathematical, computational, and statistical techniques to address problems in a range of substantive areas, including social networks, social dynamics, and disasters. Professor Butts received his doctoral degree from Carnegie Mellon University, and his BS from Duke University.

Sean Fitzhugh is a PhD student in the Department of Sociology at the University of California, Irvine. His research focuses on issues related to network sampling and online data collection in addition to structural properties of organizations and organizational networks. He holds an MA in Mathematical Behavioral Sciences from UCI as well as BAs in both sociology and political science from the University of California, Berkeley.

Britta Johnson is currently working as a research associate at the Trauma, Health & Hazards and Psychology departments at the University of Colorado, Colorado Springs. She has a MA in International Disaster Psychology from the University of Denver, as well as BAs in Psychology and Communication Arts/Journalism from the University of Wisconsin – Madison. As part of the HEROIC project, Britta has been working on contributing her knowledge in emergency response and disaster psychology to assist in data collection and analysis, as well as systematically track organizations of interest following disasters.

Matt Greczek received his Bachelor's degree in Sociology from the University of Illinois at Chicago and is currently a Master's degree student at the University of Colorado Colorado Springs. His research interests include social networks as well as community and urban sociology.