2014

RUMORS ON SOCIAL MEDIA IN DISASTERS: EXTENDING TRANSMISSION TO RETRANSMISSION

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Abstract

In recent years, the widespread use of social media has facilitated the propagation of messages after disasters. Unfortunately, because the veracity of messages is often difficult to determine in a disaster situation, social media also facilitates the rapid diffusion of rumors. Current studies have examined why individuals post or transmit rumors on social media. However, investigating factors affecting the initial rumor transmission is just the first step for rumor control after disasters. After rumors have been transmitted, understanding what accounts for message retransmission in disasters is especially vital. To address this gap, we develop a model of rumor retransmission on social media during disasters based on rumor theory and the elaboration likelihood model. We also discuss the differences between our model and the model of rumor transmission. We believe that our model can contribute to research on social media use in disasters, and the practice of disaster management.

Keywords: Social media, Rumor, Message retransmission, Disaster, Crisis management

1 INTRODUCTION

A disaster (Seeger et al. 1998) is a serious disruption of the functioning of a community or a society (National Science and Technology Council, 2005). Examples include climatic disasters, ecological disasters, and man-made disasters (Ping et al. 2011). Recent studies stress the need for better theory to explain how citizens communicate in disasters (Ping et al. 2011; Sellnow & Seeger 2013). Nowadays, people are increasingly turning to social media in such contexts (Bates & Callison 2008; Sweetser & Metzgar 2007). While social media can be (and is) used to provide up-to-date and locally-relevant information (Shirky 2011), it also has a dark side. It can be (and is) used to diffuse rumors that can destabilize situations and cause harm (Mintz 2002, Zhou and Zhang 2007).

The spreading of rumors, also known as rumor mongering, has long been examined by psychologists and sociologists (Allport & Postman 1947; Rosnow 1991). One well-known model is that rumors spread via three stages: parturition (the rumor's genesis), diffusion (the rumor's retransmission), and control (the rumor's decline) (Rosnow 1974). Oh et al. (2013) recently introduced a model that identifies several "rumor causing" (p. 407) factors on Twitter in social crises (the first stage of rumor spreading), but few studies provide insights on the second and third stages. The little research that exists tends to focus on the effects of network structures (e.g., Lai & Wong 2002; Zhao et al. 2011; Borge-Holthoefer & Moreno 2012). Research on other factors affecting online rumor retransmission remains descriptive and preliminary (e.g., Ma 2008; Garrett 2011; Liao & Shi 2013). Little progress has been made on this topic in offline contexts either because it is often hard to empirically differentiate the three stages in offline settings, e.g., distinguishing the original transmission from retransmission (Kapferer 1992). It is more feasible to study it online because online systems often provide distinct features to transmit and retransmit messages (e.g., tweet and retweet). Online systems are also an important context for studying rumor retransmission because they make it so easy (Frost 2000). As a result, the aim of this paper is to contribute to rumor research in general, and the practice of disaster management in particular, by generating new insights regarding the second stage of rumor spreading—retransmission. We will also show that the factors driving message transmission and retransmission are not the same. In particular, we address the following questions:

1. what factors contribute towards rumor retransmission on social media in disasters?
2. how do the factors that contribute towards rumor transmission and retransmission differ?

Like Oh et al. (2013), we take a cue-oriented perspective (Dennis & Kinney 1998, Carlson et al. 2004), focusing on message cues conveyed on social media. Oh et al. (2013) identify cues in a message that signal it to be a rumor. In this paper, we model how these cues influence rumor retransmission within online social media. By doing so, our work offers a more complete understanding of how rumors spread on social media than available in past work.

The paper is organized as follows. The next section defines the context and scope of our work. We then introduce two theories that we draw on in our model development: the theory of rumor transmission, and the Elaboration Likelihood Model (ELM). Subsequently, we propose a model of rumor retransmission. We then use Twitter data to re-validate Oh et al.'s model of transmission and test our proposed model of retransmission. We then discuss key findings and differences between two models. We end by discussing the paper's implications for theory, practice, and future research.

2 RESEARCH CONTEXT AND SCOPE

2.1 Disasters and Rumors

Even though rumors can spread in many contexts, they are particularly prevalent and consequential in disasters. An important feature of disasters is that it often takes time to confirm the disaster's causes and consequences. This provides a fertile ground for rumors because individuals do not receive the facts they desire (Comfort et al. 2004; Zook et al. 2010) and so they tend to fill in the blanks (Stephens & Malone 2009), improvise news (Shibutani 1966), and spread the rumors they hear (Belgion 1939). Due to the speed of message retransmission on social media (Kwak et al. 2010), the

diffusion of rumors, especially false rumors, can be particularly devastating in disaster situations (Tierney et al. 2006).

2.2 Defining Rumor

Rumor is typically defined in one of two ways. One can define rumor as "*distorted, exaggerated, irrational and inauthentic information*" (Miller 1992), which is a commonly-held view in practice (Fine et al. 2005; Donovan 2007). However, in academic research, rumor is typically defined as an unverified or unconfirmed message. For instance, Buckner (1965) define rumor as an "*unconfirmed message passed from one person to another that refers to an object, person, or situation*", and Rosnow and Fine (1976) define rumor as "*a proposition that is unverified and in general circulation*". In this paper, we adopt the typical academic definition of rumor in which rumor is agnostic as to accuracy. We define *rumor* as a message that is currently unsubstantiated by a message receiver. This can include rumors later verified to be true and rumors later proven to be false (Kapferer 1990)

2.3 Rumor Transmission vs. Retransmission

The key distinction between transmission and retransmission in a social network is novelty: transmission involves posting information that is *new* to the network. In some cases, a transmitter might generate the information him/herself (e.g., when witnessing a disaster or when making information up) and post it on social media, while in other cases a transmitter might bring the information to the online social network from some other source (e.g., from an external news service). In the second case, the content posted by the message sender is still new to social media, so the senders' behavior is still considered message transmission on social media. Retransmission, in contrast, involves resending information that is already on the network. Assuming that person B read a message sent by person A, then, if person B passes it on to person C we say that person B has "retransmitted" it. Oh et al.'s (2013) recent model of rumor transmission captures the behavior of person A (the original rumor sender on social media), while in this paper we propose a model of retransmission that captures factors affecting the behavior of person B (the rumor re-transmitter).

The retransmission of messages on social media is a simple yet powerful mechanism for message diffusion (Kwak et al. 2010; Stieglitz & Dang-Xuan 2012). There have been a few studies of rumor retransmission online but they have tended to use formal analytical models, such as models of disease propagation, to understand effects of social network structures on rumor diffusion (e.g., Lai & Wong 2002; Zhao et al. 2011; Borge-Holthoefer & Moreno 2012). While such research is important, there has been little work focusing on the content or cues of the message. By doing so, we seek to extend past research on retransmission and complement Oh et al.'s (2013) recent work on transmission.

To lend greater specificity to our analysis, we draw on past work (Stephen et al. 2010) to identify three steps in rumor retransmission. First, rumor receivers are exposed to a rumor posted online. Second, rumor receivers are at least partially persuaded by the rumor they receive, i.e., they adopt it. Third, rumor receivers determine whether to pass it on to others on that network (see Table 1).

Three steps	Examples
Step 1: Exposure	Login to social media and read the content in a rumor.
Step 2: Adoption	Feel at least partially persuaded by the received rumor.
Step 3: Retransmission	Retransmit the rumor by clicking the "forward" button.

Table 1. Steps of rumor retransmission

3 THEORETICAL BACKGROUND

Our first theoretical foundation is the theory of rumor transmission, which has been widely used to explain rumor mongering in general. It allows us to understand characteristics (or cues) of messages containing rumor that individuals are likely to transmit (Oh et al. 2013). We then focus on what leads an individual who receives a rumor to be persuaded to a sufficient extent to retransmit it. That is,

we focus on the way in which Step 2 in Table 1 provides a link between Step 1 and Step 3. To explain this step, we draw on our second theoretical foundation, the Elaboration Likelihood Model (ELM).

3.1 Theory of Rumor Transmission

In early research on rumors, ambiguity and importance were considered to be the main drivers of rumor transmission (Allport & Postman 1947). Anthony (1973) added anxiety as another important driver. Drawing on such works, Oh et al. (2013) introduced a model to explain rumor mongering on Twitter during a social crisis (shown in Figure 1). Their implicit focus was factors explaining why rumors are generated on Twitter (rumor transmission) in that they particularly identify and explain cues in a Twitter message that signal it to be a rumor. These cues also reflect feelings and behaviors of rumor senders.

Oh et al. (2013)'s model includes five antecedents. *Anxiety* reflects the negative emotional state of a rumor sender. *Source ambiguity* reflects whether a rumor sender understands the origin of a message and its trustworthiness. It is a relevant driver for messages brought into a network from outside sources (e.g., agencies or news services). *Content ambiguity* reflects the interpretability and clarity of the message itself. *Personal involvement* represents the importance of a rumor to the sender. Finally, to measure social pressures from other members on a rumor sender, Oh et al. added a new variable, *directed message*, arguing that directed messages were more likely to be rumors. A directed message on Twitter is a message sent to a specific Twitter user by attaching "@" in front of the recipient's Twitter ID. Clearly, a directed message is just a proxy for social influence; it is not necessarily an ideal operationalization. The results in Oh et al.'s paper suggested that anxiety, source ambiguity and personal involvement ($H_{Oh}1$, $H_{Oh}2a$, and $H_{Oh}3$) significantly lead to rumor transmission, while effects of content ambiguity and directed message ($H_{Oh}2b$ and $H_{Oh}4$) received no support.

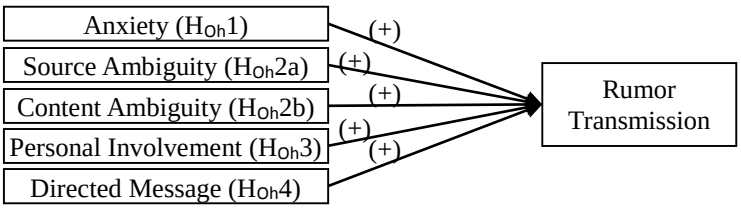

Figure 1. Oh et al. (2013)'s model of rumor transmission[1]

Oh et al. (2013) explained the first stage of rumor spreading—rumor parturition on social media. In this paper, we extend Oh et al.'s work by explaining the second stage of rumor spreading—rumor diffusion or retransmission within social media. In particular, we identify cues in a rumor that make it more likely to be retweeted on Twitter after a disaster.

3.2 Elaboration Likelihood Model

The Elaboration Likelihood Model (ELM) is a theory of persuasion. It proposes that recipients of a message will process the message via either a central route or a peripheral route. Under the central route, individuals think carefully about issue-relevant arguments and the quality of the message content (Petty & Cacioppo 1986). Under the peripheral route, individuals engage in little scrutiny of message content, and focus on peripheral cues such as source credibility (Pornpitakpan 2004).

ELM is a useful theory for studying rumors in disasters because central and peripheral cues are both important in this context. Central cues are important because there is a high demand for verified information in such contexts (Sellnow & Seeger 2013) and because rumors are more likely to be adopted if they seem truthful (Goode & Ben-Yehuda, 1994). Peripheral cues are also important because there is typically a lack of verified information in disasters and people look to peripheral cues when facts are hard to verify (Petty et al. 1976, Petty & Cacioppo 1986).

[1] To differentiate the hypotheses between the proposed model of rumor retransmission and Oh et al.'s model of rumor transmission, we use H_{Oh} to represent the hypotheses in Oh et al.'s model.

3.3 Summary

Overall, the aim of this paper is to develop a model of rumor retransmission on social media in disasters and to clarify how the factors driving transmission and retransmission differ. In our view, the theory of rumor transmission should help in studying both behaviors while ELM should be particularly helpful for studying rumor retransmission because it can help us understand the extent to which recipients adopt a message before retransmitting it (i.e., Step 2 in Table 1).

4 A MODEL OF RUMOR RETRANSMISSION

Figure 2 shows our proposed model. We developed the model in light of the three steps of retransmission outlined earlier (Table 1). The first step is exposure to a message. Accordingly, we focus our model on the cues in messages that recipients are exposed to (Dennis & Kinney 1998, Carlson et al. 2004). We then link these cues to recipients' likelihood of retransmitting the message.

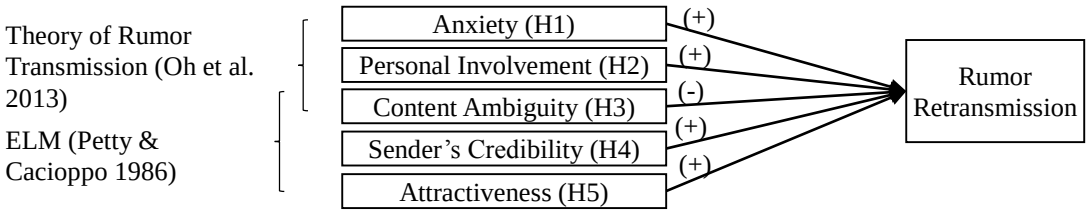

Figure 2. The research model of rumor retransmission

The second step of retransmission is adoption. Drawing on ELM, we expect that rumor receivers will need to refer largely to peripheral cues because it is hard to verify messages in such uncertain situations (Petty & Cacioppo 1986). Source credibility (Pornpitakpan 2004) and attractiveness (Cole et al. 1990; Shavitt et al. 1994) are typical cues in the peripheral route in ELM that are included in our model. In the context of retransmission, the relevant source is the rumor transmitter (sender).

The central and peripheral routes in ELM are ideal types; in reality, elaboration involves a complex mixture of both routes (Sussman & Siegal 2003). Thus, although we expect that rumor re-transmitters will refer more to the peripheral route to evaluate a received rumor, they are still likely to use the central cue in part. In this light, it is notable that content ambiguity is a key variable in the theory of rumor transmission. Since content ambiguity indicates low argument quality, it would therefore seem to play an important role in recipients' processing along the central route.

The third step is rumor retransmission. For this step, we can look to factors other than adoption that can affect retransmission. The theory of rumor transmission can help us find these variables. In particular, Oh et al. considered five antecedents: source ambiguity, content ambiguity, personal involvement, anxiety, and directed message. Some of these variables may not be relevant in our context because our model explains the behavior of the re-transmitter while their model explains the behavior of the original message sender. Specifically, source ambiguity can be excluded from our model because it measures whether the original rumor sender knows *external* sources of a rumor (e.g., an external website) whereas our model focuses on retransmission of messages within a network. Directed message can also be excluded because it measures the social pressure on the original message sender instead of the re-transmitter. Nonetheless, we propose that anxiety and personal involvement should both be included in our model. In Oh et al.'s model, these factors reflect feelings of the rumor sender. Past research shows that the emotions expressed by a message sender (e.g., expressions of anxiety and personal involvement in a message) can be perceived by a message receiver (Byron 2008). Thus, in our model, we regard anxiety and personal involvement expressed in a rumor as emotional cues affecting the behavior of rumor re-transmitter. In the following sections, we go through each of the cues and explain their associations with rumor retransmission.

4.1 Anxiety

Disasters create anxiety because situations are ambiguous and people lack explanations (Anthony 1973; Norris and Murrell 1988). According to Oh et al. (2013)'s model, a rumor posted on social media is likely to have some expressions of anxiety. The anxious expressions in a rumor indicate the rumor sender's negative emotional state. Since we focus on effects of cues in a rumor on rumor retransmission, we check whether a rumor transmitted on social media suggests a feeling of anxiety (anxious cue). Anxious expressions are arousal-inducing contents, which can be perceived by rumor receivers (Byron 2008) and are likely to evoke anxiety among rumor receivers (Berger 2011).

As rumor receivers need to vent and express their stressful or fearful mood regarding anticipated outcomes after disasters (Allport & Postman 1947; Festinger 1957), they retransmit rumors (Adams & Bristow 1979; Kimmel & Keefer 1991). By retransmitting a rumor, people give an outlet for expression to fears and hostilities, which can help sooth their tensions (Rosnow 1988). Thus, we predict anxious expressions in a rumor will affect rumor receivers' feelings and subsequently affect their rumor retransmission behavior.

H1: The anxious expression in a received rumor is positively associated with rumor retransmission on social media in disasters.

4.2 Personal Involvement

Importance has long been viewed as the basic law of rumor (Allport & Postman 1947), and is defined as a synthesis of the relevance of a situation. Rosnow (1991) use outcome-relevant involvement to represent importance, as this concept emphasizes the caring and involvement evoked by a rumor (Allport & Postman 1947). Accepting Rosnow (1991)'s argument, Oh et al. (2013) used the variable *personal involvement* to represent a rumor's importance, and they found that rumors posted on social media were more likely to have expressions of personal involvement.

Drawing on this work, and much like our arguments for anxiety, we check whether a rumor posted on social media indicates a feeling of involvement (the cue of personal involvement). As a rumor sender's feeling of involvement can be perceived by a rumor receiver (Byron 2008), we argue that expressions of personal involvement in a rumor can evoke rumor receivers' feeling of involvement. Rumor receivers' feeling of personal involvement can lead to rumor retransmission because individuals are not likely to spread rumors that are irrelevant or unimportant (Goode & Ben-Yehuda 1994). In summary, we predict that expressions of personal involvement in a rumor will influence rumor receivers' feelings, and subsequently affect their rumor retransmission behavior.

H2: The expression of personal involvements in a received rumor is positively associated with rumor retransmission on social media in disasters.

4.3 Content Ambiguity

According to the ELM, individuals can use both central and peripheral cues to process received messages. The argument quality of a message serves as the central cue influencing the adoption of a received message (Petty & Cacioppo 1986). Strong arguments should be understandable, objective, and supported with relevant facts (Lee 2009). Rumors that contain ambiguous content fail to meet these criteria because they lack sufficient interpretative clarity (Oh et al. 2013). In short, ambiguity results in weak arguments. Content ambiguity can therefore serve as a rejection cue in the central route, negatively influencing adoption. As adoption is a key step in rumor retransmission, a rumor with high content ambiguity is less likely to be adopted and thus it is less likely to be retransmitted too.

H3: The content ambiguity of a received rumor is negatively associated with rumor retransmission on social media in disasters.

4.4 Sender's Credibility

Source credibility is a peripheral cue in ELM and refers to the extent to which sources of information are perceived to be competent, trustworthy, and reputable (Bhattacherjee and Sanford 2006; Pornpitakpan 2004). Briefly, it means whether the source is qualified to provide a message (Perloff 1993). According to ELM, individuals often use cues pertaining to the message's source to evaluate a message, when they are unable or unwilling to expend the effort to elaborate on the message content (Petty and Cacioppo 1986). This should be especially true for rumor retransmission in a disaster in which the veracity of received message cannot be pinned down.

For the rumor re-transmitter on social media, the source is the original rumor sender, and thus we use sender's credibility to theorize source credibility in our paper. After a disaster occurs, people often base their judgments of credibility of a rumor on senders' credibility rather than the content itself, since perceptions of senders' credibility can support inferences about the probable validity and reliability of the rumor (Chaiken and Maheswaran 1994). It has been observed that social media users have more confidence in content from established and reputable senders even before reading them (Zhao and Rosson 2009). Hence, we predict that a rumor from credible sender is more likely be adopted and also are more likely to be retransmitted.

H4: The sender's credibility of a received rumor is positively associated with rumor retransmission on social media in disasters.

4.5 Attractiveness

Attractiveness is also a peripheral cue in ELM. Attractiveness is the affective base of receiver's image (Simons et al., 1970), specifically, whether the use of visual aids stimulates interest and increases attention (Sutcliffe, 2002). Attractive rumors with external media, such as image or video, can not only arouse the interest and attention of rumor receivers, but also convey more meaning and emotions than a rumor with only plain text. The extra meaning and emotion contained in external pictures or videos tend to be regarded as providing greater expertise and knowledge (Allen et al., 2004) and therefore make a rumor more persuasive and more likely to be retransmitted.

H5: The attractiveness of a received rumor is positively associated with rumor retransmission on social media in disasters.

5 RESEARCH METHODOLOGY

We used the Twitter dataset of the 2013 Oklahoma tornado to test our model. Before testing our model, we also retest the model of rumor transmission (Oh et al. 2013) to provide confidence in the validity of their model and our coding scheme.

5.1 Description of the Event

On the afternoon of May 20, 2013, an EF5 tornado struck Moore, Oklahoma, and adjacent areas in U.S. with peak winds estimated at 210 miles per hour (340 km/h), killing 23 people and injuring 377 others. On May 31, 2013, another tornado struck Moore, Oklahoma again. The second tornado was initially rated as EF3, but the emergency agency upgraded the ranking to EF5, as the second storm had winds of 295 miles per hour. The second storm and subsequent flooding killed 19 people, including 3 storm chasers. After each tornado, millions of users sent messages of support, advice, and condolences on Twitter. However, in the chaotic hours after the tornado, rumors also spread (Federal Emergency Management Agency (FEMA), 2013). For example, one rumor on Twitter said "*Did you know that over 8000 homes were destroyed or severely damaged in #Joplin MO as a result of the May 22nd #Tornado?*" but FEMA later corrected the rumor by confirming that there were approximately 1200 destroyed homes, much less than 8000.

5.2 Data Collection

Using the Twitter Search API, we obtained publicly available tweets containing the search term "Oklahoma tornado". The data collection started right after the first tornado plowed through Oklahoma. From 20 May to 14 June, search activity for the Oklahoma tornado resulted in 476,040 English tweets and 299,174 unique tweet authors. Figure 3 shows the number of tweets posted on each day from 20 May to 14 June, 2013. Accordingly, the number of tweets peaked around 21 May. Nearly half of the tweets in the dataset were collected around 21 May, which is consistent with previous finding (Oh et al. 2010); that is, 50% of total tweets were very rapidly posted during the initial stages after a disaster, and the remaining 50% of tweets were generated over later stages. The number of tweets also increased dramatically on 31 May and 1 June, since on 31 May another tornado came. After 1 June, the number of tweets sent on each day gradually went down again.

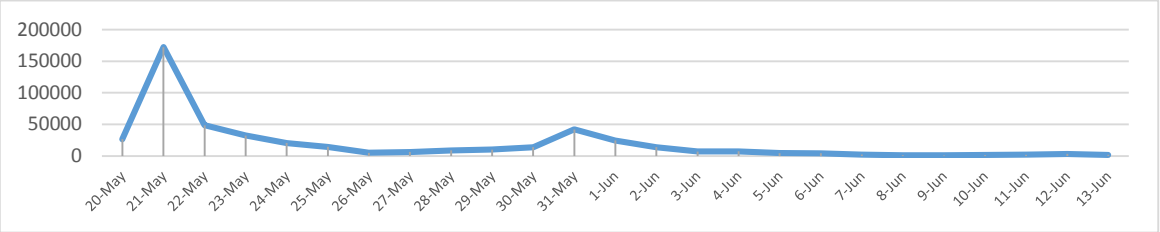

Figure 3. The number of tweets posted each day

As the dataset is huge, we randomly selected 5,069 Twitter messages out of the Twitter messages collected around 20 May and 21 May (right after the first major tornado), and the tweets collected around 30 May and 1 June (before and right after the second tornado), in order to make our sample manageable. We focused primarily on periods after the tornadoes because that is when rumor are most likely to spread, ensuring that we get enough rumors in our sample (Stephens & Malone, 2009).

5.3 Coding Scheme

Bordia and DiFonzo (2004) suggest that a paragraph or sentence should be should be dissected into a unit of "one complete thought" before coding. As our sample are all Twitter messages, which have a maximum of 140 characters, each tweet can be viewed as "one complete thought" (Oh et al. 2013). Rumors were identified based on Oh et al. (2013)'s coding scheme. In total, 1538 rumors were identified in our sample. Because we test two models (Oh et al.'s and ours), we need to code each Twitter message for the independent variables in each model. Following Oh et al., we treated each independent variable as an observable, dichotomic property—i.e., we measured whether a given message had or failed to have some characteristic.

Oh et al.'s (2013) model of rumor transmission contains five independent variables (anxiety, personal involvement, source ambiguity, content ambiguity, and directed message) and we coded them using Oh et al.'s coding scheme. Our model also contains five independent variables. Three of them (anxiety, personal involvement, and content ambiguity) were drawn from Oh et al. (2013) and were coded based on their scheme. The other two (attractiveness and sender's credibility) were coded separately. Attractiveness relates to the visual aspect of a message (Silverstein et al. 1986; Sutcliffe 2002) and so we coded Twitter messages that contained external media, such as a video or picture, as attractive. Sender's credibility means whether the sender is qualified to send a message (Perloff 1993). Popular news media, local news media, local services, and local governments are regarded as more credible (Johnson & Kaye 2004) and qualified to send messages regarding to a disaster. Thus, messages posted by the Twitter accounts of the above organizations were coded as sent by credible senders. The full coding scheme can be found in Appendix 1.

5.4 Analysis Method

As noted earlier, we report two tests in this paper: a pre-test (of Oh et al's model) and the main test (of our model). We first examined Oh et al. (2013)'s model of rumor transmission. If our re-analysis of

their model results in similar results to theirs, it would provide additional confidence in both their model and our coding, thereby allowing us to subsequently compare our model of retransmission and their model of transmission without worrying about the validity of the model or the coding.

We employed logistic regression due to the dichotomous nature of the dependent variables (Orme & Combs-Orme 2009). Specifically, we run binary logistic regression, which is used to model relationships between a dichotomous dependent variable and multiple independent variables. In this test, rumors were coded as "1", and all of other messages are all coded as "0". Such a coding scheme concerns whether or not a social media user post a rumor on Twitter. By running binary logistic regression, rumors were compared to all other messages. As all of messages in our sample were included in pre-test, the sample size is 5069.

As in our model, Oh et al.'s model concentrates on message cues. For example, Oh et al.'s model suggests that a message sender who feels anxious is more likely to transmit a rumor, while empirically the model also suggests that a message expressing a feeling of anxiety is more likely to be a rumor. Thus, in the model used in pre-test below, *Prob (Rumor)* is the probability of rumors conditional on the independent variables, which is restricted to the [0, 1] interval:

Model for the pre-test: $Prob\ (Rumor) \approx \beta_0 + \beta_1 Anxiety + \beta_2 Source\ Ambiguity + \beta_3 Content\ Ambiguity + \beta_4 Personal\ Involvement + \beta_5 Directed\ Message + e$

In the main test, we run a binary logistic regression to investigate factors driving rumor retransmission on Twitter. In this test, dependent variables are also dichotomous. Rumors that had been retweeted on Twitter were coded as "1", and other rumors that had not been retweeted were coded as "0". Such a scheme concerns whether or not a rumor is retweeted. By running binary logistic regression, retweeted rumors were compared to other rumors that had not been retweeted. Since only Twitter messages coded as rumors were included in this test, the sample size of the main test is 1538. The model tested in the main test is as follows, *Prob (Retweeted Rumor)* is the probability that a rumor is retweeted conditional on the independent variables, which is also restricted to the [0, 1] interval:

Model for the main test: $Prob\ (Retweeted\ Rumor) \approx \beta_0 + \beta_1 Anxiety + \beta_2 Personal\ Involvement + \beta_3 Content\ Ambiguity + \beta_4 Sender's\ Credibility + \beta_5 Attractiveness + e$

The two models above have three common variables: anxiety, personal involvement, and content ambiguity. By comparing the results of the above two tests in terms of the three common variables, we can examine whether cues associated with rumors can also lead to rumor retransmission.

6 RESULTS

In the following sections, we show the results of the above two tests.

6.1 Results of Pre-test

Using binary logistic regression, we re-estimated Oh et al. (2013)'s model, i.e., the probability of rumor transmission for the five independent variables. The Spearman rank correlation matrix (Table 2) shows that all of the correlations are less than 0.7, indicating that no significant multicollinearity problems exists (Dormann et al. 2012). In other words, no redundant variables need to be deleted.

	Rumor	Anxiety	Source Ambiguity	Content Ambiguity	Personal Involvement
Anxiety	.214				
Source Ambiguity	.569	.192			
Content Ambiguity	-.018	.005	.077		
Personal Involvement	.222	.082	.196	-.005	
Direct Message	-.148	-.035	-.057	-.001	-.048

Table 2. Correlation matrix of pre-test

The regression analysis indicates a good model fit, as $\chi^2(5) = 2008.85$ ($p < .001$). This means that the model including the independent variable fits the data statistically significantly better than the model with just the constant. Results of the binary regression analysis are presented in Table 3.

	B	Std. Error	Sig.	Exp(B)	**Hypothesis**	Consistent with Oh et al.?
Intercept	-2.536	.079	.000			
Anxiety	.737	.101	.000	2.090	**H_{Oh}1 Supported**	Yes
Source Ambiguity	2.907	.089	.000	18.296	**H_{Oh}2a Supported**	Yes
Content Ambiguity	-1.016	.233	.000	.362	**H_{Oh}2b Rejected**	Yes
Personal Involvement	1.239	.177	.000	3.453	**H_{Oh}3 Supported**	Yes
Direct Message	-.886	.095	.000	.412	**H_{Oh}4 Rejected**	Yes

Table 3. Results of pre-test of the model of rumor transmission

Table 3 indicates three supported hypotheses ($H_{Oh}1$, $H_{Oh}2a$, and $H_{Oh}3$), but effects of content ambiguity ($H_{Oh}2b$) and directed message ($H_{Oh}4$) upon rumor were not supported, which is consistent with Oh et al. (2013)'s results. Moreover, as in Oh et al. (2013)'s results, a comparison of the coefficient values indicates that source ambiguity is the most important, personal involvement is the next important, and anxiety is the least yet marginally important factor influencing rumor transmission. As our results are consistent with Oh et al. (2013)'s results of rumor transmission, we can now extend Oh et al. (2013)'s work by examining rumor retransmission.

6.2 Results of Main Test

The Spearman rank correlation test (Table 4) of the main test shows that all of the correlations are less than 0.7, indicating that no significant multicollinearity problems exist (Dormann et al. 2012).

	Retweeted Rumor	Anxiety	Personal Involvement	Content Ambiguity	Attractiveness
Anxiety	-.055				
Personal Involvement	-.114	.019			
Content Ambiguity	-.092	-.034	.019		
Attractiveness	.094	.033	-.101	.007	
Sender's Credibility	.166	-.071	-.059	-.031	.033

Table 4. Correlation matrix of main test

Using binary logistic regression analysis, we estimated our research model, i.e., the probability of rumor retransmission for the five independent variables. The results indicate a good model fit, as $\chi^2(5) = 101.501$ ($p < .001$). Results of this binary regression analysis are presented in Table 5.

	B	Std. Error	Sig.	Exp(B)	**Hypothesis**
Intercept	.458	.069	.000		
Anxiety	-.226	.120	.059	.797	**H1 Rejected (opposite)**
Personal Involvement	-.588	.162	.000	.556	**H2 Rejected (opposite)**
Content Ambiguity	-1.318	.404	.001	.268	**H3 Supported**
Attractiveness	.596	.184	.001	1.815	**H4 Supported**
Sender's Credibility	3.708	1.010	.000	40.762	**H5 Supported**

Table 5. Results of the main test of rumor retransmission

According to Table 5, hypotheses related to content ambiguity (H3), attractiveness (H4), and source credibility (H5) are supported. Specifically, a rumor has pictures or videos, or whose sender is credible is more likely to be retweeted, while a rumor whose content is ambiguous is less likely to be retransmitted. Different from the hypotheses, the Twitter message with expressions of personal involvement is significantly less likely to be retransmitted (H2). Similarly, the relationship between anxiety and rumor retransmission is also negative rather than positive (H1).

7 DISCUSSIONS

7.1 Key Findings

Our results provide support for three of our hypotheses. A comparison of the coefficients indicates that sender's credibility is the most important predictor, attractiveness is the next most important. Content ambiguity is the rejection factor, which can prevent the retransmission of rumors. Since the above three supported variables are either peripheral (sender's credibility and attractiveness) or central cue (content ambiguity) of ELM, and ELM is a theory explaining the adoption or the persuasion of a received message, our empirical results also demonstrate the importance of the second step in rumor retransmission - the adoption or the persuasion success of a rumor.

In contrast to our predictions, the links from expressions of anxiety and personal involvement to rumor retransmission were both negative rather than positive. In this light, it is notable that anxiety and personal involvement are both negatively correlated with sender's credibility (see Table 4). This suggests that rumors from credible senders are more neutral with fewer expressions of subjective feelings. As sender's credibility is the most important determinant of rumor retransmission, the emotional expressions (both anxious expressions and expressions of involvement) in a rumor are negatively related to rumor retransmission.

7.2 Differences between the Models of Rumor Retransmission and Transmission

By comparing results for the three common variables in the two models (anxiety, personal involvement, and content ambiguity), we found that their effects differ between rumor transmission and rumor retransmission. Although results for the model of rumor transmission suggest that messages containing anxious expressions or feelings of involvement tend to be rumors, results for the model of rumor retransmission indicate that these rumors are significantly less likely to be retransmitted. That means that although anxiety and personal involvement can affect rumor transmission, these emotions from rumor transmitters may not affect feelings of rumor receivers. On the other hand, our results suggest that content ambiguity is an important rejection cue of rumor retransmission, but is not a determinant of rumor transmission. That means whether message senders feel distrust about message content may be irrelevant to whether they want to post a rumor; but once they express ambiguity or distrust, their message are less likely to be retransmitted on social media.

7.3 Contributions to Research

Our study primarily contributes to research by developing a model explaining factors driving rumor retransmission on social media in disasters. Prior research on rumor retransmission mostly focuses on effects of social network structures, while this study extends previous rumor retransmission literature by showing the importance of message cues. This paper also complements the recent work on rumor transmission by Oh et al. (2013). Oh et al. (2013) explain factors leading to rumor transmission on social media after social crisis. This paper takes research one step further by examining factors affecting rumor dissemination after rumors have been posted on social media. Our model is the first to explain how message cues affecting rumor retransmission within social media after disasters. Our empirical tests demonstrate that different factors lead to rumor transmission and retransmission on social media, so it is necessary to discuss transmission and retransmission separately. By extending rumor transmission to rumor retransmission, our study suggests a new and more complete way for future research to study the spreading of rumors online.

This paper also contributes to both the theory of rumor transmission and ELM. On one hand, we extend the theory of rumor transmission to the theory of rumor retransmission by incorporating peripheral cues (attractiveness and sender's credibility) drawn from ELM. On the other hand, our paper also extends ELM by demonstrating that content ambiguity can serve as a rejection cue in the central route of ELM. The theory of rumor transmission and ELM are both well-established but they have not been studied together extensively in the past. Our study demonstrates their complementary nature. Specifically, our model explains how the central and peripheral cues in ELM can work with

cues suggested in the theory of rumor transmission to influence the retransmission of rumors on social media.

7.4 Implications to Practice

Our results indicate that rumors that are attractive or sent by credible senders are likely to be retransmitted, while rumors whose content is ambiguous are less likely to be retransmitted. This is reminiscent of the finding in earlier research that false rumors tend to be dead-ended (not retransmitted) (Goode & Ben-Yehuda, 1994). This is a useful finding for disaster managers because it sheds light on possible mechanisms for controlling rumor, particularly false rumors. Specifically, our model suggests that although messages containing anxious expressions or feelings of involvement tend to be rumors, these rumors are less likely to be retransmitted. That is, rumors with expressions of anxiety and involvement are less harmful, and disaster managers can pay less attention on these messages and focus instead on controlling other rumors. Disaster managers should pay special attention to rumors that are attractive (with pictures and videos) or that appear to be sent by credible sender, since these look more like a true message and are more likely to be propagated on social media in a disaster. Thus, these are the subset of rumors that disaster managers need to be most concerned with.

8 CONCLUSION & FUTURE WORK

Drawing on the theory of rumor transmission and ELM, we developed and empirically tested a model of rumor retransmission on social media use in disasters. Our study provides a more complete view on rumor spread on social media in disasters by extending the model of rumor transmission to rumor retransmission and showing that the two behaviors have different antecedents.

To enhance the generalizability of our study, different disasters should be analyzed (including natural, ecological and man-made disasters). It would also be useful to replicate our tests in other social media. Future work could also include lab experiments to manipulated cues in a rumor to supplement the current Twitter data analysis. Moreover, in this paper, we only examine effects of cues in a rumor on rumor retransmission behavior. In the future, richer measurement scales could be developed to measure perceptions of rumor receivers, and a scenario-based survey could be conducted to examine how cues in a rumor influence rumor receivers' perceptions and how their perceptions affect their retransmission behavior. In addition, as Oh et al. (2013) explained factors driving the first stage of rumor spread – rumor parturition (Rosnow 1974) on social media after disasters, and this paper explains the second stage – rumor diffusion, in future, we can take another step further by developing models to understand the third stage – rumor controlling on social media.

APPENDIX 1: CODING SCHEME

Variable	Coding Scheme
Rumor	A Twitter message which does NOT explicitly indicate a person (e.g., the prime minister of Indian government), source (e.g., BBC, NDTV, website etc), context or known data to serve as a proof or verification for the message. The message MUST be topically relevant to the incidents under this study, and it MUST refer to an object, person, or situation rather than an idea or theory. (Oh et al. 2013) **Examples** ● RT @SciencePorn_: We are giving $1 for every retweet we get for the Oklahoma tornado fund. #PrayforOklahoma ● RT @realDonaldTrump: We spend billions of dollars helping nations all over the World but with hurricane Sandy and Oklahoma tornado not one …
Anxiety	A Twitter message "that express rumor related fear, dread, anxiety or apprehension, and statement that express a 'threatened' feeling" (Oh et al. 2013). **Examples** ● RT @BrooksBeau: #PrayforOklahoma I'm so **sad** to hear about the tornado in

	Oklahoma. All my prayers and thoughts out to you. ● RT @mollydewolf: This is one of the **freakiest** tornado videos I've seen yet... #Oklahoma http://t.co/3eTpJSzvO9
Personal Involvement	A Twitter message that describes experiences of the person, in the context of the rumor (Oh et al. 2013). **Examples** ● RT @Pontifex: I **am close to** the families of all who died in the Oklahoma tornado, especially those who lost young children. Join me in pray… ● RT @BrandonDean85: We are having another night **with a tornado breakout here** in Oklahoma. Pray for safety to all who are in the path. A Twitter message that expresses that s/he is personally involved in, committed to, or has some relationship to the event (Oh et al. 2013). **Examples** ● Girl in the break room **just asked** if there was a tornado in Oklahoma... ● **Just saw** what the tornado did to Oklahoma. Good god I feel bad😔😔
Directed Messages	A Twitter message that direct to specific user account (Oh et al. 2013). **Examples** ● RT @RhoadesRhoades: Major respect to **@KDTrey5** who donated a million dollars with out thought 1 day after the Oklahoma tornado victims !! ● Sure enough **@wbcsays** comes out and says it was gods will for the tornado to kill 50+ ppl in oklahoma. Shame on their cult.
Content Ambiguity	A Twitter message that expresses ambiguity or distrust about the message content. A Twitter message that expresses that the given information is conflicting in nature. "Questions seeking information (Oh et al. 2013). **Examples** ● Gosh, **No evacuation order?**"@AP: BREAKING: Oklahoma hospitals say they have treated about 120 people, including 50 kids, after major tornado" ● **Has Oklahoma had another tornado?** God help them. They are having some time of it #oklahomacity
Source Ambiguity	A Twitter message which does not contain an external source (such as name of media or links to external media, video, picture etc.) or/and a Twitter message that expresses distrust and/or ambiguity about the source (Oh et al. 2013). **Examples** ● u good fam? RT @Dadddy_D:I witness the biggest tornado in Oklahoma history OUT OF ALL THE DAYS nigga im trippen ● @TheTweetOfGod You create the tornado that strikes Oklahoma, then retweets the Red Cross message... your idea of being neutral? ;)
Sender's Credibility	A Twitter message sent by popular news media, local news media, local services, or governments **Examples** ● RT @**cnnbrk**: Medical examiner: 51 deaths in #Oklahoma #tornado. http://t.co/HNbaRcbk1k Latest on http://t.co/8yYtSv3xg3, CNN TV & CNN mobil… ● RT @**OKCFOX**: Tornado Warning for Canadian, Cleveland, Grady, McClain and Oklahoma County in OK until 8:00pm. http://t.co/WrrjjqBK5L
Attractiveness	A Twitter message that contains visual aid (Eisenhardt & Graebner, 2007) such as video, picture etc.). **Examples** ● RT @charlespgarcia: 12 incredible pictures that define the Oklahoma destructionhttp://t.co/yI1EV9J7jy(@charlespgarcia) ● RT @adallos: 5/31/2013 CLOSE RANGE Union City, Oklahoma Tornado - **INSANE Video**: http://t.co/PWVS2q4ARF via @youtube

REFERENCES

Adams, B. N., & Bristow, M. (1979). Ugandan Asian expulsion experiences: Rumour and reality. Journal of Asian and African Studies, 14 (3-4), 191-203.

Allen, D. G., Scotter, J. R., & Otondo, R. F. (2004). Recruitment communication media: Impact on prehire outcomes. Personnel Psychology, 57 (1), 143-171.

Allport, G. W., and Postman, L. (1947). The Psychology of Rumor, New York: Holt, Rinehart and Winston.

Anthony, S. (1973). Anxiety and rumor. The Journal of social psychology, 89 (1), 91-98.

Bates, L., and Callison, C. (2008). Effect of company affiliation on credibility in the blogosphere, in Proceedings of the Association for Education in Journalism and Mass Communication Conference, Chicago, IL.

Belgion, M. (1939). The vogue of rumour. Quarterly Review, 273 (3), 1- 18.

Berger, J. (2011). Arousal increases social transmission of information.Psychological science, 22 (7), 891-893.

Bhattacherjee, A., & Sanford, C. (2006). Influence processes for information technology acceptance: an elaboration likelihood model. MIS quarterly, 805-825.

Bordia, P., and DiFonzo, N. 2004. Problem solving in social interactions on the Internet: Rumor as Social Cognition. Social Psychology Quarterly, 67 (1), 33-49.

Borge-Holthoefer, J., & Moreno, Y. (2012). Absence of influential spreaders in rumor dynamics. Physical Review E, 85 (2), 026-116.

Buckner, H. T. (1965). A theory of rumor transmission. Public Opinion Quarterly, 29 (1), 54-70.

Byron, K. (2008). Carrying too heavy a load? The communication and miscommunication of emotion by email. Academy of Management Review, 33 (2), 309.

Chaiken, S., and Maheswaran, D. (1994). Heuristic processing can bias systematic processing: Effects of source credibility, argument ambiguity, and task importance on attitude judgment. Journal of Personality and Social Psychology, 66 (3), 460-473.

Cole, C., Ettenson, R., Reinke, S., & Schrader, T. (1990). The elaboration likelihood model (ELM): Replications, extensions and some conflicting findings. Advances in consumer research, 17 (1), 231-236.

Comfort, L. K., Ko, K., & Zagorecki, A. (2004). Coordination in rapidly evolving disaster response systems: The role of information. American Behavioral Scientist, 48 (3), 295-313.

Dennis, A. R., & Kinney, S. T. (1998). Testing media richness theory in the new media: The effects of cues, feedback, and task equivocality. Information Systems Research, 9 (3), 256-274

Donovan, P. (2007). How idle is idle talk? One hundred years of rumor research. Diogenes, 54 (1), 59-82.

Dormann, C. F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carré, G., ... & Lautenbach, S. (2012). Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. Ecography. 36 (1). 27-46.

Federal Emergency Management Agency. 2013. http://www.fema.gov/disaster/4117/updates/oklahoma-tornado-rumor-control

Festinger, L. (1957). A theory of cognitive dissonance, Evanston. IL: Row, Peterson.

Fine, G., Campion-Vincent, V., & Heath, C. (2005). Rumor Mills: The Social Impact of Rumor and Legend. New Brunswick, NJ: Transaction Publishers.

Frost, C. (2000) Tales on the Internet: Making it up as you go along. Aslib Proceedings, 52 (1) 5-10.

Garrett, R. K. (2011). Troubling consequences of online political rumoring. Human Communication Research, 37 (2), 255-274.

Gray, P. H., Parise, S., and Iyer, B. (2011) Innovation impacts of using social bookmarking systems. MIS Quarterly, 35(3), 629-644.

Johnson, T. J., & Kaye, B. K. (2004). Wag the blog: How reliance on traditional media and the Internet influence credibility perceptions of weblogs among blog users. Journalism & Mass Communication Quarterly, 81 (3), 622-642.

Kapferer, J-N. (1990). Rumors: Uses, Interpretations, and Images. New Brunswick, CT: Transaction Publishers.

Kimmel, A. J., & Keefer, R. (1991). Psychological correlates of the transmission and acceptance of rumors about AIDS1. Journal of Applied Social Psychology, 21 (19), 1608-1628.
Kwak, H., Lee, C., Park, H., & Moon, S. (2010, April). What is Twitter, a social network or a news media?. In Proceedings of the 19th international conference on World wide web p.591-600. ACM.
Lai, G., & Wong, O. (2002). The tie effect on information dissemination: the spread of a commercial rumor in Hong Kong. Social Networks, 24 (1), 49-75.
Lee, S. H. (2009). How do online reviews affect purchasing intention. African Journal of Business Management, 3 (10), 576-581.
Liao, Q., & Shi, L. (2013, February). She gets a sports car from our donation: rumor transmission in a chinese microblogging community. In Proceedings of the 2013 conference on Computer supported cooperative work p. 587-598. ACM.
Ma, R. (2008). Spread of SARS and war-related rumors through new media in China. Communication Quarterly, 56 (4), 376-391.
Miller, D. E. (1992). "Snakes in the greens" and rumor in the innercity. The Social Science Journal, 29 (4), 381-393.
National Science and Technology Council. (2005). Grand challenges for disaster reduction: A report of the Subcommittee on Disaster Reduction. National Science and Technology Council, Executive Office of the President, Washington, D.C.
Norris, F. H., & Murrell, S. A. (1988). Prior experience as a moderator of disaster impact on anxiety symptoms in older adults. American Journal of Community Psychology, 16 (5), 665-683.
Oh, O. Agrawal, M. and Rao, H. R. 2013. Community intelligence and social media services: A rumor theoretic analysis of tweets during social crises, MIS Quarterly, 37 (2), 407-426.
Oh, O., Kwon, K. H., Rao, H. R. 2010. An exploration of social media in extreme events: rumor theory and twitter during the Haiti earthquake. In 31st Proceedings of the International Conference on Information Systems (ICIS), St. Louis, Missouri.
Orme, J. G., & Combs-Orme, T. 2009. Multiple regression with discrete dependent variables, vol. 63. New York: Oxford University Press.
Pendleton, S. C. (1998). Rumor research revisited and expanded. Language & Communication, 18 (1), 69-86.
Perloff, R. M. 1993. The dynamics of persuasion, Hillside, NJ: Erlbaum.
Petty, R. E., and Cacioppo, J. T. (1986). Communication and Persuasion: Central and Peripheral Routes to Attitude Change. New York, U.S.: Springer-Verlag.
Petty, R. E., Wells, G. L., and Brock, T. L. (1976), Distraction can enhance or reduce yielding to propaganda: Thought disruption versus effort justification, Journal of Personality and Social Psychology, 34 (5), 874-884.
Ping, J.W. Cui, T. Pan. S.L. (2011). Strategies of crisis management from contingent perspective, in Proceedings of 15th Pacific Asia Conference on Information Systems (PACIS), Brisbane, Australia.
Pornpitakpan, C. (2004). The persuasiveness of source credibility: A critical review of five decades' evidence. Journal of Applied Social Psychology, 34 (2), 243-281.
Rosnow, R. & G. Fine. (1976). Rumor and Gossip: The Social Psychology of Hearsay. New York, NY: Elsevier.
Rosnow, R. L. (1988). Rumor as communication: A contextualist approach. Journal of Communication, 38 (1), 12-28.
Rosnow, R. L. (1991). Inside rumor: A personal journey. American Psychologist, 46 (5), 484.
Rosnow, R. L. (1974). Communications as Cultural Science. Journal of communication, 24 (3), 26-38.
Seeger, M. W., Sellnow, T. L., & Ulmer, R. R. (1998). Communication, organization, and crisis. Communication yearbook, 21, 231-276.
Shavitt, S., Swan, S., Lowrey, T. M., & Wänke, M. (1994). The interaction of endorser attractiveness and involvement in persuasion depends on the goal that guides message processing. Journal of Consumer Psychology, 3 (2), 137-162.
Shibutani, T. 1966. Improvised news: a sociological study of rumor Indianapolis. IN: Bobbs-Merrill.
Shirky, C. (2011). Political power of social media-technology, the Public Sphere Sphere, and Political Change, The. Foreign Affairs, 90, 28-41.

Silverstein, B., Perdue, L., Peterson, B., & Kelly, E. (1986). The role of the mass media in promoting a thin standard of bodily attractiveness for women. Sex Roles, 14, 519–532.
Simons, H. W., Berkowitz, N. N., & Moyer, R. J. (1970). Similarity, credibility, and attitude change: A review and a theory. Psychological Bulletin, 73 (1), 1-16.
Stephen, A. T., Dover, Y., & Goldenberg, J. (2010). A comparison of the effects of transmitter activity and connectivity on the diffusion of information over online social networks. Working Paper. SSRN eLibrary. Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1609611
Stephens, K. K., & Malone, P. C. (2009). If the organizations won't give us information…: The use of multiple new media for crisis technical translation and dialogue. Journal of Public Relations Research, 21 (2), 229-239.
Stieglitz, S., & Dang-Xuan, L. (2012). Political communication and influence through microblogging--An empirical analysis of sentiment in Twitter messages and retweet behavior. In System Science (HICSS), 2012 45th Hawaii International Conference on (p. 3500-3509), IEEE.
Sussman, S. W. and Siegal, W. S. (2003). Informational influence in organizations: An integrated approach to knowledge adoption. Information Systems Research 14 (1), 47-65.
Sutcliffe, A. (2002,). Assessing the reliability of heuristic evaluation for Web site attractiveness and usability. In System Sciences, 2002. HICSS. Proceedings of the 35th Annual Hawaii International Conference on (p. 1838-1847). IEEE.
Sweetser, K. D., & Metzgar, E. (2007). Communicating during crisis: Use of blogs as a relationship management tool. Public Relations Review, 33 (3), 340-342.
Tierney, K., Bevc, C., and Kuligowski, E. (2006). Metaphors matter: Disaster myths, media frames, and their Consequences in Hurricane Katrina. The Annals of the American Academy of Political and Social Science, 604 (1), 57-81.
Wu, F., Huberman, B. A., Adamic, L. A., & Tyler, J. R. (2004). Information flow in social groups. Physica A: Statistical Mechanics and its Applications, 337 (1), 327-335.
Zhao, D., & Rosson, M. B. (2009, May). How and why people Twitter: the role that micro-blogging plays in informal communication at work. In Proceedings of the ACM 2009 international conference on Supporting group work, p. 243-252. ACM.
Zhao, L., Wang, Q., Cheng, J., Chen, Y., Wang, J., & Huang, W. (2011). Rumor spreading model with consideration of forgetting mechanism: A case of online blogging LiveJournal. Physica A: Statistical Mechanics and its Applications, 390 (13), 2619-2625.
Zhou, L., & Zhang, D. (2007). An ontology-supported misinformation model: Toward a digital misinformation library. Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on, 37(5), 804-813.
Zook, M., Graham, M., Shelton, T., & Gorman, S. (2010). Volunteered geographic information and crowdsourcing disaster relief: a case study of the Haitian earthquake. World Medical & Health Policy, 2 (2), 7-33.