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Communication under Fire: The Role of Embeddedness in the Emergence and Efficacy of Disaster Response Communication Networks

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ABSTRACT

Communication networks among responders are critical to effective coordination and information transfer across agencies active in a disaster response. Using the theory of embeddedness, we investigate how aspects of relational and institutional embeddedness influence the emergence and efficacy of interactions among responding agencies using network data from three significant wildfire events in the wildland/urban interface. For this study, relational embeddedness is investigated as the degree of familiarity between two responders before the incident. Institutional embeddedness is explored in terms of nesting within shared affiliations and common roles. Our findings suggest that both relational and institutional embeddedness significantly shape the disaster communication network during an incident, but relational embeddedness appears to play a stronger role. Further, the most problematic interactions appear to occur among institutionally embedded responders who do not know each other. Consequently, knowing something about relational and institutional embeddedness within the network of responders before an incident provides insight into what the communication network will look like when a disaster occurs. Findings also provide insights for how we might mitigate risk for problematic information flow and coordination during the incident.

INTRODUCTION

Failures in effective communication and coordination within the network of responding organizations and agencies during a disaster can lead to problematic and even dangerous outcomes (Eikenberry, Arroyave, and Cooper 2007; Kapucu and Van Wart 2006). For this reason, a key area of concern in the study of disasters is the interactions that take place among leaders of these organizations and their effect on the collective response. Although a growing literature has documented the structure of disaster response networks (e.g., Comfort 2007; Comfort and Kapucu 2006; Kapucu 2005, 2006; Kapucu,

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Arslan and Collins 2010; Kapucu, Augustin, and Garayev 2009; Magsino 2009), there is limited empirical knowledge of the factors that shape the emergent structure of these networks and explain variation in the efficacy of interactions within them (Drabek 2003; Drabek and McEntire 2002; McEntire 1998). Interactions among the agency leaders coordinating the response are viewed as a principal vehicle through which responders develop situational awareness to changing events on the ground and coordinate their actions with other units accordingly (Comfort 2007). Without rigorous investigations into the factors that shape the presence and efficacy of these interactions, our practical understanding of disaster response is incomplete. The theory of embeddedness provides a robust lens through which to advance our understanding of these dynamics.

Using a data set of agency leader networks, this study uses dyadic network analysis (e.g., Lamertz and Aquino 2004) to examine the extent to which predisaster relational and institutional embeddedness explains the presence and degree of interaction among responder dyads during significant wildfire incidents. The research also investigates the consequences of relationally and institutionally embedded interaction as it relates to measures of communication efficacy during the incident. The implications of these findings are important for advancing our knowledge about the role of embeddedness, as well as how we might think about managing disasters better.

Understanding Emergent Disaster Communication Networks

Networks are a specific type of interorganizational arrangement, which exist to address complex, interjurisdictional social problems where no superior superordinate authority arrangement exists (Agranoff and McGuire 2001; Kickert and Koppenjan 1997; Mandell and Steelman 2003; O'Toole 1997; Provan and Milward 2001). Disasters can be understood as large scale, complex, dynamic, uncommon events that are beyond the scope of any single organization or agency to address (Comfort 2007; Comfort and Kapucu 2006). Although disasters can differ in the response they require, most significant disasters share in common a diverse assortment of agencies and organizations that play specific functional roles and have differing jurisdictional responsibilities. For example, in the context of wildfire disasters, an array of interdependent tasks including wildfire management (i.e., firefighting), structure protection, public information, animal evacuation, road closures, human evacuation, sheltering, and mass care of evacuees are common and are carried out by a menagerie of different agencies, organizations, and groups. This network is overlaid by a patchwork of jurisdictional authority and mission focus that is brought together (or not) into a coordinated response largely through voluntary cooperation with the incident command system rather than superordinate bureaucratic coercion.

These basic characteristics lead to a set of well-tested propositions about the nature of disaster response as (1) multiorganizational rather than uniorganizational (Drabek 1985; Moynihan 2009), (2) more networked than hierarchical (Choi and Kim 2007; Magsino 2009), and (3) more emergent than programmed (Drabek and McEntire 2002, 2003). As a result, scholars have advocated against rigid bureaucratic models and have oriented toward more complex systems models of disaster response (Drabek and McEntire 2002; Majchrzak, Jarvenpaa, and Hollingshead 2007). As stated by Majchrazak et al., the operating environment of a disaster is often one

in which "information about the disaster arrives at a pace, level of detail, level of credibility and connectedness, and across a variety of sources that rapidly make any planned response too slow, disconnected, and inadequate for the task" (2007, 147). Due to the complex, emergent, and interdependent nature of disaster response, network structures have come to typify characterizations of communication during disaster management (Kapucu 2005, 2006; Magsino 2009; Moynihan 2009). Emergence is used here to describe the development of a pattern of interaction in response to a disaster that is neither fully prescribed by, nor independent from, previous institutional arrangements (Drabek and McEntire 2003).

If, as research suggests, patterns of interaction and communication in disaster response are more emergent than programmed (Choi and Brower 2006; Petrescu-Prahova and Butts 2005), the question of what factors shape the structure of the communication network during a disaster becomes critical to understanding incident response. For our purposes, we refer to the collection of organizations, units, and agencies with formal responsibilities to respond during a disaster as responders. Interactions among this collection of responders occur via agency leaders who have been tasked to coordinate their agencies' operations with other responders during the incident. The pattern and quality of these interactions are referred to here as the communication network. It is important to note that this collection of actors is conceived of as a network by disaster scholars (e.g., Choi and Kim 2007; Comfort 2007; Kapucu 2005; Nowell and Steelman 2012; Steelman et al. forthcoming) because these actors are functionally interdependent. This functional interdependence stems from the fact that they are all intervening within the same problem domain at the same point in time, thereby creating risk for negative interference and opportunity for collaborative advantage (Nowell and Steelman 2012). As a result of these interdependencies, failures in one part of the network can lead to cascading failures in other areas (Helbing, Ammoser, and Kühnert 2006). Within the framework of the incident command system, the goal of this network is to address these interdependencies and minimize the negative impact of the disaster on the local community through coordinated action within and between functional response areas. However, members themselves may have varied knowledge of the incident command system and have different perceptions about their goals, the means for achieving those goals, and the composition of the relevant network. Indeed, in our field work, we have observed that it is often failure to appreciate the need for communication with another responder that leads to coordination failures within the network. Consequently, understanding the factors that help explain the configuration of this network (i.e., who interacts with whom), as well as the variability in the efficacy of interactions within it, is of both practical and theoretical importance for two reasons.

First, significant attention in the study of disaster response focuses on the primacy of information sharing and its role in emergent coordination among agency responders (e.g., Comfort, Ko, and Zagorecki 2004; Drabek and McEntire 2003; Von Lubitz, Beakley, and Patricelli 2008). Because disasters are infrequent, complex, dynamic events, they create novel situations for responders that do not map cleanly on to past operational experience or plans (Drabek and McEntire 2002, 2003; Majchrzak et al. 2007). As the complexity of the event increases, information about the disaster, its effects, associated response needs, jurisdictional responsibilities, available resources,

and engaged organizations and actors becomes asymmetrically distributed among an array of responders (Militello et al. 2007; Steelman et al. forthcoming). As stated by Kapucu, "If responders are not in contact with each other and if information does not flow properly, it is hard to envision a successful disaster response" (2006, 218).

Second, within networked settings typified by a disaster response, scholars have emphasized the importance of collective sensemaking and network management (Comfort and Kapucu 2006; Weick, Sutcliffe, and Obstfeld 2005). This literature argues that effective response to disasters requires responders to engage in active sensemaking and sensegiving processes to develop situational awareness (Comfort and Kapucu 2006; Weick 1993) and shared mental models (Comfort 2007; Corbacioglu and Kapucu 2006; Weick 2010) to guide coordinated action. Specifically, when pursuing goals that involve the coordinated actions of multiple autonomous actors, action is driven by interactions that help responders to make sense of the situation, identify what needs to happen to address the situation, and clarify their role within that response (Choi and Brower 2006; Comfort and Kapucu 2006; Weick, Sutcliffe, and Obstfeld 2005). This leads to a dynamic situation in which multiple responders are seeking to frame the situation and determine an appropriate response in interaction with a select group of others within the network (Majchrzak et al. 2007).

Accordingly, ample evidence exists to suggest that understanding who interacts with whom and the efficacy of those interactions are critical intermediate outcomes to the overall success of the disaster response (Choi and Brower 2006; Comfort and Kapucu 2006; Kapucu 2005; Magsino 2009; Moynihan 2009). However, the literature is limited in explaining the factors associated with the emergence and efficacy of communication networks in disaster contexts. Research has suggested that a priori plans *do not* appear to be good predictors of actual interaction (e.g., Choi and Brower 2006). Accordingly, recent literature has begun to seek to understand when disaster agencies are more likely to collaborate with others (e.g., McGuire and Silvia 2010) and the processes involved in emergent coordination (e.g., Majchrzak et al. 2007). However, this body of work remains largely silent on the targets of interaction and the preexisting relational characteristics that improve the chances that these interactions will be successful.

Embeddedness Perspective of Network Emergence during Disaster Response

Scholars have argued for greater theoretical rigor in understanding disasters (Magsino 2009; Quarantelli 2005). In this study, we leverage the theory of embeddedness to investigate several aspects of preincident connections between dyads and how these characteristics affect interactions during an incident. The concept of embeddedness has had widespread influence in fields ranging from sociology, political science, psychology, public health, and management. It provides a direct challenge to undersocialized (e.g., Moody and White 2003), purely economic, rational perspectives of action, emphasizing instead that all action is embedded within a social, political, cultural context that serves to both enable and constrain action (Dacin, Ventresca, and Beal 1999). Polanyi (1944) is widely cited as the originator of the concept of embeddedness (Granovetter 1985; Portes and Sensenbrenner 1993; Zukin and DiMaggio 1990); however, much of the modern theoretical development of the concept is accredited

to Granovetter (1985, 1992). Granovetter (1985) described embeddedness as the ongoing contextualization of economic exchange in social structures. He stated that an embeddedness perspective is an argument that behavior and institutions are "so constrained by on-going social relations that to construe them as independent is a grievous misunderstanding" (Granovetter 1985, 482).

In his work, Granovetter (1985, 1992) refers to embeddedness as encompassing both the dyadic nature of overlapping relations between two actors (i.e., relational embeddedness and institutional embeddedness) and the structural position of an actor within a broader network (i.e., structural embeddedness; see also Nahapiet and Ghoshal 1998). Zukin and DiMaggio (1990) expand this conceptualization to include the cognitive, cultural, social, and political structures and institutions within which actors are nested, which serve to enable, promote, or constrain action. From these early works, a vast body of scholarship has emerged that has sought to understand the institutional and social context of human action.

An embeddedness perspective has been influential in the public management literature on networks (Berry et al. 2004). However, this work has been dominated by a focus on *structural* embeddedness, seeking to understand the antecedents and outcomes of centrality among members of a given network or set of networks (e.g., Banaszak-Holl et al. 1998; Huang and Provan 2007a, 2007b; Provan, Huang, and Milward 2009; Schalk, Torenvlied, and Allen 2010; Villadsen 2011). There has been a comparative dearth of research in the public network literature understanding other theories of embeddedness such as how ties developed between two actors in one context may influence the probability and efficacy of tie formation in another context.

Applied to the domain of disasters, a relational and institutional embeddedness perspective provides a useful lens for considering how the social and institutional contexts within which actors are nested influence their interactions during a disaster and the outcomes of those interactions. In doing so, it provides a macrotheoretical framework that can serve to integrate more microlevel theories of interaction. This line of inquiry has made significant contributions in understanding social support and recovery for victims of disasters (e.g., Iversen and Armstrong 2008; Norris et al. 2005). However, there is limited work understanding relational and institutional embeddedness of organizational actors and their role in shaping the structure and efficacy of communication networks *during* disaster response. In this study, we investigate three characteristics of dyads representing aspects of relational and institutional embeddedness and their relationship to the frequency and efficacy of communication within a disaster responder network.[1] These are (1) predisaster social ties, (2) common stakeholder affiliation, and (3) shared functional role.

Relational Embeddedness

The theory of relational embeddedness focuses on the quality of social ties between two actors (Nahapiet and Ghoshal 1998). A key proposition within this literature is

1 We do not consider structural aspects of embeddedness in this study because our dependent variables are at the dyadic level of analysis. As structural embeddedness represents a characteristic of a network member rather than the characteristic of a relationship, it is not a theory that lends itself well to understanding outcomes at the dyadic level of analysis.

that interactions between two actors who share overlapping linkages with one another will be different from arms-length interactions between previously unfamiliar actors (Moody and White 2003). Put simply, transactions between friends are not the same as transactions between strangers.

Within the field of disasters, familiarity between two actors *before* an incident has been suggested to be important to facilitating interaction and enabling more effective communication *during* an incident, but there is limited quantitative evidence to support these claims (Drabek and McEntire 2002, 2003; Gillespie and Streeter 1987; Kapucu 2006). Preincident social ties are suggested to be associated with more frequent and better communication outcomes because familiarity breeds comfort and trust. Trust embodies the relational dimension of social capital and is defined by an emphasis on norms and values, which is prevalent in the work of scholars such as Coleman (1988). In this study, we examine these relational embeddedness factors by investigating the relationship of familiarity before the incident to frequency and efficacy in communication exchanges among responders. We investigate communication efficacy in terms of the degree to which communications are deemed problematic. The following hypotheses guide our investigation here:

H1: Communication will occur more frequently within dyads that have a greater familiarity preincident.
H2: Communication will be less problematic among dyads with greater familiarity preincident.
H3: Communication will be rated as less problematic among dyads that interact more frequently.

Institutional Embeddedness

A second branch of literature embracing an embeddedness perspective is closely aligned with institutional theory and focuses on embeddedness within settings that convey unique institutional logics that serve to shape and constrain thought and behavior (e.g., Dacin 1997; Johannisson, Ramirez-Pasillas, and Karlsson 2002). A common proposition within organizational science posits that similarities in functional roles or shared affiliations create "boundaries" around sets of organizational units (e.g., DiMaggio and Powell 1983; Oliver 1990; Van de Ven and Walker 1984). These boundaries are hypothesized to facilitate interaction with those units inside the boundary while simultaneously creating challenges in communication and information sharing with units outside the boundary (Manoj and Baker 2007; Oliver 1990; Van de Ven and Walker 1984). The institutional perspective on embeddedness differs from the relational embeddedness perspective in that it does not require any assumption of a preexisting relationship to encourage or facilitate interaction between two actors. There are several streams of research and associated theories that support and explain this effect. Perhaps the oldest and most established body of work comes from the field of communication and investigations of what is referred to as the *homophily principle* (Rogers and Bhowmik 1970; Weick 1979). Homophily refers to the degree to which individuals who interact are similar to one another on a given set of attributes. The homophily principle asserts that (1) when given choice, individuals will interact most frequently with those with whom they are most similar and (2) more effective

communication occurs when interacting individuals are more homophilous (Rogers 1995). The argument here is that similarity among individuals creates a shared set of meanings that facilitates communication. There is a long history of empirical evidence to support the propositions at the individual level of analysis (e.g., Weick 1979). There is also some evidence that this principal holds true at the organizational level of analysis (e.g., Van de Ven and Walker 1984).

More recently, a complementary theory predicting homophilous communication was offered by Frank's (2009) work on the role of *quasi*-ties. *Quasi*-tie theory integrates social identity and network theory by proposing that individuals who share a common identity to a collective are linked together through a *quasi*-tie that can facilitate the flow of information and resources. In this theory, a shared identity serves as the basis for a tie that is defined as a social relationship that affects behavior and resource allocation. Consistent with this, research has found that people are more likely to provide information and assistance to someone if they view that person as part of a collective to which they identify (Frank 2009). Accordingly, members in a responder network may favor information exchange with those with whom they share an identity, which could include a common stakeholder grouping or similar job function.

Despite the substantial body of research supporting the predictions of institutional embeddedness theory, much of the literature on interorganizational relations offers a competing perspective. Although the communication literature focuses on people as humans who are driven toward exchanges that are the most interpersonally comfortable and rewarding, the management literature often views people as organizational agents driven to prioritize exchanges that are the most strategic for their organization (e.g., Berry et al. 2004; Oliver 1990). For example, Burt's (1992) structural holes theory argues that the most valuable interactions occur between *diverse* actors because it is through such interactions that one gains access to the most unique, or nonredundant, types of information. The most efficient/effective network configuration for an individual is posited as one that minimizes costs through keeping networks as small as possible while still maximizing the diversity of resources and information available through one's network (Burt 1992). This perspective, paired with strategic choice theory, has been adopted to propose that actors within a network—acting as agents of their respective units—would prioritize interactions with those more different from them (e.g., Zaheer and Soda 2009).

To the extent that the literature on disasters has considered this question, it has tended to align itself with homophily and institutional embeddedness arguments by emphasizing challenges communicating across bureaucratic, cultural, or professional boundaries (e.g., Kapucu 2006; Manoj and Baker 2007). Further, operationalizing these institutional embeddedness assumptions within a disaster context, it is likely that greater task-related interdependencies may arise among responders who carry out similar functions, are affiliated with common groups, or work at similar levels (e.g., local, state) within the response, necessitating greater interaction. However, to date, there is no literature that explicitly investigates the extent to which shared institutional embeddedness serves as a key driver of the frequency and efficacy of communication exchanges among responders. In this study, we begin to address this gap by investigating two aspects of institutional embeddedness that have emerged as salient

identifiers among responders based on our field work: shared functional role similarity and stakeholder group similarity. This investigation is guided by the following hypotheses:

H4: Responders embedded within a common stakeholder affiliation or functional role will communicate with one another significantly more frequently during the incident than those unaffiliated.

H5: Communications between dyads embedded within a common stakeholder affiliation or functional role will be perceived as significantly less problematic than communications between dissimilar dyads.

H6: Relational (familiarity) and institutional (stakeholder affiliation and functional role) embeddedness will have an additive effect resulting in significantly more frequent communication.

H7: Relational (familiarity) and institutional (stakeholder affiliation and functional role) embeddedness will have an additive effect resulting in significantly more effective communication.

METHODS

Study Context

The above hypotheses were investigated based on dyadic social network data of responder interactions during three large wildfire events occurring within the wildland/urban interface (WUI) in 2010. The WUI is the boundary where communities and forests intersect. Wildfire is one of the most frequently occurring disasters in the United States (EM-DAT 2012). The WUI covers nearly 11% of the land area in the United States (Hammer, Stewart, and Radeloff 2009). In the West, 45% of all housing units are located in the WUI (11.1 million units), and this percentage is projected to grow in the future as baby boomers retire to amenity rich, rural areas (Hammer et al. 2009; National Interagency Fire Center 2009).

The unplanned and unpredictable nature of disasters creates methodological challenges when attempting to capture patterns of interaction in the response. Past social network research on disasters has predominantly relied upon the use of archival sources such as newspaper articles and Incident Action Plans to infer the pattern of interactions among members of the responder network during a disaster (Comfort and Kapucu 2006; Kapucu 2005, 2006; Moynihan 2009). For this study, we advance the methodological rigor of these designs by recording on-site reports from leaders of their interactions during the incident. Data were collected through in-person, semistructured interviews that incorporated close-ended survey, social network roster questionnaires, and open-ended interview questions about the incident and performance of the responder network. Each participant was interviewed once, and interviews lasted between 60–90 min.

The focus of this study was the Tecolote Fire in New Mexico, the Schultz Fire in Arizona, and the Bull Fire in California. Each of these fires occurred during the summer of 2010, and all ignited on US Forest Service (USFS) land. National Forests in the United States are managed within a divisionalized structure by the US Forest Service (e.g., Santa Fe National Forest) under the Department of Agriculture. Each Forest is managed by a Forest Supervisor and is broken down into smaller geographic

units called Districts that are managed by a District Ranger. To distinguish these local forest divisions from the national parent agency (USFS), we will refer to the organization that manages the national forest as the local forest. We will further distinguish the local forest organization (e.g., Santa Fe National Forest) from the District Forest unit (e.g., Las Vegas District of the Santa Fe National Forest). When a fire ignites on USFS land, the local forest becomes the responsible authority on the incident. Should the incident exceed the local forest's capacity to deal with it, it is authorized through the USFS to request the assistance of a Regional (called Type 2) or National (called Type 1) incident management team (IMT).

Sample

Because the focus of this investigation seeks to explain variation within networks, we purposively sought to control for variation between incident networks through our sampling procedure as well as through statistical controls. Incident response networks can vary substantially in their size, governance, and composition based on the nature and complexity of the incident. In this study, we minimize variation in size, governance, and composition between networks by focusing on the most significant WUI fire events (Type 1) ignited on US Forest Service land and managed through the incident command system by a Type-1 IMTs. Type-1 IMTs are the most elite IMTs in the United States and are reserved for the most complex and costly disasters. All three fire events in this study (Tecolote, Schultz, and Bull Fires) met these criteria. Each of these fires was managed by a different Type-1 federal IMT. The three incidents were located in New Mexico, Arizona, and California, respectively, and there was no overlap between the networks across these three incidents. This sampling strategy allowed us to target incidents that were (1) sufficiently complex to require involvement from a broad range of organizations and agencies and (2) sufficiently comparable with regards to the structure of the responder network.

The focus of our investigation concerns what we refer to as the "responder network." The responder network is a network of leaders who carry out key roles during a wildfire incident, generally as the primary representative of a unit or organization. For example, on the IMT, the public information unit often consists of multiple public information officers (PIOs) who work under the leadership of a lead PIO. The lead PIO is responsible for the coordination of the public information function on the incident with other units on the IMT, as well as coordinating information with the Local and District Forest and other responding agencies.

Based on 2 years of previous field research and consultation with National Forest representatives, we have developed a roster comprised of key leadership roles and organizational units that make up the responder network during a wildfire incident in the WUI (Nowell and Steelman 2012). The roster includes key leadership roles within the Local and District Forest (e.g., Forest Supervisor, Public Affairs Office, District Ranger, District Fire Management Officer, Tribal Liaison, and Resource Advisor), IMT sections (operations, incident commander, public information), and all other cooperating agencies. Cooperating agencies refer to public, nonprofit and private organizations and agencies that have formal roles and responsibilities related to the maintenance and protection of community safety and infrastructure during a WUI

fire. Although cooperating agencies are not under the jurisdiction of the National Forest or IMT during a WUI fire, effective management of the fire and protection of community safety and infrastructure require that they coordinate closely with one another, the Local and District Forest, and the IMT. Examples of cooperating agencies include the Red Cross, County Office of Emergency Management, County Fire, County Sherriff, animal shelters, phone companies, and gas companies. Leaders were identified for every position or unit on the responder network roster. In most cases, this leader was identified by title (e.g., public information office section leader of the IMT). For responding agencies, the representative was identified as the highest ranking individual who was actively involved in coordinating their agencies response efforts with the rest of the responder network. The final sample resulted in network data from 96 responders across the three incident networks (Tecolote fire: $n = 31$; Schultz fire: $n = 35$; Bull fire: $n = 30$]. Data were collected from more than 80% of the responder network in each of the three sites. The sample composition by incident is summarized in table 1. As shown in this table, the sample composition is relatively consistent across all three incidents.

Measures

All measures for this study were operationalized at the dyadic level of analysis, which means that they represent the characteristic of a relationship or association between a pair of responders.

Dependent Variables

Two dependent variables were investigated in the analysis: communication frequency and communication efficacy. These two variables were operationalized using data from a social network roster questionnaire (Wasserman and Faust 1994), which contained a list of all members of the responder network for that incident. Each leader was asked to rate the frequency of their interaction with all other members of the responder network during the incident. Communication frequency was measured on a scale of 1–5 ranging from no interaction to communicating multiple times per day. Communication efficacy was operationalized using a 1–5 scale that asked leaders to rate the degree to which they felt there was room for improvement in their interactions with each member of the responder network.[2]

Table 1
Sample Composition by Fire

	Tecolote	Schultz	Bull
IMT section leads	31%	29%	30%
Local forest leaders	34%	28%	33%
Local responding agencies	35%	43%	37%

2 Room for improvement on a 1–5 scale with 1 = no room for improvement, 2 = a little room for improvement, 3 = some room for improvement, 4 = quite a bit, and 5 = a lot "How much room for improvement was there in the communication between you and the following?" [network roster provided].

Independent Variables

Two different operationalizations of institutional embeddedness were explored in this study: shared functional role and common stakeholder affiliation. Shared functional role was conceptualized as the extent to which two responders were similar in the primary role they played in the response. Data about the primary functional roles of each leadership position and organizational unit on the roster were obtained through interviews. Seven functional roles were identified that were consistent across all three incidents. These were: evacuation/road closure, fire management, information, finance/administration, incident command, infrastructure/utilities, and local governance. Functional role similarity was operationalized based on the presence of a match within the dyad. For example, the primary role of both the Public Information section of the IMT and the Public Affairs unit of the local forest was information. Another salient identifier across all three incidents concerned the stakeholder group to which a responder was affiliated. Six primary stakeholder groups were categorized. These were IMT, local forest, district forest, local cooperating organizations, nonlocal cooperating organizations (e.g., state level), and local government. Interactions between responders affiliated with the same stakeholder group (e.g., both parts of the IMT) were coded as 1. All others were coded as 0.

The relational embeddedness variable was measured using a social network roster questionnaire as a rating of preincident familiarity. Leaders were asked to rate their degree of familiarity before the incident with every other member of the responder network on a 1–4 scale ranging from no familiarity to a high degree of familiarity. In the cases where the member of the responder network was a local responding agency (e.g., County Sherriff) rather than a specific leadership position (e.g., IMT PIO), leaders were asked to rate their level of familiarity with their primary contact(s) in that organizational unit during the incident. Descriptives for the preincident familiarity, during incident communication frequency and during incident problematic communications ratings, are summarized in table 2. Descriptives on these variables indicate the data were normally distributed across the full scale range with good variability.

Analysis

Predictive models of dyadic relations using social network data necessitate an analysis strategy that controls for the inherent nonindependent and nested nature of the data (Krackhardt 1988). Accordingly, the primary data analysis method used in this study was cross-classified hierarchical linear models (HLM; Raudenbush and Bryk 2002) that are capable of accounting for the nonindependence associated with network data (see Frank 2009). The data consisted of 2,052 network ties nested within 96 informants across three incidents. A tie can be understood in the abstract as actor A's relationship to B. Each tie was characterized in terms of the frequency and efficacy of communication that occurred during the incident from A to B, the degree of familiarity (relational embeddedness variable) before the incident, and whether A and B shared similarity in their functional role and stakeholder affiliation (institutional embeddedness variables).

In a hypothetical network consisting of actors A, B, and C, the data analysis challenge stems from the fact that A's relationship to B cannot be assumed to be

Table 2
Network Level Descriptives by Incident

	During Incident Communication Frequency (scale range: 1–5)		Preincident Familiarity (scale range: 1–4)		Problematic Communication (scale range: 1–5)
	Mean (SD)	Network Density[a]	Mean (SD)	Network Density[a]	Mean (SD)
Tecolote fire	3.24 (1.32)	0.54	2.30 (1.23)	0.36	1.97 (.94)
Schultz fire	3.27 (1.34)	0.57	2.69 (1.23)	0.45	1.89 (.83)
Bull fire	3.23 (1.35)	0.50	2.63 (1.19)	0.37	1.93 (.90)

[a]Density scores based on dichotomized matrix.

independent of A's relationship to C because both ties are nested within A. Further, A's relationship to B cannot be assumed to be independent of C's relationship to B because both ties are nested with B. Finally, A's evaluation of the relationship of A's relationship to B cannot be assumed to be independent of B's evaluation of the relationship of B's relationship to A because both ties are nested within the same dyad. Modeled after the analysis strategy employed by Frank (2009), this nonindependence was controlled in HLM by cross-classifying all ties at level 1 within raters, ratees, and dyads. In this application of cross-classified HLMs, the purpose is to isolate the role of tie level characteristics in explaining variation across ties by controlling for variation that is associated with the actors within which those ties are nested. For example, this analysis allows us to investigate the influence of relational embeddedness on the frequency of communication that occurs during a disaster, controlling for the fact that certain members of the responder network are likely to be more active communicators overall relative to other members of the responder network. The incident identity (FireID) and duration from which the interview took place after the initial in-briefing of the Type-1 IMT (time interviewed) were also controlled for all in all analyses.

Data were analyzed in SAS 9.2 using proc mixed and GLIMMAX estimation procedures. Continuous variables were grand mean centered prior to analysis. Maximum likelihood estimation was used to allow for hierarchical comparisons between models. Preliminary variance partitioning analysis on null models indicated significant variance at level 1 (tie level) and significant clustering for all level-2 subject effects (rater, ratee, and dyad).

RESULTS

Network Level Descriptives for Incident Response Networks

Descriptive analysis was run by incident to examine variable descriptives and overall network patterns (table 2) Average communication frequency, preincident familiarity, and ratings of communication efficacy were all within range of a normal distribution and highly consistent across incidents. It is noteworthy that communication efficacy (room for improvement) scores averaged right around "a little room for improvement," suggesting that overall communications during these incidents were seen as generally unproblematic. Across all three incidents, the density of the

communication network during the incident was fairly consistent, ranging from 0.50 to 0.57 (table 2). Network density is a measure of the total number of ties relative to the total number of possible ties within the network. This indicates that, on average across incidents, responders were communicating with each other on multiple occasions in a little more than 50% of the cases. Analysis of the preincident network based on respondent ratings of familiarity with other responders before the incident suggest a somewhat less dense network and greater variation among the three sites. The greatest density of preincident relationships among responders occurred on the Schultz fire (0.45). The density of the preincident network was similar for the Tecolote and Bull fires.

Predicting Preincident Relational Embeddedness

To investigate mediational effects that might be present in subsequent models, the relationship of functional role similarity and stakeholder group similarity to preincident familiarity was examined. Dyads that shared a common role or were nested within the same stakeholder group (e.g., local cooperators, local forest, and IMT) were significantly more likely to report greater familiarity with one another before the incident (table 3). This stands to reason as those working in the same area are much more likely to have opportunity and cause to interact with one another and therefore are more likely to develop a stronger relationship before an incident occurs.

The empirical confirmation of this serves two purposes. First, it suggests that preincident familiarity must be accounted for to test whether similarity has a direct effect on communications during an incident. Second, it validates that common functional role and shared stakeholder affiliation are both important aspects of institutional embeddedness that serve to structure relations among responders before an incident. As indicated in table 3, effect size analysis based on the Pearson's *R* indicates that functional role has a small to moderate effect (.17) on preincident familiarity.[3] Stakeholder group affiliation has a large effect (.47). This means that responders were

Table 3
Modeling Relational Embeddedness

	Model	Effect Size[a]
Functional role similarity	0.389 (0.067)***	0.17
Stakeholder affiliation similarity	1.138 (0.063)***	0.47
Controls		
Time interviewed	−0.003 (0.006)	—
FireIDa	−0.200 (0.166)	—
FireIDb	0.104 (0.155)	—
FireIDc (referent class)	—	—

***$p < .001$.
[a]Effect size calculated based on a Pearson's *R*: .1 = small effect, .3 = moderate effect, and .5 = large effect (Cohen 1988).

3 Effect sizes were calculated as a Pearson's *R*, which measures the proportion of unique variance shared by the two variables: Cohen (1988) suggest the following rubric for interpretation: 1 = small effect, .3 = moderate effect, and .5 = large effect.

much more likely to be more familiar with one another before the incident if they were nested within the same stakeholder group than if they simply carried out a similar functional role during the incident.

Predicting Frequency of Communication within the Responder Network

The next set of analysis investigated factors related to the presence and frequency of interaction that occurred among responders. Findings presented in table 4 support the hypothesis that communication will occur more frequently among dyads that have a stronger degree of familiarity with one another based on a preincident relationship. Dyads that perform a similar function on the incident and that are identified as belonging to the same stakeholder group were also found to communicate more frequently during the incident. Effect size analysis indicates that preincident familiarity has the strongest influence on the frequency of communication among responders. Controlling for all other predictors, a one standard deviation (SD) increase in familiarity increases communication frequency by over one-third of a SD[4] (0.5/1.3 = 0.39).

Investigations of mediational and moderating effects of institutional and relational embeddedness in relation to communication frequency provided mixed results, as indicated in table 4. We hypothesized that institutional and relational embeddedness would have an additive effect, resulting in more frequent communication. The data are conflicted for these results. Coefficients for functional role similarity and stakeholder affiliation similarity were reduced in the model, suggesting some mediational effect of familiarity in explaining the relationship of similarity to communication frequency. In

Table 4
Modeling Communication Frequency

	Model 1	Model 2	Model 3	Model 3 Effect Size[a]
Functional role similarity	0.569 (0.067)***	0.420 (0.060)***	0.428 (0.063)***	0.20
Stakeholder affiliation similarity	0.876 (0.062)***	0.395 (0.061)***	0.347 (0.070)***	0.13
Familiarity	—	0.505 (0.027)***	0.496 (0.030)***	0.36
Functional role similarity × familiarity	—	—	−0.038 (.061)	0.01
Stakeholder affiliation similarity × familiarity	—	—	0.099 (0.068)	0.03
Controls				
Time interviewed	−0.017 (.006)*	−0.016 (.006)*	−0.016 (.006)*	—
FireIDa	0.151 (.216)	0.233 (.202)	0.229* (.201)	—
FireIDb	0.2303 (.204)	0.187 (.191)	0.189 (.189)	—
FireIDc (referent class)	—	—	—	—

*$p < .05$; ***$p < .001$.
[a]Effect size calculated based on a Pearson's R: .1 = small effect, .3 = moderate effect, and .5 = large effect (Cohen 1988).

4 SD for familiarity = 1.22; based on a 4-point scale ranging from no relationship, acquaintance, and moderate familiarity to high degree of familiarity. One unit change in familiarity (e.g., from no relationship to acquaintance) is 0.82 of an SD.

other words, these relationships are not entirely additive. As previously stated, those in a similar stakeholder group were particularly more likely to be familiar with one another before the incident. However, we also found that both common functional role and shared stakeholder affiliation maintained significant main effects in models accounting for pre-incident familiarity. Additionally, the interaction terms are not significant. Therefore, the data also suggest that there is an independent effect of institutional embeddedness on frequency of communication that is not accounted for by the mediating effect or moderating effect of relational embeddedness.

Predicting Problematic Communication

As hypothesized, models find a direct negative relationship of both communication frequency and relational embeddedness to problematic communication as illustrated in table 5. Communication occurring within dyads where there was more frequent communication and higher preincident familiarity reported less room for improvement in their interactions.

However, our hypothesis that communication between institutionally embedded dyads would be perceived as less problematic than communication between dissimilar dyads was not supported. As presented in table 5, there was no direct significant relationship for either common functional role or shared stakeholder affiliation when it came to less problematic communication. There was a significant interaction effect for stakeholder group similarity and familiarity. However, analysis of this interaction indicates a more complex relationship than was originally hypothesized. This interaction is diagrammed in figure 1. As hypothesized, the *least* problematic communication occurred among dyads who were *both* more similar and had a stronger preincident familiarity. However, post hoc analysis indicates the difference between this group and those dyads that were dissimilar but still had a high level of preincident familiarity is not significant ($t = 0.77$, $p = .44$). Consequently, relational embeddedness may be more important than institutional embeddedness (shared stakeholder affiliation) in these relationships. Interestingly, dyads that reported the *greatest* room for improvement in their interactions were those who shared a common stakeholder affiliation but had low familiarity. Further, this group reported significantly more room for improvement in their interactions relative to dyads that were dissimilar but had low familiarity ($t = -2.44$, $p = .01$). Overall, coefficients and effect sizes for models predicting problematic communication suggested that relational and institutional embeddedness variables had a stronger effect on communication frequency than communication efficacy.

DISCUSSION

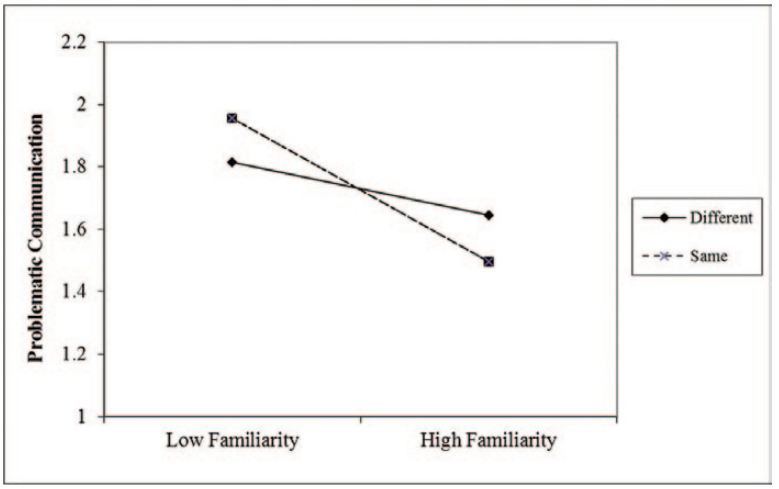
Given the emergent and networked characterization of a disaster response, understanding the factors that can condition more or less effective communication within the responder network is important. In this study, we sought to understand how relational and institutional embeddedness influenced the structure and efficacy of interactions within the response network during an incident. Findings from this study make several important contributions to advancing theory and research. First, this study

Table 5
Modeling Problematic Communication

	Model 1	Model 2	Model 3	Model 4	Model 3 Effect Size
Functional role similarity	−0.028 (0.040)	0.027 (0.039)	0.037 (0.039)	0.050 (0.041)	0.04
Stakeholder affiliation similarity	−0.122 (0.037)***	−0.040 (0.038)	0.021 (0.040)	0.080 (0.046)^	0.05
Communication frequency	—	−0.131 (0.019)***	−0.094 (0.020)***	−0.092 (0.020)***	0.11
Familiarity	—	—	−0.091 (0.020)***	−0.070 (0.022)***	0.08
Functional role similarity × familiarity	—	—	—	−0.031 (0.041)	0.02
Stakeholder affiliation similarity × familiarity	—	—	—	−0.117 (0.046)**	0.06
Controls					
Time interviewed	0.007 (0.007)	0.005 (0.006)	0.005 (0.007)	0.005 (0.007)	—
FireIDa	0.152 (.171)	0.165 (.172)	0.146 (.172)	0.149 (0.172)	—
FireIDb	−0.001 (0.161)	0.023 (0.162)	0.024 (162)	0.0247 (0.162)	—
FireIDc (referent class)	—	—	—	—	—

^$p > .1$; **$p < .01$; ***$p < .001$.

Figure 1
Significant Interaction between Relational and Institutional Embeddedness in Predicting Problematic Communication



expands the current public management literature on embeddedness in networks by broadening our understanding of embeddedness beyond the structural perspective to also consider the consequences of relational and institutional dimensions. In addition, this study advances our understanding of public management of disasters by contributing to theory concerning the relative influence of relational and institutional embeddedness in explaining both the frequency and efficacy of interactions.

Institutional Embeddedness

Our findings on institutional embeddedness indicate that although institutional embeddedness serves to positively structure interactions (greater frequency and greater familiarity) during a disaster, we cannot assume that this leads to better communication efficacy. This contradicts some established theory related to institutional embeddedness.

Institutional embeddedness theory suggests that sociocultural norms will shape organizational response (Coriat and Dosi 2000; Dacin 1997; Johannisson, Ramiriez-Pasillas, and Karlsson 2002). Consequently, those who are more similar in their sociocultural outlook within their boundaries (stakeholder group or share professional affiliation) may communicate more effectively (Kapucu 2006; Manoj and Baker 2007; Oliver 1990; Van de Ven and Walker 1984). However, our findings support only half of this proposition. Responders who were institutionally nested had higher preincident familiarity. This is common sense but served as an important validation that our institutional embeddedness variables are tapping into significant characteristics that structure interactions before an incident occurs. Consistent with the homophily proposition, institutionally embedded actors were also more likely to interact with one other during an incident. This relationship was partially mediated by preincident relational embeddedness; however, it retained a significant unique effect. Thus, we can

predict that sensemaking and sensegiving may become localized within institutional groupings. This finding has significance for practitioners as it suggests that incident command teams would be well advised to focus particular attention to perspectives, information, and assumptions that are being generating and communicated within stakeholder or functional role groupings that may not be efficiently shared with the rest of the network. This may be particularly salient in understanding the transfer of information and assumptions that are nested within functional roles as this aspect of institutional embeddedness had a stronger influence on shaping communication patterns relative to stakeholder affiliation. This finding also supports notions in the literature of a disaster being a networked response that becomes organized around specific functional areas that span state and local levels, as well as cross-agency and organizational boundaries (Comfort and Kapucu 2006).

However, although institutionally embedded actors did communicate more frequently during the incident, their shared institutional affiliation did not translate into less problematic communication. This contradicts established literature that more effective communication will occur among more homophilous individuals (Rogers and Bhowmik 1970). Although this relationship was not as hypothesized, results suggest that the influence of institutional embeddedness on communication efficacy is mediated by its relationship to relational embeddedness. When actors shared a common affiliation, they were more likely to be familiar with one another before the incident, but it was this relational embeddedness—not institutional—that significantly predicted less problematic communication. This finding suggests incident managers to avoid assumptions that simply because two responders happen to be PIOs, they will necessarily "speak the same language."

Relational Embeddedness

The relative impact of relational embeddedness (Coleman 1988; Granovetter 1985; Putnam 2001) compared with institutional embeddedness (Dacin 1997; Johannisson, Ramiriez-Pasillas, and Karlsson 2002) provide a contrast that helps us better understand the influence of different aspects of social capital on outcomes. In our study, relational embeddedness arises as the factor with the greatest influence in shaping the communication network.

The disaster management literature has emphasized preincident relationship building as a key strategy in strengthening the capacity of responders to coordinate during an incident (Drabek and McEntire 2002, 2003; Gillespie and Streeter 1987). Our study provides quantitative support for the efficacy of this strategy and provides insight into the role of preincident relationships in shaping the structure of the communication network during an incident. Responders were significantly more likely to interact more frequently with those with whom they were more familiar even after controlling for similarities in role function and stakeholder group. Subsequently, by knowing something about relational embeddedness within the responder network before an incident occurs, we have a moderate indication of what the communication network will most likely look like during the incident. This suggests that efforts by emergency managers and other key stakeholders to establish working relationships among responders before an incident will increase

the likelihood that those responders will stay in communication with one another during an incident.

Furthermore, a proposition in the disaster literature is that relationship building before an incident will be important for increasing the level of trust and mutual understanding necessary for effective communication. Our study provides quantitative evidence that supports this assumption. Social ties that are established before an incident appear to decrease the risk for problematic communication during an incident.

Interaction of Institutional and Relational Embeddedness

The interaction of relational and institutional embeddedness revealed some of the most interesting findings. Cases where there is institutional embeddedness (similarities) but not relational embeddedness (familiarity) may create a worst case scenario. There are several theoretically plausible explanations for this finding. One potential explanation for this finding may rest with a halo effect conveyed by stakeholder affiliation. Specifically, unspoken assumptions may lead to false expectations about what is commonly understood. Consequently, responders may be less conscientious and intentional in practicing good communication under these conditions. A combination of embeddedness (Granovetter 1985) and weak ties theory (Burt 1992; Granovetter 1973) may also provide an explanation for these dynamics. When a preexisting relationship exists, communication interaction is more likely to be interpersonally rewarding and meaningful for sensemaking processes. In contrast, interactions with those in a different stakeholder group may be strategically valuable because they provide access to more novel information (Burt 1992). However, in situations of institutional embeddedness in which there is no pre-existing relationship, trust may not be conveyed through relational embeddedness (Granovetter 1985) *and* information may not be perceived as strategically beneficial (Burt 1992).

A last alternative explanation for problematic communication where responders share a common stakeholder affiliation but are not familiar with each other before the incident is that this finding is tapping into within group competition between these individuals. Competition could explain instances where we see common affiliations, for example, PIOs, but we do not see familiarity. Unfortunately, we did not address competition in our research, but this leaves the question open for future work.

The practical implication of this finding is that responders need to be aware of the potential communication challenges that may arise out of situations where there are similar stakeholder groups or similar functional groups that are not familiar with each other. Understanding the significance of the relationships between relational and institutional embeddedness in these situations can allow responders to mitigate their detrimental effects during the disaster.

Study Limitations

Interpretation of the findings from this study need to take several limitations into consideration. First, it is important to note that the relational embeddedness measure was based on retrospective self-report network data of preincident familiarity collected following the incident. Given the unique challenges associated with predicting the location of a disaster in advance to collect preincident data, a retrospective design

was reasonable. However, a limitation to this design is that participants' experience during the incident may color their perceptions of familiarity before the incident. Specifically, if someone acted in a manner that was inconsistent with the expectations of a responder during the incident, we would expect this would shift retrospective ratings of preincident familiarity downward (i.e., "perhaps I didn't know them as well as I thought I did"). This is because familiarity creates expectations for how people will behave. To the extent that behavior is consistent with our expectations, our perception of familiarity is likely enhanced. To the extent behavior is inconsistent, our perception of our familiarity may be reduced.

However, confidence in our findings is bolstered by the fact that the role of surprise can operate in either direction of the hypothesized relationship with communication efficacy. If a respondent's past experience with another led them to expect proactive cooperation and yet they perceived their interactions with this actor to have gone poorly during the incident, this could bias the coefficient toward a Type-1 error. Alternatively, if a respondent's past experience led a respondent to perceive another to be noncooperative and instead communications were surprisingly unproblematic, this would bias the coefficient the other direction toward a Type-2 error. Consequently, to the extent the directionality of surprise is not systematically oriented toward negative surprises, the threat of this effect to the validity of the findings is minimized. Descriptive analyses on communication efficacy suggest that although there was good distribution across the measure, ratings trended more toward positive rather than negative across incidents.

Second, this study utilized a sampling procedure that sought to control for variation *between* incident networks to better explain variation *within* incident networks. Although this strategy has significant advantages for investigating the hypothesized relationships, it also leaves many questions unanswered about how incident networks on the whole may differ from one another. Indeed, a key limitation of the literature on disaster management networks is that it tends to focus on case studies of one or a few incidents. This leaves questions unanswered about variation that exist across networks such as how incident complexity or differences in network governance may influence incident outcomes. Although there are obvious challenges associated with identifying large numbers of comparable incidents for statistical analysis, designs that assist in understanding variation across incidents is an important area for future research.

Last, this study focuses on disaster response networks in the context of wildfire. Wildfire is arguably unique from other disasters in that it is generally characterized by an extended period of wildfire management operations. This is contrasted to a disaster such as a hurricane in which the significant operational response period occurs after the event has past. During the time of active fire operations, all other incident response functions must coordinate their operation in reaction to the fire behavior, creating a highly dynamic situation. That said, this is not unlike what we have seen in other significant disasters where the initial incident led to cascading system failures that had to be responded to in a dynamic manner. Therefore, the findings from this study are likely most applicable to emergent networks of responders that are activated during an operational period of disaster response. However, the generalizability of the findings from this study to other disasters will need to be validated through future research.

CONCLUSIONS

In this study, we have sought to advance understanding of public networks and the study of disasters by empirically investigating the relative influence of relational and institutional embeddedness on the establishment and efficacy of communication network interactions in disaster response. The broader context was that responders within a network of actors need to communicate and coordinate effectively to make sense during a chaotic situation to manage a disaster (Comfort and Kapucu 2006; Weick et al. 2005). The unpredictable nature of a disaster means that a priori planning has limited value for sensemaking during a disaster (Drabek and McEntire 2003; Majchrzak et al. 2007). Given the limited empirical knowledge of the factors that explain variation in the presence and efficacy of interactions in these emergent networks (Drabek 2003; Drabek and McEntire 2002; McEntire 1998), the findings presented here help us better understand what communication dynamics to expect so that we may be better manage responder networks during complex disasters like wildfire.

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