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Cognition and communication: situational awareness and tie preservation in disrupted task environments

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Abstract

Individuals filling specialized, interdependent organizational roles achieve coordinated task execution through effective communication channels. Such channels enable regular access to information, opportunities, and assistance that may enhance one's understanding of the task environment. However, the time and effort devoted to maintaining those channels may detract from one's duties by turning attention away from the task environment. Disrupted task environments increase information requirements, thus creating a dilemma in which individuals must sustain benefits offered by important communication channels and relieve burdens imposed by ineffective channels. Using separable temporal exponential random graph models (STERGMs), this paper examines the relationship between situational awareness (SA) and the propensity to sustain or dissolve preexisting communication channels during 10 disruptive events experienced sequentially by a large, multifaceted military organization during a 2-week training exercise. Results provide limited evidence that increased SA detracts from tie preservation; instead SA begins to predict tie preservation during the second week of the exercise. Patterns of organizational adaptation reveal that, over time, improvised coordinative roles increasingly fall upon those with elevated SA. These results suggest that over successive disruptions, the benefits of information provided by communication channels within interdependent, role-specialized organizations begin to outweigh the costs of sustaining those channels.

Keywords: organizations; communication; network dynamics; disaster; situational awareness; adaptation

1. Introduction

Interpersonal communication channels often enable essential functionality in interdependent, task-oriented organizations. Coordinated information exchange among individuals helps organizations achieve efficient, harmonious completion of a coherent set of subtasks across many actors and assets in adherence to the larger goals of the organization (Galbraith, 1977). Indeed, interdependent, coordinated task execution often *compels* communication across specialized actors in order to facilitate the exchange of knowledge and information that ultimately improve task performance (Wegner, 1987; Wageman, 1995; Hollingshead, 1998; Staples & Webster, 2008). However, maintaining these communication ties typically requires persistent effort and upkeep (Ahuja, 2000; Cummings et al., 2006; Dunbar, 2004). Humans have finite time and effort to contribute to engaging in social interaction and sustaining relationships (de Sola Pool & Kochen, 1978; Milardo et al., 1983), and these limitations fundamentally constrain the structure of organizations (Simon, 1957). When individuals try to sustain too many communication partnerships, they experience "network overload" (Steier & Greenwood, 2000), during which the constraints imposed by interpersonal ties become overwhelming. Network overload is distinct from the concept of information overload in that the quantity of information traveling across those ties is not overwhelming; instead, the effort required to sustain those ties becomes overwhelming. The costs of sustaining these ties may be at odds with one's ability to maintain a strong grasp of one's task environment, but sustaining such ties may preserve access to vital information and resources (Aldrich & Whetten, 1981; Granovetter, 1973; McEvily & Zaheer, 1999). In addition to knowing where to access knowledge in the network, those with elevated knowledge about the task environment may be particularly attractive targets for sustained communication (Contractor & Monge, 2002; Carley & Hill, 2001). Examining how one's understanding of the task environment co-evolves with one's communication channels provides insight into the processes driving adaptation of organizational communication networks in disrupted contexts. This paper examines the relationship between situational awareness (SA)—a basic understanding of one's organizational tasks and the environment in which those tasks are completed—and one's tendency to sustain or dissolve communication channels in disrupted and cognitively demanding task environments.

To capture processes driving network adaptation, we focus on the novel and demanding task environments induced by disruption. In this paper, we use the term disruption to refer to sudden, unexpected changes to the organization's routines and/or task environment, often entailing some degree of uncertainty and compelling a hasty response (Dynes, 1970; Auf der Heide, 1989). These types of novel, uncertain, and challenging task environments increase the amount of information individuals must process in order to sustain typical levels of task execution (Maitlis & Christianson, 2014; Galbraith, 1977; Cohen & Bacdayan, 1994). This produces a dilemma for members of organizations: the elevated demands of operating in such environments necessarily constrain the time and effort available for supporting one's preexisting communication ties. However, sustaining these outbound ties provides potential access to information and resources that may be particularly valuable in these disrupted task environments. Disrupted settings therefore force the individual to balance this conflict between the benefits and costs of sustaining communication channels. A disrupted task environment may then compel individuals to modify their existing networks in order to maintain satisfactory SA in such a demanding setting. Indeed, such task environments often catalyze organizational adaptation (Carley, 1992; Galbraith, 1977; Dynes, 1970).

To investigate the dilemma of balancing the costs imposed by sustaining ties against the knowledge benefits offered by those ties, we examine tie dynamics in a series of disrupted contexts. Although the conditions giving rise to adaptation are well understood, social networks scholars note that tie dynamics in organizations remain understudied (Dahlander & McFarland, 2013; Burt, 2002; Sasovova et al., 2010; Leenders et al., 2016). Furthermore, our understanding of organizational behavior *during* disruption is limited, in part due to the challenges of observing social phenomena in those contexts (Scanlon, 2007; Denrell, 2003). As such, we tend to know little about how organizations adapt to a disrupted task environment, and we know even less about how adaptation itself may change over a series of disruptive events as members of the organization become increasingly familiar with how to adapt to such environments. This paper aims to fill those gaps by examining organizational communication dynamics through comparison of the communication network during disruption to a baseline representation of that communication network. A dynamic analysis is key here, as we are fundamentally concerned with how individuals modify their *preexisting* communication channels in the immediate aftermath of a disruptive event. We examine how individuals change their networks as a function of their understanding of their task environment, and whether they choose to sustain ties to nodes who have a strong understanding of the task environment. By confronting individuals with demanding task environments, disruption provides an ideal context for identifying the determinants of tie preservation and dissolution. Through a novel framework in which we capture organizational behavior before and after disruption over a *series* of disruptive events, we aim to provide meaningful insight into adaptive behavior within organizations in a context typically plagued by challenges to collecting data.

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2. Constraints and advantages of interpersonal ties

Limits on the size of interpersonal networks appear to be a universal feature of human social networks. Patterns of differentiation across individual network sizes suggest cognitive constraints on the number of alters individuals can typically sustain (Hill & Dunbar, 2003; Roberts et al., 2009). These constraints may have a neurological basis, as in both human and nonhuman primates neocortex size predicts typical network size (Kudo & Dunbar, 2001; Dunbar, 1998, 1992; Zhou et al., 2005). Intensity of the relationship appears to moderate the number of ties a typical individual can sustain. For example, Roberts et al. (2009) find that average emotional intensity is negatively associated with the size of active ego networks. That is, stronger, more intense relationships demand more effort, which reduces resources available to support other ties. This is particularly important in organizational contexts, where tacit, non-codified knowledge more easily traverses these types of stronger, more demanding ties (Hansen, 1999; Reagans & McEvily, 2003). Because such ties require greater effort to form and sustain, they may detract from one's ability to develop an abundance of low-effort ties.

One of the primary cognitive challenges of maintaining large number of social contacts is remembering and updating personal details that help to strengthen and reinforce these ties, such as organizationally relevant details of an alter's ongoing projects and responsibilities as well as nonwork-related details such as one's family life and hobbies (Whittaker et al., 2002). The cognitive demands of organizing and managing interpersonal ties limit the total number of ties humans can sustain. To address these limitations, many individuals find it necessary to engage in cognitive management of their relationships through information fashioning (Donath, 2007) or with tools such as the Rolodex and its modern counterparts such as contact lists in email clients and mobile phones (Whittaker et al., 2002). Without effectively managing the burden of these ties, network overload becomes likely (Oldroyd & Morris, 2012). This challenge is particularly salient in organizational environments, where some degree of connectivity is necessary to support coordinated task execution.

Although sustaining communication channels imposes costs, such channels support essential functionality in role-specialized organizations. Communication channels allow individuals to synchronize task execution and access valuable information and resources. In organizations with specialized, interdependent roles, individuals enhance task performance through routinization (Cohen & Bacdayan, 1994; Tuchman, 1973). However, this interdependent task execution incurs coordination costs, which individuals satisfy through communication with fellow members of the organization (Galbraith, 1977; Hage et al., 1971; Brusoni et al., 2001). By filling specialized roles and using coordination to achieve synchronized execution of decomposable tasks, individuals contribute to organizational efficiency. In addition to enhancing productivity through coordination of interdependent tasks, communication ties within organizations deliver benefits to individuals by providing access to information and resources (Granovetter, 1973; Burt, 1992). By increasing their tie volumes, individuals tend to gain increased exposure to new opportunities, information, and ideas (McEvily & Zaheer, 1999). Weak and boundary-spanning ties are particularly valuable resources for exposure to novel information (Cross & Cummings, 2004; Reagans & McEvily, 2003). Preserving access to potentially useful information is particularly important in contexts where rapid communication is essential for the organization to achieve its goals. Indeed, the benefit of using communication to access knowledge stores within a network underlies the transactive memory system literature.

Transactive memory systems may arise in groups where knowledge or information resides in different locations. In groups where individuals fill specialized roles and execute interdependent tasks, communication becomes necessary for specialized knowledge to proliferate through the group (Wegner, 1987). Communication channels serve as catalysts for taking advantage of knowledge stores within the transactive memory system (Yuan et al., 2010). Some evidence shows that individuals working interdependently develop increased preferences for cooperation (Wageman,

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1995). Even when trust within the group is low, interdependence contributes to increased sharing of knowledge (Staples & Webster, 2008). Knowledge sharing does not appear to be reliant on a single instance of communication, but on sustained communication. Hollingshead (1998) finds that communication over multiple time points improved performance during an interdependent task by helping to reinforce roles and provide increased accessibility to strategies that underlie interdependent cooperation. As discussed previously, however, sustained communication channels may be costly to sustain. These costs increase for communication channels that exchange tacit and difficult-to-codify information that resides within individuals rather than an information database (Yuan et al., 2010). While communication channels provide access to information and may signal that a particular individual knows where to locate specialized information within a transactive memory system, the costs of sustaining those ties return us to the dilemma motivating this paper: whether knowledgeable individuals in disrupted task environments tend to utilize the benefits of ties or eliminate the constraints imposed by those ties.

Because interdependent role specialization within organizations compels information exchange, organizational contexts confront individuals with unique trade-offs for maintaining larger or smaller numbers of communication channels. While communication ties enhance organizational performance and bring valuable resources to individuals, the costs of sustaining these ties may exceed the benefits gained. The aforementioned limits on interpersonal networks constrain the number of communication partners any given individual can support and thus limit the scope of coordination within the organization. For this reason, we do not find successful organizations in which one individual is responsible for managing and coordinating the behavior of thousands of others. This challenge of optimizing communication networks to enhance performance illustrates a long-standing topic of inquiry uniting the fields of network analysis and organizational behavior (Bavelas, 1950; Carley, 1992; Cross & Cummings, 2004; Enemark et al., 2011; Galbraith, 1977; Morgan, 1986; Crawford & Lepine, 2013). Maintaining organizational ties typically requires regular communication—telephone calls, emails, visits, meetings—that can limit one's time and attention available to devote to other day-to-day duties (Boorman, 1975; Degenne & Lebeaux, 2005; Markovsky & Chaffee, 1995). As such, maintaining large numbers of ties may impede task execution or limit one's knowledge and understanding of the task environment. Morrison (2002) finds that network size moderates trade-offs between role expertise and organizational knowledge; those with fewer ties tended to have greater task mastery and lower knowledge about general matters at the organization level, while those with more ties better understood general organizational issues at the expense of their own role expertise. To limit the demands imposed by these ties and avoid succumbing to network overload (Steier & Greenwood, 2000; Elfring & Hulsink, 2007; Oldroyd & Morris, 2012), individuals often engage in strategies to trim their contacts to a manageable number (Whittaker et al., 2002). However, excessive tie reduction will jeopardize the connectivity necessary for preserving organizational functionality and limit the individual's access to potentially valuable information and resources. As such, members of organizations often face a dilemma where they must balance the costs and benefits of ties. Disrupted task environments exacerbate this dilemma.

2.1 The impact of disruption

Individuals periodically encounter task environments that demand increased communication to ensure organizational functionality. This paper uses a series of such environments as contexts for examining adaptive behaviors within the organization. Specifically, we focus on short-term disruption to a task environment. Suddenly confronting individuals with novel tasks in a tumultuous, uncertain task environment, disruption is an ideal context for observing adaptation within the organization. Novel and unfamiliar task environments impede performance by increasing the amount of information that individuals must process to enable task execution, as individuals must gather a sufficient amount of information to determine the best course of action in a situation that is difficult to comprehend (Cohen & Bacdayan, 1994; Galbraith, 1977; Maitlis & Christianson, 2014). By constraining an individual's abilities to pick up contextual cues, cognitive narrowing enhances the challenge of identifying important, task-related information (Weick, 1990). In disrupted contexts, increased flows of information threaten coordinative processes by enhancing the likelihood that information will reach a bottleneck at a given individual, thus stymieing interdependent task execution (Galbraith, 1977). These increased information requirements and elevated communication loads exacerbate individuals' cognitive constraints on network size. Staying abreast of alters' needs in an unpredictable environment and increased volumes of information individuals must process and transmit to others ultimately limit the amount of effort one can devote to supporting nonessential communication channels. These elevated cognitive burdens enhance the likelihood that individuals will become overwhelmed and engage in local network adaptation, a common response to disrupted task environments as individuals discard traditional roles and procedures as necessary in order to address the demands of their new task environment (Dynes, 1970; Carley, 1992; Butts et al., 2012; Comfort, 2007). Additionally, such environments frequently induce *sense breaking* in individuals (Maitlis & Christianson, 2014), in which individuals challenge their assumptions about the way the world (or, at least, their organization) works. These types of rare, disruptive events spur critical reflection on how to adapt in order to mitigate the effects of this disrupted task environment (Maitlis & Christianson, 2014). These environmentally induced processes further increase the likelihood of observing adaptive behaviors within the organization during a disrupted task environment. With the increased attention and effort required to understand and interpret a novel, disruptive task environment, individuals may have less capacity to support communication ties at the same time that these communication ties become vital for providing information in an uncertain task environment. Because these settings catalyze organizational adaptation, they tend to be ideal contexts for observing adaptive behaviors.

While disrupted task environments create optimal settings for observing organizational adaptation, they pose many unique and often insurmountable challenges for collecting data. The difficulty of forecasting disruption experienced in real-world environments constrains our ability to observe social phenomena over the course of disruption: from initial response to adaptation to recovery (Scanlon, 2007). Contexts such as rapid-onset natural disasters and mass casualty events are often difficult to predict with enough lead time to observe behavior in an organization before disruption begins. As such, assessments of adaptive responses to disruption typically come from post hoc analyses. Due to the difficulties collecting data from organizations that perish during these circumstances, we tend to know more about the behavior of organizations that successfully adapt rather than those whose adaptations may have contributed to their demise (Denrell, 2003). Fully understanding organizational adaptation is particularly difficult when a post hoc framework prevents us from establishing a baseline measure of the organization's typical operation (ideally, before the period of disruption). In this paper, we address these two distinct but related challenges by observing members of an organization operating in its usual domain of operations during a training environment spanning nearly 2 weeks. Continuous observation of the organization affords us the opportunity to observe behaviors before and during disruption. This gives us a baseline measure of behavior (the communication network prior to disruption) against which we can compare behavior during a disrupted task environment (communication in the immediate aftermath of disruption). Furthermore, the training exercise featured multiple disruptive events, none of which were known in advance by participants, which allow us to make repeated observations of the organizational members' responses to disruption. Beyond allowing us to compare communication structure during disrupted and typical task environments, this framework allows us to examine how adaptive behaviors themselves may change over time as members of the organization learn how best to respond to disruptive events. Rare, disruptive events allow members of organizations to familiarize themselves with what they can and cannot accomplish (Christianson et al., 2009), and increased familiarity with their capabilities may compel individuals to modify their adaptive behaviors over time. We harness this opportunity to measure multiple iterations of organizational adaptation to disruption in order to determine if organizational members appear to learn from or adapt past behavior. This novel framework gives us a unique opportunity to make multiple, comprehensive observations of an elusive organizational process.

3. Evaluating predictors of tie dissolution

In this paper, we assess two distinct phenomena associated with communication: (1) the relationship between SA and one's propensity to sustain or dissolve outbound ties and (2) the propensity for individuals to sustain or dissolve ties to those with elevated SA. We distinguish between in-tie and out-tie effects to capture, respectively, the effects of SA on one's attractiveness as a communication partner and how SA may shape one's decision to sustain or dissolve communication channels. In this paper, we utilize the traditional Level 1 definition of SA, which captures an individual's "perception of the elements of the environment within a volume of time and space" (Endsley, 1988*a*, p. 97). Maintaining SA in our case study requires careful attention to a variety of features of one's task environment; we further discuss measuring SA in the next section of this paper. The effort required to sustain elevated SA may be at odds with the effort required to maintain outbound communication ties. Disrupted settings increase information requirements for routine tasks (Maitlis & Christianson, 2014; Galbraith, 1977), and attaining a strong grasp of task-relevant information may be at odds with one's ability to support existing communication channels (Morrison, 2002). Reflecting this conflict between devoting effort toward sustaining ties and toward vigilantly observing one's task environment, Hypothesis 1(a) anticipates that elevated SA will be associated with tie dissolution. Likewise, those with lower SA and, as such, less effort expended on understanding their task environments will be less likely to dissolve their costly outbound ties.

Conversely, an alternative hypothesis posits that individuals will preferentially retain the benefits associated with communication ties in role-specialized organizations. Alternative Hypothesis 1(b) predicts that individuals with higher SA will be more likely to sustain their ties in order to take advantage of potential knowledge from their alters. Developing strong, sustained communication ties becomes essential to identify and take advantage of knowledge stores in a network (Yuan et al., 2010). As an organization increasingly relies on interdependent tasks and specialized roles, this expertise exchange becomes increasingly necessary (Wageman, 1995). Maintaining the benefits of this expertise exchange requires sustained communication (Hollingshead, 1998), therefore individuals taking advantage of a specialized knowledge and expertise in an organization ought to have an increased likelihood of sustaining communication channels, particularly in light of the increased information requirements demanded by a disrupted task environment (Maitlis & Christianson, 2014; Galbraith, 1977).

Hypothesis 1(a): The cost of maintaining higher SA is a detriment to one's ability to support ties, therefore individuals with higher SA will be more likely to dissolve their out-ties

Hypothesis 1(b): Higher SA gives individuals an opportunity to spread important information and/or demonstrates that an individual knows where to find important information in the network, thus individuals with elevated SA will be more likely to sustain their out-ties

While the first pair of hypotheses examines how SA shapes one's propensity to sustain communication channels, the second hypothesis focuses on whether individuals selectively sustain ties to alters with elevated SA. In networks where specialized knowledge resides in specific nodes, individuals tend to form and/or sustain communication ties to those with elevated levels of knowledge (or *perceived* levels of knowledge) (Contractor & Monge, 2002). When individuals have access to others' specialized knowledge, they are better able to utilize it to improve coordination within the organization (Liang et al., 1995). This coordinated exchange of information helps individuals to utilize their specialized information to help solve problems (Borgatti & Cross, 2003; Cross & Cummings, 2004; Carley & Hill, 2001). In groups large enough that individuals cannot conceivably have accurate, up-to-date information on everyone else's knowledge, we may expect that individuals instead evaluate what their direct contacts know and utilize those communication channels accordingly. This occurs in organizational settings where individuals sustain ties to generally knowledgeable alters in order to utilize them to solve future, yet-to-be-determined problems (Steier & Greenwood, 2000; Mariotti & Delbridge, 2012). Hypothesis 2 follows that intuition by proposing that individuals will preferentially sustain ties to individuals with higher levels of SA. To the extent that uncertain, rapidly changing task environments compel individuals to sustain ties to those who consistently have an elevated understanding of their task environment, we ought to observe positive in-tie effects for SA.

Hypothesis 2: Individuals with higher levels of SA will be more attractive targets for sustained communication channels

We utilize an analytic approach that measures organizational dynamics by examining how a communication network evolves from a baseline configuration to its configuration during a disrupted task environment. As we mentioned previously, this baseline measure of behavior is often infeasible to collect prior to the onset of a disrupted context (Scanlon, 2007; Denrell, 2003). Capturing observations of a network before and during a period of disruption will provide insight into adaptive processes within the organization. Disruption serves as a "shock" to the social system and we analyze individuals' adaptive responses to that shock. We believe this baseline adaptation approach is particularly useful for assessing our hypotheses. Observing adaptation from baseline allows us to distinguish, for example, between a node that sustains all 5 of its outbound ties during the disruptive period and a node that sustains 5 outbound ties but dissolved 15 of its baseline ties. During the disruption period, these two may appear similar because they both have an outdegree of five, but they have taken drastically different actions: the former sustained all of its ties while the latter dissolved most of its ties. Without accounting for that baseline network, we may incorrectly assume that both nodes acted similarly during disruption. By capturing network evolution over two time points, this baseline-adaptation approach allows us to capture more accurately individuals' out-tie behavior during the period of disruption. Utilizing a baseline network also comports well with our second hypothesis because the motivating theory is predicated on a node's perception of another's SA. Individuals' perceptions of others' attributes tend to be more accurate when they have a preexisting relationship (Kenny & Albright, 1987; Borkenau & Liebler, 1993). As such, observing *persistence* of ties to nodes as a function of the target's SA ought to offer greater validity than examining in-tie SA effects in a static environment because established communication partners will have a better opportunity to evaluate their partners' aptitude.

These types of dynamic analyses offer novel insight into organizational behavior. Time is a powerful dimension along which to measure organizational phenomena (Ancona et al., 2001), and scholars have increasingly recognized the importance of studying tie dynamics in organizational contexts (Dahlander & McFarland, 2013; Burt, 2002; Sasovova et al., 2010; Leenders et al., 2016; Cronin et al., 2011). A dynamic approach enables us to examine tie persistence and dissolution, which differ fundamentally from tie formation (McPherson et al., 2001; Dahlander & McFarland, 2013; Mariotti & Delbridge, 2012). These types of dynamic network analyses are increasingly feasible thanks to recent methodological advances (Brandes et al., 2009; Butts, 2008; Snijders, 2001; Rivera et al., 2010; Krivitsky & Handcock, 2014). As such, this paper is well situated to advance the field's understanding of tie dynamics in disrupted organizational contexts.

3.1 Data

This paper utilizes data from a large, multifaceted organization that responds to several disruptive scenarios over 10 days spanning the course of 2 weeks. This organization was convened for a 2-week joint military training exercise and experiment designed to detect and assess cognitive processes and information requirements during full-scale operations. Active-duty Soldiers and Officers primarily staffed the observed organization by filling their traditional military roles, although some civilians (retired military) also participated. In total, 87 individuals composed the organization. With an average of over 13 years of military experience, seasoned individuals staffed this organization. This organization functioned as a set of distributed units that filled interdependent, differentiated roles in the mission command domain (i.e., high-level staff roles within the military). These units were organized around nine functional cells, each focused on a specific domain of operations. For example, the "sustainment" cell ensures that support and services are available for the organization to sustain current operations, while the "maneuver" cell mobilizes resources to support the organization's current operations. Other cells include command, fires, intelligence, liaison, protection, signal, and civil affairs. Collectively, members of this organization were responsible for assigning, coordinating, and ensuring task execution for up to 5,000 ground units. To support those obligations, members of our observed organization were largely tasked with gathering, disseminating, and acting on information gleaned from the operational task environment. As such, communication and attention paid to the task environment were essential for the organization to complete its objectives over the course of the exercise.

The setting for organizational operations was a large, urban environment whose population is approximately 550,000. Participants in the training exercise sat in an array of control rooms where each of the 87 participants used a computer workstation to communicate with participants and obtain updates on the mission. This closely resembles the setting that Mission Command personnel work in during real operations. In addition to information provided by their workstations, participants also observed information feeds projected on the walls of their control rooms; these provided spatial information about the locations and activities of their ground units. Because the number of ground units under this organization was as large as 5,000, these ground units were represented by simulated actors in a virtual world. Tactical outcomes of scenario events were simulated in a live, constructive simulation in a program called OneSAF. Within this simulation, remote, virtual actors received and responded to orders issued by members of our organization under study, as they would during a real exercise. To ensure familiarity with their simulation and information systems utilized during the exercise, participants spent the week prior to the training exercise undergoing training to acquaint themselves with these systems and to reiterate the roles and functions of the staff.

The organization's primary goals over the course of this training exercise were to disrupt the local activities of a large, international terrorist group and to ensure that an upcoming local election takes place in a fair and open environment, free from undue influence. In this scenario, a terrorist organization had been trying to discredit and cast doubt on the legitimacy of the local government prior to the start of the exercise. To support the achievement of its larger goals over the length of the exercise, the military organization needed to plan and complete several subtasks, including assessing levels of anti-coalition and anti-government sentiment, identifying key leaders who favor or oppose U.S. presence, rooting out local insurgents in and around the urban area, and locating and destroying the terrorist organization's weapons caches.

The largely digital setting of the training exercise enabled continuous collection of participants' email communication, including sender, receiver, and timestamp of the message. Email was a particularly important communication medium for these participants, as orders were often disseminated in writing, even during high-tempo operations. Over the course of this exercise, 87 individuals sent over 6,000 emails; because some emails had multiple recipients, this represents a total of approximately 20,000 directed communication acts. When surveyed about communication media during a survey, participants indicated that they preferred email communication, in part due to the physical constraints of the multiroom layout. They further indicated that they expected email to be their most common communication medium and a highly rated source for gathering information, communicating instructions, and receiving urgent communication. As such, this email communication network provides a valid representation of intraorganizational communication.

Over the course of the exercise, participants monitored and responded to hundreds of events, including, for example, search and rescue of military and nonmilitary personnel, reports of infrastructure damage, mass casualty incidents, and reports of smuggling activities. Many of these events were routine and minimally disruptive, such as media interviews, supply distribution, land surveys, conflict mediation, and provision of assistance to locals. Although the timing of these events was known in advance to the researchers and personnel administering the training exercise, participants were unaware of the event timeline. Prior to the start of the exercise, each of the scheduled events was given a score ranging from 1 to 4 for its importance and immediacy. Events with lower scores were less important and required less timely action, while events with higher scores required an immediate and, often, organization-wide commitment to address. Scores of 4 in either category were rare, with only only 7.1% garnering that rating for importance and 9.7% earning that rating for immediacy. This paper examines organizational adaptation in response to events given the highest ratings for importance *and* immediacy; these 10 events encompass a variety of disruptive scenarios. Although 11 events had ratings of 4 for both importance and immediacy, this paper examines organizational adaptation to the first 10 disruptive events. A network outage, deliberately scheduled as part of the experiment, quickly followed the eleventh (and final, chronologically) event and subsequently curtailed email communication. Furthermore, that event—a visit from a high-profile political leader—did not entail the same type of disruption that occurs following more traditional crisis events such as a mass casualty event or downed aircraft. Having identified a set of disruption-inducing task environments, we now turn our attention to defining our baseline and adaptation networks during these periods of interest.

3.2 Measuring organizational adaptation

Utilizing an email network provides an opportunity to gain unique insight into behavior dynamics within an organization. Email is an asynchronous, asymmetric communication medium that has some unique implications for analysis of in-ties and out-ties. In many communication media such as face-to-face communication and telephone communication, the costs for sending and receiving ties are roughly equivalent. In email, however, the costs of sending communication ties are typically higher than the costs of receiving communication ties. One must actively compose messages to form (and sustain) outbound ties, but incoming ties may be passively accepted. In fact, one may skim an incoming email or ignore it altogether and still be the recipient of that tie. Accordingly, pressures toward dissolution will primarily fall upon the more costly outbound ties. As outgoing ties require active effort, the ties one chooses to utilize provide insight into the strategies used for preserving or dissolving communication ties. We use out-tie preservation and dissolution as behavioral indicators of which specific ties individuals find to be valuable or expendable, given the enhanced costs of communication channels during disruption. Covariate effects on outbound ties allow us to probe the determinants of an individual's propensity to sustain or dissolve ties. By linking individual attributes to behavioral dynamics, we can identify which types of individuals tend to be more likely to sustain or dissolve outbound communication channels. Incoming ties highlight a separate social phenomenon. Those who receive larger volumes of in-ties from others within the organization appear to be more attractive sources of communication, perhaps because they have specialized knowledge or skills that their alters may want to utilize. Examining the effects of individual covariates on the propensity to sustain inbound ties allows us to determine which attributes make nodes more or less attractive as communication partners. The idiosyncrasies of email allow us to capture distinct phenomena with outgoing ties and incoming ties and thus provide deep insight into adaptive organizational behavior (Fitzhugh & DeCostanza, 2017).

Utilizing a longitudinal email communication network, we now briefly define how we measure tie persistence and tie dissolution in this network. Examining rapid, short-term organizational adaptation during disruption, this paper is principally focused on two time-aggregated snapshots of that network: its baseline configuration before the disruptive event of interest and the network configuration in the immediate aftermath of disruption. We use the evolution of the network from baseline to disruption to characterize tie persistence and dissolution. We define tie persistence as the utilization of a communication channel from i to j during the disruption period, after i has *already* established a communication channel to j by sending at least one message to j during the baseline period. The tie from i to j dissolves if i fails to send a message to j during the period of disruption after establishing the communication channel by sending at least one message to j during the baseline period, even if j sends a message to i during the disruption period or if i later sends a message to j after the disruption period has ended. This framework allows us to capture organizational evolution following a sudden disruption to the organization's task environment.

To characterize the baseline communication network and the communication network during the disrupted task environment, we utilized the timing information embedded in the emails. The disruption period of time represents the immediate aftermath of the event as the organization undertakes a variety of tasks to resolve the disrupted situation. We define this period as the 2 hours following the disruptive event, which captures rapid, short-term adaptation in response to an immediate, time-sensitive event. The goal of our analyses is to determine which ties individuals decide to sustain and which they decide to dissolve. A fundamental aspect of this decision is a consideration of the benefits and costs for each of those established ties. As such, our baseline networks capture the set of ties whose preexistence has given individuals the opportunity to evaluate their efficacy. Each baseline network includes *all* email communication ties from the *current* week until the moment the crisis event begins. The baseline network for an event occurring midday on the fifth day, for example, would include all communication over the first 4 days and on the fifth day until the event begins. Although we consider one message from i to j to be sufficient to establish a directed communication channel from i to j during the baseline network, later in the paper we demonstrate robustness tests that evaluate higher thresholds of message volumes needed to establish a baseline tie from i to j. Baseline networks only cover the week during which the disruptive event occurred, such that events during week 2 do not count week 1 ties as preexisting ties. This distinction recognizes that week 2 takes place within a different time frame in the operational environment. This change in time frame may cause ties established during week 1 to have a greater propensity to be dissolved. In practice, however, the networks spanning each of the 2 weeks show considerable overlap and structural similarity, likely due to the fact that the organization was completing tasks within the same domains of operations as they were in the prior week and therefore relied on many of the same communication channels. As disruptive events accumulate over time, they necessarily become included in subsequent baseline networks, as the baseline includes *all* prior communication during the given week. For example, the second baseline network includes all communication up to the moment the second disruptive event begins, including the communication network before, during, and after the first period of disruption. As individuals evaluate which communication channels to utilize and which to dissolve, all past communication channels—during stable or disrupted task environments—ought to be evaluated. Our baseline framework captures ties consistent with that notion.

Ten disruptive events occur during the 2-week period spanning the training exercise, with six events occurring during week 1 (days 1–5) and four occurring during week 2 (days 6–10). Days 3, 5, and 9 each have multiple disruptive events, while days 2, 6, and 10 have no such events. Table 1 provides a brief description of each event: most are attacks (both successful and unsuccessful), mass casualty events, and reports of disabled vehicles that must be recovered along with any accompanying cargo and passengers before opposing forces encroach on the crash site. In addition

Table 1. Descriptions of disruptive events

Day	Event description	Baseline ties	Ties dissolved	Ties sustained	New ties formed	Total communication acts
1	Suicide attack on forward operating base	87	60	27	49	181
3	Downed unmanned aerial vehicle (UAV)	553	357	196	126	1,069
3	Surface-to-air missile attack	681	461	220	66	931
4	Downed UAV aircraft		862	114	31	479
5	Suicide bombing on Tactical Air Command (TAC)	992	959	33	19	156
5	Downed UN Helicopter	1,007	981	26	5	111
7	Mortar attack on forward operating base	800	634	166	40	536
8	UAV crash	862	714	148	30	497
9	Helicopter crash	918	744	174	29	672
9	Attacks on forward operating base and polling site	931	728	203	29	738

to describing the events, we highlight the total numbers of ties sustained, dissolved, and formed during the disrupted task environment. The number of ties sustained during the disruption period exceeds the number of newly formed ties in all events but the first (primarily due to the limited time available for individuals to establish baseline ties prior to the first event). In all but the first event over 60% of ties utilized during the disruption period are preexisting ties; in seven events this number climbs above 75%. This demonstrates that many of the communication channels utilized during disruption reflect previously established communication partnerships. Newly formed ties do not appear at random, as most of them originate from a small number of individuals who also happen to sustain relatively large numbers of ties. Finally, we include the total number of communication acts (i.e., an email sent to three people represents communication acts to three different people) sent during each of the disruptive events. While the number of emails varies substantially from event to event, the volume of emails is nearly perfectly correlated with the number of ties in the network ($r = 0.983$). The average number of emails sent along each tie ranges from 2.38 to 3.58, although that average is only slightly correlated with the total number of ties in the network ($r = 0.179$). The diverse array of disruptive events and varied volume of communication that follows suggests that we ought to observe a broad range of adaptive behavior.

Effectively reacting to these types of crisis events entails a multilateral, coordinated response from several elements within the organization. The organization establishes standard operating procedure (SOP) for dozens of specific incidents, including the types of disruptive events in Table 1. The SOP handbook outlines the series of tasks, collectively referred to as a battle drill, involved with responding to one of these incidents and indicates which individuals and/or functional cells should carry out these various tasks. Successfully conducting a battle drill requires coordinated execution of interdependent tasks among many elements within the organization. We illustrate an example of this process by highlighting several of the key tasks involved in recovering a downed aircraft. Once members in formal coordinative roles receive information about a downed aircraft, they alert the organization to begin the battle drill. This initiates several simultaneous tasks executed by various functional cells: the intel functional cell collects information about the crash site and surrounding areas; the liaison cell alerts nearby units of the ongoing situation and verifies positioning of units adjacent to the focal area; the fires cell determines the

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availability of assets within range and establishes a friendly zone; and the sustainment cell reports losses and casualties to the maneuver cell. Throughout this process, various functional cells must coordinate, disseminate, and consolidate information, as necessary, to enable them to complete their tasks. And the scope of tasks may expand if response entails additional battle drills, such as medical evacuation of casualties, reaction to an air attack, troops in contact, or any other subsequent events that may follow from the initial battle drill. These types of nested battle drills entail even more coordinated task execution within the organization. Frequently, the types of disruptive events examined in this paper spur these multiple, nested battle drills. While the tasks involved in the battle drill may be familiar to individuals in the organization, the sudden and often unexpected onset of the types of events we examine in this paper typically entails organizational disruption.

In Table 2, we illustrate several descriptive statistics for each of our baseline and disruption networks. Every disruption network includes fewer ties than its baseline, in part because the baseline time period is often much longer than the disruption time period. Across multiple descriptive statistics baseline networks appear to be more similar to other baseline networks than they are to disruption networks. Disruption networks typically have lower edgewise reciprocity and centralization than their baseline counterparts, but triadic closure remains quite similar between the two. Centralization and reciprocity vary substantially across disruption events, which suggests that no single configuration is adequate for all communication networks in disrupted task environments, even when tasks accomplished within those task environments are similar.

We illustrate in Figure 1 two examples of how these networks transform in the aftermath of disruption. Although the structure of the disruption networks varies, we frequently observe that a handful of nodes sustain a large number of ties and form the hubs in these hub-dominated networks.

3.3 Assessing the hypotheses

Recent advances to the exponential-family random graph model (ERGM) enable the modeling of tie preservation and dissolution over time. This paper utilizes separable temporal ERGMS, or STERGMs, to model these networks before and during disruptive events. STERGMs model network evolution in discrete time (Krivitsky & Handcock, 2014) and their key innovation is the separable parameterization producing two joint models: one for tie persistence and one for tie formation. The framework operates on the assumption that those processes will occur independently within a time step; that is, tie formation from time t to time $t+1$ does not affect tie preservation/dissolution during that same time period. Occurring independently, the formation and persistence processes are modeled as two separate ERGMs. Equation (1) represents the tie persistence model.

$$ln\frac{P(Y_{ij,t+1}=1|y^c_{ij}, Y_{ij,t}=1)}{P(Y_{ij,t+1}=0|y^c_{ij}, Y_{ij,t}=1)}=\theta^-\delta(g^-(y))_{ij} \tag{1}$$

The persistence model evaluates the log-odds of a tie between i and j at time point $t+1$ given all other ties at the previous time point t *and* given that i and j *already have a tie* at time t. These log-odds are a function of a vector of coefficients θ^- on a set of statistics $g^-(y)_{ij}$ for the actor pair i, j. Positing the probability of a tie where one had already existed, this framework models tie persistence. It also necessarily models tie dissolution because $Pr(dissolution) = 1 - Pr(persistence)$. In this persistence model, positive coefficients indicate a propensity for tie preservation while negative coefficients indicate a propensity for tie dissolution.

Because the STERGM framework captures network evolution across discrete time points, it serves as an ideal application for our framework examining adaptation of our baseline network during disruption. Our hypotheses are predicated on the notion that individuals will selectively

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Table 2. Descriptive statistics for pre- and post-disruption networks

Event	Timing	Nodes	Edges	Density	Mean degree	Edgewise reciprocity	Triadic closure	Degree centralization	Betweenness centralization
1	Baseline	87	87	0.011	2.000	0.207	0.227	0.131	0.014
	disruption	87	76	0.010	1.747	0.263	0.281	0.073	0.008
2	Baseline	87	553	0.074	12.713	0.488	0.347	0.258	0.133
	disruption	87	87	0.043	7.402	0.435	0.423	0.158	0.056
3	Baseline	87	681	0.091	15.655	0.540	0.420	0.276	0.109
	disruption	87	286	0.038	6.574	0.301	0.419	0.235	0.068
4	Baseline	87	976	0.130	22.437	0.551	0.495	0.396	0.115
	disruption	87	145	0.019	3.333	0.359	0.380	0.105	0.096
5	Baseline	87	992	0.133	22.805	0.560	0.497	0.400	0.109
	disruption	87	53	0.007	1.218	0.075	0.241	0.094	0.001
6	Baseline	87	1,007	0.135	23.149	0.558	0.494	0.398	0.114
	disruption	87	31	0.004	0.713	0.065	0.208	0.037	0.001

Table 2. Continued

Event	Timing	Nodes	Edges	Density	Mean degree	Edgewise reciprocity	Triadic closure	Degree centralization	Betweenness centralization
7	Baseline	87	800	0.107	18.391	0.530	0.452	0.355	0.128
	disruption	87	206	0.028	4.736	0.301	0.386	0.222	0.073
8	Baseline	87	862	0.115	19.816	0.543	0.447	0.358	0.124
	disruption	87	178	0.024	4.092	0.438	0.393	0.166	0.080
9	Baseline	87	918	0.123	21.103	0.569	0.446	0.386	0.122
	disruption	87	203	0.027	4.667	0.335	0.335	0.246	0.142
10	Baseline	87	931	0.124	21.402	0.571	0.447	0.384	0.114
	disruption	87	232	0.031	5.333	0.319	0.452	0.236	0.084

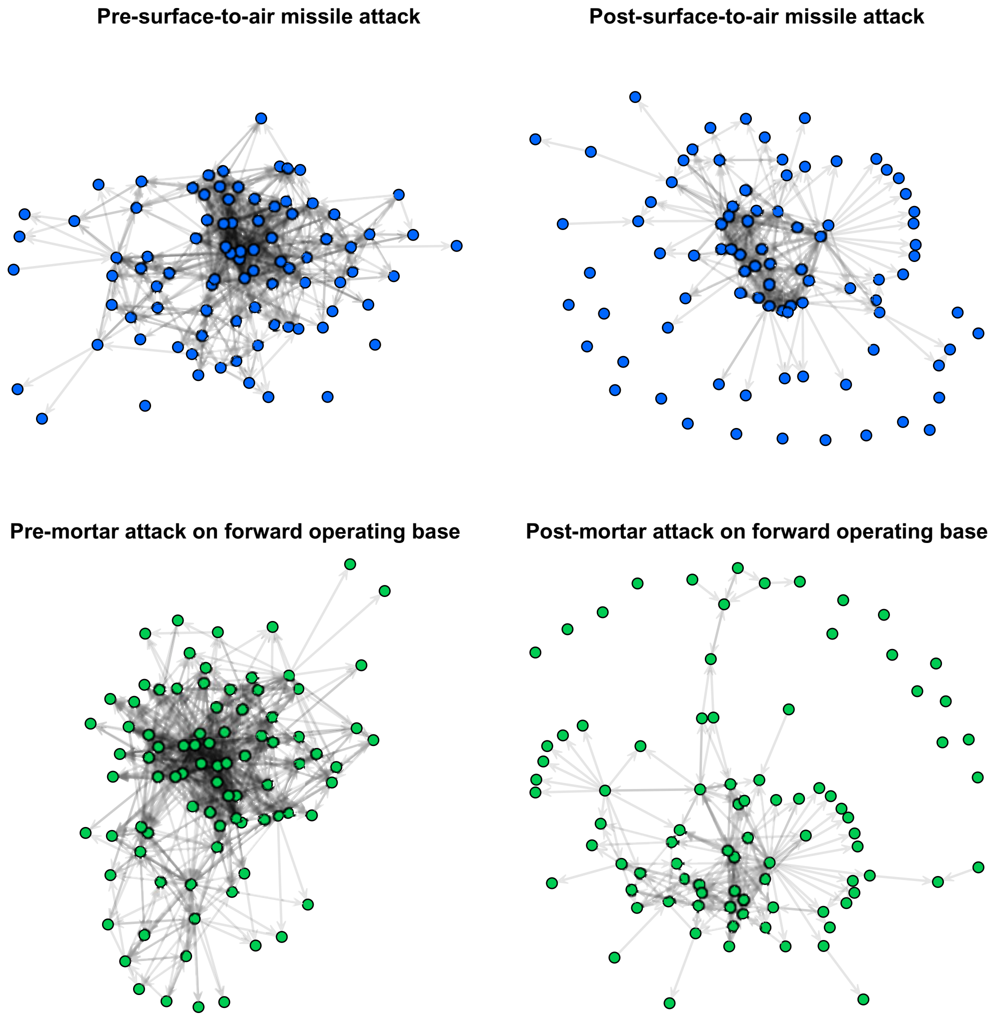

Figure 1. Two pre-event and post-event networks illustrate a pattern in which a hub-dominated network emerges in the aftermath of a disruptive event.

preserve valuable communication channels and dissolve less useful ones in order to sustain useful communication channels during a task environment whose novelty and disruption place an elevated cognitive load on the individual. As such, the amount of effort one puts into maintaining elevated SA may shape the effort available to devote to sustaining outbound ties, or SA may be enhanced by sustaining potentially useful outbound communication channels. Additionally, individuals may selectively sustain ties to those with higher SA. We focus on communication channels rather than communication acts, such as sending a message, because much of the cost of sustaining ties comes from the communication channel itself, such as establishing and updating information about the alter (Whittaker et al., 2002). In organizational contexts, this entails an understanding of an alter's task-related information (e.g., What does is this alter currently doing? What does this alter need to know? What information does this alter have that I need to know?). Because the cost of sustaining the communication channel in this context is greater than the cost of sending a message, exchanging 3 messages each with 5 different people tends to be more costly than exchanging 15 messages with a single alter. The former often requires that ego develop and update an understanding of five different alters' situations, while the latter only requires ego to

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understand a single alter's task situation. This abundance of ties contributes to the likelihood of inducing network overload (Steier & Greenwood, 2000; Elfring & Hulsink, 2007; Mariotti & Delbridge, 2012). Because communication channels impose disproportionately more costs than communication acts, we utilize a STERGM approach rather than a relational event model (Butts, 2008) that better captures features of the timing and sequence of communication *acts*.

To assess the hypotheses, we use a STERGM to model communication network dynamics during each of the 10 disrupted networks. Rather than use a joint model to capture evolution from baseline to disruption for all 10 events, we use separate models for each disruption period to account for a mismatch between the STERGM framework and our focus on how network evolution unfolds in disrupted task environments. We principally focus on evolution of a network from a baseline representation to its configuration during a period of disruption. While STERGM can jointly capture multiple instances of network evolution across several consecutive, discrete time points, it does not currently support irregular sequencing of networks (as of `tergm` package version 3.4.0). Under current functionality, a STERGM persistence model of a `network.list` object consisting of $baseline_1$, $disruption_1$, $baseline_2$, $disruption_2$, and so on would capture evolution from baseline to disruption *and* evolution from disruption back to baseline. While the former captures our phenomenon of interest, the latter captures a separate phenomenon and would therefore inject some degree of distortion into our model coefficients. Additionally, a single joint model cannot currently accommodate dynamic attributes that change with each baseline. For example, we use weight of preexisting ties (volume of past emails) as an edge covariate in each of our models; a joint model would be unable to capture that the weights change from the first baseline to the second baseline all the way up to the tenth baseline. In order to focus precisely on the evolution from baseline to disruption (but not vice versa) and to account for edge attributes that change over time, we employ a separate modeling framework. We now turn our attention to the terms we include in those models.

We developed a collection of identical models to fit to each baseline disruption instance. Each model uses a combination of terms to account for social processes driving network dynamics, controls for potentially confounding effects, and, of course, node-level effects for SA. Most relevant to the hypotheses, participants' SA was measured with Situation Awareness Global Assessment Technique (SAGAT) (Endsley, 1988*b*, 1995, 2000). The SAGAT tool measures individual SA by administering a survey about the individual's current task environment with questions featuring multi-item response options. This tool has been implemented in a variety of organizational task environments, including military operations (Salmon et al., 2006), human–robot interaction (Chen et al., 2011), team training and performance (Patrick et al., 2006), and medical care (Wright et al., 2004). We expect SA measured with SAGAT to be consistent with the definition of Level 1 SA we utilize in this paper, as Endsley developed both the definition and the SAGAT tool. Once per day during the training scenario, the exercise was briefly paused and participants' workstations displayed a survey with questions such as "Do you currently have troops in contact?," "What weapons did the Counter Coalition Forces employ in the last attack in your sector?," "Which of these infrastructure services are disrupted in your Area of Operations?," and "In your sector, which of the following civilian activities are currently occurring?." By comparing participants' answers to what had transpired or was transpiring during the training exercise, this measure of SA relies on verifiable ground truth to determine individual ratings of SA. Contracted to collect SA data during this exercise, SA Technologies Inc. provided aggregate SA measures over week 1 and week 2 of the exercise. As such, this paper treats SA as a broad, relatively static measure of one's familiarity with the task environment and organizational operations over the course of a week. This interpretation treats the SA measure as an indicator of *overall* SA rather than SA specific to each disrupted event. Because SA is an evolving process, it is best measured over multiple time points and across multiple key tasks (Salas et al., 1995). As such, this temporally aggregated measure of SA ought to produce more reliable estimates. The STERGMs use SA from week 1 to predict tie dissolution during week 1 and SA from week 2 to predict tie dissolution during the second week. SA was strongly correlated between the 2 weeks ($r = 0.628$) and week 2 SA (mean = 0.519, SD = 0.175) was slightly higher, on average, than week 1 SA (mean = 0.470, SD = 0.166), although the difference was not statistically significant. Each dissolution model uses an out-tie effect to assess the relationship between SA and the propensity to sustain out-ties. If, per H1(a), the effort required to sustain one's communication ties in a disrupted task environment is at odds with the effort required to maintain elevated levels of SA, then the results ought to show a pattern of negative coefficients for the SA effect on out-ties. This would suggest that as SA increases, we tend to see that individuals become less likely to sustain out-ties. Conversely, a positive out-tie effect would support H1(b)'s argument that preserving access to valuable knowledge stores helps to enhance SA. In addition to out-tie effects for SA, the model also includes in-tie effects for SA to test our second hypothesis. If individuals selectively maintain ties to partners with higher SA, per H2, then the results will show a series of positive in-tie effects for SA.

The models include one edge covariate term, a measure of tie inertia. Long-standing ties tend to be seen as more reliable and become less likely to be dissolved, even when factors such as resources provided by the tie begin to predict its dissolution (Seabright et al., 1992). Long-standing, reliable communication channels may be particularly valuable in unpredictable settings, such as disrupted task environments (Dynes, 1970; Auf der Heide, 1989). Including this term helps us to control for cases in which stronger ties may be less likely to be dissolved, even if they offer limited functional benefits. Tie strength is a long-standing concept in network analysis (Granovetter, 1973; Marsden & Campbell, 1984; Wasserman & Faust, 1994) and measures of tie strength may represent one or more dimensions (Brashears & Quintane, 2018), such as capacity (Desmond, 2012), interaction frequency (Jones et al., 2013), or relationship duration (Marsden & Campbell, 2012). In this paper, we use email volume as a proxy for tie strength, where the strength of an edge from i to j equals the number of emails i sent to j in the pre-disruption network.

Organizational role may account for differences in individuals' propensities to preserve both in-ties and out-ties. The models include in-tie and out-tie effects for individuals with formal coordinative roles. While organizational roles are primarily divided among domain-specific *functional cells*, 8 of the 87 members of the organization also have a role in the *integrating cell*. The primary role of this cell is to integrate information and synchronize activities across the organization. Per SOP, the tasks for this cell are to gather information about the current situation, disseminate information about current operations, and relay information about forthcoming orders and plans. These duties comprise those of a traditional coordinative role in an organization. Such roles are widely used to synchronize interdependent tasks (Marks et al., 2001; Galbraith, 1977; Van de Ven et al., 1976). Well-informed individuals who often have large numbers of contacts, individuals in these types of organizational coordinative roles are often attractive sources of information for others in the organization (Butts et al., 2007). This predisposes them to have more ties along which to send information and more incoming ties from individuals sending or seeking information. As such, the models control for in-tie and out-tie effects on tie persistence and dissolution for individuals in the integrating cell.

Finally, the models include a handful of other terms to improve fit and account for structural features within the network. A homophily term captures the propensity for individuals to preserve ties to others within the same functional cell and a mutual term captures reciprocity. The models also include a geometrically weighted edgewise shared partner term to account for transitivity, as transitive ties may be more likely to persist (Burt, 2000). This collection of structural and attribute-based terms consistently provides adequate fit to the observed data (see Appendix for further details) and notable improvement compared to a baseline edge model according to Bayesian Information Criterion (BIC). To maintain model parsimony, we declined to include additional structural terms, such as geometrically weighted indegree and outdegree distributions (whose inclusion produced no notable changes to our findings), or nodal covariate terms that failed to reduce BIC.

4. Results

We fit STERGM models with the tergm package (version 3.4.0) (Krivitsky & Handcock, 2016) in the R statistical computing environment (version 3.3.2). Focused on processes driving tie preservation and dissolution, we utilize the tie persistence model results to assess our hypotheses. Table 3 demonstrates the results across each of the 10 events. Positive, significant coefficients reflect processes associated with tie preservation while negative, significant coefficients indicate propensities toward tie dissolution.

Our models demonstrate some patterns of results that persist across both weeks, while some effects tend to appear primarily during the second week. Results consistently show positive, significant effects for tie inertia and triadic closure. We find positive, significant effects for inertia in all but the first disruptive event and we find positive, significant effects for triadic closure in every model. These results respectively demonstrate that individuals sustained ties along which they had sent larger volumes of emails prior to the period of disruption and they sustained ties to nodes with whom they share partners. Only twice do we find positive, significant effects for reciprocity, indicating that nodes do not tend to sustain reciprocal ties, net of our other model terms. We note that we removed the reciprocity term from our first model due to excessive overlap (and resulting model convergence issues) among reciprocity, coordinative role, and triadic closure. Moving to our attribute-based effects, we find three positive, significant effects for within-cell homophily, indicating that nodes occasionally sustain ties to others working in the same task domain. Coordinative role effects indicate that nodes do not consistently preferentially sustain ties to formal coordinative roles, as in-tie effects for coordinative roles are significant twice: once in a positive direction and once in a negative direction. Individuals in those roles increasingly dissolve outbound ties over time, as three of the four negative effects for that term occur during the second week. Interestingly, all four negative effects coincide with positive out-tie effects for SA. The aforementioned effects demonstrate that structural features, particularly tie strength and transitivity, more consistently play a role in shaping tie dynamics during disruption than do organizationally prescribed attributes.

The SA attribute effects directly test this paper's primary hypotheses. H1(a) posits that the effort required to maintain elevated SA diminishes one's ability to support outbound communication ties in disrupted task environments. Conversely, H1(b) argues that individuals with elevated SA will be more likely to sustain their ties in order to preserve access to potentially valuable knowledge stores in the network. Table 3 and Figure 2 show that 2 of the 10 models support H1(a), but five models contradict H1(a) and instead support H1(b). Both models supporting H1(a) occur during the first week of the training exercise, while four of the five models supporting H1(b) occur during the second week. That SA effects for out-ties emerge primarily during the second week suggests that a more complicated set of processes may underlie the relation between SA and tie persistence. Some level of organizational adaptation may explain this shift from SA's negative association with out-tie preservation to its positive association with out-tie preservation. Plausible explanations are that individuals with elevated SA become more capable of sustaining ties over time (i.e., task routinization at the individual level) or a set of context-specific, tie-sustaining roles converges on individuals with higher SA over time (i.e., development of emergent, specialized roles). Section 5 further investigates these possible explanations. At face value, however, results suggest that SA is enhanced by (or enhances) tie sustainment by the end of the exercise. Findings from the second week of the exercise are consistent with the notion that higher SA individuals sustain access to others in order to gain valuable access to information or resources.

In-tie SA effects evaluate H2, which posits that individuals will preferentially sustain ties to nodes with higher SA. Table 3 and Figure 3 show that none of the 10 models demonstrates a positive, significant effect for in-ties and SA. These results suggest that individuals are not necessarily predisposed to maintain ties to those who sustain elevated SA, and we thus cannot reject H2's null hypothesis. Given the potentially minimal costs of receiving in-ties in an email

Table 3. STERGM persistence coefficients for the 10 disruptive events

		Event 1		Event 2		Event 3		Event 4		Event 5		Event 6	
		Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Week 1	Edges	−2.949	1.65	−2.388***	0.47	−2.927***	0.49	−4.159***	0.50	−4.239***	0.80	−3.744***	0.85
	SA in-ties	−1.931	1.92	0.366	0.68	−0.352	0.62	1.170	0.79	1.745	1.39	0.600	1.44
	SA out-ties	3.244	2.30	0.076	0.63	1.484*	0.67	−0.144	0.65	−1.843*	0.93	−2.589**	0.96
	Tie inertia	0.054	0.38	0.182***	0.04	0.202***	0.03	0.085***	0.01	0.036*	0.02	0.041*	0.02
	Cell homophily	2.376***	0.58	0.428*	0.20	−0.212	0.23	0.108	0.23	0.566	0.378	0.498	0.44
	Coordinative role in-ties			−0.188	0.24	−0.579*	0.23	0.029	0.28	0.535	0.358	0.875*	0.36
	Coordinative role out-ties			0.106	0.23	−0.479*	0.22	−0.127	0.27	0.411	0.383	0.334	0.44
	Reciprocity			0.552	0.30	−0.552	0.31	0.912*	0.42	0.911	0.962	−0.321	1.30
	Triadic closure	1.577**	0.48	0.770***	0.13	0.755***	0.08	0.804***	0.13	1.104**	0.36	1.527***	0.39

		Event 7		Event 8		Event 9		Event 10	
		Coef	SE	Coef	SE	Coef	SE	Coef	SE
Week 2	Edges	−3.528***	0.50	−3.621***	0.48	−4.019***	0.55	−4.808***	0.56
	SA in-ties	0.185	0.62	−1.018	0.64	−1.107	0.64	0.095	0.63
	SA out-ties	1.373*	0.65	1.407*	0.71	2.612***	0.77	2.703***	0.71
	Tie inertia	0.178***	0.03	0.171***	0.02	0.241***	0.03	0.223***	0.02
	Cell homophily	0.136	0.22	0.645***	0.20	0.310	0.24	0.038	0.23
	Coordinative role in-ties	0.107	0.25	−0.084	0.28	−0.295	0.30	0.431	0.25
	Coordinative role out-ties	−0.766**	0.28	0.624*	0.25	−0.945**	0.30	−0.991***	0.29
	Reciprocity	0.304	0.33	1.231***	0.34	0.360	0.34	−0.139	0.32
	Triadic closure	0.587***	0.10	0.253***	0.03	0.474***	0.10	0.645***	0.08

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

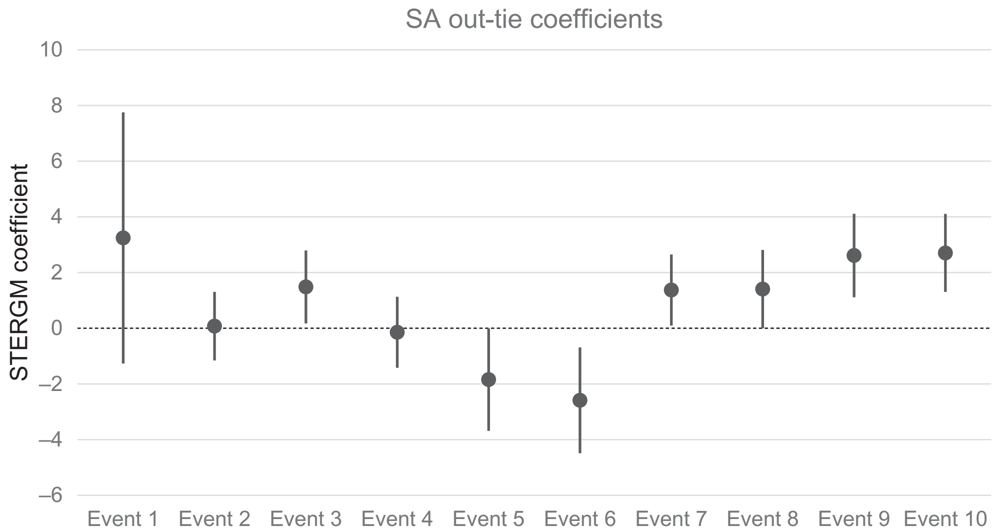

Figure 2. By week 2 (Events 7–10), elevated SA consistently predicts increased out-tie preservation (points represent coefficients and lines represent 95% confidence intervals).

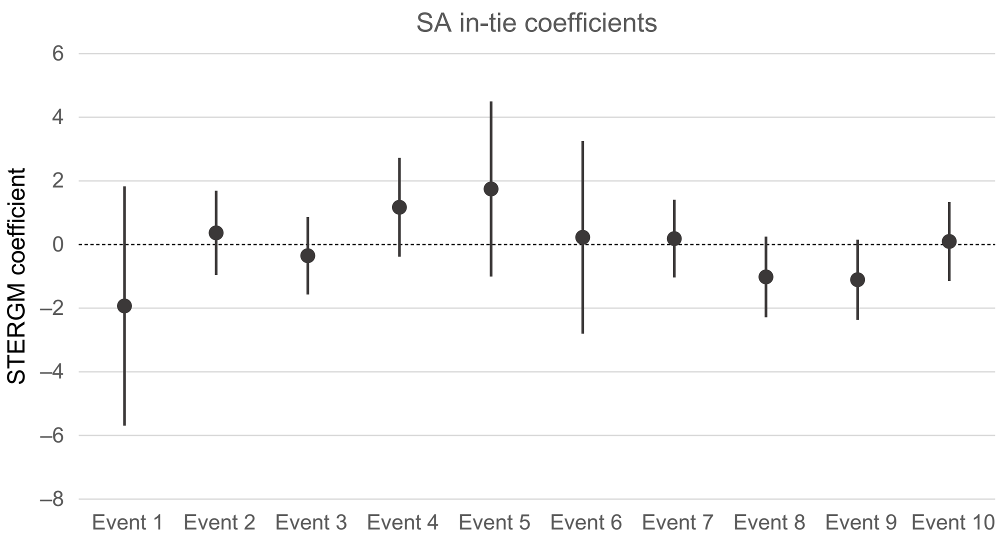

Figure 3. Results indicate no consistent relationship between SA and in-tie preservation in the aftermath of disruptive events (points represent coefficients and lines represent 95% confidence intervals).

communication network, we may not necessarily see a similar result in a more symmetric network such as a telephone or face-to-face communication network.

While the results provide more evidence supporting H1(b) over H1(a) and no evidence for H2, the pattern of results pertaining to our first pair of competing hypotheses suggests that a single response to disrupted task environments may not necessarily represent the larger pattern of organizational adaptation we observe. Our only observed support for H1(a) occurs during the first week and most of the evidence supporting H1(b) occurs during the second week, which suggests that the organization's pattern of adaptation may have evolved over time. Before we investigate this potential explanation for our pattern of results in Section 5, we first assess the robustness of our results.

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4.1 Robustness and model adequacy tests

To ensure the reliability of our results, we subjected our STERGMs to several model adequacy and robustness tests. First we examined Markov chain Monte Carlo diagnostics for each model to ensure proper convergence (Hunter et al., 2008). To verify accurate fit of our models to the observed persistence networks, we used each of our 10 models to simulate networks whose statistics we then compared to the original persistence network. This approach is based on the traditional goodness-of-fit functionality (`gof`) in the `ergm` package (Hunter et al., 2008). We compared the indegree distributions, outdegree distributions, edgewise shared partner distributions, and distribution of geodesic distances from our simulated networks to the original persistence networks. We verified that each of our ten final STERGMs provided an accurate fit to the data along those dimensions, and we illustrate the results of those goodness-of-fit tests in the Appendix.

We conducted a battery of robustness tests to evaluate how robust our findings are to different definitions of our pre-disruption networks. We originally defined our baseline network as all communication that occurs on the same week as the disruptive event, but prior to that event. For models of tie dynamics during the second week, the baseline network only includes communication channels during the second week. As discussed in Section 3.2, the second week occurred during a different operational environment and ties utilized during the first week may be more prone to dissolution during that second week. Nevertheless, we refit each of our week 2 models using baseline networks that span *all* prior communication across both weeks. The magnitude and direction of coefficients remain consistent when using these new baselines, and the pattern of significance for our SA effects remains unchanged.

We next turn our attention from the timing of baseline ties to the *strength* of those ties. By not setting a threshold for how many emails are necessary to establish a baseline communication channel, we risk potentially observing one-time communication acts that may be more ephemeral than more frequently utilized ties. While ties characterized by a single email may still represent essential, task-relevant communication, such ties may be less salient when individuals evaluate which past communication channels to utilize during disruption. Although we account for this in our models using our inertia term to control for tie strength, we nonetheless further probe the robustness of our results using a series of higher thresholds for defining a baseline tie. These increasingly stringent thresholds will account for more frequently utilized ties, which may represent stronger, more meaningful communication partnerships. Our first new threshold defines a baseline tie from i to j as one in which i has sent *two or more* emails to j. This eliminates ties with only one email, which account for between 25% and 35% of ties in nearly all the baseline networks. The only baseline network with a disproportionately large number of one-email ties was our first baseline network, which spanned the first 4 hours of the training exercise during which individuals have a relatively short span of time to communicate. During these first 4 hours, approximately 75% of ties consisted of a single email. Setting higher thresholds for baseline communication eliminates a substantial portion of ties in that first baseline network, and we accordingly exempt that network from these thresholding-based robustness tests. We develop two more thresholds for defining baseline ties: four or more emails and six or more emails. Using each of these three thresholds, we reran all our STERGMs and compared their results to our original results.

Model coefficients generally remain stable over our series of models based on different baseline tie thresholds. Only twice do we find coefficients whose significance changes in two models, and no coefficients change more than twice. The first term that undergoes two changes is our inertia term, which had been positive and significant in all our models except the first. Under the six-email threshold, the inertia effect becomes nonsignificant in two models. This change may occur because controlling for tie strength is less useful when we deal exclusively with stronger, more heavily utilized ties. The other term that changes twice is our in-tie effect for SA. In-tie effects for SA become positive and significant at the two-, four-, and six-email thresholds for event 5

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and positive and significant for event 7 at the six-email threshold. Although individuals may be more knowledgeable about an alter they communicate to more frequently (and may thus have a better assessment of that alter's SA), the results are infrequent enough that we remain skeptical of H2. The only other change pertaining to our hypotheses is that the positive out-tie effect for SA becomes nonsignificant in event 3 at the four- and six-email thresholds. Despite the minor changes observed during these robustness tests, the in-tie effects for SA remain sparse enough that we still cannot reject the null hypothesis for H2. However, the disappearance of event 3's positive out-tie effect for SA further strengthens our observed pattern of out-tie SA effects emerging during the second week. Having verified the reliability of our pattern of results, we return to the original data to investigate the pattern of results for SA out-ties.

5. Organizational adaptation: Why does SA begin to predict out-tie sustainment?

Over the first week of the training exercise, we find that those with elevated SA are more likely to sustain costly outbound ties in one event, *less* likely to sustain outbound ties in two events, and neither more nor less likely to sustain outbound ties in three events. By the second week, however, SA consistently begins to predict out-tie sustainment, as all four events have positive, significant effects. While each disruptive event provides an opportunity to observe organizational adaptation, observing a *sequence* of disruptive events allows us to observe if organizational adaptation itself begins to evolve as the organization becomes more accustomed to responding to these disrupted task environments. Evolution of adaptive strategies may explain this pattern of results, and in the following sections we investigate two phenomena that may explain our changing pattern of adaptation: task routinization and role specialization.

5.1 Evaluating individual task routinization

When confronting a novel task environment multiple times in a relatively short time span, members of an organization may change their patterns of adaptation to such task environments. Disrupted or uncertain task environments intensify the information-processing demands of organizational members, particularly if they are completing novel tasks (Galbraith, 1977; Maitlis & Christianson, 2014). After facing several, similar disruptive events during a relatively short time span, members of the organization under study here may have routinized their responses to such disruption. Repeated execution of similar tasks improves the efficiency of task performance and allows individuals to accomplish more with their existing resources (Cohen & Bacdayan, 1994). Through routinization, tasks previously requiring careful deliberation may be completed more expeditiously through the acquisition of skills retained in procedural memory (Singley & Anderson, 1989). This mitigates the demands imposed by crisis scenarios by routinizing individuals' responses to such disruptive task environments. In our context, routinization could manifest itself as a propensity for individuals with past experience sustaining ties to continue sustaining ties during future events. In such a case, increased experience sustaining ties in disrupted settings reduces the costs of sustaining ties in subsequent periods of disruption. As these disruptions become increasingly routine (insofar as members of the organization have experienced several distinct disruptions), we may observe routinization of the responses to them, particularly if individuals develop strategies for maintaining costly outbound ties in these environments. As routinization lowers the costs and effort required for task execution, individuals may then be able to devote more attention to their task environment while simultaneously sustaining larger volumes of communication channels. As a result, preserving out-ties and maintaining a strong grasp of the task environment will become increasingly compatible. This routinization could explain our pattern of results in which those with elevated SA become increasingly likely to sustain ties in the aftermath of these disruptive events.

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Table 4. STERGMs with routinization terms

		Event 2		Event 3		Event 4		Event 5		Event 6	
		Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Week 1	Edges	−2.380***	0.51	−3.341***	0.54	−3.203***	0.49	−2.662**	0.99	−2.115	1.10
	SA in-ties	0.728	0.72	−0.321	0.64	1.102	0.76	1.681	1.49	0.0127	1.15
	SA out-ties	−0.584	0.65	1.802*	0.71	−0.542	0.62	−2.164*	1.00	−3.161**	1.01
	Tie inertia	0.197***	0.05	0.203***	0.03	0.072***	0.01	0.064***	0.02	0.058**	0.02
	Cell homophily	0.403	0.21	−0.049	0.23	0.286	0.21	0.476	0.42	0.415	0.48
	Coordinative role in-ties	−0.113	0.24	−0.505*	0.24	−0.054	0.27	0.581	0.44	1.165**	0.45
	Coordinative role out-ties	0.718**	0.27	−0.748**	0.24	0.554	0.33	1.674**	0.56	1.278*	0.64
	Reciprocity	0.526	0.30	−0.450	0.33	0.975*	0.41	1.534	0.85	1.176	0.88
	Triadic closure	0.770***	0.13	0.564***	0.07	1.155***	0.17				
	Routinization: out-tie preservation	0.357***	0.10	0.020	0.02	−0.053**	0.02	−0.008	0.04	0.041	0.04
	Routinization: out-tie dissolution	−0.081**	0.03	0.021**	0.01	−0.028	0.02	−0.059*	0.03	−0.041	0.02

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Table 4. Continued

		Event 7		Event 8		Event 9		Event 10	
		Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Week 2	Edges	−4.388***	0.58	−2.631***	0.52	−4.350***	0.62	−5.773***	0.72
	SA in-ties	0.323	0.64	−1.296*	0.62	−1.076	0.64	−0.031	0.71
	SA out-ties	0.841	0.69	1.403*	0.69	2.455**	0.76	3.534***	0.79
	Tie inertia	0.183***	0.03	0.190***	0.03	0.235***	0.24	0.226***	0.02
	Cell homophily	0.220	0.23	0.465*	0.20	0.352	0.24	0.032	0.24
	Coordinative role in-ties	0.278	0.27	−0.306	0.27	−0.229	0.30	0.466	0.26
	Coordinative role out-ties	−0.984**	0.35	0.960***	0.28	−1.041**	0.37	−1.492***	0.35
	Reciprocity	0.648	0.33	0.984**	0.32	0.444	0.34	−0.091	0.34
	Triadic closure	0.635***	0.15	0.708***	0.12	0.466***	0.12	0.595***	0.09
	Routinization: out-tie preservation	−0.078***	0.02	0.031*	0.01	−0.016	0.01	−0.016	0.01
	Routinization: out-tie dissolution	0.033***	0.01	−0.023***	0.01	0.008	0.01	0.012*	0.01

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

To assess whether this pattern of routinization emerges over time, we ran a new set of STERGMs that added to our previous models new nodal covariates for the total number of ties sustained and total number of ties dissolved in previous crisis events, in addition to the terms in Table 3. These tie counts are cumulative such that, for example, the propensity for a node to preserve out-ties in the aftermath of the fifth disruptive event is a function of the total number of ties it preserved during the previous four disruptive events. Similarly, the total number of out-ties it *dissolves* during the fifth event is a function of the number of ties it dissolved during the first four events. We include terms capturing both past out-tie sustainment and out-tie dissolution in order to control for *opportunities* for tie dissolution. A node with a large number of pre-disruption communication channels may sustain *and* dissolve large volumes of ties during the same incident. Including a term to capture, for example, that node A sustains 15 ties and Node B sustains 10 ties, would be misleading without including a term controlling for the 25 and 0 ties they respectively dissolved. Although the former sustained a larger number of ties, the latter sustained a much larger *proportion* of its ties. Without controlling for dissolution behaviors, we may incorrectly conclude that A has a greater propensity to sustain communication channels. To assess routinization, we added these two terms to the full model and display the results below in Table 4.

The coefficients from our original results remain mostly unchanged in these new models that include routinization terms, where routinization reflects the propensity for past persistence or dissolution actions to predict subsequent persistence or dissolution actions, respectively. The only changes in terms related to our hypotheses are the emergence of a negative in-tie effect for SA during event 8 and a swap between significance and nonsignificance for our out-tie SA effect in model 7. These findings continue to demonstrate that our original pattern of results is fairly robust to different types of tie definitions and model terms.

To highlight the routinization findings, we include their coefficients separately in Figure 4. If individuals routinize their out-tie persistence behaviors, then we ought to observe that past out-tie persistence predicts subsequent out-tie persistence. Routinization of out-tie persistence begins with a positive, significant coefficient (event 1 was omitted because there was no past behavior on which to evaluate persistence or dissolution behaviors), suggesting that those who sustained ties during the aftermath of the first disruptive event were more likely to sustain ties during the second disruptive event. This effect does not continue, as it becomes nonsignificant during event 3 and a *negative* predictor of tie sustainment during event 4. The coefficients for routinization of persistence move back to nonsignificance over the next two events. The pattern is no more coherent during the second week, as past persistence negatively predicts out-tie persistence in seventh event, positively predicts it in the eighth event, and offers no significant effect in the final two events. While these routinization terms capture *all* past out-tie persistence and dissolution behaviors, we also found no consistent evidence of routinization if we only examined out-tie persistence and dissolution in only the *previous* disruptive event. These results collectively provide no consistent evidence that individuals engage in routinization of out-tie preservation. As such, we cannot claim that the emergence of an out-tie persistence effect for SA is due to a reduced burden of sustaining ties resulting from routinization processes.

In addition to the absence of out-tie preservation effects, we find no consistent pattern of routinization of out-tie dissolution. A consistent, negative effect for past out-tie dissolution would indicate that individuals may establish a routine of dissolving outbound communication ties. We find no such consistent effect, as the volume of out-ties dissolved in the past predicts subsequent dissolution in three events, predicts *preservation* of out-ties in three events, and shows no significant association with out-tie behavior in three events. We illustrate the coefficients for out-tie routinization effects below in Figure 4. Together, these effects fail to support the notion that individuals who routinized tie preservation were then able to enhance their SA by devoting more resources to understanding the task environment or enhance their SA by sustaining even greater volumes of ties.

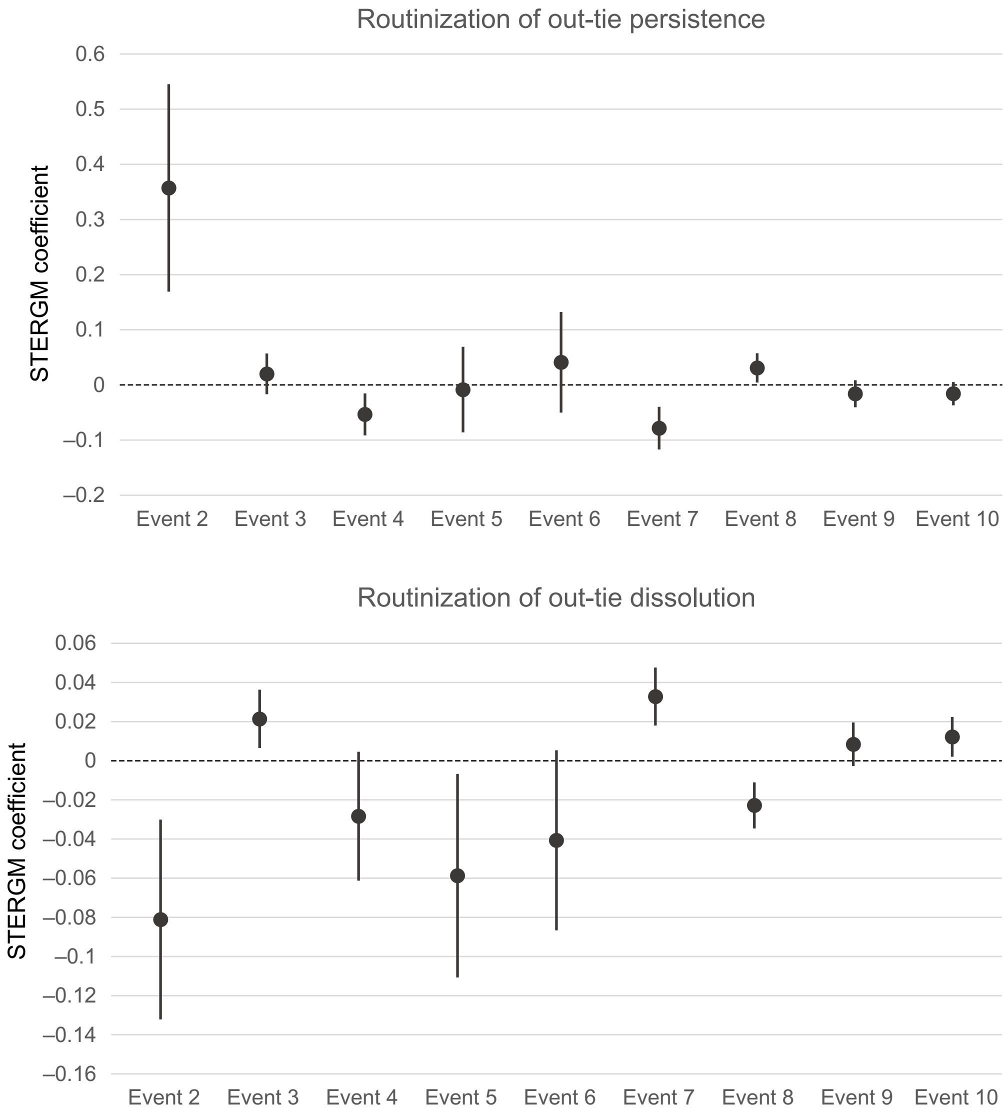

Figure 4. Individuals sustaining larger numbers of ties during past events do not consistently have elevated out-tie preservation in subsequent events (top) and individuals dissolving larger numbers of ties do not tend to engage in subsequent tie dissolution; these results demonstrate no evidence of inertial patterns of routinization

5.2 Evaluating role specialization

Although routinization did not adequately explain the second week's pattern of results pertaining to H1(a) and H1(b), we may gain insight into that pattern of results by examining another type of adaptive behavior within organizations: development of emergent coordinative roles. Organizations utilize specialized coordinative roles to achieve interdependence by synchronizing individual duties such that they collectively contribute to larger organizational goals (Van de Ven et al., 1976; Kogut & Zander, 1996). Organizational adaptation in disrupted environments contributes to the manifestation of an improvised type of coordinative role called *emergent* coordinative roles. Emergent coordinative roles appear when organizations discard traditional roles in favor of a set of roles that are better suited to the current task environment (Dynes, 1970).

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Table 5. Average SA of emergent coordinators

	Event	Emergent coordinators	Average SA
Week 1	1	4	0.500
	2	5	0.539
	3	5	0.587
	4	4	0.312
	5	2	0.238
	6	2	0.238
Week 2	7	5	0.547
	8	4	0.568
	9	5	0.607
	10	5	0.603

To achieve intraorganizational coordination, individuals in these roles typically utilize large volumes of communication ties (Petrescu-Prahova & Butts, 2008). Our original results demonstrate a potential opportunity for the emergence of these improvised coordinative roles. Model results showing the failure of traditional coordinative roles to attract incoming ties consistently—and the negative effect of coordinative roles on out-tie preservation in several cases—suggest an opportunity for emergent coordination to occur during these disrupted events. If, over time, emergent coordination increasingly falls upon those with elevated SA, then that may explain why SA becomes more strongly associated with tie preservation during week 2. In the following paragraphs, we examine if changes in the SA of individuals filling these improvised, well-connected roles correspond to the pattern of increased association between SA and out-tie persistence during the second week of the exercise.

This paper follows the Petrescu-Prahova & Butts (2008) approach of identifying emergent coordinators during each of the disruptive periods. This approach identifies individuals at the intersection of elevated degree centrality and elevated betweenness centrality. Each of these measures contributes to an important element of coordination. Elevated degree centrality puts an individual in a position to communicate directly with many others and elevated betweenness centrality puts that individual in a position to mediate communication between many distantly connected or otherwise disconnected nodes (Freeman, 1978). We designated as emergent coordinators nodes above the 95% quantile for degree and betweenness during the post-disruption period. This produced between two and five emergent coordinators during each event, a number consistent with the number of hubs observed in each of these disrupted task environments, and a total of 15 distinct emergent coordinators over the 2-week training exercise. Reflecting that these roles were frequently distinct from formal coordinative roles, only four members of the integrative cell (i.e., planners) filled these emergent coordinative roles on one or more occasion. Indeed, much of the coordination during these disruptive periods occurred through non-formalized coordinative roles.

We examine whether these emergent coordinative roles consistently fall on a specific subset of individuals or if these roles tend to be ephemeral roles with little likelihood of being retained during subsequent events. Figure 5 demonstrates this by charting emergent coordination over the course of the 10 events. The figure tracks the total number of emergent coordinators that have been observed during these periods of disruption (solid line with circles), the number of emergent coordinators observed during each event (dashed line with circles), the number of current emergent coordinators during each event who have previously filled coordinative roles (solid line with diamonds), and the number of new emergent coordinators (dashed line with diamonds). This shows that past emergent coordinators increasingly fill coordinative roles during subsequent events; in

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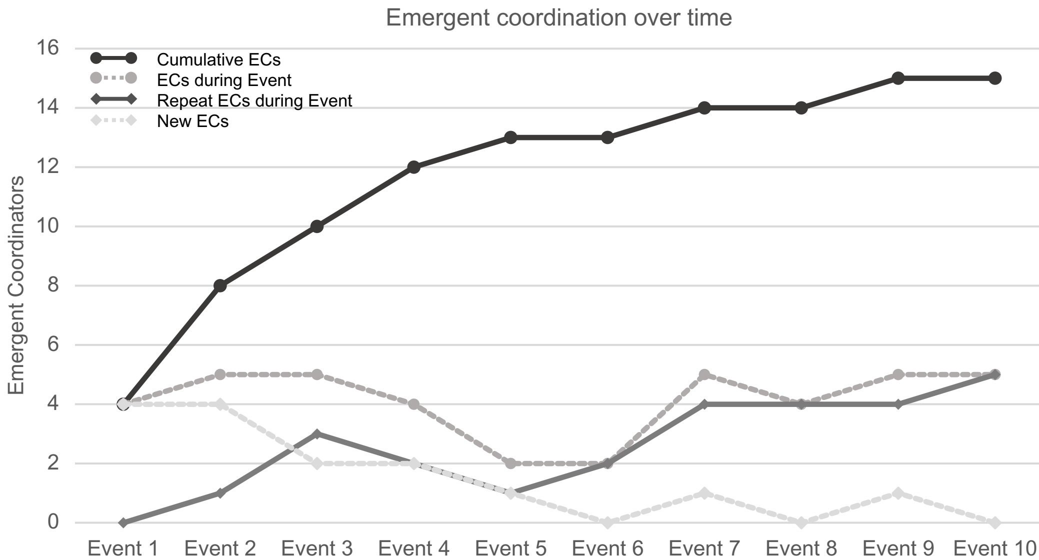

Figure 5. Past emergent coordinators (ECs) increasingly adopt emergent coordinative roles during subsequent events.

fact, of the 19 coordinative roles observed during the second week of the exercise, past emergent coordinators fill 17 of those roles. The total number of coordinators also shrinks from week 1 to week 2, with 13 individuals filling 22 coordinative roles during week 1 and 9 individuals filling 19 coordinative roles during week 2. Additionally, four of those individuals with formal coordinative roles filled these emergent roles during week 1, while only two filled these emergent roles during week 2. These counts suggest a consolidation of these roles over time onto a smaller pool of individuals. Over time, this pool of emergent coordinators decreasingly draws upon those with a formal coordinative role, thereby suggesting the emergence of a series of specialized emergent coordinative roles.

We examine the SA of this shrinking pool of emergent coordinators in order to determine whether these roles increasingly fall onto higher SA individuals and therefore provide some explanation for why higher SA individuals tend to sustain more ties over the course of the exercise. We illustrate in Table 5 the average SA of emergent coordinators during each of the disruptive events. SA of emergent coordinators is positively and mildly correlated with the day during which disruption takes place ($r = 0.208$) and week 2 emergent coordinators have higher SA than week 1 emergent coordinators ($t = 2.254, p = 0.030$), while we see no such significant increase in SA from week 1 to week 2 for non-coordinators. These results indicate that emergent coordinative roles become filled by higher SA individuals over time. However, this increase in SA pertains to the role itself rather than the individuals filling that role. We do not find that those who served as emergent coordinators during week 1 had notable increases in their SA during week 2 ($t = 1.243, p = 0.227$), which suggests that fulfilling emergent coordinative roles did not necessarily enhance their SA. Rather, emergent coordinative roles appear to fall increasingly upon those with higher SA over time. This suggests that individuals within those emergent coordinative roles did not evolve over time; rather, the role itself may have evolved insofar as it increasingly fell upon those with higher SA. While the individuals sustaining these roles vary from event to event, these roles tend to converge on a handful of individuals with higher SA. We would need to examine the content of individuals' emails to determine whether this convergence was a deliberate strategy developed by members of the organization, but the pattern of concentrating emergent coordination onto a pool of high-SA individuals is consistent with such a strategy. Rather than individual adaptation through routinization, the pattern of adaptation suggests that improvised roles within

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the organization adapted such that they increasingly leveraged individuals with elevated SA. This pattern may provide an explanation for the increased propensity for higher SA individuals to sustain larger volumes of ties during week 2, as those whose emergent roles required them to support large volumes of ties (and serve as bridges among many others) had higher SA during week 2.

6. Conclusions

Although sustaining ties in organizational contexts requires some degree of effort (Roberts et al., 2009; Ahuja, 2000; Whittaker et al., 2002; Cummings et al., 2006), which is exacerbated in a disrupted task environment, ties also offer potential to connect individuals to valuable knowledge and resources in interdependent, role-specialized organizations (Galbraith, 1977; Wegner, 1987). Over the course of this training exercise results show that sustaining communication ties is not necessarily a detriment to SA. In fact, our results suggest that over the course of this 10-day training exercise SA became associated with an *increased* likelihood of sustaining outbound ties. Individuals with a strong, sustained familiarity with their task environments became more likely to continue leveraging their preexisting communication channels during the second week. Further examination of the pattern of change over time indicates that individual-level routinization did not emerge. That is, those who tended to sustain outbound ties did not become more likely to sustain those ties during subsequent events, owing to increased ability to manage the load of sustaining ties while maintaining elevated SA. Instead, there is some evidence to suggest that the emergent coordinative roles in the aftermath of disruption increasingly converged on those with higher SA over time. By the second week, a pool of high-SA nodes sustained most of the emergent coordinative duties, and these individuals tended to have higher SA than the emergent coordinators who preceded them. Intriguingly, the propensity for high-SA nodes to sustain their ties overlapped with a decreased propensity for nodes in formal coordinative roles to sustain their out-ties. This suggests adaptation of the coordinative role itself over time, rather than adaptation of individuals within the coordinative role.

Using longitudinal data that affords multiple opportunities to observe organizational adaptation to disruption, these results provide unique insight into adaptive behaviors within organizations as well as *evolution* of those adaptive behaviors. These results have important implications for understanding behavior of individuals in organizations facing disruptive task environments. Consistently finding that SA does not detract from out-tie sustainment, our findings suggest that individuals do not face an "either or" dilemma between staying consistently abreast of what occurs in the task environment and sustaining ties during disruption to those who can benefit from or contribute to that knowledge. Contributing to the emergence of this finding over the course of the exercise is the convergence of improvised coordinative roles upon a set of individuals with elevated SA. As the role evolved over the course of successive disruptions, it did not require individuals within those roles to develop capabilities consistent with the expectations of the role (insofar as sustaining elevated SA over time enhances one's ability to be an effective coordinator). Rather, the role itself moved around until settling on a set of individuals with the proper capabilities to fill the role. This suggests that organizational adaptation need not rely on adaptation of the individuals themselves, but may instead rely on structural adaptation within the organization to achieve an appropriate match between demands of the task environment and individuals' capabilities. Emerging over multiple instances of disruption, this adaptive strategy uncovers behavior in a context where organizational adaptation remains obscure.

The difficulty in forecasting disrupted task environments for organizations of this size has largely limited the field's understanding of such adaptive behavior to post hoc analyses. Repeated exposure to such environments has been rare and costly to collect at this kind of temporal resolution. This paper provides novel insight into adaptive behavior by comparing adaptation to a baseline representation of behavior, and by capturing organizational behavior during *successive* periods of disruption. Thus, we not only capture adaptive behavior, but we capture adaptation of that adaptive behavior. While the data are presently novel, increasing availability of timestamped communication such as email logs or phone records provide opportunities for examination of behavior in these understudied disruptive environments. While we focus our analyses on how adaptive behaviors in the short term correspond to longer-term attributes (here, SA), we encourage fellow researchers to continue working to understand how individuals and organizations develop strategies to respond to disrupted and changing task environments.

Although our results provide insight into organizational adaptation during a series of disruptions, some aspects of the data constrain the generalizability of results. The lack of email content data constrains our understanding of communication dynamics within this organization to what we can glean from the structure and volume of communication among nodes over time. Additionally, although we operate under the assumption that outbound email communication channels are more costly to sustain than inbound channels, we do not actually have a measure of realized costs of emails. We may have been able to investigate that with with access to email content, but, alas, we remain constrained to the timing and structure of emails. Another limitation of this paper is the utilization of a relatively long-term measure of SA rather than an event-by-event measure of SA. Collecting SA at very narrow timescales could offer greater insight into dynamics during disruption, but collecting such data was infeasible. Collecting data at fine timescales would entail frequent disruption of participants, possibly to the point that it detracts from the very SA we intend to measure. Additionally, measuring SA during such narrow time periods may limit the reliability we obtain by measuring SA across multiple time points (Salas et al., 1995). Event-specific SA may better explain the pattern of communication observed in the aftermath of disruptive events but it would be less useful for evaluating how attractive nodes are as communication partners (per H2), as individuals' perceptions of others' SA is likely a fairly stable measure over time. Although we do not directly measure individuals' assessments of alters' SA, we operate under the assumption that existing ties enhance individuals' perceptions of their alters' attributes (Kenny & Albright, 1987; Borkenau & Liebler, 1993). While we note the novelty of understanding patterns of adaptive behavior pertaining to SA in disrupted environments, we encourage future research to explore more direct tests of the underlying mechanism in similar contexts. Finally, we expect that these results primarily apply to experienced, task-oriented organizations responding to rapid-onset disruption in an otherwise familiar domain of operations. This organization's pattern of adaptation likely would not generalize to an organization executing completely unfamiliar tasks in a novel, disrupted environment, particularly if that organization found its existing experience, training, and role to be inadequate to address the tasks it faces (Dynes, 1970; Comfort, 2007). Adaptation to immediate changes to the task environment may not necessarily generalize to slowly developing disruptions such as the replacement of an organization's CEO, formal restructuring following an organizational acquisition, or the filing of Chapter 11 bankruptcy. However, a comparison between adaptive strategies in slow-onset and rapid-onset disruption is a promising research frontier.

While the scope of our findings is necessarily limited, our repeated observations of organizational behavior both before and during disruption offer unique insight into strategies employed during such difficult-to-observe contexts. We find a lack of consistent support for the hypotheses that (1) familiarity with one's task environment detracts from one's ability to support effort-demanding communication channels and that (2) individuals deliberately sustain channels to those with strong, consistent familiarity with their task environments during disruption. While the latter finding suggests the potential for missed opportunities for nodes to reach out and learn from those with elevated SA, the former finding is functionally advantageous for an organization, as those with such task knowledge became more likely to sustain channels along which they may share that important information and knowledge with others. Such information transmission is critical in these types of disrupted task environments (Maitlis & Christianson, 2014; Galbraith, 1977). By sustaining those ties, high-SA individuals can ensure that important information will be routed where it needs to go in order to preserve the coordination necessary to sustain essential functionality in a multifaceted, interdependent organization.

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Conflict of interest. None.

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Appendix: Goodness of Fit Plots

In Figures A1 and A2 we illustrate goodness of fit for each of the 10 persistence models. We use each persistence model to simulate 100 networks and we then compare statistics from those simulated networks to the observed networks. In the following plots the solid black line represents the observed network statistics while the boxplots demonstrate the statistics of our simulated networks. We generally find accurate fits for indegree distribution, outdegree distribution, distribution of edgewise shared partners, and geodesic distribution.

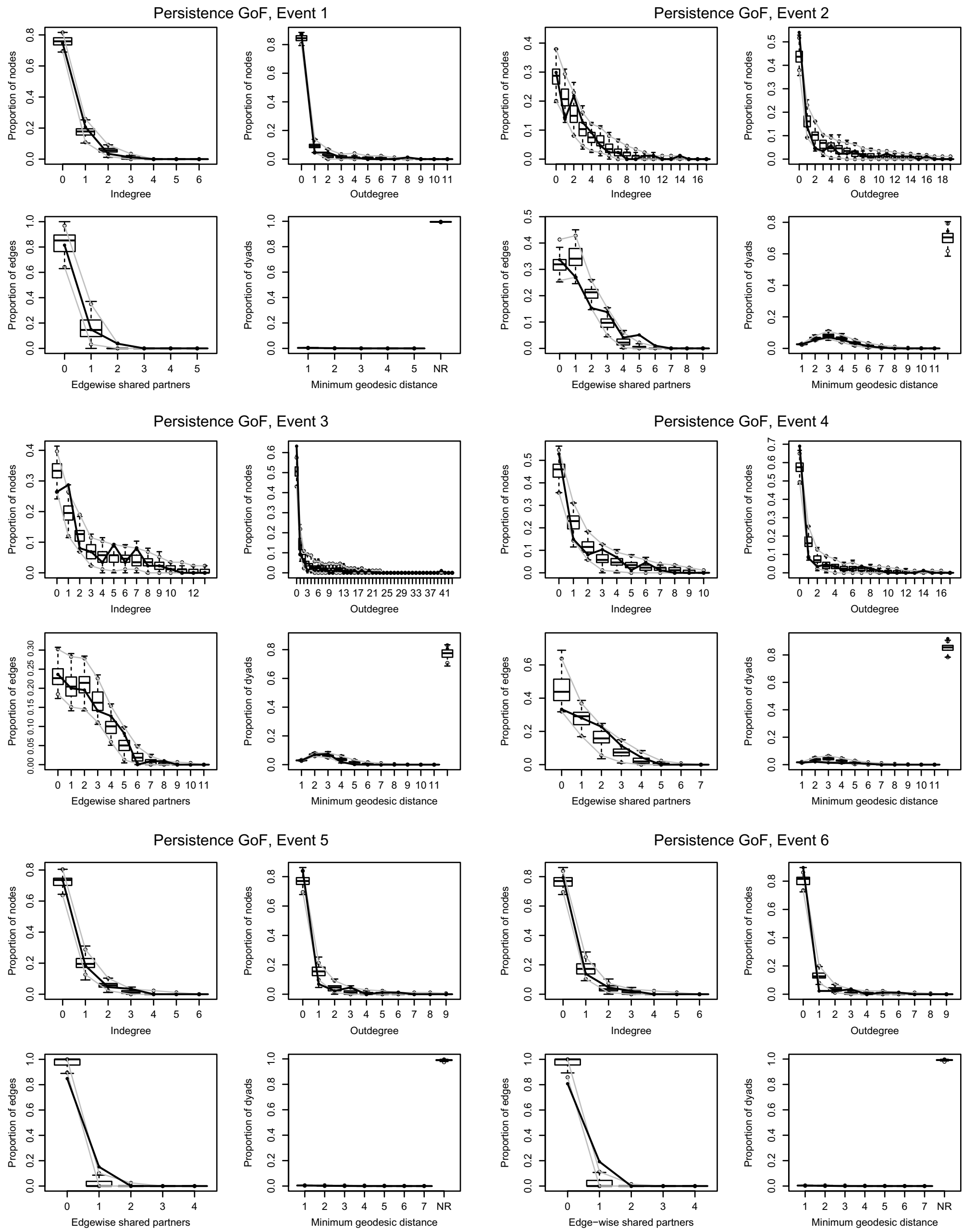

Figure A1. Goodness of fit assessments for week 1 models.

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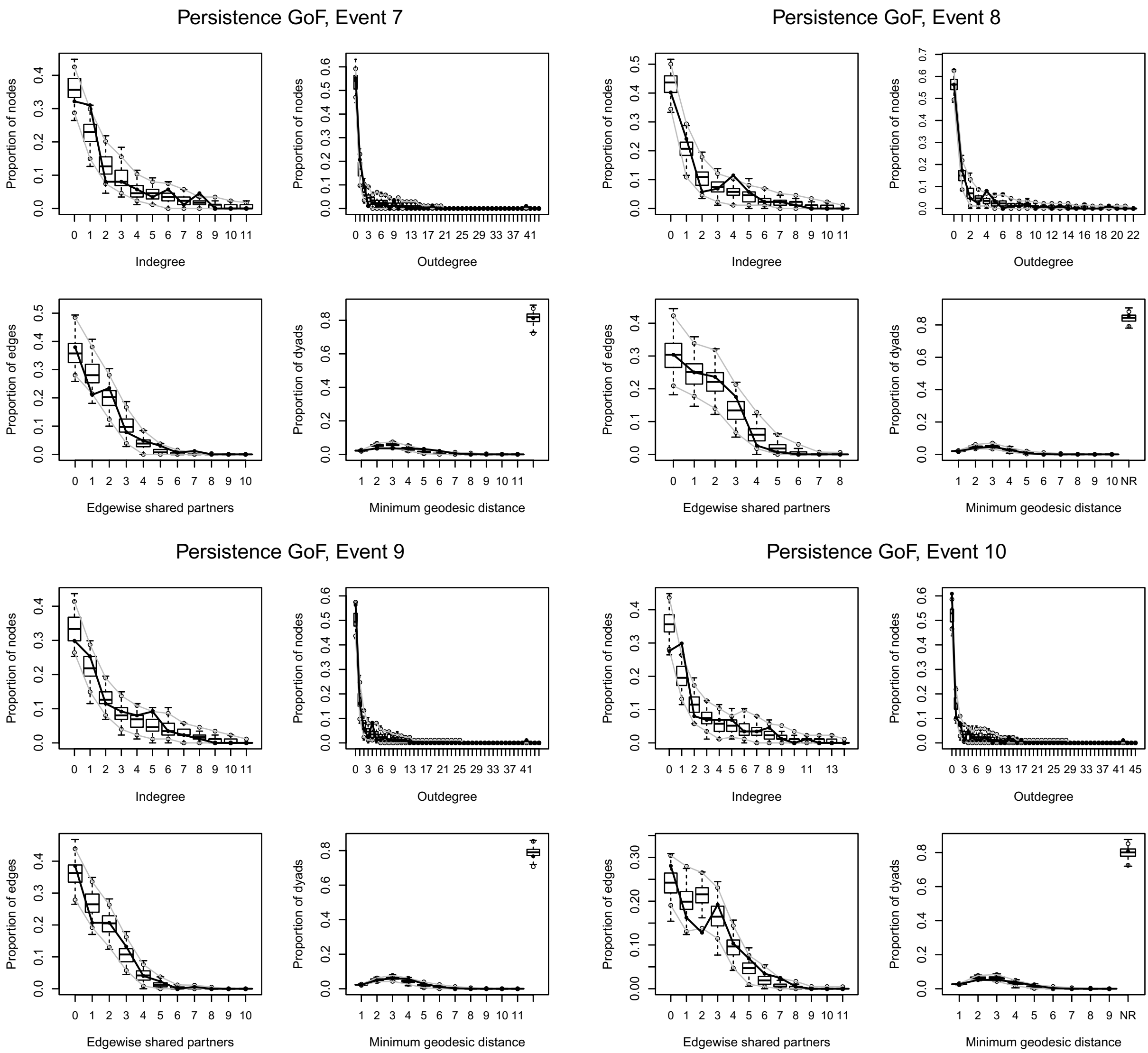

Figure A2. Goodness of fit assessments for week 2 models.

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