The Signatures of Success in Teams & Multliteam Systems (MTS)

Abstract

Research on groups and teams has spent more than sixty years trying to isolate the interaction processes that distinguish those groups who succeed from those who fail. This study advances a novel conceptualization of group process: the sequential structural signature (SSS), and an associated analytic approach: relational event network analysis. Sequential structural signatures reveal the underlying generative mechanisms through which a group's communication comes about. We test a central idea from multiteam systems theory (MTST), that communication patterns prompt countervailing effects on team versus system effectiveness, using the notion of SSSs. We begin by developing a conceptual taxonomy delineating of four classes of generative mechanisms that explain how MTS communication arises: affiliation, within-team, between-team, and homophily within roles. We then evaluate hypothesized effects of SSSs on team and MTS performance in a laboratory study consisting of 28, 20-person MTSs (560 individuals). In support of MTST, we find the signatures of team success differ from those of MTS success. Furthermore, we find some of the signatures that underpin team success undermine system performance, and vice versa. Implications of these findings for the research and practice of team effectiveness are discussed.

Keywords: Multiteam systems, team, communication networks, relational event network, longitudinal, team process

The Signatures of Success in Teams & Multliteam Systems (MTS)

For at least 20 years, there has been a well-documented move towards organizing work into teams (Devine et al. 1999, Lawler 1994). Teams form to accomplish more complex tasks than could be accomplished by individuals, and to perform those tasks with more and diverse information, and better integration of ideas and inputs. This move towards team-based work produces pockets of tightly coupled teams who then need to connect to one another in order to accomplish goals that reside at a level of analysis higher than the team but typically smaller than the organization, and often spanning the boundaries of multiple organizations. These unique organizational forms are multiteam systems (MTSs; Zaccaro et al. 2012). And were formally defined as:

> "Two or more teams that interface directly and interdependently in response to environmental contingencies toward the accomplishment of collective goals. MTS boundaries are defined by virtue of the fact that all teams within the system, while pursuing different proximal goals, share at least one common distal goal; and in doing so exhibit input, process and outcome interdependence with at least one other team in the system (Mathieu, Marks, and Zaccaro, 2001, p. 290)."

This definition points to three defining and distinguishing features of MTSs: (a) they are composed of at least two coupled component teams; (b) component teams are organized into a goal hierarchy, in which they may or may not share particular proximal goals, but all teams share the same distal goal; and (c) interactions within the MTS are driven by various degrees of task interdependencies among component teams. Indeed, perhaps the major difference between MTSs and other forms of team-based organizations is that while in most organizations, teams are only nominally or loosely coupled with their outputs pooled, in MTSs teams are linked in stronger patterns of reciprocal and intensive interdependence (Thompson; 1967; Tesluk, Mathieu, Zaccaro, & Marks, 1997; Zaccaro, et al., 2012).

A cornerstone of the MTS concept is the notion of countervailing forces, the basic idea that interactions that benefit teams may impair the overall functioning of the MTS. Additionally, interactions needed for coherence of the larger system of teams may impede the functioning of teams within the MTS.

DeChurch and Zaccaro formally defined countervailing forces as, ”combinations of teamwork processes and properties that operate differently at different levels of analysis (2013, p. 14).” A countervailing force occurs when a group process has both positive and negative consequences. We apply the notion of countervailing forces to better understand the complex effects of communication on MTS functioning.

Studying Team Dynamics

Prior work has recognized the theoretical import and the methodological challenges of studying temporal processes in groups (Arrow, Poole, Henry, Wheelan, & Moreland, 2004; Gersick, 1988; Marks, Mathieu, & Zaccaro, 2001). Building on prior research on multilevel social networks (Contractor, Wasserman & Faust, 2006; Monge & Contractor, 2003), we posit that communication patterns emerge due to different factors operating at the intra-team and inter-team levels. These SSSs represent diverse conversational norms and behaviors (Gibson, 2003; Gibson 2005). We extend this research by encoding additional SSSs that incorporate attribute-based patterns that are specific to the interactions within and between teams central to theory on MTS.

Sequential structural signatures (SSS). Explaining the rate and weight of a sequence of relational events invites a more nuanced approach to theorizing about the factors that lead to team processes. More specifically, it calls for the extension to, and development of, theories that posit generative mechanisms for the emergence of sequences of relational events. In other words, we seek to explain why certain generative mechanisms, which we term sequential structural signatures (hereafter referred to as SSS), influence the unfolding of the observed relational event sequences. More specifically, the rate and weight of a relational event from a member to one or more other members of the team is based on one or more hypothesized SSS. The influence of a proposed SSS is a function of the frequency of a specific sequence occurring in prior relational events. Perhaps the simplest SSS, which we term inertia, would posit that the rate (weight) of a relational event occurring at any given time from one member, *a*, to another team member, *b*, is based on the frequency of the prior instances of a relational event from *a* to *b*. That is, the more frequently *a* has initiated a relational event, such as a text message, to *b* in the past, the higher the rate (weight) with which *a* is likely to initiate that relational event with *b* at any given time in the future. A slightly more complicated SSS, which we term reciprocity, would posit that the rate (weight) of a relational event occurring at any given time from one member, *a*, to another team member, *b*, is based on the frequency of the prior instances of a relational event from *b* to *a*. That is, the more frequently *b* has initiated a relational event, such as a text message, to *a* in the past, the higher the rate (weight) with which *a* is likely to initiate, in response, a relational event with *b* at any given time in the future. As mentioned previously, relational events could also be defined in terms of categories of group processes such as managing conflict, monitoring progress, or coordination.

Affiliation-based mechanisms. The first set of generative mechanisms are those based on affiliation. Because of shared goals and a common identity, individuals communicate more frequently with the members of their team than with the members of other teams. Social identity theory would suggest two types of affiliation-based mechanisms in MTSs. The first is sub-team membership, teams that use this rule in forming communication networks communicate more often with individuals in their sub team. The second mechanism is team membership. Teams who use team membership as a generative mechanism are those who communicate more often with members who share the same proximal goals, than with the members of other teams who share MTS distal goals but not proximal team goals.

Intra-team communication mechanisms. The second set of generative mechanisms are called intra-team communication mechanisms. These mechanisms describe the patterns through which internal team communication come about. These are based not on shared goals as are the affiliation mechanisms, but rather, based on members roles in connecting the team to its external environment. Essentially, within team communication ties are affected by individuals' ties with members of other teams. Using the typology of between group "brokers" proposed by Fernandez and Gould (1994), we posit that individuals who have more communication ties to other teams will both send and attract more communication ties to the members of their own team (Joshi et. al., 2009; Marrone, 2010; Marrone et. al. 2007; Richter et. al., 2006). These two team mechanisms are termed intra-team representation and intra-team gatekeeping. Intra-team representation occurs when the likelihood of an actor *a* sending communication to a fellow team member, actor ***b*,** is greater when *b* has previously communicated with other teams. Intra-team gatekeeping occurs when the likelihood of an actor *a* sending communication to a fellow team member, actor *b***,** is greater when *a* has previously communicated with other teams than when they have not previously communicated with other teams.

Inter-team communication mechanisms. Next we consider the dynamics that shape the emergence of communication ties between teams. We expect communication between teams to be shaped first by lower order principles such as inertia (Oullette & Wood, 1998). Individuals who communicate with someone on another team, are more likely to communicate with that same person (inter-team personal inertia) or others on that team (inter-team generalized inertia) again (Pettigrew & Tropp, 2006).

Another set of generative mechanisms for inter-team communication stem from reciprocity, representation, and contagion effects. Dyadic reciprocity principles suggest that prior communication by members of another team ought to prompt communication to them in the future (i.e., inter-team reciprocity). Applying the logic of Fernandez and Gould (1996), as individuals gain status within their teams through repeated communication, they become group representatives. This elevated status empowers the individual to span the boundary of the team, connecting it to novel pockets of information and parading accomplishments to other teams (i.e., inter-team representation; Ancona & Caldwell, 1992). The final generative mechanisms expected to shape inter-team communication is through contagion where actors choose partners on other teams to mimic with whom their teammates partner (i.e., inter-team contagion; Fowler & Christakis, 2010).

Homophily mechanisms. The final set of generative mechanisms arises due to homophily. Two forms of homophily are likely, one based on common functions, and another based on leadership status. Roles shape communication through homophily effects. Homophily, or similarity on either expertise or authority, likely shapes the amount of communication between dyads. Accordingly, we expect more communication among members with similar authority, i.e., the leaders of each team, than among members of different levels of authority. Similarly, individuals with similar background, training, and expertise are more likely to communicate than are members with different backgrounds. Homophily operates because of the individuals' hardwired rules of interpersonal attraction (Byrne, 1971; McPherson, Smith-Lovin, & Cook, 2001), and likely leads to stronger bonds amongst them.

Impact of Communication Sequences on Team and MTS Performance

Whereas the preceding section details the mechanisms that we posit shape the emergence of communication sequences in MTSs, we do not expect that these mechanisms will be uniformly influential across MTSs. The various mechanisms outlined above enable or constrain the efficiency and effectiveness of social and informational exchanges within and between teams in the MTS. As such, variations in these generative mechanisms should explain variability in the performance of MTSs. For instance, we would expect that high levels of communication between the leaders of the component teams within an MTS will facilitate coordination between the teams. However, it could be detrimental to performance if this leader-to-leader interaction comes at the cost of the leader communicating downward with members within the team. As another example, inter-team contagion, where one team member is more likely to interact with a member in another team if a fellow team member has interacted with that individual in the past, may create confusion in terms of division of responsibility within the team and ultimately prove inefficient in managing the team boundary. Initial support for this idea was provided by Lanaj, Hollenbeck, Ilgen, Barnes, Harmon (2012) who found decentralized planning, which would arise if inter-team contagion is at play in the MTS, was detrimental to MTS performance.

Countervailing Effects of Team Membership Driven Communication on Team and MTS Performance

Despite their membership in a "team of teams," individuals naturally attach themselves to the goals and values of the team with which they directly identify. This local focus may have a strong impact on who a particular individual may choose to communicate with. By focusing their attention within, team members may become more effective at achieving their localized tasks. However, the team may become disconnected from the system of teams. As a result, MTS-level coordination and as a consequence success may suffer. Therefore, we expect the intensity of communication along team lines to be related to our measures of success. We posit the following hypotheses regarding team membership:

Hypothesis 1. Team membership-driven communication positively predicts team performance.

Hypothesis 2. Team membership-driven communication negatively predicts MTS performance.

Within the MTS structure, each component team is comprised of functionally interdependent units. These sub-teams are responsible for carrying out different types of tasks under the umbrella of team responsibilities. As a result, we expect these sub-teams to communicate at a higher rate. However, while coordination within a sub-team may yield a higher success rate for their particular assignment, overall team performance could suffer from overly insular subunits. We posit that when individuals communicate primarily with their own team, the team of teams suffers; analogously, when individuals communicate primarily within their sub team, the higher level systems suffer. Our hypothesis can be stated as follows:

Hypothesis 3. Sub-team membership-driven communication has a negative relationship with team performance.

Consequences of How Intra-Team Communication Sequences on Team and MTS Performance

In an environment where information is only partially available to each component team, the need to obtain actionable information is crucial to carrying out team-level tasks. Individuals can gather relevant information by communicating with members of other teams within the MTS. In particular, if an individual communicates with another team and subsequently engages in communication with his own team, the information gained is shared. Thus, when boundary spanning behavior spurs intra-team communication, we expect knowledge to be flowing from the MTS level to the team level. As a result, teams may become more effective. We posit that intra-team communication as a result of boundary spanning behavior yields more successful teams.

Hypothesis 4. Externally-driven intra-team communication (i.e., intra-team representation & intra-team gatekeeping) positively predicts team performance.

When external communication spurs intra-team communication, team performance should benefit in general. However, this type of emergent behavior does not necessarily lead to MTS-level success. An individual who communicates with members of other teams becomes a conduit of information. A strong representation effect would suggest that inter-team communication leads to a higher volume of information directed at the boundary spanner. Thus, we posit that intra-team representation encourages knowledge flow from the team level to the MTS level, which in turn improves MTS-level performance. Conversely, gatekeeping behavior directs external information into the individual team. As a result, MTS-level coordination is negatively impacted, and teams may act in a more disjoint fashion. Therefore, we hypothesize that intra-team gatekeeping negatively impacts MTS-level performance.

Hypothesis 5. Intra-team representation positively predicts MTS performance.

Hypothesis 6. Intra-team gatekeeping negatively predicts MTS performance.

Consequences of How Inter-Team Communication Sequences on Team and MTS Performance

As we previously suggested, when individuals engage in boundary spanning behavior, team performance improves if they subsequently communicate with their own team. However, team success is contingent on an inward flow of information. When an individual becomes increasingly likely to engage in inter-team communication, he is less likely to supply his own team with new knowledge. In particular, strong inter-team inertia effects (personal and general) suggest that an individual who engages in external communication is likely to continue such behavior in the future. Thus, we hypothesize that the tendency for individuals to increasingly communicate externally, rather than contribute to the team, may negatively affect team performance.

Hypothesis 7. Inter-team personal inertia, inter-team generalized inertia, and inter-team reciprocity negatively affect team performance.

MTS-level performance is driven by information coordination and cohesion amongst the component teams. Boundary spanning behavior supports a positive flow of information amongst the independent units. When individuals actively engage members of other teams, the multiteam system is capable of operating more as a single unit, rather than a collection of disparate interests. As a result, we posit that all forms of boundary spanning behavior will have a positive effect on MTS-level performance.

Hypothesis 8. Inter-team generalized inertia, inter-team representation, and inter-team contagion have a positive impact on MTS performance.

Consequences of Homophily on Team and MTS Performance

At the team level, performance is measured by the ability of experts to obtain useful information and act effectively. Homophily effects dictate a strong tendency for these individuals to seek communication targets with similar expertise and background. A strong homophily influence would result in a positive flow of information between specialists, which in turn would yield more actionable information for each component team. Therefore, we hypothesize that communication amongst those of similar expertise has a positive impact on the team-level performance.

Hypothesis 9. Expertise homophily has a positive relationship with team performance.

We previously suggested that when there is significant team-level communication, MTS-level performance suffers. In general, we would expect that reliance on those with similar attributes would lead to more isolated groups, and subsequently a more disjointed system of teams. This homophily effect may be particularly strong in terms of expertise or role within a unit. We expect a strong tendency for individuals of similar expertise or background to communicate more often. However, for the MTS to perform well, there must be a flow of information from experts to those who can act on the knowledge (such as the leaders). Therefore, we hypothesize that a strong homophily effect among experts will negatively impact team performance. Conversely, leaders are responsible for making MTS-level decisions, and should communicate with each other at a high level. Thus, we hypothesize that when leaders communicate, the MTS-level performance is generally improved.

Hypothesis 10. Expertise homophily has a negative relationship with MTS-level performance.

Hypothesis 11. Leadership homophily has a positive relationship with MTS-level performance.

Method

Participants

Participants include 560 individuals arranged into 28, 20-person MTSs. Participants were recruited at a Midwestern US university and participated in this study in exchange for either research credit or $50. Participants reported to a laboratory in groups of 20, forming a single MTS, and each MTS was conducted in a separate 5-hour session. Participants were randomly assigned to one of four teams within the MTS, and to a specific role within their component team.

Multiteam Simulation Task

Each MTS participated in a networked computer-based simulation game designed specifically to capture the defining aspects of MTS including multiple teams working interdependently toward hierarchically arranged goals. The goal of the MTS is to guide a convoy of humanitarian aid through hostile territory. To accomplish this goal, individuals must collect intelligence, neutralize threats, and move the convoy to reach as many destinations in the region as possible. Each of the four component teams works in one part of the region to locate enemy combatants, and disarm them so that the convoy can travel safely through the region. Because the convoy needed to travel back and forth across roads traversing regional boundaries, the four teams needed to coordinate with one another to ensure the convoy could travel quickly and safely to needed regions. In addition, each of the potential component teams had intelligence information that was potentially relevant to the other three component teams. This created an additional motivation for interaction among the component teams. Each participant was seated at an individual workstation, and performed the task using a laptop computer. Participants wore headsets and communicated with one another through Skype.

Each component team consisted of five individuals: a leader, a reconnaissance officer and a field specialist who work on counter-insurgency, and a reconnaissance officer and a field specialist who work on ordnance disposal. Each of the four teams had an appointed leader, and the leaders were charged with moving the convoy. The leaders had to agree on where and when to advance the convoy. The four non-leader team members were responsible for identifying and neutralizing threats. Each team had a counter-insurgency and an ordnance disposal unit, each comprised of a reconnaissance officer and a field specialist. The reconnaissance officer was responsible for identifying potential threats and must communicate this information to the field specialist, who would then act on engaging and eliminating the threat.

Procedure

Each MTS testing session was divided into three phases: training, practice mission, and performance mission. During the training phase, participants watched an introductory video informing them of the mission and the structure of the teams and MTS. The 20-person MTS then performed a 15-minute practice mission, followed by a 50 minute performance mission. The performance mission consisted of a 10-minute leader planning period followed by a 40 minute action phase.

Measures

Communication events were measured using digital traces from the server logs. These logs store the time the communication was sent, the sender, receiver, and duration. The accumulation of communication events over time form the basis for the sequential structural signatures that are emergent in the MTS network. For each SSS, we determine a corresponding parameter value which represents the impact of the SSS on emergent communication patterns.These values provide data on how the participants communicated with each other throughout the simulation.

Team performance was measured using the server log which documented two indicators of team performance: the number of threats accurately identified and the number of threats effectively engaged. Higher values indicate that the aggregate of the four teams performed well. Attempted engagements is a count of the number of instances when a reconnaissance officer indicated to the field specialist that a particular cell contained a threat, and the field specialist decided to engage the target in the cell. Successful engagements is a count of the number of instances when an attempted engagement results in the successful elimination of the target in the cell. If the reconnaissance officer incorrectly labeled a cell as a threat, we count that as a failed engagement.

MTS performance was measured using the server log which documented two indicators of MTS performance: the distance traveled by the convoy and the accumulated damage taken by the convoy. Convoy movement is a count of the number of times the convoy was moved. Damage taken is a count of the number of times the convoy was damaged by the enemy. The distance traveled and damage taken were used as a measure of MTS goal attainment. The two metrics are correlated, because there was a tradeoff between “not moving” and “avoiding damage” or “moving” and “incurring damage” from enemy fire (R-square = .70). Thus, there is an inherent tradeoff in the two perspectives on MTS performance; the most successful units will be highly mobile, while avoiding damage above and beyond what is expected.

Analytic Approach

Broadly there were two goals for the analysis. First we sought to estimate the extent to which the hypothesized SSSs explained the sequence of communication events unfolding within the MTSs. Second we examined the relationships between each SSS and performance at both the team and MTS levels. We describe the analytic approach for each below.

Explaining Communication Sequences

Clearly, a longitudinal network approach is needed to capture the intricacies of the hypothesized SSSs. Until recently, using stochastic actor-oriented models was the most appropriate approach to analyze longitudinal networks (Snijders, 2001; Snijders, 1996; Snijders 2005; Snijders et. al. 2006). Snijders and colleagues model the evolution of network dynamics via a Markov process, with the state transitions dependent on the current network. The models are actor-oriented because actors - who choose to create, maintain, and dissolve ties based on their current position within the network - drive changes within the network. These models are particularly appropriate when a snapshot of the network data is collected at discrete time intervals (such as a day, month or year) and is used to model the underlying sequences of network changes that occurred - but were not observed - between these time points (see for example, Whitbred, Fonti, Steglich, & Contractor, 2011). However, these models are less useful when, as is the case in this study, we are able to observe the complete underlying sequences of network changes via time-stamped logs. To leverage this additional richness of network data, Butts (2008) and Brandes et al. (2009) proposed a relational event model that applies an actor-oriented approach to event history analysis (Blossfeld, 2001; Heise, 1989; Heise, 1991; Heise & Durig, 1997). Hence, in order to accomplish our first analytic goal, we used relational event models to detect the extent to which the hypothesized SSSs explained communication sequences within the MTSs.

A relational event is a discrete action generated by a social actor and directed at one or more targets. More concretely, the event $e = (a_e, b_e, x_e, t_t)$ a tuple storing the sender, receiver, weight, and time associated with the action. In this study the relational event is the communication sent from one individual to one or more other individuals within the MTS and the event sequence $E = \{e_1, \ldots, e_m\}$, where m is the total number of observed communication events. Additionally, the network at the *i*th event is denoted G_i and is a function of the sequence $E = \{e_1, \ldots, e_i\}$. The network information G is comprised of all nodal attributes - such as team membership, or role within the team - as well as the cumulative communication event data.

In the relational event model, communication events occur within the network according to a Poisson process. The rates are independent conditional on the past history of communication events. Once an event occurs the network topology and individual rates are updated, and the process restarts. To explicitly determine the model, we assume that each potential action has a constant hazard rate given a particular prior event history. The first step is to compute the prevalence of the hypothesized SSSs within the communication relational events up to that point in time. These counts are called *sufficient statistics*. A half-life decay function is used to ensure that recent occurrences of the SSS count for more than those that were not so recent. The next step is to estimate the extent to which these sufficient statistics influence the rate at which a future communication event is likely to occur from one actor *i* to another actor *j*. The rate is defined as a function of a linear combination of sufficient statistics and corresponding parameters. In particular, we use an exponential function.

$$\lambda_{ij}(G, \theta) = \exp\left(\sum_{k \in K} \theta_k s_k(G, i, j)\right)$$

In the above equation, K is the set of all sufficient statistics; $s_k(G, i, j)$ is the k*th* sufficient statistic for dyad (i, j), which is based on a count of the corresponding SSS associated; and θ_k is the parameter estimate that determines the extent to which the k*th* sufficient statistic (and the corresponding SSS) influence the rate (and hence the likelihood) of a relational event from *i* to *j*. In general, this form is analogous to the elements of objective functions used in dynamic network models (Snijders, 1996; Snijders, 2005), and the parametrization of exponential random graph models (Pattison and Robins, 2002; Snijders et. al., 2006; Wasserman and Pattison, 1996). The sufficient statistics must be finite, dependent on past history (in terms of volume and timing), and are affine independent.

Using maximum likelihood estimation, we find the parameters corresponding to each hypothesis. The software for these analyses were implemented in MATLAB (2012). These parameter estimates represent the extent to which each sufficient statistic (and the corresponding SSS) influence the likelihood of the next communication event. If parameters are statistically significant, then we can draw conclusions regarding the respective hypotheses. In this study, we report on results based on an analysis of the main performance mission.

Explaining Variations in Performance

While the previous section outlined a method for analyzing how SSSs led to emergent communication patterns, it did not address the performance of each MTS. In general, we expect similar groups of individuals to behave in similar ways. However, the variations in how each group interacts can explain the discrepancies in their performance. Using the relational event framework, we explicitly determined the effect each structural signature had on the propensity for individuals to communicate by analyzing the standardized parameter values. Our approach was to determine a functional dependence between these parameter values and each of the success measures that we identified.

In order to determine the relationship between communication behavior and performance, we utilized Poisson regression. This approach is best suited to count data where the majority of data points are non-zero; in our MTS study, the performance metrics - engagements, movements, and damage taken - are all counts. Our Poisson regression model uses the standardized parameter values for each SSS as linear predictors for the average count of each measure of performance. These parameter values were estimated from the relational event model. Therefore, the independent variables can be interpreted as the intensity of a particular emergent effect, with larger values indicating primary drivers of communication in the MTS network. Analogous to linear regression, our output is a set of parameter estimates, which we standardized. The sign and magnitude of each estimate indicates the direction and strength of the relationship; for example, a positive sign would indicate that the larger the effect a structural signature has on emergent communication, the higher we would expect the count of the performance metric to be.

Results

In Table 1, we provide summary statistics for each of the SSSs we tested, as well as the four performance metrics. Additionally, in Table 2 we report the correlation coefficients for each pair of independent and dependent variables. Using the standardized parameter values as independent variables, four separate Poisson regressions were run. In Table 3 we present the results (all coefficients are standardized). Using the pseudo-R^2 metric, we can conclude that each of the models does a reasonable job of explaining the variance in the dependent variable.

We first observe that team membership has a significant, positive relationship with the number of engagements ($p < 0.05$). In other words, when individuals within an MTS have a higher propensity to communicate with their own team members, the teams will be more active in engaging enemy targets. As each team is responsible for neutralizing targets within their zone, teams that are more active tend to display higher levels of coordination and effectiveness; this result supports Hypothesis 1. Additionally, team membership has a negative and significant relationship with movement ($p < 0.05$). Movement of the convoy is the ultimate measure of inter-team coordination; in order to move, leaders from each team must come to an agreement. Therefore, the number of convoy movements is considered a viable measure of MTS-level performance. A negative relationship between team membership and movement therefore indicates that MTS performance suffers when teams within the MTS communicate with themselves at higher levels. Thus, we have support for Hypothesis 2. Additionally, sub-team membership is negatively associated with both the number of engagements ($p < 0.05$) as well as the number of successful engagements ($p < 0.01$). In other words, the more insular a functional unit is (implying they favor speaking within their own functional unit rather than reaching out to others in the team), the less decisive and less accurate they become. Sub-team membership also has a negative relationship on movement ($p < 0.05$), which further supports the notion that group preference effects hinder MTS performance.

Hypothesis 3 claims that any boundary spanning behavior that yields external information for the use of the team is beneficial to team performance. Intra-team representation has a moderately strong positive relationship with successful engagements ($p < 0.1$), while intra-team gatekeeping has strong positive relationships with both attempted and successful engagements ($p < 0.01$ & $p < 0.05$, respectively). Taken together, these two effects indicate that within-team communication is spurred by information gained from external sources. Thus, when individuals communicate with members of other teams and then pass the information gained on to their own team, the team performs better. However, this result does not apply uniformly to MTS-level performance. Intra-team representation is positively associated with both movement ($p < 0.01$) and damage ($p < 0.05$), which supports Hypothesis 4. Intra-team representation measures the likelihood of an individual communicating with a team member who has previously engaged in boundary spanning behavior. Thus, MTS-level performance is improved when information flows out from teams; in other words, when individuals target boundary spanners, their information is spread out amongst other teams in the multiteam system. Conversely, intra-team gatekeeping represents the flow of information into individual teams. When individuals engage in boundary spanning behavior, then proceed to communicate with their own team, they do not contribute to overall MTS cohesion. As a result, we see the negative association between intra-team gatekeeping and movement ($p < 0.05$), which supports Hypothesis 5.

Hypothesis 6 claims that as individuals increasingly communicate with others outside of their own team, team-level performance suffers. Inter-team personal inertia ($p < 0.1$) has a negative relationship with successful engagements, while inter-team generalized inertia ($p < 0.01$) and inter-team reciprocity ($p < 0.01$) are negatively associated with attempted engagements. Each of these effects reflect the tendency for individuals to initiate communication with other teams as a result of previous communication with other teams. Thus, the lack of information flow into teams hurts the ability of teams to engage targets effectively, which supports our hypothesis. At the MTS-level, we expect boundary spanning behavior to have a positive impact on performance. Inter-team representation ($p < 0.1$), inter-team generalized inertia ($p < 0.01$), and inter-team contagion ($p < 0.01$) all have a significant positive relationship with convoy movement. Therefore, we can conclude that high degrees of inter-team communication result in a more coordinated, cohesive unit. As Hypothesis 7 suggests, these MTSs are more successful.

Additionally, expertise homophily is positively associated with the number of successful engagements ($p < 0.05$). This value is higher when recon officers or field specialists communicate with each other; thus, sharing information from unit to unit leads to high performance of the MTS teams. Hypotheses 8 and 9 are supported by the empirical results. Expertise homophily has a negative relationship with convoy movement ($p < 0.05$); this result further supports Hypothesis 10: dependence on similar players makes the MTS perform worse. Finally, as Hypothesis 11 claims, leadership homophily is positively associated with movement ($p < 0.01$). This result is somewhat influenced by the design of the network-based computer simulation game; because leaders are required to agree on any movement, there should always be a positive relationship between inter-leader communication and convoy movement.

Discussion

Teams are the basic unit of collaborative work, oftentimes forming complex "team of teams (Mathieu, Marks, and Zaccaro, 2001; Zaccaro, Marks, & DeChurch, 2012)." Individuals who work in such organizational forms face the added complexity of managing information and relationships within a large collective Members balance interactions within the team, which serve to enhance cohesion and coordination, with cross-team interactions needed to maintain horizontal coordination across the system of teams (Davison et al., 2012). Whereas the members of different teams within MTSs share a distal goal, the members of each team typically value additional goals that are not necessarily shared by the members of other teams (Zaccaro, Marks, & DeChurch, 2012). The overarching research question is twofold: (1) what are the underlying generative mechanisms that explain how MTSs members communicate? and (2) which generative mechanisms are at play within successful as compared to unsuccessful MTSs?

The Generative Mechanisms of MTS Communication

We first conceptualized four classes of generative mechanisms that characterize the emergent communication sequences in MTSs. These sequences are based on characteristics of the intra-team and inter-team communication as well as individuals' affiliations and role homophily. And each has important effects on team and/or MTS performance. This is a promising attempt at creating taxonomies of generative mechanisms that might be fruitful for communication researchers theorizing potential impacts on performance.

Using Relational Event Networks to Study MTS Communication

A second contribution of this study is the advancement of a new methodology for understanding MTS communication. We used digital traces of communication coupled with relational event network analysis to develop high-resolution measures of team and MTS process. Prior research on teams and MTS, even that which is longitudinal, uses "binned" measures of interaction processes. These measures are more like slide show of photographs rather than a movie. In contrast, the analytic framework we employed allows us to watch the movie of team and MTS interaction. The relational event approach models every communicative interaction as an event, and predicts the likelihood of each event based on the accumulated past interactions. This method is particularly promising given the substantial variance in performance that is explained (with Pseudo-R^2 ranging from 47% to 60%) relative to the binned or cross-sectional measures that have been employed in prior research on the impact of communication on performance.

This methodology also has at least two important practical implications. First, by utilizing real-time communication traces, this methodology could be used to detect functional and dysfunctional team processes relatively early on in the lifecycle of a team or MTS. Such early diagnosis would be very valuable for intervening in the team to change the nature of the interaction. Second, this method relies entirely on unobtrusive measures of team process. Such measurement has the advantage of being nonreactive, economical in terms of participants' time, and allows researchers to study the processes of large numbers of teams over longer time intervals than is afforded by survey-based methodology.

The Performance Consequences of MTS Generative Mechanisms

Our analyses compared the SSSs of the MTSs based on performance at the team and MTS level. Differences in the generative mechanisms among the MTSs clearly impact the performance of those MTSs at the team and MTS level. A general theme of these comparisons was that when mechanisms unfold such that between-team communication influences subsequent within-team communication (intra-team representation & gatekeeping), performance is maximized at the team level. The representation and gatekeeping mechanisms help us to understand the sequences through which communication externally prompts communication internally (Fernandez & Gould, 1996). This finding suggests that we can positively predict success for MTSs whose external boundary spanners become targets of intra-team communication.

A similar but opposite pattern was true of MTS performance. The same functions were important as a generative mechanism of communication: representation and gatekeeping, but it was inter-team communication that was most critical. When prior within-team communication influenced subsequent between-team communication (inter-team representation & gatekeeping), MTS performance was maximized. Taken together these findings make a significant contribution to our knowledge of MTSs. The unfolding sequence of relational events plays an important role in predicting the relative success of MTSs. These SSSs provide valuable insight into the underlying mechanisms MTS members use to maintain dual coupling within and between teams. Team performance requires that between-team communication serve as a trigger for later within-team communication. MTS performance requires that within-team communication serve as a trigger for later between-team communication.

Another revealing finding was the effect of leadership homophily on MTS-level performance. While nearly all MTSs engaged in leadership homophily, there was a strong positive relationship between the magnitude of this effect and the performance of the MTS.

Conclusion

Modern organizations are increasingly built around “teams of teams” or multiteam systems (MTSs) that must manage a delicate interplay of interactions within and between teams. This study advances research on MTSs by exploring the relational dynamics that unfold within and between teams, and their consequences for success of the team and the MTS. It demonstrates that relational event network models are capable of using high resolution event-based measures of communication to explain substantial variation in performance. As a result, it has the promise of ushering in a new form of theorizing about processes and their impacts on performance from a sequential framework.

References

Ancona, D. G., & Caldwell, D. F. 1992). Bridging the boundary: External activity and performance in organizational teams. *Administrative Science Quarterly*, **37***,* 634-665.

Arrow, H., Poole, M. S., Henry, K. B., Wheelan, S., & Moreland, R. 2004. Time, change, and development: The temporal perspective on groups. *Small Group Research*, ***35***, 73–105.

Blossfeld, H. P. 2001. Techniques of event history modeling: New approaches to causal analysis. *Psychology Press*.

Brandes, U., Lerner, J., & Snijders, T. A. 2009. Networks evolving step by step: Statistical analysis of dyadic event data. In *Social Network Analysis and Mining, 2009. ASONAM'09. International Conference on Advances in* (pp. 200-205). IEEE.

Butts, C. T. 2008. A relational event framework for social action. *Sociological Methodology*, **38**, 155-200.

Byrne, D. E. 1971. The attraction paradigm (Vol. 11). *Academic Press.*

Contractor, N., Wasserman, S., & Faust, K. 2006. Testing multi-theoretical multilevel hypotheses about organizational networks: An analytic framework and empirical example. *Academy of Management Review*, **31**, 681–703.

Davison, R. B., Hollenbeck, J. R., Barnes, C. M., Sleesman, D. J., & Ilgen, D. R. 2012. Coordinated action in multiteam systems. *Journal of Applied Psychology*, **97**, 808-824.

Fowler, J. H., & Christakis, N. A. 2010. Cooperative behavior cascades in human social networks. *Proceedings of the National Academy of Sciences*, **107**, 5334-5338.

Gersick, C. J. 1988. Time and transition in work teams: Toward a new model of group development. *Academy of Management journal*, **31**, 9-41.

Gibson, R. 2003. Participation shifts: order and differentiation in group conversation. *Social Forces,* **81**, 1335-1381.

Gibson, D. R. 2005. Taking turns and talking ties: Networks and conversational interaction. *American Journal of Sociology*, **110**, 1561-1597.

Heise D. R. 1989. Modeling event structures. *Journal of Mathematical Sociology*, **14**, 139-169.

Heise, D. R. 1991. Event structure analysis: A qualitative model of quantitative research. *Using Computers in Qualitative Research*. Londres: Sage.

Heise D. R., & Durig, A. 1997. A frame for organizational actions and macroactions. *American Journal of Sociology,* **22**, 95-123.

Joshi, A., Pandey, N., & Han, G. H. 2009. Bracketing team boundary spanning: An examination of task-based, team-level, and contextual antecedents. *Journal of Organizational Behavior*, **30**, 731-759.

Lanaj, K., Hollenbeck, J., Ilgen, D., Barnes, C., & Harmon, S. 2013. The double-edged sword of decentralized planning in multiteam systems. *Academy of Management Journal.*

Marks, M. A., Mathieu, J. E., & Zaccaro, S. J. 2001. A temporally based framework and taxonomy of team processes. *Academy of Management Review*, 356-376.

Marks, M. A., Zaccaro, S. J., & Mathieu, J. E. 2000. Performance implications of leader briefings and team-interaction training for team adaptation to novel environments. *Journal of Applied Psychology*, **85**, 971.

Marrone, J. A. 2010. Team boundary spanning: A multilevel review of past research and proposals for the future. *Journal of Management*, **36**, 911-940.

Marrone, J. A., Tesluk, P. E., & Carson, J. B. 2007. A multilevel investigation of antecedents and consequences of team member boundary-spanning behavior. *Academy of Management Journal*, **50**, 1423-1439.

Mathieu, J., Marks, M., & Zaccaro, S. 2001. Multiteam systems. *International Handbook of Work and Organizational Psychology*, **2**, 289-313.

MATLAB and Statistics Toolbox Release 2012b, The MathWorks, Inc., Natick, Massachusetts, United States.

Maynard, M. T., Mathieu, J. E., Rapp, T. L., & Gilson, L. L. 2012. Something (s) old and something (s) new: Modeling drivers of global virtual team effectiveness. *Journal of Organizational Behavior*, **33**, 342-365.

McPherson, M., Smith-Lovin, L., & Cook, J. M. 2001. Birds of a feather: Homophily in social networks. *Annual Review of Sociology*, **27**, 415-444.

Pattison, P., & Robins, G. 2002. Neighborhood–based models for social networks. *Sociological Methodology*, **32**, 301-337.

Pattison, P., Wasserman, S. 1999. Logit models and logistic regressions for social networks: II. Multivariate relations. *British Journal of Mathematical and Statistical Psychology*, **52**, 169-193.

Pettigrew, T. F., & Tropp, L. R. 2006. A meta-analytic test of intergroup contact theory. *Journal of Personality and Social Psychology*, **90**, 751-783.

Poole, M. S., & Contractor, N. 2011. Conceptualizing the multiteam system as an ecosystem of networked groups. In S. J. Zaccaro, M. A. Marks, & L. A. DeChurch (Eds.), *Multiteam Systems: An Organization Form for Dynamic and Complex Environments* (pp. 193–224). Routledge.

Poole, M. S., Hollingshead, A. B., McGrath, J. E., Moreland, R. L., & Rohrbaugh, J. 2004. Interdisciplinary perspectives on small groups. *Small Group Research*, **35**, 3–16.

Richter, A. W., West, M. A., Van Dick, R., & Dawson, J. F. 2006. Boundary spanners' identification, intergroup contact, and effective intergroup relations. *Academy of Management Journal*, **49**, 1252-1269.

Snijders, T. A. 2001. The statistical evaluation of social network dynamics. *Sociological methodology*, **31**, 361-395.

Snijders T. A. B. 1996. Stochastic actor-oriented models for network change. *Journal of Mathematical Sociology*, **21**, 149-172.

Snijders, T. A. 2005. Models for longitudinal network data. *Models and methods in Social Network Analysis*, **1**, 215-247.

Snijders, T. A., Pattison, P. E., Robins, G. L., & Handcock, M. S. 2006. New specifications for exponential random graph models. *Sociological Methodology,* **36**, 99-153.

Snijders, T. A. B., Van de Bunt, G. G., & Steglich, C. E. G. 2010. Introduction to stochastic actor-based models for network dynamics. *Social Networks*, **32**, 44–60.

Wasserman S., Pattison P. 1996. Logit Models and Logistic regressions for social networks: I. An introduction to Markov Graphs and p*. *Psychometrika*, **60**, 401-426.

Whitbred, R., Fonti, F., Steglich, C., & Contractor, N. 2011. From microactions to macrostructure and back: A structurational approach to the evolution of organizational networks. *Human Communication Research*, **37**, 404–433.

Zaccaro, S. J., Marks, M. A., & DeChurch, L. A. (Eds.). 2012. *Multiteam Systems: An Organization Form for Dynamic and Complex Environments*. New York: Routledge.

Table 1

Descriptive Statistics for Key Study Variables (N = 28 MTSs).

	Mean	Std. Dev.	Min	Max
Sub-team membership	14.09	3.20	6.52	18.72
Team membership	-0.22	2.09	-5.31	4.57
Intra-team representation	1.17	2.37	-5.24	6.84
Intra-team gatekeeping	2.50	2.91	-3.20	8.96
Inter-team personal inertia	2.47	2.98	-2.46	9.18
Inter-team generalized inertia	1.14	1.78	-3.01	4.35
Inter-team reciprocity	1.52	2.76	-3.09	7.80
Inter-team representation	2.28	2.87	-3.33	8.00
Inter-team contagion	0.46	2.19	-2.80	8.35
Expertise homophily	0.25	2.11	-4.07	4.36
Leadership homophily	9.23	4.96	-1.80	21.20
Attempted Enemy Engages	59.17	17.69	14	103
Successful Enemy Engages	40.92	9.01	12	58
Convoy Movements	7.14	4.34	0	20
Damage Taken	4.14	2.77	0	12

Table 2: Correlations among Key Study Variables

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Sub-team membership	--													
2. Team membership	0.22	--												
3. Intra-team representation	0.34	0.00	--											
4. Intra-team gatekeeping	0.29	-0.06	0.70	--										
5. Inter-team personal inertia	0.08	0.12	0.63	0.62	--									
6. Inter-team generalized inertia	0.03	-0.07	0.51	0.62	0.68	--								
7. Inter-team reciprocity	0.04	0.12	0.20	0.27	-0.04	0.17	--							
8. Inter-team representation	-0.12	-0.03	-0.27	-0.23	-0.09	-0.27	-0.02	--						
9. Inter-team contagion	0.10	0.07	-0.01	0.05	0.05	-0.03	0.03	0.48	--					
10. Expertise homophily	-0.46	-0.56	0.11	0.10	-0.11	-0.01	0.00	-0.05	-0.13	--				

11. Leadership homophily	0.37	-0.40	0.30	0.19	0.06	0.15	0.11	0.08	0.28	-0.03	--			
12. Attempted Enemy Engages	0.16	0.58	-0.09	-0.18	-0.28	-0.43	0.00	-0.24	-0.35	-0.17	-0.33	--		
13. Successful Enemy Engages	0.61	0.34	0.39	0.42	0.33	0.08	-0.04	-0.08	0.08	-0.28	0.10	0.21	--	
14. Convoy Movements	0.02	0.11	0.02	-0.15	-0.19	0.00	0.01	0.22	0.31	-0.17	-0.02	0.08	0.11	--
15. Damage Taken	0.01	0.13	0.07	-0.05	-0.22	-0.15	-0.07	0.07	0.26	0.00	-0.15	0.26	0.12	0.84

Table 3

Poisson Regressions of Team & MTS Performance on Sequential Structural Signatures (N = 28 MTSs).

	Team Performance		MTS Performance	
	Attempted Enemy Engagements	Successful Enemy Engagements	Convoy Movements	Convoy Units Damaged
Hypothesis	Coefficient	Coefficient	Coefficient	Coefficient
Affiliation Mechanisms				
Sub-team membership	-2.01 **	-3.13 ***	-2.11 **	-0.88
Team membership	2.29 **	0.87	-1.99 **	-1.40
Team Mechanisms				
Intra-team representation	1.33	1.82 *	3.23 ***	2.34 **
Intra-team gatekeeping	4.58 ***	2.14 **	-2.39 **	-0.41
Inter-Team Mechanisms				
Inter-team personal inertia	0.04	-1.74 *	-2.72 ***	-2.13 **
Inter-team generalized inertia	-3.05 ***	-1.31	3.54 ***	1.48
Inter-team reciprocity	-2.70 ***	-1.24	0.01	-0.61
Inter-team representation	-0.15	-0.68	1.85 *	0.46
Inter-team contagion	-0.34	0.02	3.22 ***	2.97 ***
Homophily Mechanisms				
Expertise homophily	1.49	1.97 **	-2.30 **	-2.33 **
Leadership homophily	-0.46	-0.47	2.66 ***	2.09 **
Pseudo R-square	0.50	0.59	0.48	0.46

*Note: *=p<0.1, **=p<0.05, ***=p<0.01*