The topology of collective leadership

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ABSTRACT

Over the past decade, there has been a surge of both theoretical and empirical research to explore the possibilities of shared leadership, a reorientation of leadership away from understanding the actions and interactions of "leaders" to understanding the emergent, informal, and dynamic "leadership" brought about by the members of the collective itself. Naturally, this focus on topology (or structural patterning) has prompted researchers to leverage the advancements in network analytic methodology to understand this paradigm of leadership. Despite the recognition of the unique advantage of studying collective leadership using network analysis, there has been a translational gap. The current paper aims to fill this gap, bridging the core ideas that epitomize collective leadership to the social network metrics and analytics needed to fully understand its antecedents and consequences.

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1. Introduction

The scientific study of leadership has long recognized that the behavior of leaders can have extraordinary effects on collectives including teams, units, and organizations (Kaiser, Hogan, & Craig, 2008). At the turn of this century, systematic inquiry into a new paradigm of leadership, dubbed shared leadership, took seriously the idea that the leadership responsible for these extraordinary effects could be attributed to the collective leading itself (Pearce & Conger, 2003). This paradigm reflects a shift in the focus of leadership research; from understanding the actions and interactions of "leaders" to understanding the emergent, informal, and dynamic "leadership" brought about by the members of the collective itself.

Over the past decade, there has been a surge of both theoretical and empirical research to explore the possibilities of this new leadership paradigm (Denis, Langley, & Sergi, 2012; Friedrich, Vessey, Schuelke, Ruark, & Mumford, 2009). Much of that research has exploited the topology inherent in viewing leadership as an emergent, collectively enacted phenomenon. Naturally, this focus on topology (or structural patterning) has prompted researchers to leverage the advancements in network analytic methodology to understand this paradigm of leadership. Despite the recognition of the unique advantage of studying collective leadership using network analysis, there has been a translational gap. The current paper aims to fill this gap, bridging the core ideas that epitomize collective leadership to the social network metrics and analytics needed to fully understand its antecedents and consequences.

We accomplish this in three parts. First, we integrate prior conceptual research on collective leadership, drawing out three structural aspects of collective leadership: people (i.e., leaders, followers, & their relations), roles (i.e., leadership functions), and time (i.e., dynamics). Second, we develop a bridging framework to enable these three dimensions to be fruitfully examined with network methodology. Third, we detail a range of metrics and analytic approaches that can be used to study these three core dimensions of collective leadership.

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2. A structural conceptualization of collective leadership

Although the core idea of collective leadership entered the scholarly discourse more than 60 years ago (Gibb, 1954), it was not until the past decade that significant attention has been paid to understanding collective leadership (Pearce & Conger, 2003). In contrast to the fifty-year period where the attention of leadership scholars was focused elsewhere on traits, behaviors, and the like, the past 10 years has witnessed a flurry of energy and attention aimed at understanding collective leadership.

Pearce and Conger (2003) defined shared leadership "as a dynamic, interactive influence process among individuals in groups for which the objective is to lead one another to the achievement of group or organizational goals or both (p. 1)." Pearce and Conger went on to elaborate the structural nature of shared leadership, observing that leadership is "broadly distributed…instead of centralized in the hands of a single individual (p. 1)." Cox, Pearce, and Perry (2003) called attention to the temporality inherent in shared leadership, defining it as a "dynamic exchange of lateral influence (p. 48)." Fletcher and Käufer (2003) honed in on the informal nature of shared leadership. Seers, Keller, and Wilkinson (2003) and Hiller, Day, and Vance (2006) have emphasized the fact that collective leadership is a property of the group rooted in social exchange-based roles. Hiller and colleagues (2006) assert that "the epicenter of collective leadership is… the interaction of team members to lead the team by sharing in leadership responsibilities (p. 388)."

For the purpose of this review, we adopt the term "collective" leadership, which encompasses not only shared leadership but also includes a variety of highly similar concepts (i.e., distributed and rotated leadership). In Table 1, we synthesize five works that introduce important notions of the essence of collective leadership. These five works lay the groundwork for the model and associated methodology presented here. The left half of Table 1 summarizes four key aspects of how collective leadership has been defined in prior work: the conceptual definition, the focal unit of analysis, the informal nature of collective leadership, and the essence of the leadership phenomena.

2.1. The forms of collective leadership: concentration

First, inherent in these works is the notion that multiple individuals are enacting leadership. Gronn (2002) discusses "one individual, an aggregate of separate individuals, sets of small numbers of individuals (p. 428)." Pearce and Conger (2003) reference "individuals and groups (p. 1)." Hiller et al. (2006) discuss multiple "team members." The fact that multiple individuals are enacting leadership requires that we focus on the structural form as well as the intensity and direction of leadership relationships.

Three papers have advanced our understanding of the forms of collective leadership. Mayo, Meindl, and Pastor (2003) were the first to apply a social network approach to mapping collective leadership. Mayo and colleagues used two aspects of forms to capture shared leadership: decentralization and density. Decentralization captures the distributed aspect of collective leadership. Maximum decentralization occurs when leadership influence is evenly dispersed among all members of the collective. In contrast, a centralized form of leadership occurs when the leadership influence is concentrated in one or very few members of the collective. Mehra, Smith, Dixon, and Robertson (2006) also advanced our understanding of the topology of collective leadership by describing four patterns of leadership: leader centered, distributed, distributed–coordinated, and distributed–fragmented. Whereas Mayo et al. proposed the use of centralization and density metrics to capture leadership topology, Mehra qualitatively coded observed leadership structures into the four types. Carson, Tesluk, and Marrone (2007) applied Mayo et al.'s approach, using density as a metric reflecting the amount of shared leadership. In summary, there have been some efforts to describe the topology of collective leadership networks. Further, the focus has been on capturing the extent to which the topology provides a measure of the concentration of collective leadership in one or a handful of individuals.

2.2. The multiplexity of collective leadership: roles

The second aspect of collective leadership stems from the fact that leadership serves multiple collective functions or roles. Mayo et al. (2003) used the transactional and transformational leadership framework, describing collective leadership as multiple members of the group engaging in contingent reward, management by exception, charisma, individualized consideration, and intellectual stimulation behaviors. Though Mayo et al. proposed the integration of transformational and transactional behaviors with the collective leadership paradigm, empirical research has yet to utilize this framework. Empirical work has tested a multidimensional framework, but a different one. Hiller et al. (2006) presented a four dimensional typology including: planning and organizing, problem-solving, support and consideration, and developing and mentoring. Although Hiller and colleagues expanded our view of the dimensionality of collective leadership, they failed to look at the structure. Rather, Hiller et al. captured the amount of enactment of these four functions within teams, but did not model the pattern of *who* was enacting *how much* of each of these functions with whom.

A role perspective lends itself well to understanding leadership activity in social groups. A role is defined as a dynamic set of recurring behaviors, both expected and enacted, within a particular group context (Zigurs & Kozar, 1994). Thus, roles serve two important functions by both establishing patterns for individual behavior through the interaction of members in a social unit (Katz & Kahn, 1978), and also establishing expectations for the behaviors of others.

There is general agreement among scholars that leadership involves a complex of roles (e.g., Hollander, 1985), and a number of scholars have offered theoretical typologies of the various roles or functions that leadership must provide within team settings. While there has been no convergence on a single typology as preeminent, there is a surprising degree of overlap in the basic ideas

Table 1
Progression of ideas about collective leadership (2002–2012).

	Defining collective leadership			Collective leadership conceptual dimensions to be elucidated with network analysis		
Conceptual definition	Focal unit of analysis	Leadership as formal/informal (are leaders preordained?)	Leadership phenomena (what's in the ties?)	People—concentration of leadership (what pattern?)	Roles—multiplexity of functional behaviors (what collective needs does leadership serve?)	Time—Temporal dynamics (how does the phenomenon unfold over time?)
Gronn (2002)						
"Leadership is defined ...as status ascribed to one individual, an aggregate of separate individuals, sets of small numbers of individuals acting in concert or larger plural-members organizational units. (p. 428.)"	Organization or other collective	Informal—"The individuals or multiperson units to whom influence is ascribed include, potentially, all organization members, not just managerial role incumbents (p. 429)."	A [dyadic] influence relationship	Distributed influence manifest as one of three patterns: (1) "distributed practice...evident in the interaction of many leaders (p. 430)", (2) "two or more... members rely on each other and develop a close working relationship (p. 430)", or (3) "a leadership group headed by a first among equals (p. 430)."	NA	"The duration of the attributed influence may be short or long term (p. 429)."
Pearce and Conger (2003)						
"Shared leadership [is] a dynamic, interactive influence process among individuals in groups for which the objective is to lead one another to the achievement of group or organizational goals or both (p. 1)."	Group and/or organization	Informal—"Leadership...is not determined by positions of authority or depth of expertise but rather by an individual's capacity to influence peers and by the leadership needs of the team in a given moment (p. 2)."	Peer-based influence	"Leadership is broadly distributed among a set of individuals instead of centralized in hands of a single individual who acts in the role of a superior (p. 1)."	NA	"Individuals who are not formally appointed as leaders can rise to the occasion to exhibit leadership and then step back at other times to allow others to lead (p. 2)."
Hiller et al. (2006)						
"The epicenter of collective leadership is not the role of a formal leader, but the interaction of team	Team	Informal—"Collective leadership is ....the holistic concertive action of a group (p. 388)."	Shared [team] perceptions of how much collective leadership exists within the team	Collective enactment of the leadership role by all team members	Multiple roles; "Collective team leadership as a role structure that is based on leadership roles that are	NA

members to lead the team by sharing in leadership responsibilities (p. 388)."				informally adopted and enacted by team members (p. 388)." Roles include: planning & organizing, problem-solving, support & consideration, & developing & mentoring	NA
Mehra et al. (2006) "Leadership in teams [is] a shared, distributed phenomenon in which there can be several (formally appointed and/or emergent) leaders (p. 233)."	Team	Informal—"...focus is on the emergent network of leadership perceptions within work teams. (p. 233)."	Dyadic perceptions of leadership	Topological structure; patterns of leadership are either: leader-centered, distributed, distributed–coordinated, and distributed–fragmented	NA
Friedrich et al. (2009) Collective leadership is "a dynamic leadership process in which a defined leader, or set of leaders, selectively utilize skills and expertise within a network, effectively distributing elements of the leadership role as the situation or problem at hand requires (p. 933)."	Network; Team	Formal & Informal—Defined leader or leader set	"Communication is the currency of collective leadership (p. 936)."	Dynamic forms "... there may be shifts in the need for a single leader, multiple leaders sharing the leadership role, or even a shift in the roles that each individual engages in (p. 935)."	Dynamic "...collective leadership is not static. As different problems emerge, different skills and expertise will be more appropriate (p. 935)."

suggested by most of these scholars. Some of the earliest empirical work on team leadership points toward dual task and relational leadership roles in teams. Bales (1950) and Bales and Slater (1955) studied emergent leadership in leaderless teams and found that two leaders consistently emerged: the first was highly task-oriented (instrumental behaviors focused on assisting the team in achieving its goals) while the second most influential was focused on the socio-emotional needs of the team (reinforcing and guiding group behavior, inter-member relations, and group solidarity.) Hollander's (1961) review of research on emergent leadership also concluded that both task-focused (task competence and skill in coordination of team task goals) and relational behaviors (skill in building trust) were important for individuals to be selected as leaders. More recent research has also supported both task coordination behaviors and member support and development behaviors as being important for emergent leadership in teams, with task behaviors being slightly more important (Kellett, Humphrey, & Sleeth, 2002; Taggar, Hackett, & Saha, 1999).

Carson and Tesluk (2007) observed that there is a large degree of convergence around four distinct roles that are important for team leadership (see Table 2): Navigator, Engineer, Social Integrator, and Liaison. The Navigator role enables the collective to establish and maintain a clear purpose and direction. The Engineer role structures the collective and the task, coordinating the contributions of members to meet the goals of the collective. The Social Integrator role maintains healthy and productive social interactions and relational processes within the collective. Lastly, the Liaison role develops and maintains productive relationships with key external stakeholders, serving as both an advocate and ambassador for the collective. We build on this typology of roles to elaborate on how collective leadership can be tested with network analysis.

Seers et al. (2003) provide the most coherent theoretical elaboration to date to explain how multiple leadership roles constitute collective leadership. Seers and colleagues define collective leadership as "the extent which more than one individual can effectively operate in a distinctively influential role within the same interdependent role system (p. 79)." This definition emphasizes that the multiple individuals enacting leadership are occupying different social roles, a view that builds on the early work of Bales and colleagues (Bales, 1958; Bales & Slater, 1955) who observed that two individuals tend to emerge as leaders in leaderless group discussions. The most respected expert occupies the "task leader" role, and the most liked member occupies the "social leader" role. This role differentiation naturally occurs over the course of member interaction as "influence over others is purchased at the price of allowing one's self to be influenced by others (Homans, 1961, p. 286)." Seers and colleagues posit that leadership differentiation, where members have little overlap in the focus of their leadership activities, benefits group performance.

An alternative view is supported by research on the role of networks on collective action. Multiplexity in relationships, defined as relations involving more than one type of relationship, result in more creative outcomes (Albrecht & Hall, 1991). Applied to collective leadership, this view suggests that an advantage accrues to those collectives whose leadership ties carry more than one type of leadership relationship. An example of this using the Hiller et al. framework is that teams where the individuals who are setting direction are also developing and mentoring. The relative cost and benefits would seem to stem from the tradeoff between specialization of labor versus coordination costs. Specialization in leadership roles allows particular individuals to focus on a narrower scope of activities and to devote all of their attentional resources to those activities. However, specialization comes at a cost to coordination *across* roles. There may be times when the planning and organizing role would be better enacted to simultaneously consider the development and mentoring needs of the team. Having the same individuals influencing the same others in both ways, i.e., leadership multiplexity, increases coordination across leadership functions.

The preceding discussion draws out the need to adequately test the impact of leadership multiplexity, as it is a core aspect of collective leadership which has until now, received only scant attention. Thus far, we have explained that collective leadership involves multiple individuals (i.e., forms) enacting multiple roles (i.e., multiplexity). We now turn to the third aspect of collective leadership: time.

2.3. The dynamics of collective leadership: time

The third core aspect of collective leadership holds that multiple individuals enact multiple roles, and this topological multiplexity (i.e., forms and role structure) changes over time. The importance of applying a temporal lens to the study of collective leadership originates with the work of Pearce and Conger (2003), who observe that "individuals… can rise to the occasion to exhibit leadership and then step back at other times to allow others to lead (p. 2)."

At the most basic level, incorporating time into collective leadership recognizes that a general leadership role is cycled among different members of the collective. This is a variation on the vertical leadership form in that, at any given moment, the leadership structure is hierarchical, top–down. However, the individual who enacts the hierarchical leadership role shifts over time. Moreover, this form represents a structurally vertical form, but one in which the responsibility for leadership is shared sequentially or serially among group members. An exemplar of this approach is Erez, LePine, and Elms (2002), who find that rotation of leadership role allowed all team members to feel responsibility for the team's success. They also reported that such leadership increased the degree to which members offer suggestions for change in the team, and the overall level of cooperation within the team. However, rotated leadership may reduce continuity over time, and this form may not always be matched to team or task needs.

Accordingly, an extended view of the role of time was advanced by Friedrich et al. (2009), who advocate that "…collective leadership is not static. As different problems emerge, different skills and expertise will be more appropriate (p. 935)."

As with many fields, the theoretical developments surrounding leadership as a collective phenomenon have progressed more rapidly than have empirical findings. To date, the empirical studies examining the relationship between collective leadership and

Table 2
Integrated taxonomy of team leadership roles.

	Navigator	Engineer	Social integrator	Liaison
Key	Why?	Who?	How?	Who?
Questions	Where?	When?		What?
Hackman and Walton (1986)	Clear, engaging direction	Group structure	Effective coaching and process assistance	Context support; adequate material resources
Barry (1991)	Envisioning	Organizing	Social integrating	External spanning
Zaccaro and Marks (1999)	Direction-setter	Operational coordinator		Liaison
Hollander (1985)	Communicator; problem solver/planner	Director of activity	Adjudicator of conflict	Advocate; liaison
Gibb (1954)	Initiator; energizer	Expediter	Harmonizer	–

group performance have shown mixed support, and have assessed the phenomena in multiple ways (e.g., Avolio, Jung, & Sivasubramaniam, 1996; Carson et al., 2007; Carte, Chidambaram, & Becker, 2006; Ensley, Hmieleski, & Pearce, 2006; Hiller et al., 2006; Mehra et al., 2006; Pearce, 1997; Pearce & Sims, 2002). In order to empirically validate theories of collective leadership, we need more appropriate methodological linkages to the conceptualization of leadership as a phenomenon rooted in people, roles, and time.

2.4. Operationalizing the topology of collective leadership

The preceding discussion illustrates that the three essential aspects of collective leadership theory are people, roles, and time. In order to illustrate how we can use network analysis to appropriately model these three aspects of collective leadership, we introduce a bridging framework depicted by the expression: $L_{ij}RT$. According to this model, L is leadership as viewed by member i about member j. R is the leadership role: for instance, Navigator, Engineer, Social Integrator, and/or Liaison. And T is the time period. Time could be conceptualized developmentally using team stages—forming, storming, norming, and performing (Tuckman, 1965). Alternatively, time could be conceptualized using performance episodes (Marks, Mathieu, & Zaccaro, 2001). We can understand collective leadership and the interplay among its components, i.e., people, roles, and time, using this integrated model.

To begin, let us distinguish the two pure forms of leadership that have been articulated: vertical leadership and shared simultaneous leadership. With vertical leadership, one person enacts all four leadership roles at all points in time. At the other extreme, we have shared simultaneous leadership where all members of the team enact all of the leadership roles at all points in time. These are likely to be artificial extremes of team leadership, with the leadership of most teams falling somewhere in between. The $L_{ij}RT$ model is offered as a way to formalize the range of possibilities of leadership arrangements that lie in between these two extremes. The components of this model build on extant work on collective leadership that has considered multiple people (Pearce & Sims, 2002), temporal rotation (Klein, Ziegert, Knight, & Xiao, 2006), and roles (Carson et al., 2007; Hiller et al., 2006). Though these aspects of team leadership distribution have been advanced, we have lacked a coherent framework for thinking about how these three dimensions of leadership forms result in a range of possible leadership arrangements. Formalizing this model is a necessary first step to operationalizing collective leadership through networks. Let us next consider the $L_{ij}RT$ model of leadership in more detail.

According to this view, we can think of leadership in a team as represented by a three dimensional cube. We depict this cube in Fig. 1. The x-axis of the cube depicts the leadership role. The y-axis of the cube depicts the team member. The z-axis of the cube depicts meaningful units of time.

The three dimensions of collective leadership—member concentration, role multiplexity and temporal stability—can be graphically described by filling in the section of the cube that depicts who on the team is enacting which leadership role at which time point. In order to illustrate this view, we consider scenarios based on the two ends of the continuum on each of these dimensions. In the case of member concentration, one end of the continuum is completely shared simultaneous leadership where every member is enacting each of the four leadership roles at all time periods. In this case, the cube is completely full. This leadership arrangement is depicted in Fig. 2, in the cell labeled A. At the other end of the continuum is a scenario when all roles of leadership are concentrated across all points in time in just one individual. In this case, the cube has one flat horizontal slice projecting into it. This situation is depicted in Fig. 2, in the cell labeled B.

The second dimension of collective leadership is role multiplexity. One end of the continuum on the role multiplexity dimension describes a scenario where each individual enacts only a single leadership role. This is depicted in cell C of Fig. 2, where each team member is only enacting leadership in one role. At the other end of this continuum is a scenario where a single individual is enacting leadership in multiple roles. This is depicted in cell D of Fig. 2 where one team member, C, is taking on all four leadership roles leading to high role multiplexity. This form of leadership is similar to Mehra et al.'s (2006) notion of distributed leadership. It is noteworthy that cells B and D in Fig. 2 are identical but are being used to illustrate two distinct characteristics of the collective leadership. As such the graphic in cells B and D, indicates a scenario where there is both high member concentration *and* high role multiplexity.

The third dimension of collective leadership discussed in the literature is rotation, or its converse, which we label as temporal stability. Imagine the scenario where the functions of leadership are being distributed to different individuals. So one individual is enacting the Navigator role, another the Engineer role, another the Social Integrator role, and still another, the Liaison role. If there
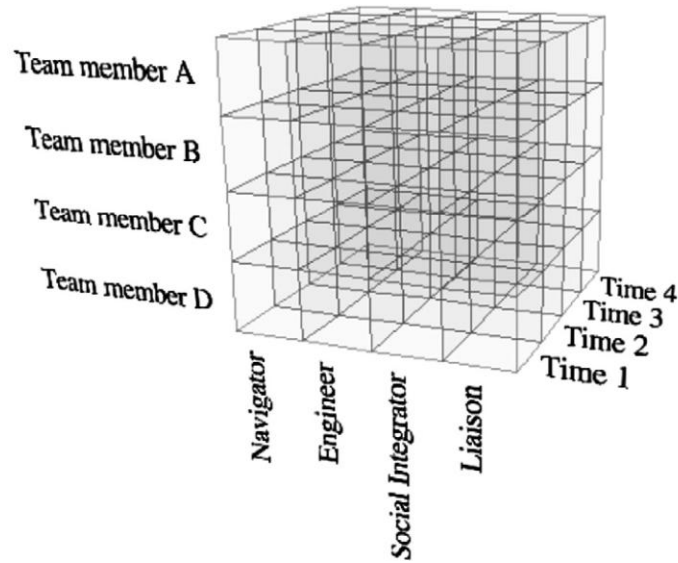
Fig. 1. A tripartite representation of collective leadership.

	Low	High
Member Concentration	(A)	(B)
Role Multiplexity	(C)	(D)
Rotation	(E)	(F)

Fig. 2. Depicting forms of collective leadership based on member concentration, role multiplexity, and temporal stability.

is distribution across roles, but not across time, meaning each individual enacts the same role throughout time, then we would have the leadership arrangement depicted in Fig. 2, in the cell labeled E. Here we essentially have four beams projecting into the time dimension of the cube; each one at the position of a given member and their role. There is no rotation in roles among team members over time. It is again worth noting that although the graphics in cells C and E are identical they represent one end of the continuum on two different dimensions. As such, this graphic describes a scenario where the collective leadership has low role multiplexity and low rotation (or high temporal stability). We can contrast this stable form of leadership to its dynamic counterpart. In Fig. 2 cell F, we see the case of fully rotated leadership. Here, for instance, all four leadership roles as enacted by team member D at Time 1, team member C at Time 2, team member B at Time 3, and team member A at Time 4.

Lastly, it is useful to depict the complexity that is possible by viewing combinations of these three aspects of collective leadership: member concentration, role multiplexity, and temporal stability. Fig. 3 depicts a situation where leadership roles are being enacted by different team members at different time points, and so the beams do not protrude all the way to the back of the cube, rather they shift in location on the Y-axis corresponding to the members that are enacting the role at the new time point. It is also important to note that each cell in the cube can include valued data about leadership roles, not simply a binary "yes/no" about whether a particular person is enacting a particular role at a particular point in time. Using shades to indicate the extent of role enactment can graphically depict this.

It is also informative to consider leadership arrangement using several two-dimensional projections of the cube. First, let us consider a plot of people by role. These plots are generated at each meaningful time point in the team. Again, the meaningful time point could be derived based on task cycles: transition and action phases (Marks et al., 2001), based on developmental stages: forming, storming, norming, and performing (Tuckman, 1965), or based on important phase shifts such as the equilibrium shift that occurs at the team midpoint (Gersick, 1989). We would have as many people by role plots as there are meaningful time points. This plot conveys who in the team is enacting which leadership functional roles.

The second plot we would want to consider is a plot of people by time. This plot would convey who is serving as a leader for the team at each meaningful time period. We would have four of these plots, one for each leadership role.

The third plot that we could consider is roles by time. In this case, we would have as many plots as there are individuals in the team. So for each person, we are depicting the leadership roles that they are enacting, and the time at which they are enacting them. This plot is especially valuable for examining how an individual's leadership roles are changing over time.

In sum, what have previously been considered as distinct aspects of collective leadership, i.e., shared simultaneous, rotated, distributed forms, can be well captured using this integrated model of leadership using these three planes to depict the three dimensions of variations in aspects of leadership. We can now understand these three aspects of collective leadership—people, roles, and time—as an integrated phenomenon.

3. Collective leadership as networks

In this section we describe how collective leadership can be characterized as particular configurations of social networks. A social network consists of a set of individuals and the relationships that bind them. There has been a modest but growing interest in applying a network perspective to leadership (Balkundi, Kilduff, & Harrison, 2011; Brass & Krackhardt, 1999; Hoppe & Reinelt, 2010; Sparrowe, Liden, Wayne, & Kraimer, 2001). We extend this line of research by focusing specifically on applying a network perspective to collective leadership. Hence, we are interested in the leadership and influence relationships that bind a set of
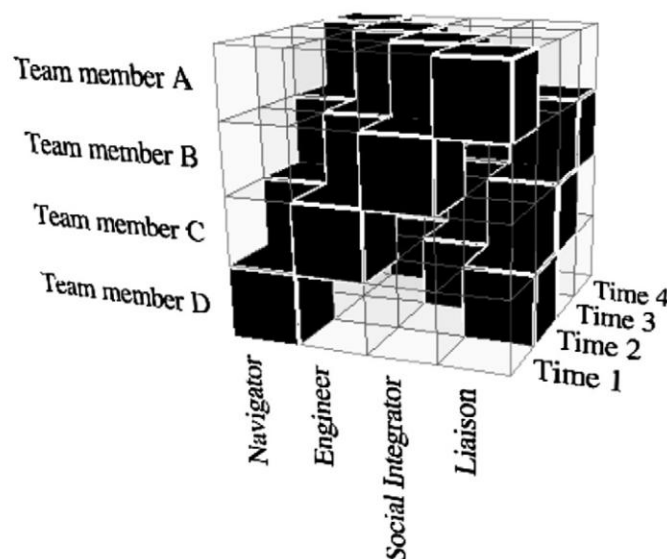

Fig. 3. Depicting complex collective leadership across people, roles and time.

individuals together, thereby regulating activity. In this way, collective leadership is a specific type of social network relation. Other types of social network relations include friendship, advice, and hindrance ties (Brass, 1985; Cross, Borgatti, & Parker, 2001; Lincoln & Miller, 1978). The leadership and influence network is then amenable to analysis using network analytic techniques that both (a) describe the pattern of leadership activity in the collective, and (b) afford inferences about the antecedents and consequences of these structural patterns of leadership.

The first step in using network analysis to study collective leadership is to define the collective and identify the members of it. These individuals then constitute the nodes in the leadership network. The next step is to determine the leadership relations that bind them. The two key decision points in using network analysis for the study of collective leadership are: elicitation and structural representation (Mohammed, Klimoski, & Rentsch, 2000). Elicitation describes the content of the relational tie about leadership. Elicitation of leadership networks can be accomplished using sociometric measures, i.e., "who leads whom" or "*j* as perceived by *i*", obtained via self-report, observation, or digital trace. Representation refers to the manner in which the structure of relational ties about leadership is depicted. Mohammed et al.'s (2000) distinction between elicitation and representation is particularly useful for thinking about collective leadership measures. Elicitation refers to the technique used to determine the connections among individuals in the network (i.e., who is leading whom). Representation refers to the technique used to reveal the structure of leadership.

3.1. Step 1: elicit leadership relations that make up the network

The first step in applying network methodology to the study of leadership is to elicit sociometric information about who is leading whom. There are two important decision sets at this stage: elicitation method, and elicitation level. The elicitation method describes the technique used to construct the leadership network. We detail two techniques: direct measurement and unobtrusive measurement. The second decision is the level of analysis at which the technique is eliciting leadership networks, and here we detail the distinction between leadership ties occurring at the person-to-person level versus those leadership ties which connect a leader to a social entity. These are termed atomistic and molar views.

3.1.1. Elicitation method

The elicitation approach that most closely builds on current practice in leadership research is to elicit the network using direct measures. Essentially, each person provides ratings of the leadership behavior of each other person. Table 3 presents examples of prompts that can be used to elicit collective leadership. This basic approach was used by Carson et al. (2007) who asked participants to rate each of his or her peers on the following question: "To what degree does your team rely on this individual for leadership?" The molar section of Table 3 indicates an example of how Carson and Tesluk (2007) used a definition of each role followed by a few sample behaviors to elicit leadership networks for each of the four leadership roles.

Because of the inherently psychological nature of leadership and influence, this elicitation approach maximizes the psychological fidelity of the network, however it is extremely labor intensive for participants. A related approach is to use observers, subject matter experts, to generate the leadership networks. This method is unobtrusive, but produces a network one step away from the psychological meaning that would be revealed by asking the group members themselves.

An approach even further removed in terms of psychological fidelity, is to elicit the network using an unobtrusive source of information. Relational information could be obtained by content coding a variety of unobtrusive sources of information including

Table 3
Elicitation prompts for capturing collective leadership.

		Leadership roles		
		Navigator	Engineer	Social Integrator	Liaison
Atomistic		Helps to establish *your* purpose and direction and ensures that it stays aligned with *your work group's* purpose and direction.	Helps *you* to understand and change your personal roles and responsibilities within *your work group* as needed.	Provides *you* with a sense of social support within *your work group*?	Helps connect *you* to valuable relationships outside *your work group*?
Molar		Helps to establish the *team's* purpose and direction, and keeps *team* focused on that direction as it proceeds with its work.	Helps to structure and restructure the *team* and the task in the most efficient and effective ways for meeting goals.	Helps to develop and maintain *team* cohesiveness and effective conflict management.	Helps to develop and maintain positive and useful relationships with external stakeholders.
		• Initiates and energizes *team* action in pursuit of its purpose and goals • Communicates and reminds *team* of its overall purpose • Helps develop specific goals toward achieving *team's* purpose	• Manages internal task and workflow dynamics of the *team*—Who does what, and When (relevant timelines)? • Matches tasks with individual strengths and skills in order to optimize members' individual contributions to the *team* • Pushes the *team* to clarify roles and responsibilities for individual team members	• Ensures effective communication and collaboration among members • Helps develop healthy *team* norms, *team* cohesiveness, and promotes active involvement of ALL *team* members • Facilitates effective conflict resolution within the *team*	• Serves as an advocate for the *team* and solicits needed outside resources and help • Seeks out and coordinates relationships with parties outside the *team* • Solicits information and feedback from external *team* stakeholders

participant observation, speech, texts, interviews, etc. and using this to construct the leadership network. This approach was used recently using digital trace data.

Zhu, Kraut, and Kittur (2012, CSCW) used digital trace measures of shared leadership. Zhu et al. used an archival data source, the posts left by Wikipedia contributors on other Wikipedia contributor's profile page. Then they identified types of "leadership" visible in these posts. For example, transactional leadership was reflected when one member rewarded another, and made it clear that the reward was based on good performance by the other member. Aversive leadership was indicated if one member used a set of strong negative words, including "block," "revert" and "remove." Raters first identified theoretically-meaningful coding categories, then classified a set of Wikipedia posts into them identifying features such as the contingent reward language used to capture transactional leadership, and then used machine learning (i.e., a computer codes a huge number of messages based on a preset algorithm) to code more than four million messages for their leadership content.

3.1.2. Elicitation level

We distinguish between two elicitation levels for assessing leadership networks. These are: a) leadership ties occurring at the person-to-person level; and b) those which connect a person (i.e., leader) to a social entity.

The first elicitation level, the person-to-person level, takes an atomistic perspective. Elicitation techniques such as sociometric prompts that ask members of a collective questions such as "Who do *you* rely on for leadership?" elicit atomistic leadership networks. The atomistic perspective is aligned with theories of leadership that acknowledge that leaders may have different relationships with different people. For instance, theories of transformational leadership (Bass, 1998; Burns, 1978) have acknowledged that leaders individualize their behaviors depending on the particular follower in question.

On the other hand, assessing leader-to-social entity (e.g., team, system, and organization) takes a molar perspective. From this perspective, sociometric prompts identify individuals whom others perceive as leaders of the collective, not necessarily leaders of the focal individual. For example, sociometric prompts such as "Who does *your team* rely on for leadership?" elicit molar leadership networks. Prior work (e.g., Carson et al., 2007) has assessed shared team leadership using prompts that elicit these molar networks.

Whereas in smaller collectives (e.g., 5-person teams) molar leadership prompts can be used to identify the degree to which members are perceived by other members as leaders of the team as a whole, networks within this perspective may be more difficult to interpret as the size of the collective increases. As the level of analysis increases, from teams to larger systems to entire organizations, it may be much more difficult for individuals to accurately rate the degree to which the *entire* collective entity relies on a given person for leadership. Taking an atomistic view, therefore, may be more appropriate for understanding leadership in larger collectives.

Trace data can be either atomistic or molar, and it is important to distinguish these. Because Zhu et al.'s study used directed interactions from "leaders" to "followers", they are atomistic. On the other hand, digital trace data could capture molar leadership if "leaders" address their communication to entire online communities. In this case, members of the community not only perceive this information, but are aware that others are perceiving this information as well.

3.2. Step 2: represent the topological structure of the leadership network

While the previous section described the various strategies to elicit network data here we describe how these data are represented. Let us re-consider the entry in each cell within the cube depicted in Fig. 1. Each cell captures the extent to which a particular person exhibits leadership on a particular role during a specific time interval. However, it does not depict which individuals perceived this person to demonstrate a certain level of leadership. As such, the cube only represents $L_j RT$ (the extent to which an individual j was perceived to be a leader on a certain role, R, at a particular time, T) rather than $L_{ij} RT$ (the extent to which individual i perceived an individual j to be a leader on a certain role, R, at a particular time, T). Hence each entry in the cube is itself computed from a structural representation of the overall $L_{ij} RT$ leadership network.

The cube, as depicted in Fig. 2, is very appropriate to characterize collective leadership along the three dimensions of member concentration, role multiplexity and rotation (or temporal stability). However, for analytic purposes it is necessary to explore metrics that characterize collective leadership at higher levels of resolution than can be depicted in the cube. There are a suite of "diversity" metrics that can be used to index the extent to which leadership roles are spread across people and time in the cube. These include Shannon's (1948) information theoretic measure, *H*, of entropy, and the Gibbs–Martin index (Gibbs & Martin, 1962) more commonly known as the Blau index. These single measure diversity indices would take on higher values if there were lower member concentration (diverse set of individuals are leaders), lower role multiplexity (diverse set of individuals are enacting different roles) and lower temporal stability (diverse set of individuals are enacting leadership roles at different points in time).

While these single measure indices can be useful to gain a more nuanced characterization of the collective leadership prevalent in the team, one can compute additional metrics based on the overall $L_{ij} RT$ network at the actor, dyadic, triadic, subgroup, and overall network level. It is important to make a distinction between the more common use of the term "level" in organizational studies from how the term is sometimes invoked in network analysis. In organizational studies, the term level of analysis is used, for instance, to describe the level of the outcome variable, which could be, for instance, at the individual, group, or organizational level. In network analysis, the term "level" is often used to describe the locus of the emergent phenomena (Contractor, Wasserman, & Faust, 2006). More specifically, in the remainder of this section we explore how we can characterize the three dimensions of collective leadership based on network metrics computed at the (i) actor level (such as the number of

times an actor is cited as a leader by other in the network), (ii) dyad level (the pairwise similarity between actor's leadership ties), (iii) triad level (the presence of a leadership hierarchy among individuals taken three at a time), (iv) group level (the presence of a core group of leaders) and (v) network level (the overall level of leadership centralization). Table 4 presents an overview of these metrics, and depicts the connection between the three dimensions of collective leadership: member concentration, role multiplexity, and temporal stability and each of these metrics at each level of analysis.

3.2.1. Actor (individual) level

In network parlance, actor level measures refer to network metrics that are computed for each actor (in our case, individual) in the network. One of the simplest, and most intuitive, actor level measures is in-degree centrality. An individual i's in-degree centrality is defined as the strength and number of links received from other individuals. Hence an individual i's *role leadership* is the extent to which other individuals, j, rate i (say, on a scale of 1 to 5) as providing leadership in a particular role (for instance, as a navigator, engineer, social integrator, or liaison) during a given time period. The presence of a few individuals with high role leadership scores would reflect a high concentration in the collective leadership. This in-degree measure of role leadership is what gets entered into the various cells within the cube describe above and depicted in Fig. 1. A darker *shade or* black in a particular cell indicates that a person was widely perceived as a leader for a particular role during a given time interval.

Role leadership could be cumulated across roles. The measure of an individual i's *multi-role leadership* is the extent to which other individuals, j, rate i as providing leadership in all of the four roles during a given time period. The presence of individuals with high multi-role leadership scores would indicate high role multiplexity in the collective leadership. An individual who scores high on multi-role leadership is represented by a horizontal beam in the cube in Fig. 1.

Finally, an individual's role (or multi-role) leadership can also be cumulated over time. The measure of an individual's *sustained role (or multi-role) leadership* is the extent to which other individuals, j, rate i as providing leadership on each (or all of the four roles) across all time periods. The presence of individuals with high sustained role (or multi-role) leadership scores would indicate stability in the collective leadership. A beam that is piercing into the cube (Fig. 1) represents an individual who scores high on sustained (single) role leadership. A horizontal slice in the cube (Fig. 1) represents an individual who scores high on sustained multi-role leadership.

3.2.2. Dyadic level

Dyadic level measures refer to network metrics that are computed for pairs of actors in the network. Structural equivalence is one such dyadic measure (Burt, 1987). It can be used to measure the extent to which two individuals rate (or are rated) similarly by all other individuals in the network in terms of their leadership on a specific role during a given time period. It is most commonly computed as a standardized Euclidean distance or a Pearson correlation (Faust, 1988). The presence of only a handful of structurally equivalent leaders for a particular role would indicate concentration in the collective leadership. It would also indicate congruence in individual's perception of the concentration in collective leadership.

Structural equivalence can also be computed across roles. It can be used to measure the extent to which two individuals are rated similarly by all other individuals in the network in terms of their leadership across all four roles during a given time period. The presence of only a handful of structurally equivalent leaders across roles would indicate role multiplexity in the collective leadership.

Finally, structural equivalence could also be computed across time. That is, it can be used to measure the extent to which two individuals are rated similarly by all other individuals in the network in terms of the leadership for each (or across all four) of the roles across all time periods. The presence of only a handful of structurally equivalent leaders for a particular role (or over all four roles) across all time periods would indicate stability in the collective leadership.

3.2.3. Triadic level

Triadic level network measures are computed for sets of three actors and the relations among them. Transitivity is one commonly used triadic measure. A triad is defined as transitive if for a specific role in a given time period, actor i selects actor j,

Table 4
Representing the tri-partite dimensions of collective leadership across levels of analysis.

Leadership conceptual dimension	Network property	Level of analysis				
		Actor (individual)	Dyad	Triad	Group	Network
Team member	Member concentration	Number of members with high in-degree centrality	Number of structurally equivalent (SE) dyads	Transitivity	Number of members in the k-core	In-degree centralization
Role	Role multiplexity	Number of members with high in-degree centrality aggregated across roles	Number of dyads who are structurally equivalent (SE) across roles	Transitivity across roles	Number of members in the k-core across roles	In-degree centralization across roles
Time	Temporal stability	Number of members with high in-degree centrality aggregated over time	Number of dyads who are structurally equivalent (SE) over time	Transitivity over time	Number of members in the k-core over time	In-degree centralization over time

actor *j* selects actor *k*, and actor *i* selects actor *k* (Holland & Leinhardt, 1971). A transitive triad signals a concentration in leadership, in this case, in actor *k*. Transitivity of a network is defined as the number of transitive triads as a ratio of all the possible triads in the network. Hence it follows, that a leadership network with high transitivity for a specific role in a given time would indicate concentration in the collective leadership.

Transitivity can also be computed across roles. In this case the triad is defined as transitive if for a given time actor *i* selects actor *j*, actor *j* selects actor *k*, and actor *i* selects actor *k* on any or all of the four leadership roles. A leadership network with high transitivity across roles would indicate role multiplexity in the collective leadership.

Finally, transitivity can be computed across time. In this case the triad is defined as transitive if actor *i* selects actor *j*, actor *j* selects actor *k*, and actor *i* selects actor *k* on any or all of the four leadership roles in all of the time periods. A leadership network with high transitivity across time for any or all four of the leadership roles would indicate stability in the collective leadership.

3.2.4. Group level

Network analysis can also be used to identify a group of actors within the network that share some common structural property. One such measure is a k-core (Hanneman & Riddle, 2005). A k-core is the largest group of actors, all of whom are selected by some number (k) of other members of the group as providing leadership on a specific role for a given period of time. As such, the k-core represents the set of individuals who are most frequently identified as leaders on a specific role for a given time period. For any given group, as k (the number of individuals required to select a leader) increases the size of the k-core will decrease. For instance, if k is chosen so as to represent 75% of the members in the network, the number of individuals in the k-core is likely to be far fewer than if k was chosen to represent 25% of the group, the number of individuals in the k-core is likely to be far fewer than if k was chosen to represent 25% of the group.

The membership of the k-core can also be computed across roles. In this case the k-core is the largest group of actors, all of whom are selected by some number (k) of other members of the group as providing leadership on two or more of the four specific roles for a given period of time. For a given k, a large number of members in the k-core would indicate higher prevalence of role multiplexity in the collective leadership.

Finally, membership of the k-core can be cumulated across time. In this case that the k-core is the largest group of actors, all of whom are selected by some number (k) of other members of the group as providing leadership on two or more of the specific roles at two or more of the given time periods. In this case, for a given k, a large number of members in the k-core would indicate stability in the collective leadership.

3.2.5. Network level

Our progression up the levels of analysis from the actor to the dyad, to the triad, and to the group culminates at the overall network level. The centralization of the network is one useful measure to characterize collective leadership. This measure, computed at the network level, is based upon the actor level measure of in-degree centrality discussed earlier. A network has a high level of in-degree centralization if one or a few of the actors have high in-degree centrality, while others have relatively low in degree centrality. Networks often demonstrate such a pattern giving rise to so-called scale-free networks where proverbially 80% of the network ties are directed at 20% of the nodes (Barabasi & Albert, 1999). One commonly used measure is in-degree network centralization (Freeman, 1977). It benchmarks the variability in the centrality among actors of the observed network to a star network where one actor receives links from all other actors and none of the other actors receive any incoming links. More specifically, in-degree network centralization is computed as the ratio of the variance in the in-degree centrality scores of the actors in the observed network to the variance that would be found in a star network of the same size. A high in-degree centralization score for a specific role leadership network at a given time period, would indicate that one or a few individuals were identified as leaders for that role. As such it is a measure of concentration in the collective leadership.

As in the previous cases, in-degree network centralization could be computed based on actor's in-degree centrality scores in the multi-role leadership network at a given time period. In this case, high in-degree network centralization would indicate that one or a few individuals were identified as leaders across multiple roles thereby reflecting high role-multiplexity in the collective leadership.

Finally, in-degree network centralization could be computed based on actor's in-degree centrality scores across one or more of the four roles and across all time periods. Here, high in-degree network centralization would suggest that one or a few individuals were identified as leaders on one or more of the roles consistently across all time periods, thereby reflecting stability in the collective leadership.

4. Using inferential network models to explain the antecedents and consequences of collective leadership

Until recently, most research on leadership from a network perspective, like most network research in general, has been descriptive in nature. That is, network metrics are computed to characterize certain qualities of the network at the actor, dyadic, triadic, group or network level. In the preceding section, we considered metrics that would be particularly appropriate for the study of collective leadership. As in other methodological approaches, the descriptive metrics serve a useful purpose in characterizing the underlying data.

While computing descriptive metrics are a necessary starting point in our analytic journey, it is often not the destination. Instead these measures can serve as the basis for asking and testing multi-theoretical and multilevel explanations for the emergence and outcomes of collective leadership. For instance, at the actor level we might seek to understand why a particular

individual is more or less likely to be perceived as serving a specific leadership role. These explanations might include attributes of the actor such as their gender or formal hierarchical level. It could also include relational measures such as their in degree centrality. At the dyadic level, we might want to explain why pairs of individuals are more or less likely to perceive one another as serving a certain leadership role. Likewise, at the triadic level, we might choose to theorize the extent to which the triads in which they are embedded influence individuals' 'perceptions of others' leadership roles. Moving up to the group level, we might consider the extent to which cohesive subgroups (or, say, teams within multi-team systems) might influence perceptions of leadership. At the network level, we can assess the extent to which global network characteristics might influence individuals' perceptions of others' leadership in a specific role. Finally, we might want to determine if the explanations for the emergence of leadership roles are different for high performing teams versus low performing teams.

In all of these examples, with the exception of actors' attributes (such as gender and formal hierarchical level), we seek to explain the extent to which an individual perceives another as serving a specific leadership role based upon other individuals' perceptions of who else serves in that same leadership role. As such, it seeks to explain *endogenously*, the emergence of, say, a specific navigator leadership tie, based upon all other navigator leadership types in the network. The use of the term "endogenous" here refers to the fact that we seek to explain the presence of a tie (on, say, navigation leadership) between actor *i* and *j* based on the presence or absence of the same (hence, endogenous) type of tie (navigation leadership) among other actors in the network. In addition to endogenous influences, we may seek to explore the emergence of a specific navigator leadership tie based upon other *exogenous* relations such as other forms of leadership ties (e.g. social integrator, liaison, and engineer), other network ties (such as trust), or the same leadership tie at a previous point in time. Clearly, these represent rich possibilities for building and testing theories for the emergence and outcomes of leadership ties. But there is a reason why we have not seen such questions addressed in the research literature.

Until recently, the most common way in which researchers—including those studying leadership—had tested network related hypotheses is by computing network metrics at the level of the individual actor and using it as an explanatory or dependent variable in traditional statistical techniques such as ANOVA or regression. However, in most cases these approaches disregard the fact that network data and the metrics computed using them violate the independence assumption central to these statistical techniques. Most traditional statistical techniques assume that the observations represent collection of random variables that are independent and identically distributed (i.i.d.). This is patently not the case for network data where one observation (i.e., a network link between two individuals A and B) cannot be assumed to be independent of another observation (i.e., a network link between A and C or between B and C). In the past decade there has been considerable progress in the development of inferential statistical techniques that overcome this limitation. These new approaches, described next, will strengthen the validity of research findings in the area of leadership networks. They will also catalyze the consideration of multi-theoretical multilevel explanations, such as those illustrated above, which go beyond the individual level metrics most often utilized in current research on leadership from a network perspective.

Developing a statistical model of social networks requires a framework that accounts for the intrinsic interdependencies in network data. Over the past 15 years, a class of statistical models called p^* or exponential random graph models (ERGM) have been developed which explicitly incorporate dependence assumptions for network analysis (Anderson, Wasserman, & Crouch, 1999; Frank, 1981; Frank & Strauss, 1986; Pattison & Wasserman, 1999; Robins, Pattison, Kalish, & Lusher, 2007; Robins, Pattison, & Wasserman, 1999; Wasserman & Faust, 1994; Wasserman & Pattison, 1996; Wasserman & Robins, 2005). The basic premise of these models is that any theoretical explanation for the emergence of leadership ties can be represented as a specific structural signature. For instance, let us suppose we were to hypothesize that individuals are more likely to perceive someone within their own unit, rather than in another unit, as serving a leadership role. We can describe this mechanism in terms of the structural signatures shown below. The one on the left indicates two individuals who belong to the same unit (both the nodes are shaded). The structural signature on the right indicates individuals who belong to different units. Based on our hypothesis, we would expect greater likelihood of seeing leadership ties as described by the structural signature in Fig. 4A than in Fig. 4B. As another example, suppose we were to hypothesize that if individual *i* rated individual *j* as a leader, it is unlikely that the ratee, individual *j* would in turn rate individual *i* as a leader on the same role. In this case, we are positing that the structural signature shown in Fig. 4C is very unlikely to occur in the leadership network.

While the structural signatures described above are fairly simple, the same approach can be used to define more sophisticated structural signatures that would represent the three dimensions we used earlier in this study to characterize collective leadership: member concentration, role multiplexity, and temporal stability. For instance, one commonly studied structural signature, called *k-star*, is the likelihood that there are a few nodes (consider these as stars) in the network that are cited as leaders by many others while the majority of nodes are cited as leaders by none or only a few. This is clearly a structural signature that would characterize the member concentration dimension of collective leadership. While one might expect to find a few nodes that receive more links than others even in a random network, the strength of the p^*/ERGM approach is to statistically confirm if the extent to which there are a few stars in the network is more than would be expected by chance. Another commonly
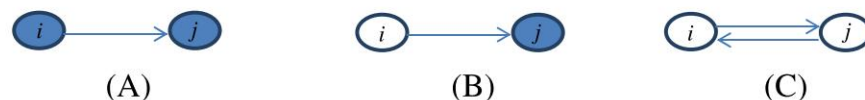

Fig. 4. Structural signatures in leadership networks.

used structural signature, called *multiplexity*, assesses the extent to which two different relations appear together between pairs of actors. An example would be if individuals would frequently cite the same other individuals as a leader based both on the navigator role and social integrator role. As the name implies, this structural signature is clearly of relevance in characterizing the role multiplexity dimension of collective leadership. Here again we would expect a certain amount of multiplexity (the co-occurrence of two types of relations between pairs of actors) to occur even in a random network. The p^*/ERGM approach assesses the extent to which the observed multiplexity is, ceteris paribus, more than would be expected by chance. Finally, one can consider temporal structural signatures in longitudinal networks. Here we consider the case where we have individuals citing others' leadership roles at multiple points in time. A temporal structural signature is one where the configuration of ties at one point in time influences the configuration of ties at a subsequent point in time. For instance, if i cites j as a leader and j cites k as a leader at one point in time, how likely is it that i will cite k as a leader at a subsequent point in time? The extent to which these changes occur would signal a lack of temporal stability in the collective leadership. The techniques to statistically infer the extent of temporal stability (or lack thereof) in longitudinal networks rely on longitudinal extensions to p^*/ERGMs (Wang, Robins, & Pattison, 2006) as well as the statistically related stochastic actor-oriented models to study coevolution of networks (Steglich, Snijders, & Pearson, 2010).

Once the structural signatures are theoretically specified, the next step is to count the frequency of the hypothesized structural signatures in the observed network. That is, for instance in the above example, we compute how frequently we observe leadership ties between two nodes belonging to the same units. The next question is to assess whether the frequency with which we observe these structural signatures are above or below what we might expect by chance. In order to do this, we need to generate a distribution of networks and then compare the frequency of the hypothesized structural signatures in the observed network with the frequency of these structural signatures in the distribution of generated networks. The general form of the class of (homogeneous) exponential random graph models used to create this distribution of networks is as follows:

$$P(X = x) = \kappa^{-1} \exp\left(\sum_{A \subseteq N_D} \lambda_A z_A(x) \right),$$

where:

(i) the summation is over structural signatures of type A;
(ii) λ_A is the parameter corresponding to structural signatures of type A;
(iii) $z_A(\mathbf{x})$ is the network statistic (or frequency) corresponding to structural signature A
(iv) κ is a normalizing quantity to ensure that (1) is a proper probability distribution.

The model represents a probability distribution of networks on a fixed node set, where the probability of observing a network depends on the presence of the various structural signatures hypothesized in the model. One can interpret the structure of a typical network in this distribution as the result of cumulating these particular structural signatures. The estimated parameters provide information about the presence of those structural signatures in the observed network (Robins, Snijders, Wang, Handcock, & Pattison, 2007). In essence, p^*/ERGM analyses test the likelihood for the theoretically hypothesized structural signatures to occur in the observed network thus reflecting the underlying social processes that generate the emergence of leadership (Robins et al., 2007; Shumate & Palazzolo, 2010).

In summary, p^*/ERGMs allow us to test the hypotheses about the network without losing—and indeed leveraging—information about interdependencies among relations by estimating the probabilities that the hypothesized structural signatures are observed more (or less) frequently than by chance. In an exponential random graph model, the range of possible networks and their probability of occurrence under the model are represented by a probability distribution on this set of all possible networks. The model is constructed by specifying parameters corresponding to the structural signatures(s), which are more (or less) likely to occur in the distribution. There are numerous structural tendencies to characterize these networks and the particular signatures tested must be theoretically deduced. In the case of collective leadership they would correspond to member concentration, role multiplexity, and stability. These structural signatures, in turn, can be interpreted within a multi-theoretical framework that accounts for various endogenous and exogenous processes occurring at multiple levels of analysis that potentially govern the evolution of the network (Contractor et al., 2006; Monge & Contractor, 2003).

The discussion thus far has focused on testing hypotheses about factors (at the actor, dyad, triad, subgroup, and network levels) that influence member concentration, role multiplexity, and stability of collective leadership. There is clearly merit in understanding how, for instance, the attributes of an actor (such as their tenure within the organization) influence their perception of the extent to which they consider their peers taking on leadership roles. Likewise, at the dyadic level, it is theoretically interesting to understand how an actor's perception off another's leadership is shaped by other dyadic relationships such as trust from one actor to another. However, in addition to advancing our understanding of the antecedents to collective leadership, there is considerable interest in investigating the *outcomes* of collective leadership, in terms of, say, performance and satisfaction. For instance, we might want to understand the extent to which characteristics of collective leadership—member concentration, role multiplexity, and stability—influence, the performance of the group.

While the antecedents of collective leadership can be investigated by studying a single collective (team, department, multi-team system, or organization), exploring the outcomes of collective leadership would need to investigate multiple collectives. This is because we seek to explain the variance in outcomes based upon actor, dyad, triad, subgroup, and network level structural signatures in each of the collectives. Hence in order to explore the impact of the three facets of collective leadership—member concentration, role multiplexity, and stability—on the outcomes of collectives, the unit of analysis would have to be the collective. Following the collection

of data from multiple collectives, exploring the impact of collective leadership on outcome would require a two-part analytic strategy. First, we would conduct the aforementioned p^*/ERGM analysis on each of the collectives. These analyses provide us with parameter estimates that reflect the extent to which specific structural signatures (at the actor, dyad, triad, etc. levels) characterize the collective leadership in each of the collectives. The next step is to explore the extent to which these structural signatures, which characterize the collective leadership in each of the collectives, can explain the variance in the outcome measures for each of these collectives. If the outcome measure is binary (failure vs. success) or ordinal (low versus medium versus high performance), one can conduct an ANOVA where the parameter estimates for the structural signatures serve as the explanatory variables. If, on the other hand, the outcome measures are continuous (e.g., level of performance and time to completion), one can conduct a regression or a path analysis where, once again the parameter estimates for the structural signatures in each collective serve as the explanatory variables.

As an illustration, considering member concentration, substantive thinking holds that there are at least four advantages to teams with less concentrated (highly dispersed) leadership structures (Cox et al., 2003). These teams are thought to benefit from greater member engagement and enhanced coordination as members come to understand the nature of their interdependencies. Greater dispersion in leadership provides teams access to more ideas and information that may well translate into higher creativity and innovation. Finally, greater involvement in leadership by more members increases the task meaningfulness. An alternative possibility is that greater dispersion in leadership may well come at a cost to coordination, conflict, and effort (i.e., owing to free-riding). As mentioned earlier, *k-star* is a structural signature that indexes the extent to which there is a high member concentration (the presence of a few stars) in the leadership network. Our p^*/ERGM analyses will provide us with estimates of the *k-star* parameter for each collective. A large, positive and statistically significant value for the parameter estimate would indicate the prevalence of stars in that collective more than one would expect by chance. In order to empirically test the hypothesis that high member concentration leads to lower performance, we use appropriate analytic techniques (such as ANOVA, regression or path analysis) where the k-star parameter estimated for each of the collectives is the explanatory variable and the performance measure for each of the collectives is the outcome variable.

Additionally, one might posit that the role multiplexity dimension of collective leadership will lead to the generation of more creative ideas. Albrecht and her colleagues (Albrecht & Hall, 1991; Albrecht & Ropp, 1984) show that individuals are only likely to discuss creative (or innovative) ideas with those with whom they have both strong work and social ties. This is because discussions about innovative ideas require both a certain measure of familiarity on task related issues as well as a level of trust as one explores under-developed ideas. Based on this line of reasoning we might posit that collectives where individuals rely on the same set of leaders for multiplex roles might nurture the development of more innovative ideas than collectives with lower multiplexity. To test this hypothesis, we begin by using p^*/ERGM techniques to estimate the multiplexity parameter (described above) for each collective. A large, positive and statistically significant estimate for this parameter would indicate that this collective has a higher level of role multiplexity in its collective leadership than one would expect by chance. As in the case described above for member concentration, we can use these estimates as explanatory variables to test their influence on the outcome variable, which in this case would be team creativity.

For a final illustration, let us consider temporal stability. Prior research offers two ways to think about the impact of dynamic leadership structures on performance. The first notion suggests that as collective needs change, moving from exploration to exploitation and back, effective collectives are those that can shift their relative level of role enactment initially focusing on liaising, needed for identifying new ideas and opportunities, and then switching toward engineering, critical to the execution and exploitation of ideas (Carter & DeChurch, 2012; Gupta, Smith, & Shalley, 2006). A second approach draws upon Friedrich et al. (2009) who posit that "as different problems emerge, different skills and expertise will be more appropriate (p. 935)." The preceding approaches emphasize the dynamicism of either roles or people, but a more complex view would concurrently capture changes in both. Both of these approaches imply a certain level of churn in the leadership network. To test this implication we would need longitudinal leadership network data from each of the collectives. We begin by using p^*/ERGM or stochastic actor-oriented models to estimate the temporal structural signature of transitivity (described above) for the set of longitudinal networks for each collective. A large, positive and statistically significant value would indicate a higher level of churn caused by transitivity than would be expected by chance. As described in the two cases above, we can use these estimates as explanatory variables to test their influence on team performance, the outcome variable.

We began this section by acknowledging that network metrics computed using the $L_{ij}RT$ framework offer a more nuanced characterization of the three dimensions of collective leadership. However, being descriptive in nature, they are by themselves unable to help us statistically test the extent to which member concentration, role multiplexity and temporal stability observed in a network are more than we might expect by chance. The problem is further exacerbated by the fact that standard statistical tests which rely on assumptions of independence among observations are not appropriate when analyzing network data. We proposed that the three dimensions of collective leadership would manifest themselves as distinct structural signatures in leadership networks. We offered *k-star* as a structural signature that is positively associated with member concentration, *multiplexity* as a structural signature positively associated with its namesake, role multiplexity, and *transitivity* as a temporal structural signature negatively associated with temporal stability. We proposed the use of p^*/ERGM approach to estimate parameters that index the extent to which these structural signatures are more (or less) prevalent than by random chance. The parameter estimates can then be used as explanatory variables to test the extent to which these structural signatures—and the dimensions of collective leadership they manifest—will influence outcome variables such as performance or creativity.

5. Discussion

The fundamental nature of organizations is rapidly transforming. Work is being organized around teams, knowledge is distributed up and down organizational hierarchies as workers become increasingly specialized, and globalization and digitization both require

and enable greater connectivity between distributed sets of knowledge workers. These changes have important implications for leadership. In this review, we cumulate thinking in a relatively new genre of leadership research, one particularly well suited to understanding the informal and emergent nature of leadership in modern organizations. We draw out three core aspects of collective leadership and elaborate an analytic framework enabling these aspects of collective leadership to be adequately tested. This framework was developed to be levels-generic, so that collective leadership can be studied in a variety of collectives ranging from teams to units to multiteam systems to full-scale organizations and the alliances between them.

We lay out an analytic framework intended to enable these core ideas about people, roles, and time to be fully tested. Extant work on collective leadership falls within one of three categories: (1) conceptual developments, (2) empirical tests of leadership *forms* on outcomes (e.g., Carson et al., 2007; Mehra et al., 2006), or (3) empirical tests of the effects of leadership *roles* on outcomes (e.g., Hiller et al., 2006). The proposed framework is intended to accelerate and provide greater conceptual coherence to empirical tests of collective leadership theory in a manner that more fully captures the essence of the phenomenon. In particular, we hope that future research will populate two new categories: (4) empirical examinations of the factors that give rise to particular forms of leadership, to multiplex leadership relationships, and to the likelihood that collectives can reconfigure their leadership structures, and (5) empirical examinations of the attitudinal, cognitive, motivational, behavioral, and performance consequences of various leadership forms, multiplex leadership relationships, and dynamic leadership structures.

5.1. Future research directions

When testing collective leadership theory, it is important to isolate the effects of collective leadership, that is people, roles, and time, from the consequences of that leadership. For example, extensively evidence supports the role of team processes (c.f., LePine, Piccolo, Jackson, Mathieu, & Saul, 2008) as important drivers of collective success. The true test of collective leadership is do they give rise to these processes, in turn affecting performance? In order to be uniquely valuable, collective leadership needs to demonstrate that there is something special in the *topology* of influence relationships that extends our capacity to predict collective outcomes beyond that which we can already explain with the *amount* of various leader behaviors and the amount of team processes.

While much research has looked at social networks and leadership (c.f., Balkundi et al., 2011), an important point of departure of this work is that we are explicitly looking at leadership and influence as a social network. Prior research has looked at communication networks and drawn inferences about the effectiveness of leaders based on their embedded positions within those communication networks (Sparrowe & Liden, 1997; Sparrowe et al., 2001). Studies of leader embeddedness in advice, communication, friendship or other types of networks essentially study situational moderators of the effects of leadership. Others have focused directly on the leadership relations rather than the communication ties. Both types of investigations of networks are useful, but they yield different inferences about leadership. Investigations of leadership and influence networks (e.g., Siebert, Sparrowe, & Liden, 2003) are necessary to directly test propositions about collective leadership.

Leadership ties can be weak or strong. In network terms, this implies that the leadership times are valued or continuous and not binary (influence relationship either exists or not). Unfortunately contemporary versions of the p^*/ERGM analytic techniques require that the focal relationship (in our case, one actor's perception of another actor's leadership role) is constrained to be binary. While this is an area of active research, this is certainly an analytic limitation of the proposed framework at the current time.

5.2. Conclusion

Modern leadership theory is inherently relational, holding that leadership is the confluence of leaders, followers, and their relationships (e.g., Avolio, Walumbwa, & Weber, 2009; Graen & Uhl-Bien, 1995). Such a relational perspective is well suited to testing with network approaches, particularly when one considers the implications of topology in various collectives. Network methods provide an appropriate language to distinguish between different topologies of collective leadership that involve multiple people, exhibiting multiple types of influence relationships, with relational patterns that are fluid over the course of team development. Further, network methods provide a higher resolution multi-level approach to study the emergence of these different forms of leadership based on attributes of individuals (leaders and members), dyadic relational ties (such as trust), as well as higher-order triadic (balance) and group level effects (such as cohesion). The precision afforded by network methods will help to more accurately reflect the processes posited by extant leadership theories.

We have summarized the core thinking about collective leadership over the past decade, and distilled out three integral ideas about collective leadership that then translate into an operationalization framework so that ideas can be tested appropriately with network analysis. The fact that empirical work in this area has attended to one of these defining aspects, i.e., either people (e.g., Carson et al., 2007), roles (e.g., Hiller et al., 2006) or time (e.g., Erez et al., 2002) but not multiple aspects, evidences the need for such a framework. Our primary contribution is to enable better translation between the conceptual advances of understanding leadership as complex and emergent with corresponding advances in network analytic methodology.

In closing, we hope this framework advances research on collective leadership in two ways. First, the framework serves to guide research practices, ensuring that researchers make informed decisions in choosing the appropriate network elicitation and structural representation techniques most suitable to answering their conceptual questions. The second advancement is that such a framework may actually broaden the theoretical approaches. The relational paradigm of network analytic methods may well generate new types of questions on the emergence, patterns, and effects of leadership at multiple levels of analysis (Monge & Contractor, 2003). Thus, we hope that a richer understanding of the range of elicitation and representational techniques available

in network approaches will enable leadership researchers to generate new questions, and new types of questions about collective leadership.

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