Academic

Leadership style as an enabler of organizational complex functioning

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The postmodern organization has a design paradox in which leaders are concerned with efficiency and control as well as complex functioning. Traditional leadership theory has limited applicability to postmodern organizations as it is mainly focused on efficiency and control. As a result, a new theory of leadership that recognizes the design paradox has been proposed: complexity leadership theory. This theory conceptualizes the integration of formal leadership roles with complex functioning. Our particular focus is on leadership style and its effect as an enabler of complex functioning. We introduce dynamic network analysis, a new methodology for modeling and analyzing organizations as complex adaptive networks. Dynamic network analysis is a methodology that quantifies complexity leadership theory. Data was collected from a real-world network organization and dynamic network analysis used to explore the effects of leadership style as an enabler of complex functioning. Results and implications are discussed in relation to leadership theory and practice.

Introduction

Postmodern organizations have a design paradox where they simultaneously maintain a bureaucratic nature and complex functioning (McGrath, 2001). Complex functioning is the co-evolution of human and social capital that results from the interdependent interactions among autonomous agents with diverse knowledge. Complex functioning produces learning and adaptation, both of which are needed for effective response in highly volatile environments (McKelvey, under review). Accordingly, postmodern organizations must have efficiency yet learn and adapt; have control yet be responsive; and have centralized vision yet be autonomously decentralized.

Due to this, the nature of leadership has changed and traditional leadership theory has limited applicability in the modern era. Traditional leadership theory mainly studied bureaucratic contexts that focused on leading for efficiency and control (Streatfield, 2001; Zaccaro and Klimoski, 2001). Postmodern organizations must now balance leading for efficiency and control with leading for learning and adaptability. As a consequence of this paradox, traditional leadership theory only speaks to part of the overall nature of leadership. The complexity theory approach to leadership, as is argued in this special issue, speaks to the learning and adaptive nature of leadership – leading for organizational complex functioning.

Our interest is in exploring how traditional leadership roles integrate with leading for learning and adaptability. In particular, we focus on the interaction of formal leadership style with the complex functioning of the informal network. Leadership style is defined by how decisions are made in the organization. We use the directive/participative leadership style delineation as described by Tannenbaum and Schmidt (1958). Directive leadership is a style in which the leader makes and declares decisions without consulting subordinates. Participative leadership is a style in which the leader consults subordinates before making decisions.

Leadership style may be important to complex functioning because differences in how decisions are made within the organization could affect the co-evolution of human and social capital. For instance, directive and participative styles of decision making are theorized to have an affect on information flows in an organization (Anthony, 1978). From a structural perspective, these different leadership styles imply different information flows within the organization. For example, information needed for decision making would flow into a directive leader and, in contrast, out from a participative leader. As such, the different information flows could lead to different co-evolutions of human and social capital.

In this research, we collected social network data on a real-world organization that had two different leaders. We modeled the organization as a complex adaptive system using a multi-

agent network model. The leadership styles of each formal leader were represented in the model and the effects of the respective leadership styles on the complex functioning of the informal network were examined. In this way, we synthesized traditional leadership roles with a complexity science approach to explore the phenomena.

The next section of this paper gives the background to traditional and postmodern leadership. This is followed by the conceptual framework used in this study, complexity leadership theory. The research question is subsequently described and dynamic network analysis, the computational methodology used to explore the research question, is explained. Next, the virtual experiment design is described and followed by the presentation and discussion of results. Lastly, the conclusion provides both theoretical and normative implications of the study.

Background
Traditional leadership theory

Prior research has explained leadership using trait (Argyris, 1953; Stogdill, 1948), behavioral (Blake and Mouton, 1994; Tannenbaum and Schmidt, 1958), situational (Hersey and Blanchard, 1977; Vroom and Yetton, 1973), transformational (Bass, 1985; Burns, 1978) and leader–member exchange (Graen and Scandura, 1987) approaches. The above approaches focus on topics such as leading members to produce efficiently and effectively (Zaccaro and Klimoski, 2001), motivating members to successful goal attainment (House and Mitchell, 1974), inspiring members to vision commitment (Yammarino, 1994) and developing quality leader–member relationships that improve organizational outcomes (Graen, 2003).

Although each of these approaches views leadership from a different angle, they also form a single dominant paradigm. This paradigm is about the influence that leaders have on followers, with the goal of getting the follower to achieve some objective. The influence of a leader is due to a personal characteristic, behavior or skill. As such, this paradigm mostly emits a top-down view of leadership that is concerned with the influence of a single, "heroic" leader.

In addition, the research within this paradigm was predominantly conducted in bureaucratic organizations (Zaccaro and Klimoski, 2001) with the focus being on centralized power and formal leadership within hierarchical structures. As a consequence, traditional leadership theory's main concern is leading for efficiency and control within a relatively stable context.

A new era of leadership

In contrast, the context of the postmodern knowledge economy is characterized by uncertainty and turbulence. This new, dynamic context is driven by technological revolution and economic globalization (Hitt, 1998), resulting in rapid and continuous change, diminished product lifecycles and the need to turn large amounts of data into useable information (Ireland and Hitt, 1999). Organizations now have to increase the rate at which they learn (Bettis and Hitt, 1995; Child and McGrath, 2001) in order to survive in this environment.

Accordingly, there has been a switch in organizational core competency. Intellectual assets are now the core competency of organizations (Nonaka and Takeuchi, 1995; Prusak, 1996) rather than capital and labor assets, which were the core competencies of organizations in the industrial era (Stewart, 1997). Faster, productive learning provides an organization with the flexibility and mental agility to quickly identify and exploit emergent opportunities in the ever-changing environment (Ireland and Hitt, 1999).

Along with this new economic context and change in organizational core competency has come the recognition that previous standard practices of leadership offer limited insight for dealing with the challenges of postmodern organizations: challenges such as adapting to rapid change and enabling faster learning (Davenport, 2001; Hitt *et al.*, 1998; Streatfield, 2001). Again, standard leadership practices have dealt more with efficiency and control rather than adaptive change and learning. Therefore, a new leadership mindset has developed that realizes the different paradigm that postmodern organizational leaders face. The following quotes exemplify this new paradigm:

"Increasingly, networked and globalized thinking will be essential for coping with the accelerating pace of change" (Heinrich von Pierer quoted in Ireland and Hitt, 1999: 47).

"The problem facing almost all leaders in the future will be how to develop their organization's social architecture so that it actually generates intellectual capital" (Bennis, 1997: 87).

"John Browne, CEO of British Petroleum Company, believes that the top manager must stimulate the organization rather than control it" (Ireland and Hitt, 1999: 47).

This new mindset recognizes several characteristics of leading for adaptive change and learning in the new era. First, collective change agents are the competitive source of adaptive response and learning. Tapping the collective intelligence of the organization's citizenry allows for a quicker response to change. This moves the paradigm away from the single "heroic" leader who has all the strategic answers to one where the responsibility for learning and reasoning about strategic change falls onto the collective organization.

Second, collective intelligence is the combination of both human and social capital. Developing human capital has long been recognized as an advantage (Becker, 1975), but having an adaptable social structure that can respond to changes and connect human capital in various ways is seen as just as important for sustaining competitive advantage (Baker, 1992). The rise in organic or network forms of organization demonstrates the importance of the social network. Therefore, organizations need to create conditions or cultures that simultaneously stimulate the development of human and social capital.

Third, organizations need to be stimulated, not controlled. Creative change occurs by way of interactions among an organization's citizenry (Bennis and Biederman, 1997). These interactions are what generate collective intelligence. Top-down, command-and-control style leadership can stifle the development of collective intelligence by limiting the development of human and social capital (Bennis, 1997; McKelvey, under review). Quick, adaptive interaction patterns cannot be prescribed by fiat. They are stimulated by conditions such as an accepted and strong learning culture.

Conceptual framework: Complexity leadership theory

Realizing that traditional leadership theory has limited ability to explore and understand postmodern leadership, some theorists are using complexity theory as a new science approach to explaining leadership processes (Marion and Uhl-Bien, 2001; McKelvey, under review; Regine and Lewin, 2000; Wheatley, 1999). The premise is that complexity theory will help explain some of the emergent change processes that are now prevalent in organizations but yet defy explanation when current theories are used (Smith, 2004).

One such theory that uses complexity science and matches the new mindset extremely well is complexity leadership theory (Uhl-Bien *et al.*, 2004). This new theory recognizes that adaptive change and learning result from the collective action response of agents who are interdependently interacting at the nexus of diverse knowledge. It further recognizes that while organizations need to stimulate emergent collective action, they also have a bureaucratic nature and a need to efficiently control organizational outcomes for exploitation. This is known as the organizational design paradox (Child and McGrath, 2001). Therefore, Uhl-Bien *et al.* (2004) have proposed that postmodern leadership is composed of three separate but entangled roles that accommodate the paradox: managerial leadership, adaptive leadership and enabling leadership (see Figure 1).

Managerial leadership is the traditional notion of formal leadership roles with top-down control and strategic planning. Leadership style is a behavior that is associated with formal leadership roles. *Adaptive leadership* is leadership that occurs within the interdependent interactions of emergent collective action and that helps produce emergent outcomes such as learning and adaptation. Adaptive leadership is important to the complex functioning of the network. *Enabling leadership* has two roles. First, it creates conditions that stimulate emergent collective action and adaptive leadership. Second, it channels productive emergent outcomes originating in the collective action response back up to managerial leadership for strategic planning and exploitation.

The focus of complexity leadership theory is on enabling leadership and adaptive leadership. This is due to the need for understanding the new
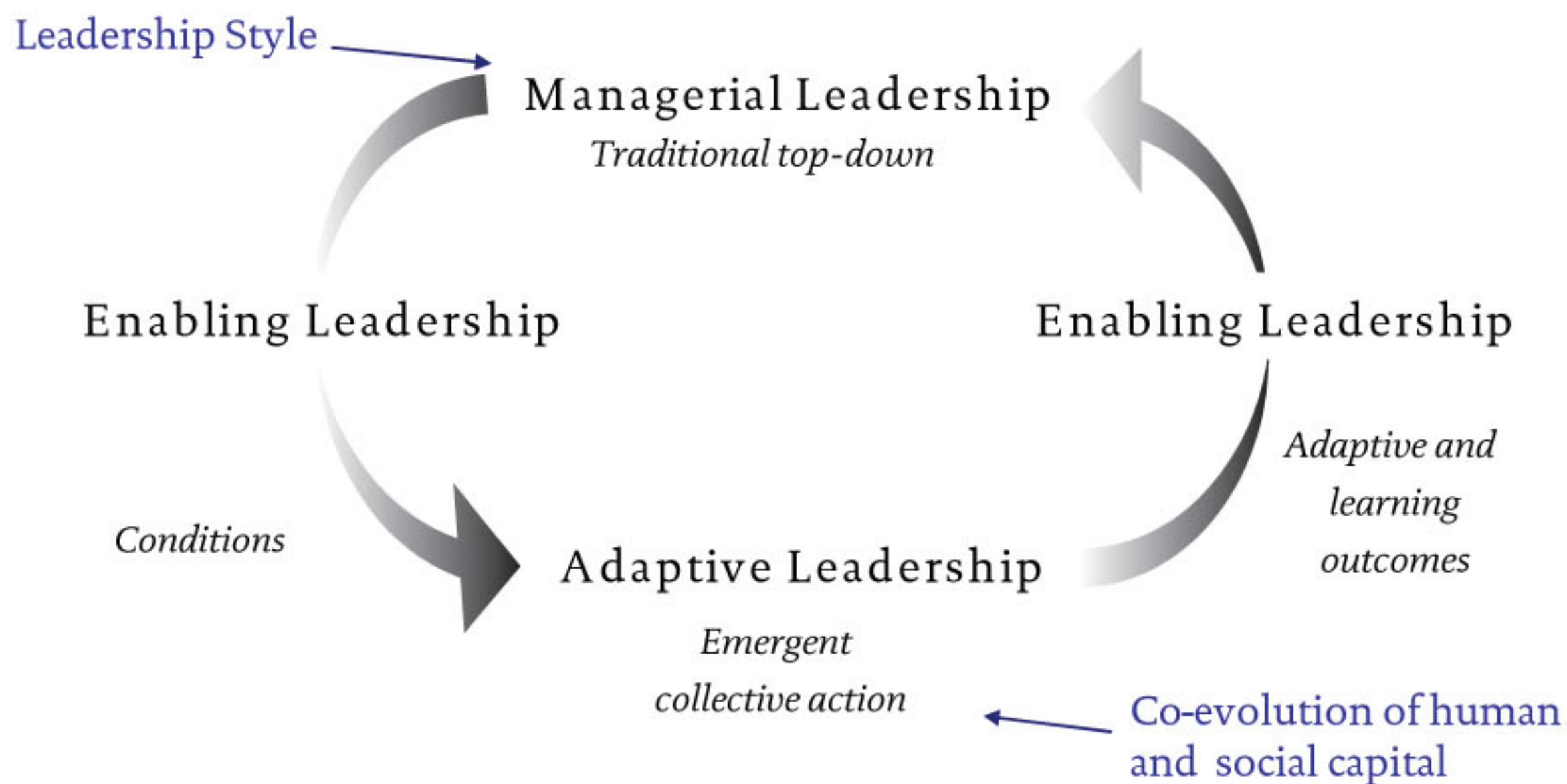
Figure 1 *The three entangled leadership roles of complexity leadership theory*

leadership paradigm. Enabling leadership creates conditions that foster complex functioning and the enactment of adaptive leadership within the informal network. It creates these conditions by injecting tensions into the organization, which induce interactions and create interdependencies among the agents. The combination of interactions and interdependency is needed for complex functioning and the production of emergent outcomes. Interactions facilitate knowledge flow and interdependency stimulates learning by pressuring agents to act on knowledge.

The heart of the complex functioning process is the co-evolution of human and social capital[1] (Carley and Hill, 2001; McKelvey, under review) – the production of collective intelligence that occurs through an emergent collective action response. This process is akin to the neural network theory of how the brain functions and learns. Neural networks learn by neurons making dynamic connections to themselves through synaptic links. Organizations learn by human capital components making dynamic connections to themselves through social capital relations. Human capital appreciation accumulates energy in the form of knowledge. Energy flow in the informal network is knowledge flow through social interactions that are actuated by tensions originating in the conditions created by enabling leadership. These social interactions are fluid and can change in response to changes in knowledge and tension. Change in social interactions can affect where in the network knowledge accumulates and builds on

itself, and therefore where learning and adaptation occur. Analyzing the co-evolution of human and social capital can give us insights into the effects of enabling conditions for producing productive learning and adaptive outcomes.

Adaptive leadership occurs within the complex functioning process. Adaptive leaders are those who are particularly influential in facilitating interactions and knowledge flows (Uhl-Bien *et al.*, 2004); that is, complex functioning. In other words, adaptive leaders are those who shape the overall communication structure and help advance the co-evolution of human and social capital. Adaptive leaders are not necessarily formal leaders. Adaptive leaders emerge due to the organization's learning and adaptive needs. Anyone in the informal network can emerge as an adaptive leader. In addition, adaptive leadership can be enacted by several agents simultaneously during a distinct event or over time. Therefore, adaptive leadership can also be distributed (Gronn, 2002) and/or shared (Pierce and Conger, 2003) leadership.

Research question: Leadership style as an enabler of complex functioning – synthesizing traditional leadership roles with complexity

The question we ask is: Does leadership style have varying effects as an enabler of complex functioning? Leadership style, as shown in Figure 1, is a behavior within the managerial leadership role. According to Uhl-Bien and colleagues

(2004), a formal leader is in a particularly advantageous spot for performing enabling leadership due to their authority position. Therefore, studying the behavioral differences of formal leaders and the associated effects on complex functioning is appropriate. What we are exploring is whether the decision-making behavior of a formal leader, which is enacted in the managerial leadership role, can also act as enabling leadership and affect the co-evolution of human and social capital.

Within the traditional paradigm, leadership style is a behavior that has been well studied. Several dichotomous distinctions have been used to describe leadership style, including directive/participative (Tannenbaum and Schmidt, 1958), authoritative/democratic (Lewin and Lippitt, 1938), consideration/initiating structure (Fleishman, 1953) and task/relational orientation (Hersey and Blanchard, 1977). While all of these distinctions have a concern for how decisions are made, the directive/participative distinction is mainly focused on this behavior. In addition, as previously noted, the directive/participative distinction has been theorized to affect the flow of information within an organization (Miller and Monge, 1986). More specifically, participative leadership is theorized to increase the flow and use of pertinent information (Anthony, 1978; Frost et al., 1974). Information flow is also an important factor in the co-evolutionary process (Carley and Hill, 2001; Uhl-Bien et al., 2004). If the directive/participative distinctions lead to differential effects on information flow then they may also lead to different co-evolutions of human and social capital. The directive/participative distinction, therefore, is the distinction that is used in this study.

Prior research has shown that directive/participative leadership has effects on employee satisfaction and performance (Miller and Monge, 1986). To date, there are no studies of the effects of leadership style on network structure and complex functioning.

Methodology
Computational modeling

We needed to analyze the co-evolution of human and social capital in order to study the effects of leadership style on organizational complex functioning. Computational modeling was used to explore the research question for two main reasons. First, the data collected in the field was cross-sectional. Computational modeling affords the ability to evolve empirical networks through simulation and thereby overcome the limitations of cross-sectional data (Schreiber and Carley, 2004a). Second, the co-evolution of human and social capital is inherently computational and complex. It is computational in that it involves information-driven activities. It is complex in that it involves not only information-processing factors but also social and cognitive factors. The co-evolution of human and social capital is a property of complex adaptive systems.

Computational modeling is an appropriate methodology for analyzing organizations as complex adaptive systems (Carley and Gasser, 1999), especially within the complex context of the postmodern knowledge economy (Hazy, in press).

Several recent efforts have used various computational modeling techniques to explore leadership from a complexity science perspective (Hazy, in press). For example, Vroom and Jago (1988) used an expert system; Anghel et al. (2004) and Hubler and Pines (1994) used a multi-agent model; Schreiber and Carley (2004b, 2005) used dynamic network analysis; Solow et al. (2005) used an NK model; and Hazy (2004a, 2004b) as well as Jacobson and House (2001) used system dynamics models.

The dynamic network analysis technique was chosen for two reasons. First, dynamic network analysis has been formally described and used as a methodology for quantifying complexity leadership theory (Schreiber, 2006). The methodology uses a bottom-up modeling approach that represents, captures and analyzes the complex interactions among agents in the informal network. Second, out of all of the techniques, only dynamic network analysis allows for the quantification and exploration of the co-evolution of human and social capital at multiple levels of analysis. The analysis in this work required the longitudinal representation of the knowledge network and the social network at both the node and graph levels. Changes in social capital are analyzed at the graph (organizational) level, and human capital and adaptive leaders are analyzed at the node (individual) level.

Dynamic network analysis, as explained in the next section, not only represents complex network structure by way of the MetaMatrix but also represents co-evolutionary network dynamics

	People / Agents	Knowledge / Resources	Tasks / Events	Groups / Organizations
People / Agents	Social Network	Knowledge Network / Resource Network	Assignment Network / Attendance Network	Affiliation Network / Membership Network
Knowledge / Resources		Information Network / Substitutes Network	Needs Network	Core Capabilities
Tasks / Events			Precedence Ordering	Institutional Relation
Groups / Organizations				Inter-organizational Network / Inter-group Network

Figure 2 *Illustrative MetaMatrix*

through the use of multi-agent simulation (Carley, 2003). This technique can overcome the limitations of cross-sectional data and allow for longitudinal reasoning about the effects of leadership style on dynamic network structure.

Dynamic network analysis

Dynamic network analysis is a methodology for modeling and analyzing the complex relational qualities and longitudinal dynamics of organizational systems. The techniques of social network analysis and multi-agent simulation are combined in this methodological approach: social network analysis to analyze complex relational qualities and multi-agent simulation to reason about longitudinal dynamics.

In dynamic network analysis, the MetaMatrix framework (Carley, 1999; Carley, 2002; Krackhardt and Carley, 1998) is used to represent organizations as systems of complex relations that are multi-mode and multi-plex (see Figure 2). Multi-mode refers to the various entity classes that are within an organization such as people, knowledge, tasks, and resources. Multi-plex refers to the various types of relations between the entity classes such as communication, knowledge acquisition, task assignment, and resource allocation. Any unique combination of two entity classes and a relation makes a network in the MetaMatrix.

Representing relations between networks is just as important as representing relations within each network, as changes in one network can affect changes in other networks. For instance, human and social capital co-evolve because the social network and knowledge network are intricately related. As agents interact in the social network, they can learn knowledge or create new knowledge and this changes the knowledge network. Likewise, changes in the knowledge network can affect future

instances of the social network, as changes in knowledge and understanding will influence who an agent subsequently interacts with. Representing organizations as a multi-mode, multi-plex system of networks captures more of the complex interdependencies inherent in the system.

Multi-agent network models simulate organizations as complex adaptive systems of individual cognitive agents who can take action, learn, and alter their networks. The particular multi-agent network model we use for reasoning about organizational complex functioning is Construct (Carley, 1990, 1991; Carley, 1999; Carley and Hill, 2001; Schreiber and Carley, 2004a, 2004b; Schreiber and Carley, 2005; Schreiber *et al.*, 2004).

Agents in Construct are defined as information processing units, which interact and communicate based on well-known social and cognitive processes. Theoretical foundations of these processes in Construct are homophily (Lazarsfeld and Merton, 1978), proximity interactions (Festinger, 1950), double interact (Weick, 1969), structuration (Giddens, 1984) social information processing (Salancik and Pfeffer, 1978), and situated learning (Lave and Wenger, 1991). Natural evolutionary processes of the organizational system, such as learning and network alteration, are based on these theories of social and cognitive processes.

To understand the emergent organizational dynamics we need to reason about basic network evolutionary and strategic intervention processes. Multi-agent network models such as Construct allow for reasoning about these processes. For instance, we can reason about a given set of relations in the MetaMatrix and how these networks constrain or enable behavior such as emergent collective action and adaptive leadership. We can also reason about the co-evolution of multiple networks, such as the human and social capi-

tal networks that generate collective intelligence. The focus is on interactions and processes, not outcomes. System-level outcomes such as collective intelligence emerge due to bottom-up interactions and processes.

Data

MetaMatrix data was collected on Team X at NASA's Jet Propulsion Laboratory. Team X is a first-phase conceptual design team that designs spacecraft for non-human space flight missions. The team for this particular design session was composed of 19 members with one formal leader and the rest of the team being a network organization.

Network organizations are forms of organizing characterized by flexible structures that are horizontal in nature (Miles and Snow, 1986; Nohria, 1992). These forms of organizing are advantageous for organizational adaptation and learning in rapidly changing environments (Hitt *et al.*, 1998; Powell, 1990).

Team X is designed to be a network organization due to the specific design task that is performed (Wall, 1999). The design task is exemplary of knowledge work in that it is data intensive, intellective and integrative with an innovative product outcome. In addition, the NASA faster, better, cheaper initiative (McCurdy, 2001) influenced the conception of the design task and the team is under extreme time pressure to complete the design. Designing a complex spacecraft requires the team to deal with many unexpected exceptions. So, the team needs to have the ability to form dynamic relations in order to solve problems quickly. These dynamic relations are emergent collective action responses that provide collective intelligence for faster learning and for dealing with change.

Network organizations are ideal for studying the dynamics of the informal network, such as the co-evolution of human and social capital, because the informal network is usually more pronounced in these organizations. This by no means limits the findings of this research to only network organizations, as informal networks are within all organizations.

Team X used two different formal leaders during this particular design session, with the change in leadership occurring midstream. Each leader had opposite styles of decision-making behavior.[2] Leader 1 had a directive leadership style and centralized decisions more. Leader 2 had a participative leadership style and decentralized decisions more. The team was co-located in a single room and, from a qualitative perspective, had a distinct feel and noticeably different behaviors under each leader.

The MetaMatrix data was collected via survey and interviews. Only one data collection period was obtained due to the inability to interrupt the design process, but data was collected on both leaders.

Examination of the task dependency network for Team X also indicated a difference in leadership style (see Figures 3 and 4). The task dependency network is a digraph where the tasks of agent i depend on input from agent j. Figure 3 indicates that Leader 1 centralizes decisions, as the ties are directed in toward the leader node. Leader 1 used tighter control over the design task and coordination. Figure 4 indicates that Leader 2 decentralizes decisions, as ties are directed out to other team member nodes. Leader 2 used looser control of the design task and coordination.

The limitation of one data collection period precluded the empirical study of human and social capital co-evolution for each leader. Consequently, we used multi-agent network simulation to evolve the Team X networks under the influence of each leader.

Experimental design

Using the MetaMatrix data with the distinct delineation of each leadership style, directive and participative, we produced a representation of Team X under each leader. These representations were separately used to initialize Construct and a virtual experiment was run to test the effect of each leader's style on complex functioning. The virtual experiment also included conditions where the knowledge base of each leader was used with the other leader's distinct leadership style representation to ensure that any significant effects were not due to the particular knowledge base of each leader (instead of leadership style). The knowledge base is the specific knowledge that each leader possesses. In other words, it is the ego knowledge network for each leader.

The virtual experiment was run for 150 time periods and the results were averaged over 100 Monte Carlo runs. Output obtained from the model was in terms of performance from agent learning (human capital) and interaction networks
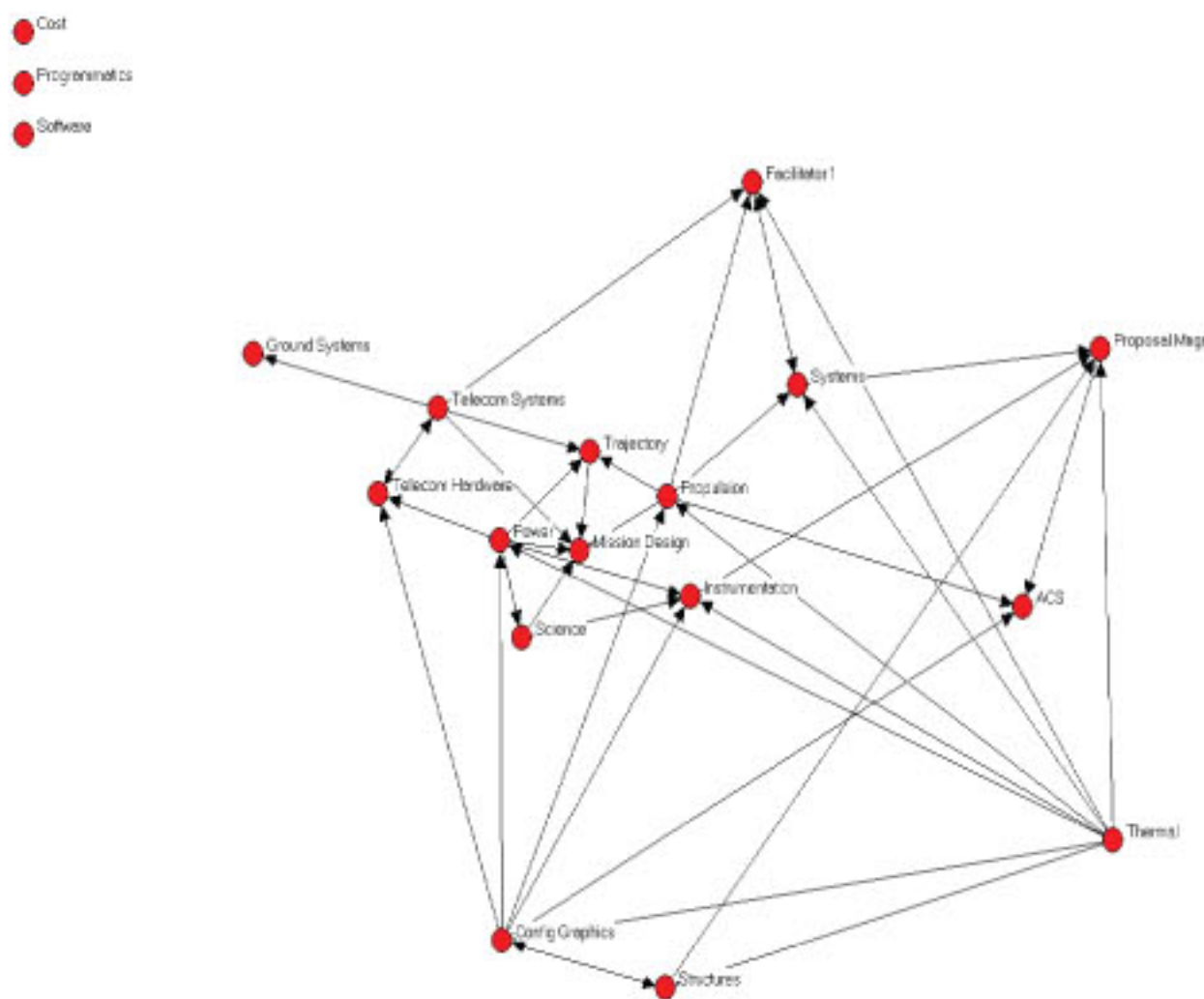
Figure 3 *The directive, centralized style of Leader 1 (task dependency network)*

(social capital) over time.

Performance from agent learning is represented by the task-relevant knowledge measure in Construct. This measure is the amount of task-relevant knowledge that each agent has, expressed as a percentage of the total amount of task-relevant knowledge that is knowable. Agents perform more accurately with higher levels of task-relevant knowledge. The overall performance measure is an average over all the agents in the organization. Each agent has task-relevant knowledge that is initialized using the empirical knowledge network from the MetaMatrix. An agent can learn additional task-relevant knowledge through interactions with other agents.

Social capital is measured by the graph density and clustering coefficient measures. Graph density is the number of existing relations over the total number of possible relations, and the clustering coefficient is the average density of all ego networks in the graph. Each of these measures is an indicator of social capital at the organizational level of analysis.

In addition, we identified adaptive leaders: individual agents who are central to shaping the overall communication structure of the organization and who therefore facilitate complex functioning. Betweenness centrality was calculated on the simulated interaction networks to identify the adaptive leaders. Betweenness centrality is the normalized percentage of shortest paths that pass through an individual agent. In essence, it measures the degree of influence an agent has in the
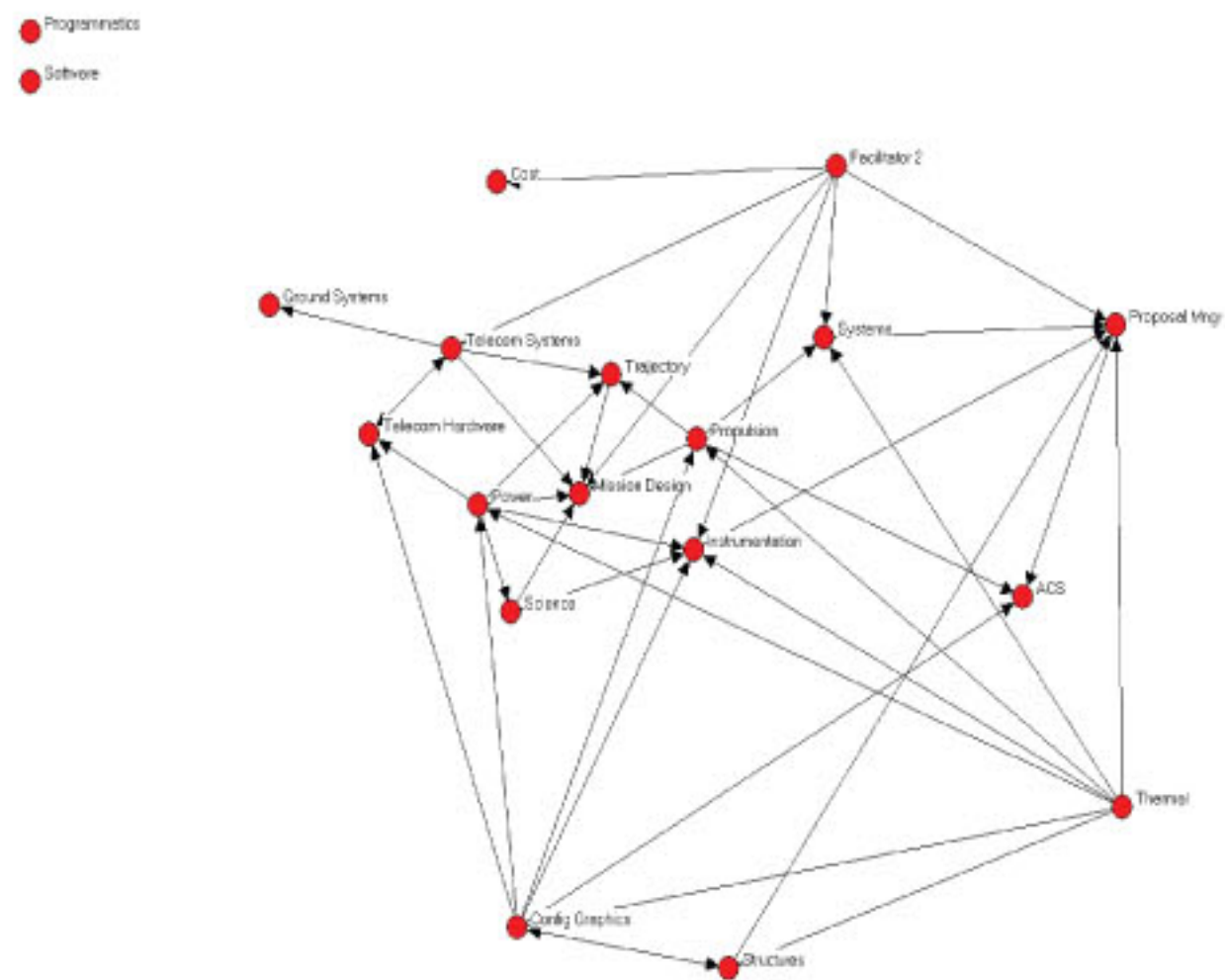

Figure 4 *The participative, decentralized style of Leader 2 (task dependency network)*

communication flow of the informal network. This measure is appropriate for identifying adaptive leaders for the simulated team, since agents in Construct are not withholding knowledge or using their network position as a brokering advantage.

Tool chain

We used the CMU dynamic network analysis tool chain to analyze and reason about the effects of leadership style on the complex functioning of Team X. The specific tools used in this research are depicted in Figure 5 and consist of:

- DyNetML, an XML-based interchange language for representing MetaMatrix relational data (Tsvetovat *et al.*, 2004).

- ORA, a statistical tool for the analysis of dynamic network data (Carley and Kamneva, 2004; Carley and Reminga, 2004).

- Construct, a multi-agent network simulation model for reasoning about network change (Schreiber *et al.*, 2004).

- Social Insight, network visualization tool

Results and discussion

Figure 6 shows the ending performance results of the virtual experiment. Clearly, the team under the influence of the participative leadership style performs better and the performance difference is not due to any distinction in the knowledge base of the leaders. In other words, any disparity in expertise between the leaders did not significantly affect the outcome measure. What is underlying the difference in performance is an increase in overall human cap-
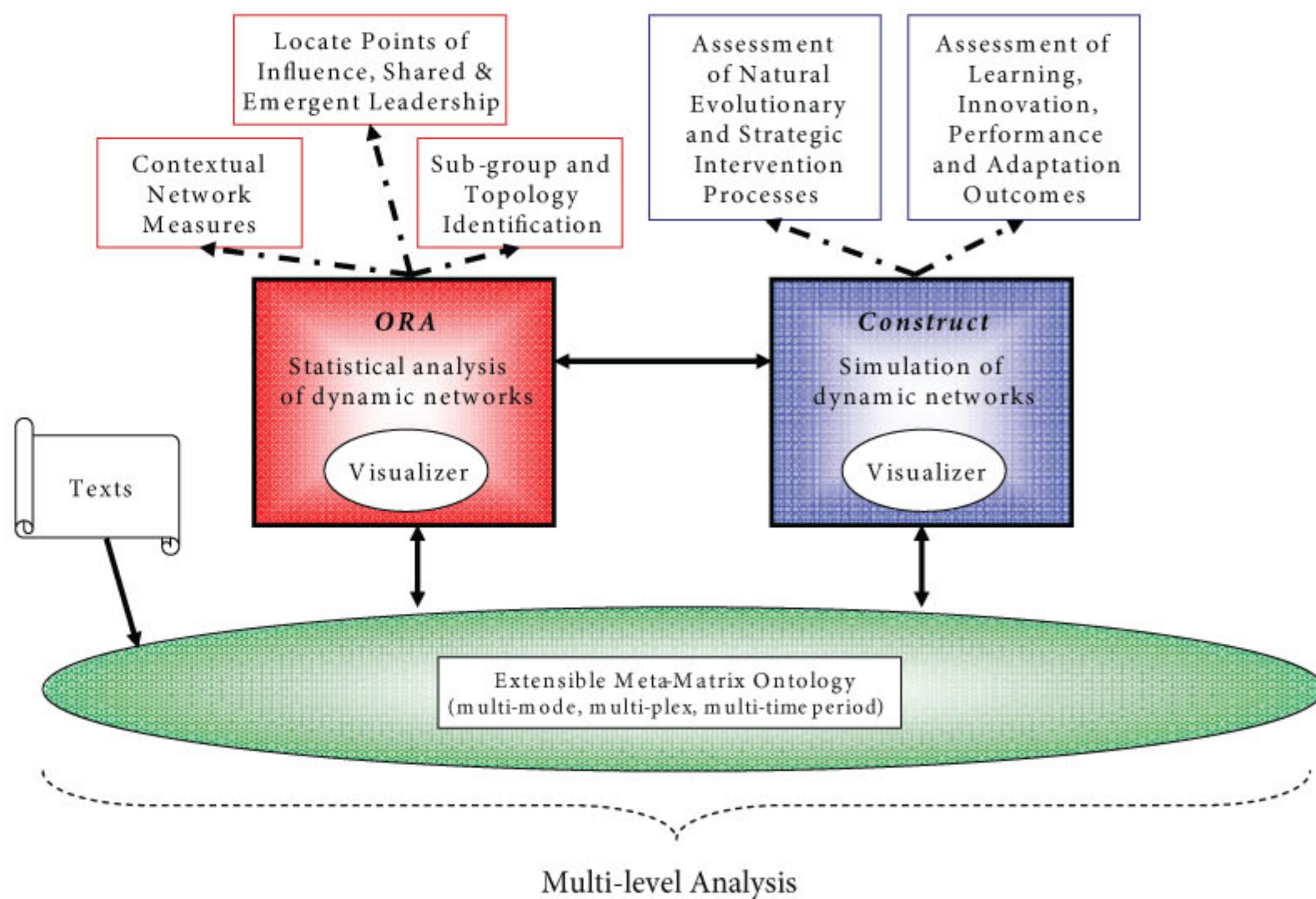
Figure 5 *CMU dynamic network analysis tools for reasoning about complex adaptive systems*

ital. Human capital in the simulated team increased by 63 percent under participative leadership compared to an increase of 59 percent under directive leadership. The higher level of learning resulted in higher performance as agents in the model attained more task-relevant knowledge and were therefore more accurate in performing the task.

With a difference in human capital evolution established, we now turn to graph-level measures of social capital over time. Figure 7 shows the clustering coefficient and Figure 8 shows the graph density. Both of these measures reveal consistently higher levels of social capital in the simulated team under participative leadership. The increased evolution of social capital under participative leadership contributed to higher learning by facilitating knowledge flows among the agents.

The difference in the co-evolution of human and social capital under the distinct leadership styles is due to a couple of reasons. First, there are differences in information flow due to the leadership style: the directive and participative leaders acted as a sink and a source respectively. In the case of the directive leader, information flowed along fewer paths and toward a central point, as the influence of this leader was to gain knowledge for centralized decisions. The case of the participative leader was different, however. The participative leader acted as a source and pushed information

into the team for decentralized decisions. Information flowed along more paths, which not only induced more interactions but also increased interdependencies through a subsequent heterogeneous distribution of knowledge. As heterogeneous knowledge increased in the team, agents searching for information were interdependent with a larger number of other agents. In other words, they could find the information they needed from multiple others rather than just a few, as was the case under directive leadership. Heterogeneous information represents variety in the organization and variety is necessary for increasing organizational learning (Hazy, 2004a, 2006; Hazy and Tivnan, 2004).

Second, the level of emergent adaptive leadership in the informal network varied. Table 1 shows the top three agents in betweenness centrality across all time periods under directive leadership and participative leadership. There is a higher degree of betweenness centrality among the top agents under participative leadership. This result is also obtained at the graph level, as betweenness centrality for the overall team under the directive leadership style is 3.818 and under the participative leadership style is 5.710. The participative leadership style enabled conditions that allowed for greater levels of adaptive leadership, mainly through increased interactions and interdependencies. This higher level of adaptive leadership enhanced infor-
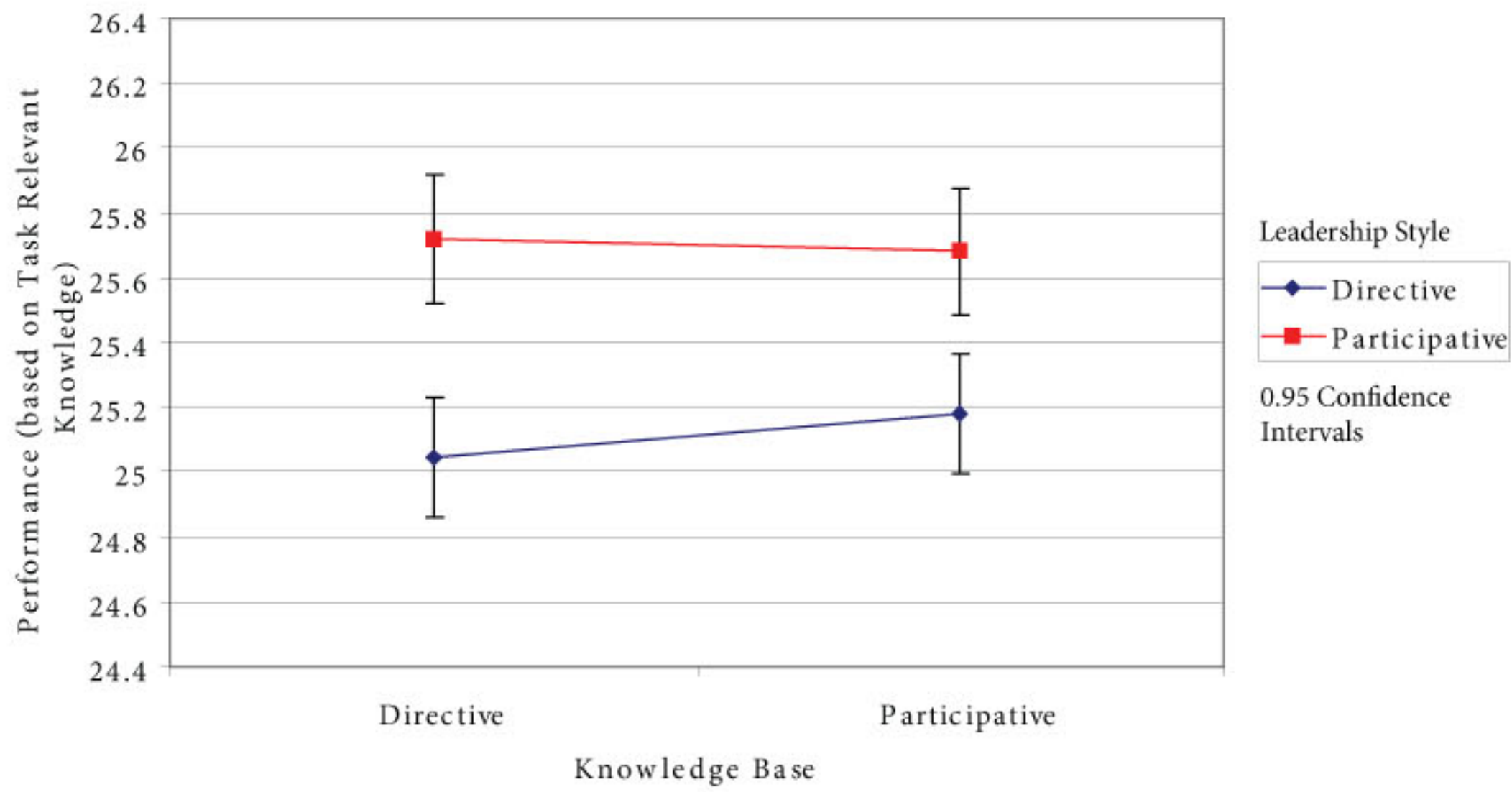
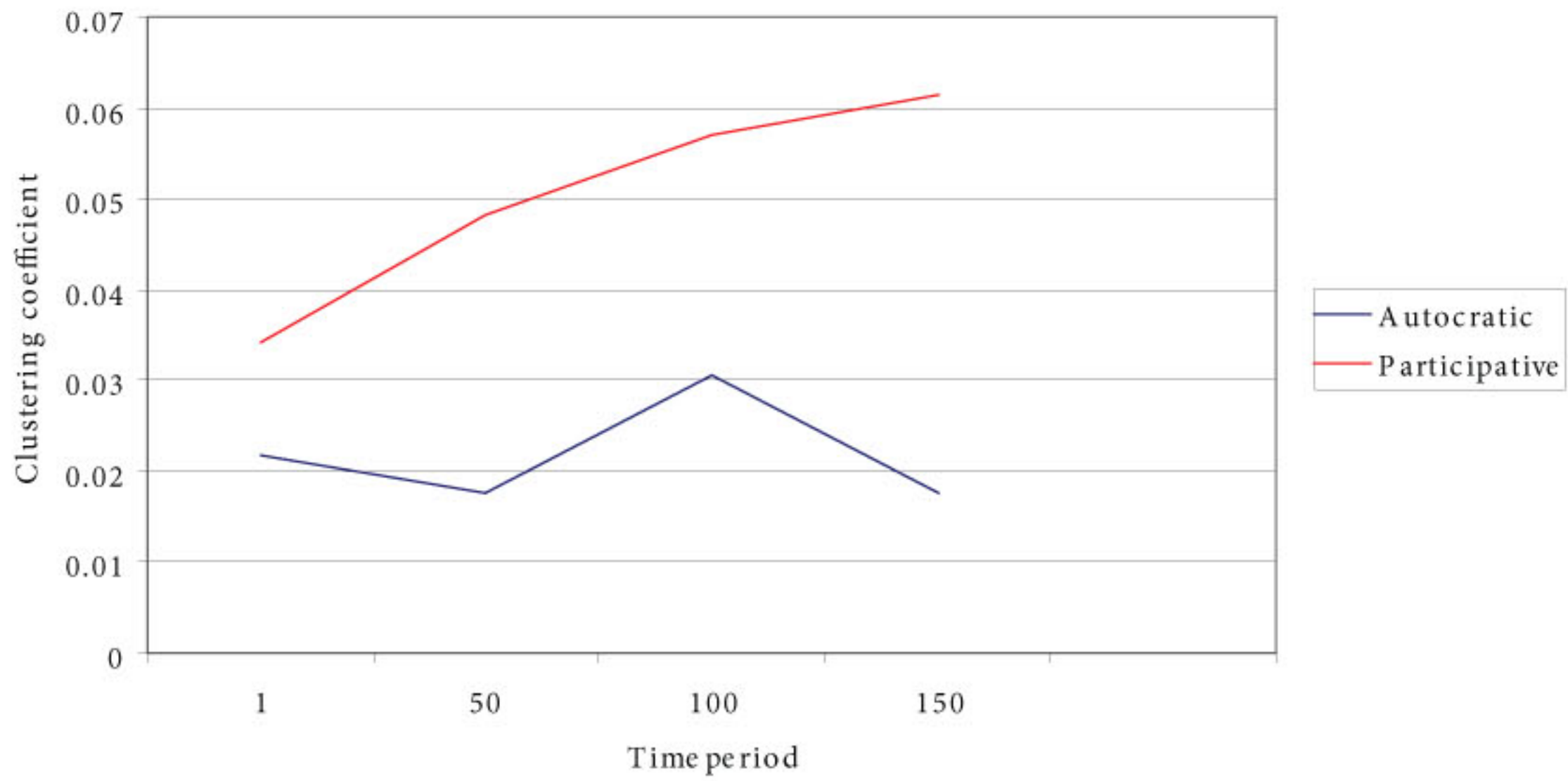**Figure 6** *Aggregate human capital performance analysis (based on agent learning)*

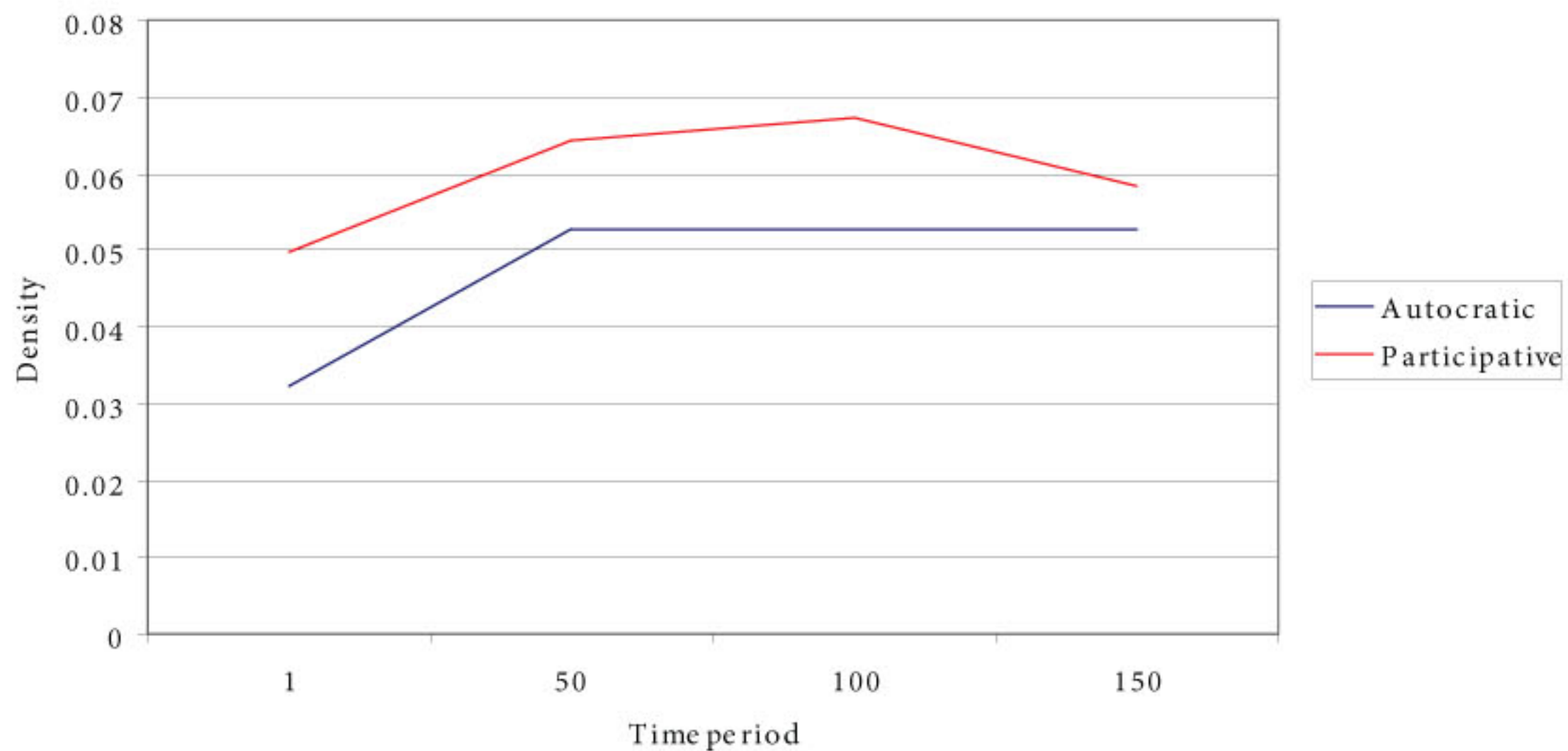**Figure 7** *Social capital measure: Clustering coefficient over time*

Figure 8 *Social capital measure: Density over time*

Directive leadership		Participative leadership	
Telecom S	(11,438)	Leader 2	(27,028)
Thermal	(10,246)	Proposal Mgr	(14,630)
Propulsion	(9,434)	Telecom S	(13,722)

Table 1 *Top three adaptive leaders under each leadership style based on betweenness centrality (in parentheses)*

mation flow and facilitated the complex functioning of the informal network.

In addition, these results suggest that agents will be conduits of adaptive leadership to a greater or lesser degree depending on the conditions. For instance, decentralized decisions created tensions that increased interactions and interdependencies among the agents. The agents under this condition, on average, enacted higher levels of adaptive leadership. In contrast, centralized decisions led to a condition with less interactive tensions and lower levels of adaptive leadership.

Another interesting result is the difference in the specific agents who were adaptive leaders. Only one of the agents is an adaptive leader under both leadership styles. This suggests that agents in the informal network will serve different roles – such as leader, peer, and subordinate – depending on the conditions. This includes formal leaders, as they are also embedded in the complex functioning of the informal network. We would like to note that we are not predicting exactly who will be an adaptive leader and at what level through this analysis. What we are saying is that there will most likely be a difference in who is an adaptive leader and at what level given different conditions.

Conclusion

The postmodern era entails an organizational design paradox and a new paradigm of leadership. The needs of organizations are now centered on knowledge work to produce faster learning and adaptive responses in an environment that is characterized by high-velocity change. Standard leadership practices are less effective in the new era as they have traditionally focused on efficiency and control (Zaccaro and Klimoski, 2001) whereas learning and adaptation are vital to survival in this new volatile economy (McKelvey, under review). Yet, efficiency and control are still needed in order to effectively exploit organizational outcomes for gain.

Realizing that there is a need for a leadership theory that addresses the challenges of postmodern organizations, Uhl-Bien and colleagues (2004) have proposed complexity leadership theory. This theory recognizes the organization design paradox and the simultaneous need for leading for efficiency and control and leading for learning and adaptability.

Our interest is in the paradoxical integration of traditional leadership roles with leading for learning and adaptability. In particular, we explored the effects of formal leadership style on the complex functioning of the informal network. This question was explored because the directive/participative leadership styles are theorized to have an effect on organizational information flows (Anthony, 1978) and information flows are also important to organizational complex functioning (Carley and Hill, 2001). This meant that leadership style may affect organizational complex functioning.

Our results suggest that participative-style leadership enables conditions that stimulate higher levels of human and social capital co-evolution. This was due to an increase in knowledge flows that induced more interactions and created more interdependencies among the agents. Along with this, our results suggest that participative leadership allows for higher levels of emergent adaptive leadership. Adaptive leaders were central agents who were influential in facilitating interactions and knowledge flows, thereby advancing the co-evolution of human and social capital. In addition, who emerges as an adaptive leader can vary depending on the conditions in the organization. Different agents emerged as adaptive leaders when under the influence of the two distinct leadership styles. These leadership styles induced different levels of tension in the form of knowledge flows.

There is an auxiliary result of this research that is worth mentioning. This is that a change in leadership can lead to unintended structural changes. The only thing that was different for the initial networks in each experiment was the leader and their connections. The initial network structure of the members was exactly the same. Yet, two very different member networks resulted over time as a consequence of differential information flows. This means that leadership style has second-order effects in the network. Each leader had no more than six direct connections, but nodes indirectly

connected to the leader were also affected.

There are some practical implications that come from this research. The most obvious is that a participative style of leadership stimulates interactions and interdependencies. This leads to higher levels of complex functioning as well as productive learning and adaptive outcomes. However, a more important implication is that such outcomes are achieved by managing tensions that induce interactions and create interdependencies. Complex functioning is a process that results from tensions. It is not controlled or managed by objectives. In fact, traditional top-down control methods, such as centralized decision making, can limit the emergent collective action and slow down the co-evolution of human and social capital, thus lessening productive outcomes. Other practices besides leadership style can create tensions in an organization and stimulate the process of complex functioning. For instance, self-forming teams enable interactions and heterogeneous workgroups inject interdependencies.

Nevertheless, tensions do need to be managed. Self-organizing processes have the advantage of quick adaptation and learning, but these processes can also self-define their evolutionary path. The complex self-organized process of complex functioning could stray into counter-productive directions (Uhl-Bien *et al.*, 2004) such as over-socialization, negative conflict, or strategic goal incongruence. Strategic interventions may need to be invoked that guide the adaptive process in productive directions. For instance, reassigning personnel or reframing problem definitions may reduce negative conflict and restore productive interactions.

In conclusion, the practical main points are that complex functioning is stimulated by tension, complexity leadership is a process that manages tensions, and complexity leaders recognize that the postmodern organization is a complex adaptive system.

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Notes

[1] Carley and Hill (2001) use the term dual-level learning where the organizational system learns at both the individual agent level and the structural level, but it is the same concept.

[2] The extreme difference in leadership styles was verified through observation and interviews.

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