FLOCK THEORY: COOPERATION AND DECENTRALIZATION IN COMMUNICATION NETWORKS

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Research has shown that decentralized organizations and groups perform better and have more satisfied members than centralized ones. Further, decentralized self-organizing groups are particularly superior when solving complex problems. Despite mounting research in support of decentralization, the means of how to foster and maintain a decentralized, coordinated group remains a particular problem for organizations. The current line of research proposes a theory of decentralized organizational communication, flock theory, and conducts preliminary tests of the theory. Grounded in literature from social networks, flock theory represents a theoretical model for the decentralized evolution of communicative systems. The flock model is then extended to integrate roadmap based flocking, bipartite networks, and findings from small world research to create a theory of cooperation, coordination, and navigation within decentralized communication networks. Empirical illustrations of flock theory are conducted via two studies on two different research-based organizations, as research organizations focus on complex problem solving and coordination of knowledge. Findings provide initial support for flock theory, confirm parallel research on decentralization, and indicate that research-based organizations may be different from traditional corporate organizations in several ways.

BIOGRAPHICAL SKETCH

Devan Rosen received his B.A. from the University at Buffalo in 1997 as a double major in Communication and Ethnomusicology, and a minor in Sociology. After working as an organizational communication consultant, he returned to the University at Buffalo, where he received is M.A. from the Department of Communication in 2000 with a focus in organizational and international communication networks. He then received his Ph.D. from the Department of Communication at Cornell University in 2007, with a focus in organizational and computer-mediated communication networks; his minor area was Sociology with a focus on collective action and self-organizing systems.

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CHAPTER I - INTRODUCTION

Human interaction may be more like jazz improvisation than a classical symphony. It may not seem like this would impact organizations, but this analogy has a great deal of application. At the basic level, the comparison between the two forms of musical performance revolves around the structure, or pattern, of the interaction. Improvisational jazz allows the individuals flexibility of expression (Berliner, 1997; Csikszentmihalyi & Rich, 1997), and a symphony has highly centralized control providing little latitude of interpretation to the individual performers. The jazz group still has a base level of structure, such as what key and tempo the performance will be in, but there is substantial room for interpretation and flexibility of group direction.

The structure of interaction amongst individuals in organizations can have as much variation as musical performance; some are decentralized and open, providing employees more freedom to make decisions and pay close attention to each other. On the other hand, some organizations are highly centralized, with most decisions coming from higher levels of the hierarchy; individual employees are not able to participate in decision-making or communicate as freely with other employees. Further, there is a great deal of impact that the structural composition of the organization can have on the performance and satisfaction of the employees, and the organization as a whole (Baron & Hannan, 2002; Cummings & Cross, 2003). As such, some organizations invest a great deal of energy in creating a "culture" that reflects organizational goals, expectations of the employees (Ouichi, 1981), socialization processes (Miller, 1995), as well as the desired structural architecture of the organization (Trice & Beyer, 1993).

How structure impacts success and satisfaction has become an important topic of research across several disciplines, including research on the organizational success of high-tech startups and emerging companies (Baron, Burton, & Hannan, 1999;

Baron, & Hannan, 2002), performance and satisfaction of organizational work groups (Cummings & Cross, 2003; Sparrowe, Linden, Wayne, & Kraimer, 2001), effectiveness of strategic business units within multi-business organizations (Govindarajan, 1986), knowledge sharing amongst work groups and organizations (Cummings, 2004; Govindarajan & Gupta, 1991; Monge & Contractor, 2003), and even the educational effects of structure in primary school classrooms (Baker-Sennett & Matusov, 1999). Findings across the disciplines suggest that the organizational architecture greatly affects the overall success; additionally, findings suggest that more decentralized structures result in better performance, both organizationally and individually, and increase individual satisfaction.

Social network analysis and other sociologically based methods have been widely used in the study of organizational structures, and have provide fruitful findings, yet the majority of the research is limited to implications of methodological results regarding structure and related variables (e.g. performance). Much of the literature comes from research done in business schools that is generally more driven by methods and findings than theory. What is lacking from the literature is a theoretical base indicating the means by which the groups and organizations studied can foster and maintain a decentralized structure, and how communication networks are central to the maintenance of these structures. Further, there is little research that extends the existing decentralization literature to research-focused organizations such as universities.

Monge & Contractor (2003) provide the most exhaustive review of the theoretical approaches to communication networks to date, with the review having a tendency towards organizational implications, and they point out several shortcomings (p. xi-xiii); 1) little research published on communication and organizational networks is motivated by network theories, 2) the field doesn't have an overarching framework for integrating conceptual, theoretical, and empirical work, 3) few network studies utilize theories as the basis for formulating hypotheses, and those that do often use single theories, 4) studies rarely tap into multiple network levels, and 5) emergent system properties has not been integrated very far into the domain of network research. These problems, and related issues, are central to the purpose of this dissertation.

This dissertation discusses the impact that structural differences can have on organizational performance; specifically, the advantages of decentralized structures on employee performance, collaboration, and knowledge sharing.

Research Goals

The function of this dissertation is to propose and illustrate a new theoretical framework for the study of cooperative evolution in communicative social systems. This dissertation has five goals. First, to review the social network concepts that contribute to research on decentralization, then review both foundational and recent research relating to structural decentralization in social systems.

Second, to propose a theory of decentralized interaction, flock theory. Grounded in literature from emergence, jamming, the emergence of creativity, autopoiesis, and simulations of bird flocks; flock theory represents a theoretical model for the decentralized evolution of social systems (e.g. organizations, work groups, or any communication network).

Third, the flock model is then expanded to integrate roadmap based flocking, based initially on computational simulations of communicative bird flocks (Bayazit, Lien, & Amato, 2002), where individuals in a communication network can remain decentralized yet refer to a "roadmap," i.e. central repository of information. Since decentralized organizations cannot rely on centralized structure to disseminate information, a roadmap allows the individuals to be better informed of the knowledge of other individuals, goals of the group or organization, and current status regarding those goals.

Fourth, elaborate the roadmap concept with a bipartite[1] model applicable to flock theory and social systems. Using phenomena and findings from small world research, the bipartite model of communication networks extrapolates the roadmap concept for application to organizations and groups.

Finally, the dissertation provides empirical illustrations of the proposed flock and bipartite models. Specifically, secondary data analysis is performed through two case studies. The first case study is on a multi-national project, coordinated by UNESCO, investigating the organization and performance of scientific research units. The second case study is done on network data from a large midwestern university.

The Structure of the Dissertation

This dissertation is organized as follows. Chapter II is broken down into three sections. The first section provides a review of social network concepts and research on group and organizational decentralization, including foundational work and recent advances. Specifically, findings from Shaw (1961) are specified and extended through research by Sparrowe et al (2001), Cummings and Cross (2003), and Baron, & Hannan (2002). The second section covers flock theory, provides contributing literature, and extends the flock theory model to roadmap based flocking. The third section proposes the bipartite small world model as a means for a social system roadmap, covers contributing literature, and applies the model to flock theory.

Chapters III and IV apply and illustrate portions of the theory covered in Chapter II via a two case studies. Study 1 (Chapter III) is on the performance of 1,222

[1] "Partite" means broken into parts, thus bipartite means broken into two parts. More specifically, two separate forms of connections that exist amongst the same group of individuals.

scientific research groups, using secondary-level analysis data collected in an extensive research effort by UNESCO. Study 2 (Chapter IV) is on the performance of individuals within a research-based college in a large university in the Midwest of the United States. Background on both studies is provided, along with case study rationale, fit, specifics of the portion of the data used, and hypotheses. Statistical results are reported along with findings and discussion.

Chapter V synthesizes the results from Chapters III and IV in a discussion of findings, research drawbacks, and future implications.

CHAPTER II - THEORY

Social Networks

Social network perspectives focus on the structure of social systems and how the elements of a social system come together. Individual characteristics are only part of the story, the people influence each other, and ideas and materials flow throughout the network. From the network perspective, the social environment can be expressed as patters or regularities in relationships among interacting units. These patterns are often called structure. This section elaborates some of the network concepts and terminology used in the subsequent literature review.

The form of network that will be utilized herein is a communication network, defined as the patterns of contact that are created by the flow of messages among communicators through time and space (see Monge & Contractor, 2003; Rogers & Kinkaid, 1981). Communication network analysis identifies the communication structure, or communication flow. Relation ties (linkages) between actors are channels for the transfer (flow) of either material or nonmaterial resources, or for an association between actors, such as a friendship tie. The ties that exist between the nodes can vary along several elements, including direction, reciprocity, and strength.

Links between actors can be measured as being either directional, or non directional. Links that are directional indicate the movement from one point to another, such as the number of phone calls one person makes to another, or the degree of liking one person has for another. Additionally, these links can also be symmetrical or asymmetrical. If the link is directional but there is not the same value of relation the link is asymmetrical and lacks reciprocity. Non-directional links simply indicate an association of two actors in a shared partnership, such as two students being part of the same class.

Centrality

The degree measure of centrality is calculated by counting the number of adjacent links to or from an actor in a network (Brass & Burkhardt, 1992). Freeman (1979) conceptualized this measure as an indicator of individual activity, yet it does not capture system-wide properties of the network.[2] It does, however, represent the number of alternatives available to an individual in the network. This in turn makes it a viable centrality to use in conjuncture with structural holes (discussed below).

Degree centrality may also be appropriate for capturing such power-enhancing behaviors that happen via direct interaction, such as integration and reciprocation. Likewise, degree centrality can also indicate other direct interactions such as coalitions and the avoidance of relying on mediating actors for indirect access to resources (Brass & Burkhardt, 1992). While a relatively straightforward measure, degree centrality provides insight into individual contributions to the interconnectedness of the overall network (Rogers & Kincaid, 1981).

Strength of Ties

Strength of the ties between actors, indicating quantity of the relation, can vary greatly and has profound impact of the nature of the network. Strength of the tie can be measured as dichotomous, indicating simply the presence or absence of a link, or valued, indicating the degree of the relation (e.g. how many times per week does one person talk to another).

One of the most important findings related to network analysis was discovered by Granovetter (1973), who found that most of our interaction is with members of our own close groups, thus we gain most of our information from these ties; however, the

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[2] Although, when summed and averaged, centrality results in the overall density of the network (Wasserman & Faust, 1994).

most novel and often the most important information comes from those individuals outside of our in-groups, our weak ties.

The tight clusters are groups of people in social networks that are associated with each other through redundant ties that allow for local clustering, catalyzed by strong ties or close ties. This local connectivity establishes multiple independent pathways, which can provide reliable accessibility. Yet, there are also a substantial amount of "weak" ties that we have in our networks; these are the connections that our close ties have with people that are not necessarily connected to, or have much in common, with us. Weak ties have been shown to offer a greater possibility for effective social coordination, needed in tasks such as finding a job (Granovetter, 1973). So it is paradoxically the weaker ties that link people to each other and to novel resources that reside in other tight clusters within a network. Likewise, bridges between different tight clusters, represented by weak ties, catalyze accessibility to a large number of nodes (people in a social network) (Amaral, Scala, Berthélémy, and Stanley, 2000).

Structural Holes

Structural holes have been widely studied yet are largely based on the work of Ronald Burt (1992a, 1992b). Burt (1992a) states, "A structural hole is a relationship of nonredundancy between two contacts. The hole is a buffer, like an insulator in an electric circuit. As a result of the hole between them, the two contacts provide network benefits that are in some degree additive rather that overlapping" (p.65). Structural holes can have different effects for individuals with different attributes as well as for organizations of different kinds.

Burt (1992b) performed a longitudinal study looking at the promotional rate of managers in a large diversified company. He found that managers in conditions of higher structural holes were promoted more quickly, suggesting that structural holes lead to increased recourses and network influence.

Susskind, Miller, and Johnson (1998), researching organizational downsizing, summarize structural holes as existing when two members who are not directly connected to each other also lack a common network contact. Likewise, structural holes make a network more constrained or sparse as individuals have less opportunity to access novel information and resources. Structural holes can also lead to inequality between network members and power opportunities.

Constraint, as presented by Susskind et al. (1998), represents the distribution of relationships across a member's network or to what extent an actors network is dependant on a limited number of network members. "Constraint is positively related to the formation of structural holes, as high constraint indicates more structural holes for an employee," (Susskind et al, 1998, p. 36).

Knowledge Networks

As discussed above, networks are systems of interacting units linked to one another with structure and pattern. Knowledge networks (KN) are "distributed repositories of knowledge elements from a larger domain that are tied together by knowledge linkages within and between organizations" (Monge & Contractor, 2003). One interesting element of KN is that the links that bind the network together are the perceptions that the people have of the knowledge networks within which they are associated. Thus, being abreast of what the other individuals know is crucial for a knowledge network to be utilized.

Knowledge networks are bound to the health of organizations, as distributed knowledge allows for people to bring unique knowledge enabling a *collective to accomplish complex tasks* (Monge & Contractor, 2003). Further, knowledge networks represent complex communicative systems, and can foster self-organizing. The greater the knowledge becomes part of the network, the more people can pool together their knowledge and spin off much more new knowledge. Similar to transactive memory theory (Thompson, Messick, & Levine, 1999), this proposes that different people have different levels of knowledge and expertise, so fostering a structure for access and allocation of knowledge is beneficial to the success of the organization. Further, organizations should foster community and sharing of knowledge in decentralized manner (Chen, 1997).

In summary, the central power of social network analysis is to bring to life an otherwise static social structure, and to path the development of this structure over time. Although a static analysis can reveal a traditional organizational structure, for example, such as a hierarchical organization, the ability to identify emergent structures greatly increases the understanding of social systems and better contributes to our understanding of organizational behavior (Krackhardt & Hanson, 1993; Krikorian, Siebold, & Goode, 1997). Further, network measures allow for analyses of the relationship between structure and several variables, including performance, satisfaction, and organizational success, as discussed in the next section.

Decentralization and Effects on Performance and Satisfaction

Several early laboratory studies (Bavelas, 1950; Leavitt, 1951; Shaw, 1964) provide a base for inquiring into the relationship between the communicative structure of groups (and organizations) and performance. Yet, there has been relatively little subsequent field research done on the structural properties of work groups and performance (Cummings & Cross, 2003). Parallel research on centrality associated with decision making (Friedkin, 1993), innovation (Ibarra, 1993), and power (Brass, 1984), has produced interesting findings related to instrumental outcomes. Recently, there is a growing body of evidence suggesting that the structure of groups' centrality can have a profound impact on group and organizational performance as well (see

Cummings, 2004; Cummings & Cross, 2003; Reagans & Zuckerman, 2001; Sparrow et al., 2001).

This section does not provide an exhaustive review of work done on small group processes and performance/satisfaction or a covering of all network based research. Rather, this section reviews the foundational work on small group networks and centrality done in the early 1950's, and then a review of more recent research regarding network centrality and performance is offered. Finally, a discussion of domains where decentralization is and is not appropriate is offered.

Foundational work on decentralization

Shaw (1964), building off of earlier studies by Bavelas (1950) and Leavitt (1951), directly investigated the relationship between communication structure and group performance. A notable contribution of Shaw's research is the integration of prior research (Bavelas, 1950) on structural properties and group efficiency regarding problem solving, leadership emergence, and adaptability to environmental changes. Bavelas' method of controlling communicative structure was simple, yet extremely elegant. Group members were placed in cubicles interconnected by slots through which messages could be passed, or which could be closed to control the structure. Using this method, structural indices were derived, such as relative centrality measures. Relative centrality is computed as the ratio of the network sum of distances[3] ($d_{x,y}$) to the sum of distances for the given position.

$$\text{Relative centrality} = \Sigma\, d_{x,y} / d_{x,y}$$

Generally, total centrality for networks has been found to correlate poorly with group performance and satisfaction (Shaw, 1964). Yet, relative centrality did not sufficiently

[3] Sum of distances ($d_{x,\,y}$) is defined as the minimum number of communication links that must be crossed in order for that position to communicate will all other positions in the group.

permit comparisons among positions amongst different networks. For this purpose, Leavitt (1951) proposed peripherality indices.

The relative peripherality of a position in a network is computed as the difference between the relative centrality of that position and the relative centrality of the most central position in the network[4] (Leavitt, 1951). Whereas a total peripherality index for a given network is calculated by adding all of the individual peripheralities in the network. One of the advantages of the peripherality measure over the centrality is that it allows for the comparison of networks of different sizes. However, the positions in the different networks do not necessarily produce the same behavior; as such the indices do not sufficiently reflect differences amongst networks. Shaw (1954, 1964) introduced the independence index to overcome these shortcomings.

Independence indices introduced by Leavitt (1951) and Shaw (1964) combined three main characteristics that contribute to position independence, (a) the number of channels available to the given position, (b) the total number of channels in the network, and (c) the number of positions for which any given position must relay information. The independence index (I)[5] has been shown to be superior to either the relative centrality or peripherality index.

Findings related to network structure and subsequent effects on group performance and satisfaction (for a compete review see Shaw, 1964) suggest that decentralized networks perform better and made fewer errors than centralized

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[4] Thus, relative peripherality and relative centrality are perfectly negatively correlated.

[5] Independence index: $I = n + [n\ (1\text{-}n/\mathrm{N}] + \log \mathrm{R}_d + \log \mathrm{R}_i$

Where:

n = number of channels available to the given position

N = number of channels in a completely interconnected network of the same size

R_d = number of positions for which the particular position must serve as a direct relayer (directly connected).

R_i = number of positions for which the position must serve as an indirect relayer (one or more links away) networks with complex tasks such as arithmetic and discussion problems (for examples of these networks see Figure 1 – Network Examples). Further, decentralized groups were more active (i.e. sent more messages), and were more satisfied.

Informational variables have different effects given different centralization in the network. Noise (channel, coding, or information noise) reduced effectiveness across the board, but had a more negative effect on centralized networks. Information distribution, either uniformly or with unequal distribution, also varies in its effect. For example, performance and satisfaction decreased when the central person has increased informational load, as well as when the information is distributed randomly, indicating that both highly centralized and completely random networks are both problematic (this notion will be revisited in the third section of this chapter).

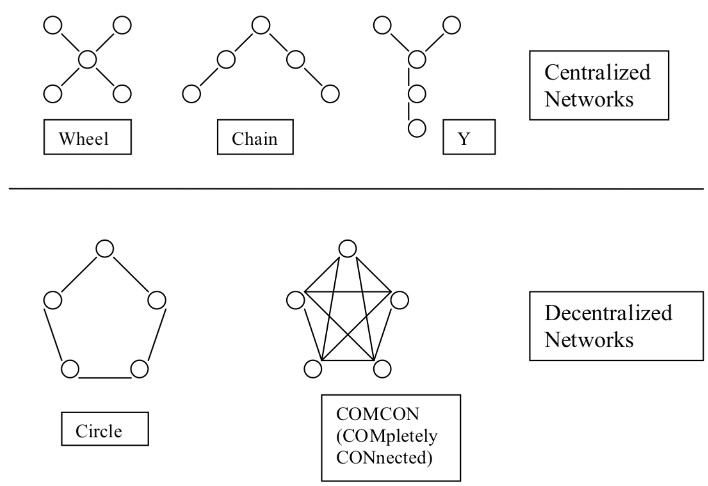

Figure 1 – Network Examples from Shaw (1964)

Characteristics of group members also affected satisfaction. Bales (1956) found that groups with authoritarian leaders have decreased independence and satisfaction. Similarly, Shaw (1964) found that groups with democratic, non-authoritarian leadership were better satisfied.

In summary, decentralized groups were found to be superior to centralized groups when solving complex problems, i.e. where information collection is key, and further operations on this information is required to complete the task. Decentralized networks were found to be more satisfying, regardless of the type of task.

Recent advances in decentralization research

Several recent research streams extend the laboratory research done on networks and performance (reviewed above) to natural settings such as organizations and academic institutions. The remainder of this section reviews and evaluates these research efforts.

Work Groups

One of the essential explanatory tenets of network theory is that structure in social networks has the ability to either constrain or augment contact with important resources (see Brass, 1984; Ibarra 1993). Sparrowe et al. (2001) extends this research, as well as that done by Shaw (1964) and Leavitt (1951), by researching group network structure and performance in work settings, and how informal relationships potentially hinder individual and group performance.

Work-related resources (e.g. task advice and strategic information) are exchanged through informal organizational networks, yet these networks also transmit social support and identity (Podolny & Baron, 1997, from Sparrowe et al. 2001). Specifically, Sparrowe and colleagues focus on the exchange of task advice and information via *advice networks*, and on obstructive relations via *hindrance networks*. Advice networks are the means by which individuals can exchange informational resources essential to task completion. Hindrance networks are relationships between coworkers who thwart task behaviors, i.e. the level to which other individuals in the network are described as making it difficult to complete work by withholding valuable information or resources.

At the individual level, centrality of individuals within work groups is used[6], as central individuals have more relations to choose from and have control over resource acquisition. At the group level, network density and network centralization are used. Network density can be defined as the overall level of interaction, or the mean number of ties per group member; and network centralization can be defined as the extent that interactions are concentrated in a small number of individuals as opposed to equal distribution amongst the entire network. Network centralization is analogous to the variance in network ties per group member; when the variance is low, specific group members do not benefit from substantially more ties than other individuals in the network (similar to the measures introduced by Shaw, 1964, reviewed above).

Centrality in the advice network was positively related to individual performance, and centrality in the hindrance network was negatively related to individual performance. These trends do not suggest that centralized groups are superior, rather that those individuals that are central to the flow of information, and extend beyond the job expectations, perform better. These findings do not exclude the possibility that an even amount of performance amongst all individuals will result from an even level of advise, especially in situations where different individuals can offer unique information and advice. Likewise, the finding that individuals central in the hindrance network (withholding crucial information) performed worse may further suggests that centralized networks that lead to decreased satisfaction (see review of Shaw, 1964 above), may be fostering hindrance networks. Further investigation is needed regarding this claim.

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[6] This study differs in this manner as other recent studies (e.g. Brass, 1984; Friedkin, 1993, Ibarra, 1993) focus on centrality within the organization as a whole.

Regarding group performance, no support was found for group advice network density and performance, yet there was marginal support found suggesting a negative relationship between advice network centralization and group performance. This finding is directly in line with the Shaw (1964) findings, where groups with complex tasks performed worse when highly centralized. Likewise, there are also parallels that can be made to recent work on knowledge networks and their importance to organizational success (Monge & Contractor, 2003).

Hindrance network density was negatively related to group performance, which points to the conclusion that uncooperative behaviors are just as closely related to performance as cooperative behaviors, further compounding the importance of satisfied group members.

It is important to note that these findings assume that structure precedes performance, yet it is entirely plausible that people seek those who can help in situation of informational need. This alternate explanation is similar to theories of instrumental action (Linn, 2001), where resources within a social network will be sought after by individuals to achieve a goal.

Cummings & Cross (2003) researched similar effects of the structural properties of work groups and their consequences for performance. Like Sparrowe et al. (2001), the analysis was done to extend the laboratory research of Shaw and Leavitt in a field setting, where information flow is emergent and hinders on the skill level, expertise, and knowledge distributed in the groups being analyzed. Yet, field-testing differs from laboratory testing, in so far that the researcher does not predetermine the problems in the field and the correct path of information diffusion is not established (Cummings & Cross, 2003).

In Cummings & Cross's study the research expectations were (a) that integrative structures are related to higher performance, and that structural properties of work groups that inhibit lateral communication or integration of expertise will have negative affects on performance. And (b) those more integrative structures may be effective for leveraging expertise of a group. This expectation is related to studies on transactive memory and knowledge networks (discussed earlier in this chapter) which suggest that groups benefit from a cogent knowledge of who knows what (Contractor & Monge, 2002; Monge & Contractor, 2003). It should be noted that these expectations are not simply to imply that increased connections among individuals in a network or group will improve performance, but certain network structures will be related to performance.

Structural properties used by Cummings & Cross (2003) were, (a) hierarchical structure, as there is evidence that hierarchy can play a functional role in communication (Ahuja & Carley, 1998); and the connectedness of the network has implications for dealing with difficult situations (Krackhardt & Stern, 1988). (b) Core-periphery structures, where a there is a cohesive core and a sparse, unconnected periphery, which can hinder the ability of the more peripheral individuals from offering valuable information, often by marginalizing them. And (c) structural holes, which, as discussed, earlier, forces individuals in the network to navigate through the actors that bridge the structural holes. For visual representation of these variables see Figure 2 - Structural Examples. Variables tested in relation to the structural variables were: number of years' known, psychological closeness, and communication frequency.

Analyzing 122 work groups in a large telecommunication company working on complex, non-routine projects, Cummings and Cross (2003) found that hierarchical and core-periphery structures were negatively associated with group communication. Greater hierarchical structures were negatively related to group both manager- and member-rated group performance. Greater core-periphery structure was negatively related to the manager-rated performance of the group, and greater structural holes of the group leader were negatively related to both manager- and leader-rated group performance.

These findings add to the small but growing body of research suggesting that structural properties such as hierarchical groups and leaders with many structural holes may be harmful to group performance where tasks and require information are emergent. As suggested by Cummings & Cross (2003, p. 209), “in such settings, it might be more effective to engage in processes that help to promote lateral connectivity so that groups can leverage their collective intellect”.

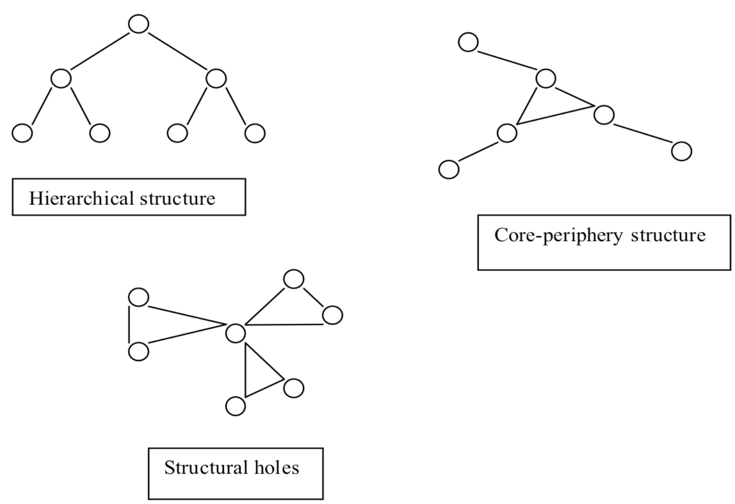

Figure 2 – Structural Examples from Cummings & Cross (2003)

Organizations

In addition to research on work groups in organizations, there has been parallel research on the structure of organizations as a whole and the subsequent impact on performance.

Baron & Hannan (2002, 2004) examined how the founders of nearly 200 emerging companies in the Silicon Valley approached key organizational and human resource (HR) challenges in the earlier times of building their firms. Their research represents the most comprehensive database on histories, structures, and HR practices of high-tech companies in the Silicon Valley (SV). Impacts of organizational and structural decisions on several aspects of the company's performance were measured. The firms examined were, on average, just over five years old and employed 75 people. Analyses in this study assess which startups were able to last through the dot-com burst in the late 90's, and prosper during a difficult time for high tech start-ups.

The main variable analyzed by Baron and Hannan is the organizational models, or blueprints, that the founders chose for their companies. There is a fairly stark contrast in the models that were chosen, especially given the similar nature of many of the business types, and that the founders are fairly well connected due to dense social networks and high labor mobility in the SV.

Analyzing transcripts from interviews with founders and chief executive officers (CEOs) notions of work and employment are organized along three dimensions - attachment, coordination/control, and selection; characterized by several distinct approaches. The three dimensions led to five basic structural models for employment relations, described below.

Dimensions:

1. Attachment

Three main forms of attachment were found to exist; love, work, and money.

1) Love - The founders that envisioned intense emotional, family-like bonds in the workplace saw this as leading to increased effort and retention (the latter is a large problem, with highly mobile personnel in SV). These founders see the employees as having a personal belonging with the company, referred to here as love.

2) Work – Since many of the firms pursue cutting-edge technology, the primary motivator for many employees relates to the opportunity to work "at the technological frontier." For these employees the attachment was for interesting and challenging work, and their loyalty was generally to a project instead of the organization or co-workers.

3) Money – The employment relationship was the simple exchange of labor for money.

2. Basis of Coordination and Control

1) Informal control through peers, or organizational culture

2) Professional control, emphasizing autonomy and independence

3) Formal procedures and systems, more traditional organizational control

4) Direct oversight

3. Selection (basis for selecting employees)

1) Skills and experience needed to accomplish some immediate tasks

2) Long-term potential

3) Values and cultural fit.

Model types for structuring employment relations:

1) Engineering - Attachment through challenging work, peer group control, and selection based specific task abilities.
2) Star - Attachment based on challenging work, reliance on autonomy and professional control, selecting elite personnel based on long term potential.
3) Commitment - Reliance on familial ties of employees to organization, selection based on cultural fit, and peer group control.
4) Bureaucracy - Attachment cased on challenging work, selection for particular control, formalized control.

5) Autocracy - Employment based on monetary motivations, coordination through personal oversight, selection based on pre-specified tasks.

Regarding structural indication of these models, the Bureaucracy and Autocracy model represent the most centralized structures, since they both rely on highly formalized, hierarchical control mechanisms. The Commitment and Star models represent the most decentralized structures, followed by the Engineering model.

The results from the research show that the structural models of the companies have substantial effects on the success and evolution. First, administrative overhead for the companies, which can hinder the ability to react to rapid technological and market changes (Walton, 1985), was lowest for the Commitment model, followed by the Star. Indicating that self-management is somewhat programmed into the companies based on the structure, and is most representative in decentralized companies.

Second, labor turnover was highest when the organization shifted to the Bureaucracy or Autocracy model. In the high-tech startup market retaining employees is crucial, as their knowledge is often the firms' most valuable asset. It was also found that companies that had higher turnover experienced significantly slower revenue growth; thus, decentralized companies are better at retaining employees, indicating higher satisfaction and better performance.

Organizational performance was influenced along three dimensions: the likelihood and speed of going public, the likelihood of surviving versus failing, and, for companies that went public, the decline or growth in market capitalization following the initial public offering (IPO). The Commitment model is the fastest to go public (IPO); almost 150% more likely than Bureaucratic or Autocracy model. The

Autocratic model is 240% more likely to fail than that the Commitment model, and 200% more than the Star model, as the Commitment and Star models are the least likely to fail. Similarly, the Bureaucratic model is 35% more likely to fail than the Star model, and 65% more likely than the Commitment model. The Star model is 140% better than the Autocratic model for annual growth market capitalization; the Commitment was 36% better.

In summary, the findings associated with Baron and Hannan's research on the implications of organizational structure of high-tech startups on performance suggest that decentralized organizations are more likely to succeed, have less employee turnover, and decrease the administrative overhead. Much like the work group research presented above, this research on organizations further validates that decentralized groups perform better and have more satisfied members.

Decentralized networks, on both the group and organizational level, have been presented in this section as better than centralized networks regarding performance and satisfaction. However, there are three domains in which decentralization may not be desired. First, centralization may be preferred in situations where a group is not solving complex problems. Shaw (1964) pointed out that the centralized groups structures were more efficient at solving simple, routine problems.

Second, when a decision, or action, is needed very rapidly. Since decentralization allows all individuals to be involved with decision-making, there is an increase in overall interaction (see Shaw, 1964; Sparrowe et al., 2001), and thus an increase in the amount of time to come to a decision. Although decisions reached by decentralized groups are generally superior, they do take longer, which is less preferable in situations where an immediate decision is needed.

Third, when there is a leader that is not interested in egalitarian control and decision-making. People that simply want control over decisions and actions lead some groups and organizations. As pointed out above, decisions will be rapid and, if involve simple problems, might not require decentralized interaction.

Since there are situations that decentralization is not applicable, the current research is specifically directed towards situations where it is beneficial. Situations where high quality, well though out decisions are needed, or when solutions to complex problems that require a variety of viewpoints are required.

Research on the social structure of groups and organizations, as presented in this section, provides a chorus of findings indicating that decentralized structures are superior regarding group performance, satisfaction, and retention. However, there is a lack of theory suggesting the means by which these groups can maintain this decentralized structure while still interacting in a cohesive manner. The following section covers flock theory, proposed as a means by which a group or network can have a decentralized structure while also allowing for a cohesive interaction.

FLOCK THEORY

At the very heart of human interaction is emergent cooperation. Whether the situation is a regular conversation, an organizational work group, or an improvisational performance, communication is always an emergent and evolutionary process. The nature of emergent systems is relevant to communicative systems because it is the interaction and interdependence of components that allows emergence to take place. System (network) components, covered in the previous section, can be humans in an improvisational music group, agents in computer simulations, or organizational managers in a task group. Regardless, the interaction and coordination of components is necessary for a system to emerge as a specifically *communicative* system.

A situation that exemplifies the cooperative evolution that flock theory seeks represents is an open, organic discussion among a group of people. The level of familiarity or friendship within the group having the discussion is not necessarily important; what is important is that the conversation is cooperative in nature, allowing all people to express opinions and ideas freely. Those who can recall such conversations might remember losing track of time, discovering perspectives with which they agree (or disagree) that were formerly unknown, generally becoming deeply engaged, and frequently losing some sense of self. This section addresses what the properties are that allow for such decentralized interactions to thrive. Likewise, this section also addresses the means by which a group, professional or informal, can foster a means of organizing itself (or self-organizing) that is both cooperative and purposeful.

Emergence research has outlined the some of the substantive elements of evolutionary systems because the nature of the states of entities within such systems is fairly well defined (see Hodgson, 2000). In general however, this effort has not been explicated in terms of emergent communicative interaction in cooperative settings. Flock theory models the cooperative evolution of human interaction via communication. As a combination of self-organizing systems theory, network theory, and emergence theory, flock theory bridges disciplinary boundaries. The literature covered in this chapter first provides a definition of emergence and its relation to scientific explanation, along with commentary on the shortcomings of emergence theory to date. Next, organizational communication research by Eisenberg (1990) on jamming and organizing is covered, followed by Sawyers' (1999) work on the emergence of creativity, and an explanation of the concept of autopoiesis. Reynolds' (1989) work on the successful simulation of flocks is then described as an initial model of flock behavior, leading to the presentation of flock theory.

Contributing Literature

The objective in this section is to describe the relevant research streams focusing on emergence, cooperative evolution (jamming and the emergence of creativity), and non-linear dynamics (autopoiesis and "boids").

Emergence

The majority of emergence research has focused on the states and entities of systems. Actors are mainly viewed as behaving in context, such as work groups, yet the properties that allow actor's emergence are not well understood.

An example of an emergent situation is an organizational brainstorming session. Individuals become interdependent in that the ideas that they create arise out of interaction, and thus would not necessarily arise without interaction. Further, some level of self-organization is required through turn taking, suspension of extreme criticism, etc., so that new ideas can arise and be initially supported (Osborne, 1953). It is in this sense that emergence allows for the creation of new ideas, as Goldstein (1999, p. 49) elaborates, "Emergence … refers to the arising of novel and coherent structures, patterns, and properties during the process of self-organization in complex systems." Emergence research has a rich and multidisciplinary history of investigation into the characteristics associated with emergent phenomena, often falling under the titles of emergence (see Darley, 1994; Gilbert, 1995; Hodgson, 2000; Wheeler, 1928), complexity theory (see Gleick, 1987; Prigogine & Stengers, 1984), or self-organizing systems (see Contractor, 1994; Contractor & Grant, 1996; Contractor & Seibold, 1993; Maturana & Varela, 1980; Monge & Contractor, 2001; Monge & Eisenberg, 1987).

Emergence describes the patterns (e.g. building off of one another's ideas), structures (e.g. no formal leader), and properties (e.g. constantly changing informal leaders) that some systems embody on the macro level. Emergence focuses on systemic self-organization, not particular outcomes. A common criticism of emergence has been that the concept is an "epistemic recognition of the inadequacies of any current theory for deriving macro-level properties from micro-level determinants" (Goldstein, 1999, p. 59). It is argued here that the provisional nature of emergence can actually be a supportive element because science must be able to deal with phenomena for which there is less than perfect knowledge. Sperry (1988) pointed out that the mind emerges out of brain functions, yet the mind can have contributory power in affecting the brain – if emergents have causal power, then they cannot be simply recognizing the inadequacies of other theories. For example, in brainstorming groups the very structure (as in decreased leadership) has causal power by fostering increased involvement from group members.

With the increase of work in fields such as nonlinear dynamics and complexity theories (see Nicolis, 1989; Prigogine & Stengers 1984), natural systems and processes were elaborated that cannot be explained by an overly reductionistic perspective due to the mathematical complexity of such phenomena (Goldstein, 1999). As a result, the estimation of initial conditions will not suffice for accuracy, undermining the prospect for simplified prediction and reductionist explanation. A basic conversation, for example, may start in a cooperative manner, where novel ideas emerge through the interaction. But this does not imply that these initial conditions will determine the course of the entire interaction.

Developments in the study of emergence challenge how both the social and natural sciences have traditionally worked. Since reductionism traditionally assumes that the elemental parts should explain the whole, complex phenomena must be elaborated in terms of one level or type of unit (Hodgsen, 2000). Reductionism remains conspicuous in social science; it characteristically appears as methodological individualism, "or the doctrine that all social interactions are only explicable in terms of individuals goals and beliefs" (Elster 1982, p. 453). For example, socioeconomic status cannot be fully explained in reference to individuals and individual acts, which would be methodological individualism (Hodgeson, 2000).

Hodgson (2000) notes that reductionism should be distinguished from reduction, which involves the fractional breakdown of elements at one level into parts of some different level. The idea of reduction is not being challenged, since any measurement is an act of reduction. Only complete analytical reduction is unworkable. As Popper (1974) points out, there is frequently an "unresolved residue" (p. 260) left by attempts at reduction, even if successful. Emergent properties are, by definition, not explainable in conditions of basic elements, and to explain systems of complexity it is essential to rely on more macro levels. Thus, flock theory balances partial reduction, concerning individual actions, and macro elements, such as group norms.

Emergence perspectives may be crucial for social sciences as they provide a means to explain higher-level relations, avoiding the problem of analytic reduction to lower-level units. Yet, while emergent phenomena provide the ability to analyze at a more macro level, Hodgson (2000, p.75) comments,

> "We must never lose sight of the dependence of these higher-level properties on lower-level units. The marks of an emergent property include its novelty, its association with a new set of relations, the stability and boundedness of these relations, and the emergence of new laws or principles applicable to this entity."

Where traditional physics has had the ability to study complete order or utter randomness, emergence offers the ability to understand the middle ground where there are elements of randomness paired with elements of order (Goldstein, 1999). As a result, the absence of adequate frameworks for emergent order acts as a hurdle to emergence being accepted as ontologically viable. This thesis hopes to fill some of this gap.

This chapter explores mechanisms by which cooperative evolution occurs by providing a framework for a model of emergence based on naturally occurring phenomena. Two main areas of work that have attempted to visit cooperative evolution are Eric Eisenberg's writings on "jamming" and R. Keith Sawyer's research on the evolution of creativity.

Jamming

Eisenberg (1990) describes characteristics of "jamming" experiences (such as a music group that is improvising or an enthralling conversation). Characterized by fluid behavioral coordination that occurs without detailed knowledge of the personality of the participants, these experiences are seen as sparking a balance between autonomy and interdependence. According to Eisenberg (1990, p.139), "Jamming celebrates the closeness that can arise through coordinated action. Jamming is nondisclosive but fulfilling…As such, [jamming situations] offer a different route, other that reciprocal disclosure, to community." Eisenberg (1990) notes that traditional perspectives on communication and organizing fail to account for several aspects of organized action, mainly experiences associated with minimal disclosure. "Jamming encourages both cooperation and individuation," (p. 146). Further, "Jamming stresses coordination of action over the alignment of cognitions, mutual respect over agreement, trust over empathy, diversity over homogeneity, loose over tight coupling, and strategic communication over unrestricted candor" (p.160).

From a communicative perspective, jamming allows for several unique dynamics. The lack of dependence people have in relation to disclosure allows for a freedom from communication apprehension. Further, the ambiguity that results from increased autonomy allows communicators to "enable a self that would otherwise be fractured to remain unified" (Flanagan, 1985), making room for epiphany (Eisenberg, 1990).

Jamming also facilitates diversity, where communication between individuals is not contingent on prior knowledge of each other. Self-consciousness can disappear, and communicators can "transcend their separateness and live not only in themselves but also in community" (Eisenberg, 1990, p. 147). The ultimate measure of communicative success is the degree to which people establish and maintain a balance of autonomy and interdependence, securing a sense of meaning and purpose (Eisenberg, 1990).

Similar to mutual equivalence structures (Weick, 1979)[7], jamming situations may be highly rule-governed, structured activities in which little to no personal information is exchanged. Yet, goals are accomplished and a strong bond is formed amongst jammers. Such jamming situations become appealing because they enable the actors to feel a part of a larger community, without the commitment of revealing much personal information. As a result of the lack of personal disclosure required in jamming, self-consciousness can be reduced.

Jamming, however, may not be a condition easily attained or maintained. Eisenberg argues that jamming requires a clear set of rules. Some rules, such as a person's need to surrender to the experience and engaging respectfully in the interaction, can catalyze jamming situations. Violation of some rules can corrode the cooperative nature of the interaction. Dominant leader qualities, such as using the open nature of the exchange to control others, dissolve the possibility for a jamming interaction. For example, the situations represented by Shaw (1964) and Cummings &

[7] Mutual equivalence structures describe the capability of an individual to accomplish something as depending on the completion of an instrumental act by another individual. Individual acts do not give meaning, interlocking behaviors provide the meaning. Thus, structure is a web of organic processes.

Cross's (2003) findings that centralized control led to decreased satisfaction amongst group members.

Structurally, jamming illustrates a case where interaction can maintain a social structure that can be seen as liberating instead of constraining. There are low expectations for future interaction as a result of the lack of emphasis on individual interpersonal knowledge. Likewise, jamming situations place relatively few requirements on dealing with and accounting for individual personalities, "Jamming is a kind of minimalist view of organizing, of making due with minimal commonalities and elaborating simple structures in complex ways" (Eisenberg, 1990, p. 154).

Improvisation is an important aspect of jamming, and includes formal and informal rules. For example, in jazz these can be seen as rules of musical keys or progressions (*formal*) and how long one performer should play (*informal*). As local conventions vary, there is a set of core rules that a person must know and follow in order for the interaction to take on a collaborative, improvisational evolution. However, *too much* attention to the rules increases the possibility of ego by moving the individual toward self-consciousness, illustrating that jamming is only possible when rule and role structures are assumed and taken for granted.

Another important element of jamming is the surrender of control, because one cannot jam at will and without interdependence on the other actors. Much can be gained by preparation and development of the right attitudes as well as seeking compatible partners. Organizational settings may foster a structure for surrender, where risk is rewarded and work groups are kept sufficiently autonomous to ensure an influx of novel ideas.

Emergence of Creativity

Working on the emergence of creativity, Sawyer (1999) has established a body of work visiting notions such as collaborative emergence and its evolution, called the emergence of creativity. Central to his constructs is wholeness, the idea that a result is not necessarily reducible to the sum of its parts. Lewes (1877) initially discussed similar perspectives,

> Every resultant is either a sum or a difference of the co-operant forces … and is clearly traceable in its components … the emergent … cannot be reduced either to their sum of their differences. (Lewes, 1877, pp. 368-369)

Sawyer analyzes improvisational theater as analogy to Morgan's (1923) notion that higher levels of complex organization emerge from lower levels. Much as improvisational actors create a dialogue with no preconceived notions of where they will go, an understanding of this knowledge cannot stem from each individual actor. Understanding can only arise out of the collaborative creation and the understanding of the group as a whole.

Wholeness in group behavior is emergent in instances where a structured plan directing the group is not present or where there is no defined leader directing the group. Thus, collaborative emergence occurs in such routine situations as conversations and brainstorming sessions, where improvisation results from the lack of a director or script.

Improvisational theatre, much like jazz improvisation, can be highly egalitarian. There is no group leader and any attempts to control the situation corrode the structure and are often shunned by other members. The communication in these situations is collaboratively emergent because with each actor's input a possible path is chosen, closing off a multitude of other paths. This element of the emergence of creativity is related to self-organizing systems in that the moves of each actor cause a need for internal organization based on a series of rules intended to maintain the egalitarian (and thus cooperatively emergent) setting, and as such provides an impetus for this thesis.

However, it is important to establish the nature of the self-organization that is most applicable to emergent phenomena when a system has a set organization that is closed to environmental forces, yet remains structurally open to these forces, such as in the case of autopoiesis.

Autopoiesis and Self-Organizing Systems

An example of an autopoietic system is a flock of birds; the flock doesn't have to change its means of organizing in order to respond to environmental obstacles, such as buildings and trees. The flock may have to change its structure, but not the way it organizes itself. Similarly, the process that individuals undergo to attempt to increase the level of coordination with each other can be seen as a function of autopoiesis, or the recursive self-reproduction of components in a system.

One of the main functions of an autopoietic system is to maintain its autonomy, and thus can be further defined as "a network of processes that produce all the components necessary to embody the very process that produces it" (Krippendorff, 1991, p. 138). In this sense, autopoietic systems recursively produce all the components necessary to have a historically reproductive network, and are likewise self-reproducing. Maturana and Varela (1987) argue that within the reproduction it is important for organization, or the system (i.e., the "flock"), to maintain its identity while its structure can change to adapt to the environment. Thus, autopoietic systems have the ability to maintain organization in relation to its structure while remaining operationally closed. The system is *structurally coupled* with the environment and *organizationally closed* to it at the same time.

Organizational closure refers to the ability of the system to use its own identity as the crucial trajectory point of reference when attempting to undergo change. The system changes in reference to previous elements in a process of self-reproduction. Maturana and Varela (1987) point out that autopoietic organization is a process of self-reproduction based on internal rules, thus closed at the level of organization, yet still open to structural environmental change. This can be applied to emergent systems where a set of parameters of interaction can remain constant regardless of structural changes, both internally and environmentally.

Structural coupling is the process of how self-organized systems influence each other (Luhmann, 1995). Structural coupling allows for operational autonomy of autopoietic systems with the environment. Likewise, the structural coupling of the system and the environment, or other systems, does not necessarily direct the internal rules of the system. Instead, the environment only causes structural changes within the system, revealing recurrent interdependencies between the environment and system (Maturana & Varela, 1987). Thus a system lacks the ability to undergo structural change without structural coupling, explaining the foundation of the evolution of a system to a self-organizing system.

In the case of structural coupling of a system with another system (e.g. work groups within a larger organization), the result of ontogenic[8] structural coupling is a consensual domain, defined as "a domain of interlocked (intercalated and mutually triggering) sequences of states, established and determined through ontogenic interactions" (Maturana, 1975, p.326). Participants as well as the history (or structure) by which they came to exist are shaped by the consensual domains. Further, the conduct of each individual is constitutively independent of the conduct of others, but serves as a source of "compensable deformations that can be described as meaningful in the context of the coupled behavior" (Varela, 1979, p.49).

Considering the concept of communication convergence (Kincaid, 1988), the systems (or individuals) participate in the realization of the other system while

[8] The process of an individual organism growing organically; an unfolding of events involved in an organism changing gradually from a simple to a more complex level.

maintaining their own core organization. This approach is used instead of a traditional input/output model in that the system is structurally coupled to its environment when it uses events in the environment as perturbations in order to build up its own structure (Luhmann, 1995). This concept focuses on the axis of change being the relationship (or consensual domain), not the identity of the individuals, similar to Eisenberg's (1990) balance of autonomy and interdependence in the jamming construct.

The convergence of communication via emergent systems (Kincaid, 1988) is then a coupling of the individuals, in which the individual organizes the internal structure of the group to adapt to the environmental forces. It is important to maintain internal organization, enabling this structural coupling to evolve based on pattern recognition and accommodating replication. It is in this sense that a set of rules of interaction can maintain the cooperative evolution of a group regardless of the shifting of group members (e.g. employee turnover) or the setting the group is in.

Benefits and Limitations of Self-Organizing Systems

There are both drawbacks and benefits to decentralization, as discussed in the section on decentralization earlier in this chapter. Similarly, there are both benefits and limitations of self-organizing systems (see Contractor, 1999 for a review of benefits and limitations of self-organizing systems as metaphor).

Limitations

A limitation of a self-organizing system is in a situation where there is a social dilemma, such as civil unrest, or when order needs to be restored to a highly entropic situation. Solutions to such situations cannot rely on the group to self-organize, as the group may not have all of the components necessary to produce organization. Thus, organization must arise from an outside force, e.g. a police officer gaining control over a rapidly decaying situation of unrest. This is not to say that there will not be a continued decrease in organization and order with the presence of an organizer (i.e. police officer), yet it may be the only means of order.

Another situation where a self-organizing system is undesirable is where the individuals within the system desire organization and the decrease of entropy, yet cannot figure out the means by which cooperate with each other to organize. An example of this would be a large population of people that wish to protest a specific governmental decision, yet do not have the means by which to organize. Such situations represent systems that benefit from an external organizer; such people are often fittingly called *organizers*. However, if the system lacks an organizer, coordinated roadmap communication can be used as a means for self-organization, which is covered later in this chapter.

Perhaps the most undesirable effect of self-organization is in the case of herd behavior. Commonly discussed in relation to flock behavior, herd behavior is characterized by local organization, similar to a flock, but is far more vulnerable to dangerous headings that can lead to system destruction. Much like a herd of cattle leading each other off of a cliff, herd behavior can typify situations where the lack of a central point of organization allows even a small direction change to cause widespread entropy.

One of the most common contexts that herd behavior is used both as metaphor and measure for social movement is in economics and investment trends. A wide range of research has used the herd metaphor as a basis for economic research and the explanation of cascading trends in investment (see Abhijit, 1992; and Bikhchandani & Sharma, 2001). Research on herd behavior has been done in financial markets (see Andrea & Welch, 1996; Christopher & Zemsky, 1998; Froot, Scharfstein, & Stein, 1992; Guillermo & Mendoza, 2000; Huang, Huang, & Huang, 1995; and Persaud, 2000), stock investment (see Scharfstein & Stein, 1990; and Wermers, 1999), and information spread about markets and investment (see Graham, 1999; Trueman, 1994; and Welch, 2000).

Findings across the financial disciplines suggest that investors and analysts will make investment moves similar to that of a herd, even when they believe the investment is a bad decision. A principle reason for this misguided action is that the investors believe that others may know something about the return on investment and their actions reveal this. Central to this kind of herding is the lack of knowledge about what they other individuals know, i.e. allowing local organization to be predicted by only localized action, disregarding the need for global information and coordination.

For example, consider fifty investors each with their own assessment, possibly different, of the profitability of investing in a specific opportunity. Ten of these investors believe that the investment is sensible and the remaining 40 do not. Each investor knows their own estimate of returns, yet they do not know the estimate of others' or which way a majority of the inventors are leaning. If the investors shared their information, they would concretely decide that the opportunity is not worthwhile. However, the investors do not make their information public, and they are not making their decisions at the same time. Thus, if the first several investors that make their move are amongst the ten that believe positively, others that were initially more pessimistic may revise their conclusions assuming that others knew something that they didn't, and invest.

Herding examples such as these are not rare in emerging market investments, which clearly points out a potential problem with this form of self-organizing system; without a means of real-time information sharing and retrieval a decision-making group can easily become a blind herd headed for a cliff. In the example presented above, if the investors pooled their knowledge they would have come to a collective, self-organized decision not to invest. The current research stream presents a model by which a group can be both self-organized and able to react to potentially dangerous outcomes.

Benefits

Situations where self-organization is beneficial are similar to those where decentralization is beneficial, as presented in previous sections. Groups or organizations that are looking to promote creativity or to fully utilize the knowledge potential of their members should promote self-organization. Research in organizations has shown that people that are able to organize themselves perform better (Cummings & Cross (2003), are more satisfied with their job (Sparrowe et al, 2001), and are internally motivated (Hertzberg, 1968). Likewise, research on knowledge networks indicates that knowledge sharing increases in self-organized groups (Monge & Contractor, 2003). Much like a good brainstorming session, self-organization can lead to group cooperation and idea generation.

An additional benefit of self-organization is the increased opportunity for spontaneity. During self-organization the interaction is in a constant state of producing the outcomes, there is a parallel constant opportunity for the group to spontaneously change direction. Additionally, individuals in the group are afforded the possibility of expressing new ideas, or problems with current ideas, in a more rapid and real time fashion because the group is self-organizing. Situations where an individual is organizing and directing the groups interaction, spontaneous direction is suppressed in exchange for structure and predetermined organizational structure.

The following section introduces a specific context, bird flocks, that characterizes self-organization and is used as a framework and metaphor for self-organizing group interaction.

Boids

In 1987, computer scientist Craig Reynolds undertook the task of creating a dynamic computer rendering of a bird flock, where each movement of each bird (which Reynolds, being from New Jersey, called "boids") is not pre-programmed, but arises organically from a set of predetermined rules. He comments on flocks,

> A flock exhibits many contrasts. It is made up of discrete birds yet overall motion seems fluid; it is simple in concept yet is so visually complex, it seems randomly arrayed and yet is magnificently synchronized. Perhaps most puzzling is the strong *impression* of intentional, centralized control. (Reynolds, 1987, p.2)

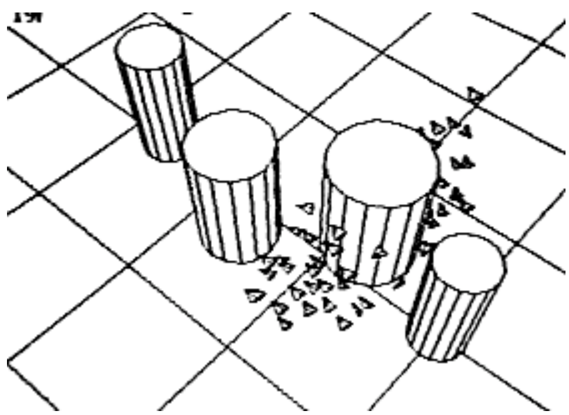

Figure 3 – Boid Example
The flock of boids steers around the obstacles and rejoins with the larger flock, maintaining the group regardless of environmental input.

As Reynolds was working with the representation of such group movement, he derived three simple rules that can incorporate the vast complexity of a flock, and render an accurate rule-based simulation of its behavior (Reynolds, 1987).

Rule 1. *Separation*: avoid crowding local flockmates.

Rule 2. *Alignment*: match average heading with nearby flockmates.

Rule 3. *Flock Centering*: move to the average position of nearby flockmates.

When birds following these rules they can avoid environmental objects as well as split of from, and rejoin, the flock (see Figure 3, or for a movie of the simulation go to http://www.red3d.com/cwr/boids/).

Reynolds' ability to capture coordinated evolution in a flock setting is extraordinary, yet to apply this phenomenon to human interaction is quite a different task; there are similarities and differences. Similar to a flock, emergent human interaction (such as jamming and the emergence of creativity) is comprised of a series of autonomous individuals who "move" (e.g., through a musical performance or a brainstorming discussion) so that no individual predicts precisely where the group is going at each iteration, nor does any individual decide the moves at all times. Yet, the group moves as a whole where all members participate in an egalitarian fashion, such that everyone has equal control over the course and outcome of the interaction. Unlike a flock, human groups often need to keep in mind the goal of the interaction (although certain jamming interactions exist with the absence of an end goal, e.g. free jazz). Even in improvisational theatre, the group might not be able to decipher the exact evolution of the interaction, but there needs to be some sense that the scene will lead to some form of conclusion or closure.

Brainstorming sessions in organizational settings must also keep in mind the end goal, even if the trajectory of the interaction may not be constrained. Generally brainstorm sessions exist to come up with novel conceptions for a specific problem or opportunity; thus a general goal needs to be present. Also, humans interact using symbol sets as the means of understanding group movement; unlike a bird flock, any coordination during the interaction assumes that the individuals will use the symbols to maintain organization.

The transition from simulated physical flocking of birds to human interaction includes a theoretical model based on efforts of other researchers to investigate similar phenomena. In summary, this section provided the basis for flock theory combining conceptions of emergence, cooperative evolution, and non-linear dynamics. Emphasis is placed on the importance of a non-reductionist approach of emergence, the importance of rules, and interaction complexity.

Flock Theory

Combining the central concepts of emergence (Goldstein, 1999; Hodgson, 2000; Monge & Contractor, 2001; Monge & Eisenberg, 1987), jamming (Eisenberg, 1990) and the emergence of creativity (Sawyer, 1999), and autopoiesis (Maturana &Varela, 1980) as explanatory processes, and groupthink (Janis, 1971) as an example of the breakdown of the cooperative emergence of the situation, flock theory models the self-organizing principles of cooperative evolution in human interaction. The structure of the theory, based on the rules "template" that Reynolds (1987) used to simulate a bird flock, is extended to include concepts based on social science research (e.g., leadership and centralization concerns), and further specify original tenets of "Boids" in human contexts.

Flock theory may be viewed as an emergent theory of decentralized human interaction. The throng of collective action between flock members exemplifies the self-organizing ability of individuals that, despite their complexity, can demonstrate cooperative evolution. The coordinating ability of birds is viewed as an exemplar that is used to elucidate structure, while simultaneously establishing mechanisms of interaction (Reynolds' rules) that serve as a foundation for axioms explicating cooperative evolution in human interaction.

What follows are the main elements and corresponding subsections of flock theory, presented with supporting social science research. A discussion of the rules of engagement is followed by a possible means measurement of the model via an example of newsgroups.

Structural Distance

This construct captures the concept explained by Eisenberg (1990) as the balance of autonomy and interdependence, the "close but not too close, far but not too far" element. Groups that foster excessive autonomy may dissolve and groups that foster too much interdependence may stifle creativity (Bolman, & Deal, 1997; Mumby & Stohl, 1991; Tjosvold, Andrews, and Struthers, 1991). Organization is created by the shared repertoire of communicative behaviors; the members of a group need to maintain a level of cohesion that allows for individual input without sacrificing group acceptance of new information (be it an idea for a task group, or a new key in a musical interaction). On one hand, a group can become to close and, much like Reynolds' biods, corrode the ability for the group to navigate and change direction when necessary. A common effect of the high-cohesion that a group can encounter is groupthink, where the closeness of the group members leads to several problems that inhibit the groups decision-making abilities, especially at critical points.

One well-known result of excessive cohesiveness is groupthink, including self-censorship and perceived unanimity (Janis, 1971). Research has found that high levels of cohesion can lead to Groupthink and decay the quality of the group interaction. For example, Turner and Pratkanis (1992) found that Groupthink occurred more frequently in situations of extremely high cohesion, where the group members perceived themselves as being very close to each other in both group, lacking the ability to voice dissenting opinions. It is the feeling of distance within the group that hinders their ability to see alternative viewpoints, or listen to those that suggest them.

Additionally, accountability can be related to two Groupthink conditions of insulation and impartiality. First, accountability inhibits the possible insulation of the group by forcing the members to consider other party's point of view. Second, the lack of impartial (promotional) leadership and accountability makes it crucial for all individuals in the group to be able to justify the decision reached by the group, resulting in a decrease in the concentration of power in one domineering leader. For example, Groupthink typically occurs in decision making about nonroutine, crucial issues, which may affect large numbers of people (Kroon, van Kreveld, & Jacob, 1991). Kroon et al. (1991) also postulate that accountability is expected to reduce the likelihood that group members will give in to conformity pressures. Accountability is also expected to induce evaluation apprehension, catalyzing normative behaviors and causing one to have a tendency to "cover one's tracks" and underestimate the performance of one's group. For example, Kroon et al. found that accountability led to more complexity in reaching consensus, better decisions, and less risky decisions.

In summary, the structural distance construct proposes that groups need to include members in decision making to allow for accountability and the avoidance of conformity. Yet, the group must also allow for freedom of expression to avoid self-censorship. Structural distance should also not get too distant, as in the core/periphery research on work groups by Cummings and Cross (2003) presented in the first section of this chapter, as maintaining the structural distance of the group will allow for a greater likelihood for collaboration.

<u>Collaboration</u>

If structural distance is to be maintained in evolutionary processes, then the direction of change (either topically or task oriented) and the rate of change need to be a cooperative function amongst the group. This relates to Sawyer's (1999) concept of processual intersubjectivity, or the establishment of a constantly changing emergent shared understanding; where that which is currently being established, as well as future emergence of creativity, has to proceed within the frame being created by this emergent interaction. Thus, to have a shared understanding the group members must attempt to match both the direction (norms) and velocity (tempo) of the other members. Central to this construct is the creation and maintenance of a group culture, or the norms and tempo that allow group members to reach a mutual understanding of both their interaction direction and velocity. Baron & Hannan's (2002) findings that organizational cultures that allow for mutual influence are more successful suggest the importance of collaboration.

Group members should reflect the direction that the group is moving. This could be a change of topical direction in a conversation, a novel idea in a brainstorming group, or a change of key in improvisational music. The purpose of direction matching is to allow the group to evolve in a collaborative manner, while maintaining the structural properties of the system via normative behavior. Thus, a new direction posed by a group member should (at least initially) be supported the group. The norm of reciprocity (Gouldner, 1960) provides further theoretical justification for by matching the topical direction and depth of relativity of group communication.

Group members should accommodate the rate at which other members are delivering messages, making successive moves, and allowing for space between these moves. In a face-to-face context this is theoretically justified through communication accommodation theory (Gallois, Franklyn-Stokes, Giles, & Coupland, 1988), which defines further moves of the group whether convergent or divergent.

For example, a cross-functional team must maintain the rate at which its attention moves from function to function amongst its members. Likewise, as bursts of activity are demanded from the group, it becomes increasingly important for the individuals to attempt to match the velocity of moves of the group. In this case, "getting with the group" may be more of a pacing issue that results in the accommodation of group and member rules. Central to this shift in cross-functional teams is the maintenance of leadership, as discussed below.

Collaboration is associated to Reynolds' concept of direction matching, and related measures can be applied to the newsgroup context, as discussed in the previous section. Measures

Decentralization

If a leadership role is present, it must shift in a manner such that no one actor maintains leadership for too long, and that the group is led in a purposeful direction. This concept hinges largely on the differences between individual and group emergent leadership. This is extremely pertinent in the case of cross-functional teams, where each member of the group has embedded knowledge that cannot be obtained from any other group member. It is in this sense that the leadership shifts and the group must self-organize with purpose.

It is helpful to conceptualize a decentralized leadership as a "goose rule," where a goose flock must shift leadership in an effort to maximize energy decay. This energy decay can be related to groups in that a leader can exhaust their energy within the group, and the individual that has not led for the longest time has build up the most potential energy, and should then lead in one of the successive moves. This also guarantees the efficient use of intellectual capital, much like a brainstorming session. Eisenberg (1990) and Sawyer (1999) both stress the importance of the lack of leadership within a collaborative evolution. Findings presented earlier regarding the success of decentralized work groups support the use of decentralized structures.

Decentralized structures also secure that the symptom of one strong leader, as one of the main causes of Groupthink, does not proliferate. For example, Flowers (1977) studied directive or participative leaders and found that groups with single directive leaders proposed fewer solutions, covered less case information, and used fewer case facts both before and after reaching a decision. Leana (1985) used a similar design by assigning either participatory or directive leaders in groups. These groups were then given twenty minutes to select five employees to lay-off from a hypothetical business. As in the Flowers (1977) study, the groups with directive leaders discussed fewer solutions than the groups with participatory leaders.

Central to the role of leader is to maintain that the group is moving in a direction of purpose. Often the goals of group interaction can change over the course of the interaction or life of a group. It should be duly noted that in an emergent group, the leadership shift does not need to be clearly defined, in that there can be more that one leader at any given moment. This is most clearly revealed during the actual shift of leadership, much as a relay racer successfully passes the baton by having both runners maintaining a firm grip until an understanding is reached that the new runner has control (extending the concept to include the transition phase between leaders). Although not a necessary condition, the multi-leadership model allows for the building of knowledge or novel ideas where any given move may indeed spark a vibrant trajectory in another potential leader.

Maturana and Varela (1980) note the importance of structural coupling in terms of autopoietic systems, and this concept is applied to group leadership as self-organizing. Thus, the role of leader is indeed passed from one actor to another in such a manner that intersubjectivity exists in the transformation of leadership shift.

Rules of Engagement

Norms

Groups of individuals often display coordinated behavior, frequently without a central authority to intervene, based on the presence of norms (Axelrod, 1986). A norm exists in a social setting to the extent that individuals act in a certain way and can be reprimanded when not acting in this way. The cooperative structure discussed in flock theory sets forth a series of norms that catalyze the decentralization of groups and organizations. However, the current research subscribes to the notion that norms are evolutionary, and the use of them in initial interactions will propagate the establishment of the norms in a self-organizing way.

Axelrod (1986) proposed an evolutionary perspective of norms, what works well for an individual is more likely to be used again, and what doesn't work well is like to be discarded. The evolutionary perspective of norms highlights the importance that groups foster norms of cooperation and support these norms with action. Individuals will internalize a behavioral norms as more correct to the degree that they see others performing them, the actions of other individuals in a group is central in how every individual decides to act (Cialdini, 1984). Additionally, by conforming to the actions of others, we fulfill the need to be part of the group. In the case of the current research, the individuals would be conforming to a group structure. Based on an evolutionary approach, a cooperative, decentralized group structure will foster the maintenance of that structure, as cooperators are more likely to stay in a group than are defectors (Orbell, Schwartz-Shea, & Simmons, 1984). Axelrod also found that norms could become established surprisingly quickly, and that cooperative norms can be hurried along with relatively modest interventions.

Four group norms that relate to flock theory are homophily, trust, reciprocity, and the age of relationships. The following section covers the basics of these group norms and their application to flock theory, and are extended thorough an example of university research groups.

Homophily

Homophily, defined as *the selection or presence of others who are similar* (Monge & Contractor, 2003), or *contact between similar people occurs at a higher rate than among dissimilar people* (McPherson, Smith-Lovin, & Cook, 2001) has been utilized in a variety of contexts to explain network and group dynamics. The notion that similarity breeds connection, i.e. birds of a feather flock together, will result in people's personal networks being homogeneous across many sociodemographic, behavioral, and interpersonal characteristics. Likewise, such homogeneous connections can act as a network constraint on the information people receive and the interactions they encounter. McPherson et al. posit that distance via social characteristics can translate to network distance, and that any entity that relies on networks for transmission will tend to be localized in social space. Yet, Brass (1995) notes that similarity in groups can ease communication, increase predictability of behavior, and foster trust and reciprocity. Similarly, in a review of the literature on diversity in groups, Mcleod, Lobel, & Cox (1996, p.251) found that "both laboratory and field studies have shown that heterogeneity among group members with respect to age, tenure, education, and functional area is related to group and organizational creativity, adaptability, and innovation." The disparity in research findings regarding the effects of heterogeneous and homophilous group composition on performance suggests the need to focus on areas of homophily that is not centered on personal status.

Although much of the homophily research has been centered around *status homophily* (i.e. similarity based on informal, formal, or ascribed status), such as race and ethnicity (Ibarra 1995; Kalmijn, 1998; and Marsden, 1987), gender (Marsden, 1987), age (Fischer, 1982), religion (Fischer, 1977), education (Marsden, 1987), and age and gender in distributed teams (Yuan & Gay, 2006), homophily research centered on network position and organizational foci is presented below as more closely related to the group structures discussed in flock theory.

Festinger (1950) discussed using structural position as a means of social comparison, and thus a means of deciphering similarity. Burt (1982) and Friedkin (1993) confirmed the initial claim by Festinger, finding that people who are more structurally similar to one another are more likely to communicate about attitudes, that their attitudes would be similar, and as a result they would have more influence over each other. Similarly, Lawrence (2006) found that some strong homophily effects regarding whom people consider to be relevant others in an organizational environment, including watching for signals about the environment and those who opinions we attend to. Advice, friendship, and association respond to this type of homophily as well (McPherson et al. 2001).

Research suggests that a group or organization that has a decentralized structure will foster increased interpersonal homophily and interaction based on the similarity of structural position, and a hierarchical/bureaucratic structure would inhibit interaction and divide members along structural lines. Research on group and organizational structure, presented earlier in this chapter, echo these findings with decentralized groups and organizations communicating more, and being more satisfied with their interaction than centralized groups. Structural homophily is the first form of homophily that augments the flock model; the second is organizational foci.

Focused activity place people in contact with each other and forms personal relationships, and interaction is more likely to occur among individuals who share similar organizational foci (Feld, 1984). The relationships formed around organizational foci are capable of reinforcing nonhomophilous ties and allow them to operate as homophilous ones would (McPherson et al. 2001). Caldeira & Patterson (1987) found that ties formed around organizational foci led to shared friendship, information, understanding, and behavioral homophily. Yuan & Gay (2006) point out that groups where knowledge sharing and knowledge creation is key it is increasingly important for individuals to have contact with people that are *dissimilar* from them, and allow the goals of the group to organize the ties. That organizational foci can lead to homophily represents an important shift in the concept of homophily, as the central means of getting the birds to flock together is not that they are of the same feather by demographics, but by purpose.

Combining research on structural position and organizational foci as means of representing similarity, and thus homophily, crystallizes a central point of flock theory; decentralized groups cooperating for a common purpose may be able to transcend traditional norms of homophily (age, race, gender) and allow their purpose to be the tie that binds. So, as the adage says, birds of a feather do indeed flock together, but they can flock together regardless of the color of their feathers.

Trust, Reciprocity, and the Age of Relationships

Reciprocity has been proposed as essential for the running of complex societies (Doreian, Kapuscinski, Krackhardt & Szczypula, 1997), and has been found to be a dominant strategy for dealing with problems that require coordination (Axelrod & Hamilton, 1981). Likewise, Gouldner (1960) proposed that a norm of reciprocity obligates people to reciprocate others pro-social advances. Trust among group members is important in sustained cooperative group structures (Jarillo, 1988). While investigating network exchange relations in organizations, Larson (1992) found that norms of reciprocity and trust take an invisible but powerful role, and impose expectations and obligations along several aspects of behavior, all centering upon confidence that the other individuals can be relied upon for effort and to adjust to change. The moral control that an expectation of reciprocity is flexible and penetrating. Under norms of reciprocity and trust, it was found that traditional, centralized controls and incentives are less relevant when objectives are jointly determined (such as homophilous organizational foci) and implementation is accomplished through collaboration.

Larson (1992) also found that organizational structures that represented sustained, stable relationships, especially when lacking formal contracts, were found to have a high degree of cooperation and collaboration. "They were governed in important ways by social controls arising from norms of trust and reciprocity. The governance was explained in a large part by understanding the subtle control of interdependent and self-regulated players engaged in and committed to mutual gains" (p. 98). Aspects of organizational theory that acknowledge patterned histories of interaction that create mutual expectations capture an explanation of coordination in this manner. Social patterns take on a rule-like status, where the rules control and coordinate behavior by defining what actions are appropriate in engagement; Larson describes this mode of exchange as a network form of governance. The development of trust and reciprocity along these lines is contingent upon the creation of norms and expectations, which develop as the members make sense of the interaction and create boundaries (Weick, 1996).

Boundaries can be conceptualized as being both real and perceived (Weick (1996; Wright & Ehnert, 2006). Real boundaries have a physical representation, such as bureaucracies and organizational charts, where the physical boundary allows individuals to understand what this means for effective communication and responsibilities. Perceived boundaries have no fixed state, they are social constructions and products that are made and remade. Understanding the perceived boundaries in any social relationship allows the individuals to interact in ways that are appropriate for the context. For example, highly structured interactions, such as courtroom interaction, requires a certain understanding of the boundaries that is distinctly different from a more loosely coupled groups, such as a brainstorming groups. Yet, describing boundaries as *perceived* implies that they have become and are fully formed. A more fitting consideration is that they are in a mode of *perceiving* draws attention to the notions of how and why they are being created (Wright & Ehnert, 2006).

One of the main ways that boundaries are created is through trust (Weick, 1995). Weick claims that the initial act of sensemaking in an interaction revolves around trust and boundaries, and these initial cues provide individuals with the frame by which they will use for organizing subsequent signs. Trust and sensemaking are inexorably bound, and the combination has powerful implications on the social boundaries one perceives and creates, and thus on the degree of cooperation one is willing to partake in. Organizations that want to improve the decision making of their members would be well served to focus on the sensemaking of the individuals prior to the decision-making. Weick (1996) claims that sensemaking is improved through improvisation, respectful interaction, cooperation, and communication. Groups that enact a cooperative, improvisational means of interacting and communicating will be able to making better sense of the interaction and understand the relationship between reciprocal trust and where they perceive that boundary to lie.

Trust and reciprocity have their trajectory from the first moment of interaction, but are created as the relationships grow over time. A review of group communication and decision making literature revealed a shortage of research on the impact of the age of relationships on group communication. Three recent substantive reviews of group theory and research (Frey, 1996; Hirokawa, 1996; & Poole, 1999) also contained no mention of the impact that the age of relationships has on group processes. In the most recent Handbook of Group Communication Theory and Research (Frey, 1999), the only related topic discussed in the 20 chapters is the process of group socialization (Anderson, Riddle, & Marin, 1999). Socialization research, or the process by which newcomers become part of the group's patterns of activities, is generally focused on phasic models of group decision-making, where a certain amount of personal information is required for group membership. Socialization is indeed crucial for the decentralized structures discussed in the current research, as the norms of engagement need to be understood by all group members, but the phases one goes through while becoming part of an in-group are specifically not necessary.

There are several topics related to the age of relationships already discussed in this chapter. The development of trust, reciprocity, and homophilous foci discussed above, and the Jamming perspective discussed in the contributing literature section of flock theory.

Eisenberg's Jamming model (1990) specifically discusses the ability of a group to interact in a cooperative and emergent manner regardless of the level of personal disclosure and familiarity. Indeed, what is more central to the jamming situation is the familiarity with the norms of engagement that catalyze cooperative interaction. Yet, it is the level of familiarity with those norms that allow the flock interaction to flourish, and the longer a group interacts in a jamming manner, the more comfortable they will become with norms, and with each other.

There are, however, drawbacks to the connections that form and flourish in a cooperative small group, as discussed below.

Limitations of flocking behavior

Along with the many beneficial effects of decentralized flocking, there are various drawbacks and limitations to flock theory. The limitations are the possibility of non-compliance to group norms, overt moves to gain control, and difficulty coordinating collective movement.

Flache & Macy (1997) extended the work of Granovetter (1973) on the strength of weak ties and Homans' (1974) social exchange theory by positing and testing a weakness of strong ties model. The model that was investigated challenged the assumption that strong ties promote informal control and that it is a given that actors will seek group compliance for approval. Findings pointed to the possibility of highly cohesive networks that exhibit very low levels of compliance, particularly when there is bilateral exchange of approval. Additionally, small groups can achieve fairly high levels of compliance in the absence on informal social control. These findings, when extended to the flock model, introduce problematic effects, as an increased need for approval can thwart a groups' ability to organize a significant mass. Findings also pointed to the possibility that group members might become preoccupied with approval that smothers any concern about the cost of contribution.

Combining the findings above leads to a condition that is very likely to thwart collective action and cooperative evolution; the combination of a high cost of contribution compared to the collective benefit and the need for approval being insufficient to fully compensate this cost. The possibility that peer pressure can work inversely in these situations means that the group norms must be enacted by each individual member of the group, instead of from a collective group expectation of conformity. Thus, a major limitation of flock theory is in cases where individuals are not internally motivated, even when socialized into group norms.

Flache & Macy (1997) do point out the possibility that group cohesiveness might lead to group solidarity if altruistic preferences were to emerge amongst group members, which would allow compliance with group obligations even when strong bilateral ties exist. In this case the high density of bilateral exchanges leads to a higher degree of importance individuals place on the collective good.

<u>Measurement in an Applied Context</u>

Conceptualizing a group as being "close but not too close" helps to understand the application of flocking to groups, but applying specific methods of measurement that parallel the "distance" concept catalyze that application. Network analytic measures aid in the evaluation of the structural distance of actors in an organization or group, as discussed earlier in this chapter. Using network measures that maintain the original boids framework of flock centering and direction further clarify ways of measuring structural distance. A specific communicative context that provides a template for the testing of structural distance is Usenet newsgroups[9] (see Smith, 1999). Network measures that can be used to measure the "close…" aspect of a newsgroup are network reachability and closeness centrality, and for the "…but not too close" aspect are the average diameter of the message network and the core/periphery measure. These measures can then be applied to existing newsgroup models that reveal the health of the newsgroup (see Krikorian, in press). Network measures similar to those discussed in relation to newsgroups can also be used to measure the structural distance of other online communities, decision-making groups, organizational networks, and other groups that benefit from utilizing member potential.

Collaboration in a newsgroup context can be measured by focusing on the two main aspects of Reynolds' boids, direction and velocity matching. As discussed, members in a collaborative group should attempt to support each other's topical direction, as well as the pace of interaction and topical change. Similar to the brainstorming concept of piggybacking, where a new idea should be supported to catalyze creativity, direction matching provides support for new and creative ideas. Direction matching can be measured in a newsgroup by measuring the thread length. A thread is a new topic that is posted in a bulletin board style, to which other members of the group can post subsequent comments on the topic, forming a discussion. Additionally, sub-thread length can be measured, representing a piggybacking effect where new discussions related to the initial topic are started and become sub-threads within the initial thread. Newsgroups that exhibit long threads, and sub-threads, may

[9] USENET is a worldwide bulletin board system accessed via the Internet or through many online services. The USENET contains more than 14,000 forums, called newsgroups, which covering a vast array of interest groups

represent groups that are matching the direction of each other in a collaborative manner.

The post rate, the number of topic changes, and the change length can measure velocity matching in a newsgroup context. For example, if new topics are being posted and supported representing direction, but the same person continuously starts them, the group is not exemplifying a collaborative evolution. Measuring the burst leader ratio can also indicate if the direction of the group is being centrally controlled. A burst leader is an individual that causes a burst, or sharp increase, in interaction or attention. The ratio of burst leaders in a group will indicate if there are proportionately fewer leaders in the groups' interaction and direction.

An additional measure that augments the burst measure is measuring the alpha-centrality of the individuals in the group. Alpha-centrality (Bonacich, 1987) measures the relative prestige of those that one is connected to in a network. For example, if I only know one person at a large university, but that person is the president of the university, I would have very low centrality if measured in most other ways, but a very high alpha-centrality. Thus, alpha-centrality can measure the access to resources and levels of influence over other in the network, indicators that would otherwise be cloaked.

Alpha-centrality would be represented in a newsgroup at those individuals that only post comments to, and match the direction of, burst leaders. Analyzing the spread of alpha-centrality across group members would indicate which individuals were only supporting the few centralized leaders. Combining this data with the ratio of burst-leaders themselves would give a clear picture of how centralized, or decentralized, the newsgroup was.

Combining the length of threads, the rate of topical change and posts, and the ratio of burst-leaders the collaborative nature of the newsgroup can be measured. It is important to point out that these measures do not take into consideration the content of the postings, that the group can be based more on conflict that on cooperation. The likelihood that the group is negative does not limit the ability to measure collaboration. Conflict is an important phase for group development, and is one of the most important phases to promote collaboration (Fisher, 1970).

Flock theory, as presented above, expresses a model for decentralized group organization. See Table 1 for a summary of flock theory constructs, the related Boids concepts, and measures for application to newsgroups. However, the means by which the group communicates and maintains a cogent knowledge of group goals and status, i.e. global information, needs to be established. The following section covers a roadmap based coordination system, where there can be *local organization* and *global information*.

Table 1 –Summary of Flock Theory Concepts

Flock Theory Construct	**Concept**	**Related Boids Rule**	**E.g. Newsgroup Measure**
Structural Distance	Autonomy	Separation	Closeness centrality Core/periphery
Collaboration	Convergence	Alignment	Thread length Sub-thread length
Decentralization	Cooperative Evolution	Flock Centering	Burst-leader Ratio Alpha-centrality

Roadmap Based Flocking

Given the potential problem of a fully bottom up organizations' maintenance of a common purpose and cohesion, the main issue then relates to the nature of group organization given a decentralized structure. Since research has shown that centralized groups and organizations inhibit performance, the solution lies in the ability for a decentralized group working on complex problems to maintain a cohesive idea of group purpose and direction. Research on flocking behavior and complex problem solving poses a “roadmap” solution. Contrary to Reynolds (1987) flocking simulations, where global behavior can arise from local influence and lead to emergent behavior, the flocking behavior explained in this section exhibits both local and global influence via *communication*.

Bayazit, Lien, & Amato (2002), researching flocking behavior in complex environments, have found that goal oriented tasks are completed by the flock with more success when the group has global information along with local organization. Earlier flocking methods (i.e. Reynolds’ boids), albeit elegant, do not perform very well if complex navigation is needed. A map, containing a network of representative feasible paths, can provide path-planning queries in the environment. An example of such roadmap-based navigation is when various scientific research groups cooperate as to not duplicate efforts. Whereas each unit may be only locally organized, the global coordination of a research roadmap will diminish the likelihood of unnecessary resource duplication (e.g. research similar to the distributed human genome project; see US Dept. of Energy, 2003).

Bayazit and colleagues investigated whether flocking models that use planning methods provided by roadmaps support more sophisticated group behaviors than purely locally organized flocking can allow. Two behaviors investigated will be discussed; 1) homing, where the goal is to move the entire flock from a starting point to a goal position, and 2) two kinds of exploring, covering and goal searching. Covering requires all flock members to explore the environment attempting to visit all points of the environment. Goal searching requires individual members to explore the environment searching for a specific goal that is know known a priori, then, once the goal is located, all of the flock members should move to the goal. It is important to note that after the goal is found, it is communicated to the other group members by modifying the roadmap, making the roadmap both a *coordination device* and a *communication mechanism*. For examples of the environments see Figure 4.

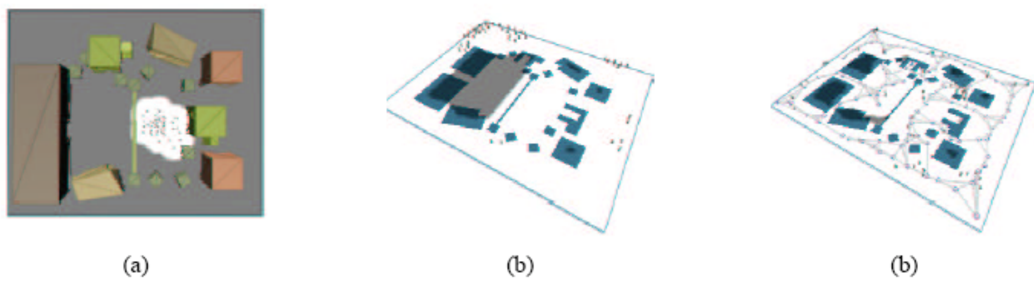

Figure 4 – Examples of Roadmap Based Flocking, Covering Behavior
The dark area represents unexplored regions. (a) Initial configuration of flock. (b) Normal flocking system. (c) Flocking system with roadmap-based method.

Homing Behavior

Homing behavior consists of two models, the first representing behaviors of individual flock members and the second influencing the global behavior of the entire flock. Parallel research into goal oriented homing behaviors have utilized two main alternate methods, potential field (Khatib, 1986) and the grid based "A*" (Russell & Norvig, 1994) method. The potential field method uses two directional vectors, one toward the goal and the other away from obstacles, yet this method is easily trapped by local minima in complex environments. A* methods, often used in computer games, uses a grid of the environment where the flock's path is controlled by expanding towards the promising neighbor of previously covered positions. Unfortunately, this approach requires a completely new path for each new goal, greatly decreasing efficiency when complex environments are introduced.

Roadmap methods for homing behavior do not suffer from the two drawbacks of the other main methods, 1) being trapped by local minima, and 2) requiring new path exploration for new goals. Since the roadmap allows the flock to work and communicate on a global scale, the discovery of new paths is faster and more efficient. Each flock (group) member keeps track of the sub-goals; so that when a specific sub-goal is reached the next sub-goal becomes the steering direction for the global goal. Additionally, different members can be on the same path but exploring different sections of the path, and different sub-goals, since there is both individual and environmental interaction (Bayazit et al., 2002).

Combining the "boid" rules from Reynolds (1987) model with use of a roadmap prevents local collisions and avoids collisions with obstacles, while simultaneously steering toward the sub-goal (which has the lowest priority in the simulation behind flock and obstacle collision avoidance). Thus, the flock can still move together while moving towards the goal, and avoid getting trapped in local minima.

Exploring Behavior

Two exploring behaviors are considered; covering the environment, and searching for a goal and moving towards the goal once it is found. A roadmap graph with adaptive edge weights is used, where each possible path represents an edge, and the weight of the edge is updated as individuals traverse the path. This method is similar to the pheromone trail that ants use to navigate environments (i.e. ant colony optimization, ACO). Each time an ant travels a path it leaves a pheromone trail increasing the total pheromone presence weight of the trail. Thus, as the individuals in the flock traverse the paths, they can update the roadmap, and explore the entire environment more efficiently.

If the ACO method is applied to the flock's manner of searching for an unknown goal, each time an individual reaches a goal it increases the edge weight of the route that it took, thus updating the roadmap and increasing the success of the group. Likewise, if the path leads to a node without any outgoing connections (i.e. dead-end) or a node already contained in the current past (i.e. a loop), the individual will decrease the edge weight of the path and increase the efficiency of the entire group. Such optimization is similar ACO, given that ants will travel paths to and from food sources often, the greater the weight the more promising the trail. Additional investigation was done into the searching of a moveable goal. Since the goal can now move, the flock members need to keep the goal in sight as well as update global information. To solve this problem, all solutions are treated as suboptimal and the edge weights decrease over time, similar to evaporation of pheromone trails in ACO. Examples of searching and goal behavior can be found in Figure 5.

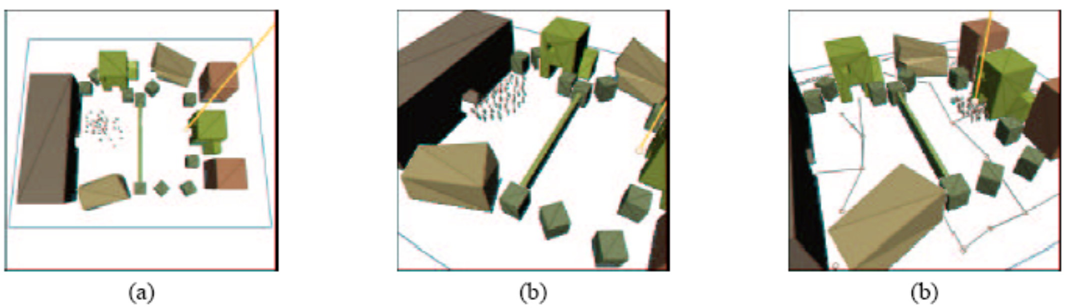

Figure 5 – Examples of Searching and Goal Behavior.
Searching for a goal behavior. There are 80 boids in the scene and the light tower on the right is the goal. (a) Initial configuration of flock. (b) Normal flocking system, and Flocking system with roadmap method (far right).

Experimental results obtained from computational experiments compared traditional flocking behaviors (i.e. Reynolds' boids) with roadmap-based techniques. For the homing behavior a flock of 40 individuals was given 30 seconds to reach a goal; the roadmap-based flock was able to get all 40 members to the goal, and the basic flock was only able to get 10 to the goal. Exploring behavior was tested on both traditional and roadmap flock, as well as an *ideal* behavior with complete knowledge of the search status at all times (i.e. *a priori* knowledge of the goal). Comparing results to ideal behavior allows for the extrapolation of comparing roadmap techniques with optimal performance, establishing a best case for simulation efficiency.

Results revealed that the ideal behavior was able to cover almost 91% of the environment in the first 30 seconds; the roadmap-based behavior took 90 seconds reach a similar coverage point of 91.6%, and the traditional (boid) flocking behavior was only able to cover just over 80%. The traditional behavior reached the 80% coverage slightly faster than the roadmap behavior due to its tendency to bounce around and discover easily accessible areas quickly.

Goal searching experiments revealed that individuals in the traditional flocking behavior were not able to reach the goal, and none of the individuals were able to discover the narrow passage out of the small region in which they started. Roadmap behaviors were very close to ideal behaviors, with the group reaching the goal only 5 seconds later. However, the roadmap behavior was able to get two individuals to the goal before any of the individuals in the ideal behavior.

In summary, these findings indicate that augmenting the locally organized flock model with the global knowledge of a roadmap results in more efficient goal achievement and exploration of new territory. Yet extrapolating these findings to human social systems requires explication of the means by which such systems can maintain the decentralized social structure, while simultaneously knowing what each other knows and where the group is going.

An example of roadmap coordination in human interaction is that of Jazz improvisation. One specific example is the way that Miles Davis recorded some of his albums. Miles Davis' 1969 album *In a Silent Way* was recorded by bringing in 7 musicians that were of equal musical standing to Miles (Miles played trumpet, Wayne Shorter on soprano saxophone, John McLaughlin on electric guitar, Herbie Hancock on electric piano, Chick Corea on electric piano, Joe Zawinul on organ, Dave Holland on bass guitar, and Tony Williams on drums), creating a group where there was no real leader *during* the actual interaction.

Before the musical interaction happened, Miles simply provided the musicians with a roadmap of what he wanted to do. He gave them moods that he wanted to be the goal of the interaction, along with some basic keys that they could use to navigate towards each other in finding the goal, or mood. What resulted was a shift in the way that Jazz was recorded. Most interaction in Jazz recording was more similar to a structured business meeting, where there is one person running the meeting and informing the individuals what is being covered, in what way, and who is supposed to do what. What happened in this recording was more akin to a brainstorming group, coordinated decentralization with interpersonal support, a group flocking towards a goal by using a roadmap to navigate. However, how a group can navigate and locate the information they require to navigate needs to be better understood.

Recent research into a network phenomenon called the small world theory provides a useful vocabulary and construct to model the balance of decentralized structure and a centralized repository of knowledge. Small worlds suggest that any individual is potentially connected to any other individual, regardless of the size of the population. Thus, small worlds are potentially inherently decentralized. The following section covers related small world research and proposes a model that explains how social roadmap based flocking behavior can take place.

BIPARTITE SMALL WORLDS

This section uses the rich set of findings that have come from the scientific investigation into complex problems of social organization to explain how human communication can contribute to both the decentralization of social structure, and the dissemination of information that augments this decentralization. First, concepts underlying small-world phenomena are discussed, during which the models used to explain the dynamics associated with these phenomena are covered, along with potential problems when associating these models with social and communicative networks. The concept of bipartite networks is then offered as a theoretical and methodological mate for the small-world effect. Then, a communication perspective on bipartite small-world networks is covered in a new model, elaborating the role of communication as a roadmap in social organization.

Small Worlds

Karinthy was the first to write about the concept of *six degrees of separation* in *Minden Masképpen Van* (*Everything Is Different*) (1929, translated and summarized in Barabási, 2003). In Karinthy's collection of short stories, one particular story entitled *Chains* is about the ability of any person on earth to connect to anybody else using at most five connections, or degrees of separation. Although this now common conversation topic can fascinate us (especially when one meets someone that they discover has a friend in common), it does not explain how one could *connect* to someone they *didn't* know, or locate information in a network of people.

Milgram (1967) revisited notions of global connectivity, and was centrally concerned with the ability of an individual who doesn't know you to know someone, who knows someone, who does know you (Watts, 2003). He conducted an experiment where two selected populations from Omaha, Nebraska, one random and one specific, and one population from Boston, Massachusetts, were to try to get a letter to a specific target; a stock broker in Sharon, Massachusetts. Instructed only to send the letter to someone they knew on a first name basis, the letter would continue until it eventually reached the target or simply disappeared. The average degree of separation amongst people in the three populations and the target was 5.5, thus the saying “six degrees of separation” (popularized in a play of the same name by Guare, 1990).

A small world can be explicated in a graph[10], represented by a network, which exhibits two properties; tendencies of local clustering, and short distances between nodes (individuals) such that any node could be reached in an average of only a few steps (Watts, 2002; White & Houseman, 2002). The tight clusters are groups of people in social networks that are associated with each other through redundant ties that allow for local clustering, also called strong ties or close ties. This local connectivity establishes multiple independent pathways, which can provide reliable accessibility. Yet, there are also a substantial amount of “weak” ties that we have in our networks; these are the connections that our close ties have with people that are not necessarily connected to, or have much in common, with us. Weak ties have been shown to offer a greater possibility for effective social coordination, needed in tasks such as finding a job, called “the strength of weak ties” (Granovetter, 1973, reviewed earlier in this chapter). So it is paradoxically the weaker ties that link people to each other and to novel resources that reside in other tight clusters within a network. Likewise, bridges between different tight clusters, represented by weak ties are catalyzed by accessibility to a large number of nodes (or people in a social network) (Amaral, Scala, Berthélémy, and Stanley, 2000).

The combination of tight clusters (strong ties), and the *diameter* of the network[11] increasing logarithmically with the number of nodes, gives the network its small-world properties (Amaral et al., 2000). The diameter of the network remaining small in relation to the addition of nodes allows the nodes in the network to be

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[10] A network graph is represented by a set of points connected in some fashion by a set of lines, often used to represent networks.

[11] The diameter of a network can be quantified by the average shortest distance of links between two nodes.

connected with only a few links, even if the network gets quite large. Thus, any person on the planet could be only a few links away from any other person by navigating their strong ties (local clustering) and utilizing the large number of weak ties associated with each strong tie (long range reachability).

Several different models have been developed to explore and explain the dynamics of the small-world phenomena; the following section reviews the main approaches and evaluates their use for communication networks.

Models and Dynamics of Small Worlds

The Random Graph Model

The simplest account for the small-world phenomena is the random graph model (Newman, 2000). Erdös and Rényi (1959) established random graph models of networks; as they saw the ultimate goal of science as a search for the simplest possible explanation for very complex phenomena. They offered a graceful mathematical explanation describing all complex graphs within a single framework, the simplest solution that nature *could* follow; connect the nodes randomly (Barabási, 2003). Random graphs play little role in assembling the real world, but do allow a window into the nature of network dynamics and small-world properties.

In a random graph, N number of people have an average of z links, thus there are ½ $N z$ connections between people in an entire population. A network created from this model would have N nodes (or people) with ½ $N z$ connections between randomly chosen pairs of people, linking nodes in an egalitarian manner (having the same chance of getting connected to other nodes). Extrapolating this model reveals its heuristic explanation of the small world effect; if person A has z neighbors, and each of A's neighbors also has z neighbors, then A has about z^2 second neighbors (two degrees away), z^3 third neighbors; and if people have between 100 and 1000 acquaintances, by z^4 A would be linked to between 10^8 and 10^{12} people (equivalent to the entire population of the world). In terms of degrees of separation, D degrees of separation needed to reach N people (the diameter of the network) is given by setting $z^D = n$, implying $D = \log N / \log z$. The logarithmic increase in the number of degrees of separation in relation to the size of the network is in line with the small world effect, where log N increases at a slow rate with N allowing the degrees of separation to be relatively small even in large networks (Newman, 2000).

However, the assertion that random graphs can elegantly represent the small-world nature of a network does not transfer to their use as a viable explanation of social networks. In real social networks people do not pick their friends at random; likewise, our social circles tend to overlap – ones friends are likely to also be friends with each other. Almost everything that has been studied about real networks, from social networks to neural networks, suggests that they are not random (Watts, 2003). The issue of random graphs' applicability to social networks poses a profound issue concerning communication networks. Even if our social networks could manifest some randomness (we do tend to meet some people somewhat randomly at times), one's communication is almost always purposeful, with little reason to exhibit random allocation. Thus a model that is more representative of networks in the real world would be more useful in embodying social perspectives.

The Scale-Free Model

While studying the structure of the World Wide Web (Web) via hyperlink[12] networks, Barabási and Albert (1999) found that the network revealed very central connectors - very highly connected nodes - also known as hubs (see also Albert, Jeong, & Barabási, 1999; Barabási, 2001; and Faloutsos, Faloutsos, & Faloutsos, 1999). Hubs are nodes that have a disproportionately large number of links as

[12] Hyperlinks are URL's (Uniform Resource Locators, the World Wide Web address of a site on the Internet) on a Webpage that can connect a user to another Webpage. Thus can be *outgoing* links to the Webpage they point to, as well as *incoming* links concerning the Webpage they are linking to.

compared to most other nodes. In interpersonal social networks, these would be the people that maintain an extraordinarily large number of contacts. On the Web, hubs are the WebPages that are most linked to and are extremely visible; almost everywhere on the Web there are links pointing to them (e.g. Amazon.com and Google.com).

Barabási and Albert (1999) also found that the presence of hubs allows any node to connect to any other node with only a few degrees of separation, again displaying properties of small-world networks. In the network behind the Web, the hyperlink network, many unpopular or rarely noticed nodes with only a small number of links are held together by the few highly connected websites.

Looking to further explore the presence of hubs, and elaborate the nature of the small world, Barabási and his colleagues analyzed the degree distributions of the networks they were studying. Degree distributions reveal the probability that a randomly chosen member of the population will have a given number of nodes linked to it (Watts, 2003). It was found that in all of the networks that are dominated by hubs, the degree distribution followed a power law distribution. Power law distributions don't have a peak at the average value, such as a normal distribution; rather, they start at the maximum value and decrease rapidly to infinity, but with a much slower decay rate than a normal distribution. Power laws indicate the absence of a scale, where the hierarchy has no node that can be chosen to be characteristic of all nodes. Such networks are called *scale-free,* since there is no inherent scale (Barabási, Albert and Jeong, 1999).

Prior to power-law findings of the Web network, many other networks have been found to follow the same scale-free power law distribution, calling for further investigation into the dynamics behind such a powerful finding. For example, Zipf (1949) found that the rank ordered occurrence frequency of words in the English language follows a power law distribution (see also Mandelbrot, 1953), also known as

Zipf's law[13]. Subsequently, such distributions have come to be known as Zipfian distributions, since they have a distribution of probabilities of occurrence that follows Zipf's law. Following Zipf's findings, Simon (1955) used a similar approach to study multiple distributions such as; distribution of scientists by number of papers published, distribution of cities by population, distribution of incomes by size, distributions of biological genera by number of species, and frequency of words in prose. Simon found similar scale-free distribution in his analyses of the various different datasets; further leading to propositions about the ability of larger cities, frequent words, larger incomes, etc., to grow larger than smaller examples. This finding becomes very important when understanding the nature of power-laws, discussed below.

Uncovering the mystery behind the existence of hubs, Barabási, Albert and Jeong (1999) posed preferential attachment as the means for the creation of hubs and connectors. As the network grows over time, nodes with a larger number of links have a greater chance of acquiring new nodes, even if the nodes are assigned randomly. Specifically, a node with twice as many links is twice as likely to receive a new link. The process of certain nodes gaining more and more links can be though of as a *rich-get-richer* phenomenon (Barabási, 2003), where given a certain amount of time the degree distribution of the network converges to a power law distribution. Barabási and colleagues went on to incorporate a *fit-get-richer* model, where a node's ability to "make friends" in a competitive environment will predict the creation of hubs, yet regardless of the means of preferential attachment a very specific problem remained in the scale-free model, vulnerability.

Due to the nature of a scale-free network having a small subset of highly connected nodes connecting most of the less connected nodes, it becomes quite easy to

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[13] Zipf's law is the observation that frequency of occurrence of some event (P), as a function of the rank (i) when the rank is determined by the above frequency of occurrence, is a power-law function $P_i \sim 1/i^a$ with the exponent a close to unity. This also known as a Yule distribution.

disconnect the network by simply removing the few central hubs, as various Internet viruses have done. MafiaBoy and Eligible Receiver (severely destructive Internet viruses, discussed at length in Barabási, 2003); broke the Internet into hopelessly isolated pieces by removing a few very central hubs.

Another problem with the scale-free model is the assumption that network ties are costless; a node can have as many as possible, without considering any difficulties in making or maintaining them. In social networks there is a limit to the number of links an individual can maintain. Further, new nodes can't always find the most connected nodes to attach to; when an individual moves to a new location they can't simply find the person with the most connections (Watts, 2003). Thus, to explain the dynamics of small-worlds in a more social and communicative context, other models need to be considered.

The Watts-Strogatz Model

Central to the Watts-Strogatz (WS) model is the balance of order and randomness (Watts, 1999). At one side of the spectrum individuals always make friends through their current ones, at the other side they never do. This duality can also be related to the difference between random graphs (discussed above as the random graph model), and regular lattices, where every site is identical to every other site, so once a location is known every other location can be found (much like a grid system for laying out roads). The WS model attempts to strike a balance between these two opposed structures, allowing for local clustering to occur, such as in a lattice, but also allowing for random long distance links to occur, such as in random graphs; relating to the fundamental properties of a small-world.

To measure the properties of small-world networks, the WS model uses a quantity called a *clustering coefficient*, meaning that a person's friends are, on average, much more likely to know each other than two randomly chosen people

(Watts, 1999). The clustering coefficient reveals how closely knit one's circle of friends is, where a value of 1.0 implies that all of someone's friends are good friends with each other. To quantify the global connectivity of a network, the WS uses a measure of *path-length* - the measure of how many degrees of separation nodes are from each other. These two measures can be combined to indicate the likelihood a specific network represents a small-world network (Watts, 1999).

Starting with a regular lattice, where each node is rigidly connected to only its neighbors, the clustering coefficient is fairly high yet the path length is also very high since one would have to go through every node to get to one that is far away. The WS model introduces a few random links into the regular lattice, rapidly dropping the path length between nodes. It is in this sense that a random graph will automatically be small where a lattice is large. A few random links does not affect the clustering coefficient much, maintaining local clustering, yet these random links make large chunks of the network available to each other, fostering global connectivity. We only know who we know, and generally your friends know the same sort of people that you do. However, if just one of your friends is a friend with one other person that is not like you, than a connecting path exists (Watts, 2003). The general result of the WS model is that there is a wide interval in the space between randomness and order, a balance between social structure and individual agency where local clustering is high and path lengths are small.

Much like the scale-free model, the WS model was extrapolated to other networks, specifically the Hollywood actor network, the neural network of the C. Elegans worm, and the power grid of the Western Systems Coordinating Council. In all three cases the WS model was successful in describing these networks as small-world networks with local clustering and small path lengths. Yet, much like the scale-free model, these findings still do not allow us to better understand social communicative networks as small-world networks. Once any social or group structure is introduced, some basis for distinguishing "close" from "far away" is needed. There is much room for inquiry into the means through which people can navigate the small world and find who or what they are looking for. Navigation and searchability is an important issue for the heuristic application of small-world phenomena, and are covered in the following two sections, respectively.

The Kleinberg Model of Small World Navigation

The WS model allows for the understanding of networks as containing a variable amount of disorder, where shortcuts are created via random allocation. Although this seemed like a good assumption to make when developing the model, Kleinberg (1999) introduced the notion that individuals do indeed have to take distance into account when differentiating themselves; whether it is physical distance or distance felt from disparate individual interests.

Using Milgram's (1967) experiment as the basis for the algorithmic component, Kleinberg developed a model in which random links are added to a lattice, but the likelihood of two nodes getting connected together decreases as a function of their distance on the lattice. A message-passing problem was given to the nodes on the lattice, with links added following a power-law probability distribution. The exponent of the distribution changed according to the likelihood of accessing other nodes with short paths. If the exponent is zero, than all nodes are equally likely to be random contacts, so there would be an abundance of short paths but there is no way for a decentralized algorithm to find these chains. When the exponent of the distribution is large, only nodes that are close on the lattice can get connected. However, Kleinberg found that when the exponent is equal to exactly two, the network reaches a balance between long-range shortcuts and navigational ability of the lattice (Watts, 2003).

Kleinberg's findings indicate that individuals do not have to solve the message problem on their own; rather, they simply have to get the message to the next stage of the search. Short cuts alone do not pose enough information to locally informed individuals; they must also have an underlying understanding of the social structure of the network. However, it is difficult for people to have a full knowledge of the social structure of the network. They may know their friends, or even some of their friends' friends, but there is still the problem of how one could find something that they are looking for if they don't know where to look. The network search conundrum needs to be unpacked before a proposition can be made as to how one can find a specific person or information utilizing the highly connected small-world.

Search in networks

There is a fundamental difference between the notion that a short path can connect any two people, and their ability to find that path (Watts, 2003). Underscoring this issue is the difference between *broadcast* and *directed* searches. A broadcast search involves an individual activating every link in their network, telling everyone they know, in turn telling everyone they know, and on. Thus, if a short path exists the message will eventually navigate this path. The WS model used this form of search, thus displaying dynamics of small world networks.

Directed searches involve the passing of a message one link at a time, much like Milgram's (1967) experiment. A directed search is far more efficient than a broadcast search in terms of the number of messages sent, but far less efficient in finding the shortest path for that message to take. Using a broadcast search, Milgram's subjects would have had to send their letters to everyone in the country in order to find the target person, nearly 200 million people.

Thus the problem remains, how does an individual in a network find what they need in only a few links? The scale-free model of Barabási and colleagues would require the use of a hub or connector to navigate to the target, but this solution still suffers from the vulnerability issue relating to hubs, and the difficulty of application to social networks. A potential answer, as it turns out, is concerned with the social lives of people and the identities they develop; specifically, the affiliation of people with their interests (i.e. a social roadmap), represented by "bipartite" networks.

Bipartite Networks

When uncovering the notion of distance in a network to construct groups, it is useful to start with the groups and use them to define measures of distance (Watts, 2003). Watts, being a sociologist, realized this and incorporated an important addition to the WS model, affiliation networks, or bipartite networks[14]. Watts had come to realize that people know each other because of the contexts they exist in, more specifically the groups they belong to. The more contexts people share with each other, the greater the likelihood they will be connected. In real social networks people belong to groups and have characteristics that make them more or less likely to interact with one another. The use of this approach requires conceptualizations of two kinds of structure, social structure and network structure, often referred to as affiliation networks.

In affiliation networks, or bipartite networks, two nodes can be thought of as affiliated if they participate in the same group or event (see Breiger, 1974). Affiliation networks differ from single mode networks in several ways. Affiliation networks are dual-mode, or two-mode, networks where a set of actors and a set of events describe collections of actions instead of simple ties between pairs of actors. Connections among members of one of the modes are based upon the linkages formed via the second mode (Wasserman and Faust, 1993).

[14] "Partite" means broken into parts, thus bipartite means broken into two parts.

Much of the importance in studying affiliation networks is the individuals' membership in collectives, or social circles (Simmel 1950; Kadushin, 1966), which provide conditions for development of interpersonal connections. Individuals are brought together through joint participation in social events, and participation in more than one event establishes a linkage between the two events; thus overlapping group membership allowing for the transmission of information between groups. Therefore, this can be interpreted as either actors being linked by events, or as events linked by actors (Breiger, 1974). See Figure 6 for an example of a bipartite network.

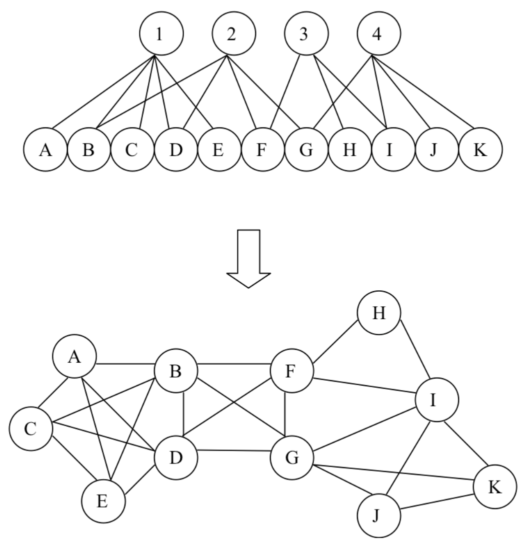

Figure 6 – Example of a Bipartite Network
The upper example is a bipartite graph where the nodes A through K can be thought of as individuals in a network, and the nodes 1 through 4 as event they were present for. The lower example is a unipartite representation of the same network, in which two individuals are connected by an edge (line) if they were present for the same events.

In a bipartite representation of an affiliation network every actor in a group is affiliated with every other actor in that group, thus a fully connected clique. Affiliation networks then can be thought of as networks of overlapping cliques, connected through the co-membership of individuals in several groups. Random affiliation networks, with no structure built in, will be highly clustered, while the randomness results in short global path lengths. Thus, random affiliation networks are small-world networks, highlighted by Watts (2003, p.129).

> The true power of the bipartite approach is that all these processes – the dynamics *of* the network can be represented simply and explicitly in a single framework, one that can track evolution of both the social and network structure, and the endless folding of one into the other that constitutes the heart of social process.

Although this is a very important advancement in small-world modeling, as well as utilizing some of the elegance of the random graph, there is still a lack of real world application in communicative social networks.

Bipartite small worlds – A communication perspective

Combining the powerful findings from the various models of the small world with the inclusion of bipartite networks discussed in the previous sections, this section proposes a multi-theoretical model of communicative small worlds. Weaving together the quantitative findings of the physicists (Barabási) and applied mathematicians (Watts and Strogatz), this model strives to meld these perspectives to better explain the role of communication in the small-world effect. Further, the bipartite communication network model represents the social system contingent of the roadmap.

Bipartite Communication Networks as a Roadmap

Barabási and colleagues found, in extremely precise mathematical terms, that many real world networks display a power-law distribution with a few central hubs as the most connected nodes, allowing for the navigation of a network similar to a small world. Further, they extrapolated these findings to include both a rich-get-richer and fit-get-richer parameter, highlighting the evolution and growth of hubs in the networks. Yet, what they didn't consider is that the hubs and connectors do not have to be part of a physical network, they can be present in a network of ideas, interests, group direction; a roadmap. Much like the explosion of fads (see Barabási, 2003; and Watts, 2003) or an online community, the *content* of the links that connect people become the connectors that allow people to navigate their networks. It is this sense that a bipartite network can catalyze the shrinking of the real world and structure of organizations to match that of the small world.

Consider an example where the two modes in a bipartite network are 1) a social network created via an online newsgroup focused on sailing, where individual *A* is linked to various other individuals through their association in the newsgroup, some connections being stronger and some weaker; and 2) the network of *topics* that the newsgroup discusses, the affiliations that the individuals in the newsgroup are connected through. The structure of the first, or social mode of the network is treated here as behaving similarly to the WS model; where there are individuals that are locally clustered as a result of similar interests in sailing (e.g. wood hulled boats, catamarans, etc.), and connected to other clusters via the individuals that have multiple interests, satisfying the global connectivity requirement. The second, or content mode could follow the more hub-dominated world of the scale-free model, where topics and discussions arise that become very central – connecting the individuals based on their affiliation with the topic. A roadmap is another description of this mode, where a roadmap of who knows what allows people to navigate their networks to find important resources. Thus, the bipartite network allows individuals to navigate their world via a roadmap expressing affiliations with topics, similar to a knowledge network.

In the example described above, individuals can navigate their network by directing themselves first to the content/knowledge network, exacting either information needed or proposing information contained; then honing in on the person that they need to reach, either to get information from or give information to.

Further, the problems associated with the scale-free model are resolved, such as the vulnerability of network structure with the removal of hubs and the unrealistic ability for individuals to have enough connections to satisfy a power-law distribution. If it is a network of ideas, or content, there is no limit to number of people that can be connected - a hub can become as rich as is needed, regardless of the nature of the wealth (because it is already rich, or it was the most fit). Likewise, there is a natural shift in the focus of ideas and interests among groups of people, even among specific interest groups (e.g. antique collecting, football fans, etc.), so removing a hub will allow for a new one to replace it (e.g. if a football player retires, there is certainly another that will assume the attention of the newsgroup). It is in this sense that the communication of the ideas or topics allows the social structure to emerge, and the links formed between the individuals are a residue of the communication. Yet, searchability in the network is still one of the central goals of a small-world perspective, so our discussion shifts once again to that issue.

Searching in a bipartite small-world

Watts (2003) discussed the ability of multidimensional networks, where people have several dimensions to their identity – thus belonging to multiple groups, as having the ability to catalyze an individual’s navigation of their network. Yet, this proposition, albeit robust in the associated findings (see Watts, Dodds, and Newman, 2002), still requires the use of existing social networks for the acquisition of information on the reachability of a specific person. What is being proposed here is that searching for information contained by someone that is unknown, searching via the content of what is needed will allow for a more directed navigation, much like in the roadmap based flocking experiments covered in previous sections.

If someone needed to know how to fix a paper jam in a printer (a problem many researchers have encountered), they may not know anyone who can tell them how to do this, or even a friend of a friend that can; so multidimensional or hierarchical networks will not assist in finding the information. What is needed is a means of searching through the content network, a roadmap, in this case the content of what someone knows, to find the person that can provide the necessary information[15]. Even if the distraught individual looking to fix the paper jam were to turn to the Internet for help, they would search for the content of the information to find the person that could help them.

Another quite applicable example is that of Usenet newsgroups[16]. If someone needs to gain specific information about a paper jam, they could go to the USENET listing of groups, find the one on printer maintenance, search the *content* to find a discussion that relates at an even more specific level, and discover the specific user that has the knowledge they need. The degrees of separation would effectively be shrunk to one. An individual could also post a question to the newsgroup, to which an informed user can then contact the poster to provide the needed information, displaying the use of the content network to augment the social network in the searching for information.

Applications to flock theory

As covered in the previous section of this chapter, the fundamental notions of flock theory allow for a network of individuals to: a) manage their social structure, b) collaborate (i.e. propose ideas and concepts that are supported by the network), and c) maintain decentralized, cooperative evolution.

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[15] Such a means of searching relates to the management of knowledge networks (see Contractor, Zink, and Chan, 1998; Farace, Monge, and Russell, 1977; Gore, 1996; and Wegner, 1987).

[16] USENET is a worldwide bulletin board system accessed via the Internet or through many online services. The USENET contains more than 14,000 forums, called newsgroups, which covering a vast array of interest groups.

Structure, mode one.

The first element of flock theory proposes that for cooperation to occur, individuals in a social network should maintain a structure that is *close-but-not-too-close* (extreme cohesion) and *far-but-not-too-far* (breakdown of cohesive group). Notions of distance are central to the small-world construct, where local clusters are close, but no so close as to prohibit long range connections (as seen in clusters that are only strongly tied to themselves); and the random links to other clusters allow them to be far, but not too far (as is the case when short path lengths don't exist). The challenge then becomes the management of this distance.

We have already seen that the balance between randomness and order is crucial in small-world networks (in the WS model); extrapolating this to the flock model asserts that the group of individuals needs to maintain a balance between autonomy and interdependence. Notions of distance based on a balance of randomness (autonomy), and order (interdependence), are discussed here as relating to the social structure mode of a bipartite (two-mode) network.

Individuals in a group (treated here as a network) maintain a structure that allows for the close reachability of other members, while simultaneously allowing a certain amount of distance, or freedom, from the group structure. Much like the bipartite network discussed in the previous section, this is done in relation to the second mode of the network – the roadmap.

Roadmap, mode two

The second element of flock theory posits that the collaboration requires the maintenance of distance, and is achieved through matching the "motion" of the other individuals. If distance is to be maintained in the evolutionary processes, than the direction of change (either topically or task oriented), and the rate of change needs to be a cooperative function amongst the group. However, without the roadmap, it is difficult for individuals to understand how far they are from each other, given that distance can be both physical as well as topical.

Outcomes of group interaction can often come from the peripheries of the network instead of from the center of a network (its leaders). Seemingly small events can result from group members' knowledge that seemingly random encounters can lead to a plethora of individual decisions, each made without a knowledge of a larger plan; yet, by some means aggregating into a momentous and unanticipated event (Watts, 2003). In such cases the centralities of the individuals in the network would not reveal much about the outcome, as the center emerged as a result of the event itself. In the absence of a central actor, the attention then turns to the roadmap reveal where the hubs truly are.

If hubs form in the content mode of a bipartite network, than these content hubs allow the individuals to affiliate themselves with the topics and connect with each other in the physical mode via these affiliations. Further, the evolution of the system can be better understood as a shift of the hubs, either during a conversation or as a society at large (e.g. fads). Individuals remain clustered in their networks and navigate their distance based on their affiliation with the changing topic, or their position on the roadmap. Thus, supporting an idea in a brainstorming session or adding to a discussion in a newsgroup allows the other individuals to have a deeper understanding of how far they are from each other. It is important to note that if a topical direction change is to occur, the structure and connectivity of the network can have as much of an influence on the likelihood of adoption as the attraction of the idea itself (Watts, 2003), so the social distance mode is a precursor to the development of the content mode.

A group's reception of a directional change, or shifting of a topical hub, can be conceptualized as an information cascade, or the widespread reception of an idea.

Information cascades occur when there is a specific network structure that allows for the breadth of the individuals in the network to be receptive to some specific information, as Watts (2003, p. 248) elaborates:

> This is what makes cascades so hard to understand – *the seed alone is not enough*. In fact, as far as the success or failure of a cascade is concerned, seeds of change, much like their biological counterparts, are a dime a dozen…But its realization depends almost entirely on the nurturing qualities of the substrate on which it lands…The trick is to focus *not* on the stimulus itself but on the *structure of the network* that the stimulus hits.

It is in this sense that the combination of both modes of a bipartite network must be considered to understand how decentralization can exist amongst a set of individuals. The positing of an idea allows people to attach to it, either supporting it or not. If there is to be a cooperative evolution amongst the group, directional changes need to be initially supported (creating a new hub), as the individuals will be structurally linked to each other via new ideas and, at least initially, thus the distance is also maintained. Individuals in the network can maintain a close but not too close distance by connecting through the hubs, as well as supporting directional changes by allowing the new hubs to form and develop.

Even a fairly small group of individuals interacting can maintain a small-world structure, where everyone is only a few degrees of separation from each other, embodied by central hubs as well as local clustering. Yet there is still an important element to consider in this model - the avoidance of central hubs in the distance (social) mode of the network, as this can lead to network vulnerability. Hubs in the social mode can lead to dominant leaders as well, breaking down the cooperative element. Both of these issues can be resolved by shifting any presence of a leader (or at least having a decentralized decision process) in the social mode of the group, often as a result of individuals posing new ideas or topics.

Decentralized Evolution

The final element of flock theory posits that decentralization in crucial, and leadership amongst the group must shift in order to maintain an egalitarian, decentralized evolution. Instead of a network where a central leader directs network evolution, such as in the hub dominated scale-free small-world, important innovations can originate from the less central individuals (see Shaw, 1961; Sparrowe et al., 2001; and Cummings & Cross, 2003). The first two elements of flock theory, discussed above, unpack the means by which a network can have the content of the interaction predict the connections that form amongst people, yet there is still a possibility that all of the ideas presented will come from a small set of individuals (core/periphery), even in the case of an information cascade. To resolve this issue the group should attempt to shift the sources of input through the entire group, allowing each individual to update the roadmap.

In small-world terms, the presence of a strong leader will have a similar effect as a hub, dominating the network and making the least connected nodes practically invisible. More importantly, the less connected nodes would have to go through the hub to access each other, which creates a situation that is far from egalitarian. Likewise, the group would be very susceptible to breakdown if the central hub were to possess an inability to solve a specific problem or distribute information properly. Much like a hierarchical organization, information brokering by individuals in upper levels of the hierarchy can often lead to information overload and a limited response to environmental ambiguity (Lewin & Stephens, 1995).

Ambiguity requires communication between people who have a variety of expertise and are thus mutually dependent, thus requiring distributed communication in an information-processing network (Stark, 1999). A successful information-processing network will then distribute information to the roadmap with as much equality as possible, where a hub based scale-free model would require the central actors to process an exponential amount of information; "people are simply not scaleable" (Watts, 2003, p. 277). A robust information-processing network needs to distribute the workload of leadership as well as the redistribution of information; in line with the flock model, where the leadership shifts and information stems from the breadth of individuals. The research on decentralization presented at the beginning of this chapter (Shaw, 1961; Sparrowe et al., 2001; and Cummings & Cross, 2003) underscores the need for distributed leadership and information distribution.

A particularly fitting example of distributed leadership and information distribution is the trade off of specialization and cross-fertilization in academic research. The division of labor in research groups requires a large amount of information retrieval and sharing, yet the leadership is often distributed across several departments or campuses. Difficulties of distributed leadership are compounded by the frequency of the research group members often having an equal organizational rank (e.g. full professor, co-principal investigators). Research team members are often spread across different specializations, creating communication problems. Combining distributed leadership of equal stature with cross-fertilization creates many potential problems for research teams, problems that may be explained by the model proposed in this chapter.

The first problem that may be experienced is that of leadership. Flock theory specifically models interactions where distributed leadership is a necessary component of collaboration. The second problem is that of coordination. The bipartite small world model offers a mechanism by which a distributed group can access information and coordinate activities by using a roadmap. Combining the theoretical utility of flock theory and bipartite small worlds allows for a view of academic research teams as highly coordinated and easily navigable. By each member of the team sharing their personal expertise as well as what they are currently working on, much like the roadmap flocks discussed earlier, would allow the entire group to know who is working on what, and how that work is helping the group relative to their goal. The human genome project, mentioned earlier, is a fine example of distributed coordination. Many equal ranking researchers were mapping an extremely complex genome by specifically sharing what parts they had solved, how those parts fit together, and what that contribution meant for the overall goal. The research groups used an information roadmap to see where they were relative to the other researchers, and were structurally collaborative and decentralized. In this sense, the research group is self-organizing by using communication to update the roadmap, and decentralized by allowing the roadmap to coordinate the groups.

Academic and research organizations are particularly fitting examples to elaborate the theory proposed in this chapter, as the conventional problems of distributed leadership and informational coordination are beneficial to the groups in that the research often requires several different specializations. Academic organizations differ in several ways from traditional corporate organizations, as such, the next 2 chapters illustrate several of the theoretical notions discussed this chapter through two case studies on academic organizations. The first is on 1,222 research groups in Europe, and the second is on a single academic institution in the American mid-west.

CHAPTER III – STUDY 1

Introduction

This chapter illustrates portions of the theoretical model proposed in Chapter II. Data utilized for the this study was collected as part of a cooperative six-country project coordinated by the UNESCO secretariat, the International Comparative Study of the Organization and Performance of Research Units (ICSOPRU) (Knorr, 1999). First, background on the UNESCO data is provided along with rationale of fit with the theory. Next, related variables and hypotheses are explicated followed by statistical results. Finally, findings are presented followed by some initial discussion and limitations of the study.

The ISCOPRU study provides for a multi-faceted evaluation of scientific productivity and effectiveness at the levels of the individual scientist and the research unit, as well as individual perceptions. The survey was conducted by six participating national research teams that administered standardized questionnaires to a sample of scientists drawn from nine major fields of science and technology, and represented about 200 research institutions in each of six countries (Knorr, 1999). The questionnaires incorporated a wide array of indicators for socio-psychological and sociological factors such as perceptions of influence patterns, organizational/group climate, structure, involvement, value of work, and the distribution of information.

Rationale and Fit

A distinctive feature of the UNESCO study is that it was designed to specifically recognize purposeful *systems* and communication as the main organizing concept of research and development (R & D). Having the main goal of the initial research design focus on systemic organizing allows for several applications of the theory explicated in the previous chapter to the data. Additionally, the theoretical and practical foundations of the approach adopted for the International Comparative Study derive from the theoretical perspectives of cybernetic modeling and systems analysis (Andrews, 1979).

Two research questions that were identified at the outset of the initial study associated with the theoretical and practical foundations are (Andrews, 1979): 1) How do the basic *structural elements* of national R & D systems (the research units) interact and work together, both within and across the boundaries of these systems? 2) What are the significant elements in human behavior and perception of situations that affect or reflect creativity and efficiency in the performance of R & D?

In addition to the relevant research goals of the ISCOPRU study, this case study provides the opportunity to explore the effects of structure and collaboration in organizations that differ from more traditional, corporate organizations that are the subject of the majority of the research reviewed in Chapter 2.

Research organizations may differ from the more traditional organizations such those studied by Burt (1992a; 1992b, reviewed in Chapter 2), as ties in research organizations are generally distributed to limited actors within the overall network. For example, departmental units in an educational and research context tend to cluster around functional linkages instead of bureaucratic connections. By its very nature, pockets of clusters would seemingly reflect intra-departmental communication within departmental cliques. Constraint, as dependency among actors, can be viewed in a negative characteristic in oligarchical, or diffused, organizational structures. This research stream is continued in Chapter 4 of this thesis, with specific testing on constraints and performance.

The combination of a) the initial research design of the UNESCO being centered on gaining information to allow for a structural, systems based approach; b) the foci on communication, creativity, and performance; and c) the potential difference between the relationship of the structural makeup and performance of a research organization as opposed to a traditional organization, provide an ample base to test the theory proposed in this dissertation.

Data and Sample

The data used for this case study was collected in six European countries during an international comparative study of the organization and performance of scientific research units. Surveys were collected by six participating national research teams that administered five standardized questionnaires to a sample of scientists chosen from nine major fields of science and technology, representing approximately 200 research units in each of the six countries[17] and 1,222 research units in all. The questionnaires incorporate indicators such as satisfaction with the work environment, perceptions of influence patterns and inclusion of decision-making (leadership style), information on the professional experience, and extent of communication within and between research units. Additionally, data on research performance was collected via research output of the scientists individually and of the research units as a whole.

A number of considerations influenced the selection of the countries, research units, and respondents. The countries were selected based on 1) the relatively well developed state of the scientific development, 2) the medium size of the country, 3) the socio-political systems and scientific traditions in the countries, which when considered together are very heterogeneous, 4) geographic proximity, 5) necessary resources for participation, 6) interest in participation.

Research unit selection was based on three criteria. 1) The group had to have at least one specific unit head that was involved in the unit's work. 2) The group had to include a total of *at least* three people who were significantly involved in its work, each of which had to be a member for at least one year. 3) The group had to have an expected life span of at least one year.

[17] Austria, Belgium, Finland, Hungary, Poland, and Sweden

Five types of respondents provided data about the research units, each answering a questionnaire designed specifically for his or her role in the research unit. The five respondent types were: unit heads, staff scientists, technical support personnel, unit administrators, and external evaluators. Each questionnaire was unique to the role but contained substantial overlapping portions. The development of the questionnaires was a two and a half year project, during which two substantial pilot tests were conducted.

The selection of research units resulted from a sampling procedure that allowed for a multistage, stratified, probability sample. Three factors were considered when selecting the subpopulations from which to sample the units: 1) existence of the units, i.e. similar units must exist in the other countries, 2) interests of the authorities that sponsored the study, and 3) potentials for cross-national comparisons. When the subpopulations were established, research unit sampling occurred. Though the manner of this representative sampling is of concern when investigating descriptive information for particular countries, this is not a concern for this study since the sample is being treated as a set of heterogeneous units drawn from a variety of national, disciplinary, and organizational settings.

The specific portions of the sample used for this study are the responses from the staff scientists, who comprise the majority of the research unit population and represent the core of the creative group process within the unit. Data for each specific unit is the average of all of the scientists' responses, representing a group measure.

Hypotheses

Drawing from research findings on decentralization in traditional, corporate organizational settings, and extending the theoretical notions presented in flock theory and the bipartite model (as presented in Chapter 2), hypotheses are introduced below.

One of the main constructs of flock theory, and parallel organizational research (Cummings and Cross, 2003; Sparrow et al, 2001), is that decentralization and cooperation are positively related to an atmosphere of supportiveness.

H1: Perceived need for the organization and planning of work to involve extensive cooperation is positively associated with the perceived general atmosphere and supportiveness of the group.

Additionally, members of groups that require a high level of cooperation, an atmosphere of supportiveness, and influence over group decisions should have a greater perceived value of group performance.

H2: Perceived need for the organization and planning of work to involve extensive cooperation is positively associated with the perceived value of group performance.

H3: Perceived general atmosphere and supportiveness of the group is positively associated with the perceived value of group performance.

H4: Perceived influence on managerial decisions is positively associated with the perceived value of group performance.

Concerning the distribution of information in a decentralized group, as discussed in the roadmap based flocking section in Ch 2, groups that have an increased need for cooperation should have a greater amount of information on planning and research of the group.

H5: Perceived need for the organization and planning of work to involve extensive cooperation is positively associated with the perceived amount of information available to group members on group activities and involvement in planning of the group activities.

Combining the roadmap model and the bipartite model indicates that an increased amount of information on planning and research should lead to increased involvement and influence in group decisions, general atmosphere and supportiveness, and an increased perception of group performance.

H6: Perceived amount of information available to group members on group activities and involvement in planning of the group activities is positively associated with the perceived influence on managerial decisions.

H7: Perceived amount of information available on group activities and involvement in planning of the group activities is positively associated with the perceived general atmosphere and supportiveness of the group.

H8: Perceived amount of information available to group members on group activities and involvement in planning of the group activities is positively associated with the perceived value of group performance.

Finally, combining the multiple constructs of flock theory, the group members perceived value of the units work should be predicted by a combination of their involvement in research (structural distance), influence on decision-making within the research unit (decentralization), and general atmosphere and supportiveness (collaboration).

H9: Group members perceived value of their units work is predicted by their involvement in research, influence on decision-making, and the general atmosphere within the research unit.

Method

For the current study, the raw data was obtained from the Inter-University Consortium for Political and Social Research (ICPSR) at the University of Michigan[18]. The data matrix obtained from ICPSR contains 1,224 variables and 1,222 cases. The data was retrieved in LRECL format, entered to a standard SPSS data file, and variable labels were added. Finally, the data was checked for errors in coding, missing

[18] Retrieved using Cornell Universities' ICPSR license.

values were accounted across all cases, and variables names and values were checked against the original coding sheet.

Measures

Four scales were created from the 1,224 variables in the original UNESCO instrument, and an additional item was used independently as a variable. (see Appendix A for all items used). Exploratory factor analysis procedures were conducted on each scale, and all were determined to be internally consistent and one-dimensional.

General atmosphere and supportiveness (Atmosphere)

Staff scientists' of general atmosphere and supportiveness is a 6-item scale ($\propto = 0.85$). Items were answered on a 1 (*X applies*) to 5 (*Y applies*) response scale where the *X* and *Y* were opposite statements that required the staff scientists to evaluate the general atmosphere and supportiveness (e.g. *X – Nearly all new ideas for improvement in non-technical matters are given serious consideration; Y - Nearly all new ideas for non-technical matters are ignored and existing practices are generally maintained*).

Influence on decisions (Influence)

Staff scientists' perception of their influence on decisions is a 5-item scale ($\propto = 0.86$). Items were answered on a 1 (*high influence*) to 5 (*low influence*) response scale that required the staff scientists to evaluate their personal influence on decisions in specific areas of research work and managerial issues (e.g. choice of methods used, allocation of work within units).

Amount of information received on research and planning (Information)

Staff scientists' perception of the mount of information received on research and planning is a 3-item scale (N = 1161, $\propto = 0.88$). Items were answered on a 1 (*X applies*) to 5 (*Y applies*) response scale where the *X* and *Y* were opposite statements that required the staff scientists to evaluate the amount of information received on research and planning (e.g. *X –I am kept very well informed of all aspects of the research planning of the unit; Y –I am kept in ignorance of most aspects of the research planning in the unit*).

<u>*Value of unit work and performance*</u> (Value of work)

Staff scientists' perception of the value of their research units' work is a 4-item scale (N = 1117, ∝ = 0.84). Items were answered on a 1 (*X applies*) to 5 (*Y applies*) response scale where the *X* and *Y* were opposite statements that required the staff scientists to evaluate the value of their research units' work (e.g. *X – The unit has been highly productive in the sense of adding knowledge, methods or innovations in its field of work; Y – The unit's productivity has been very low in the sense defined*). The value of the units work is used as a performance measure for this case study. The items in this scale assessed the members' perception of the units' productivity, innovation, effectiveness, contribution to science, and usefulness of research.

The first variable that is comprised of individual items in the instrument, *organization*, is used because it indicates a direct association to a construct in flock theory, and are not included in a scale or index. The second individual item variable, *cooperation*, is a single item from the *atmosphere* scale discussed above, and used exclusively for post hoc exploration because of its particularly relevant content.

<u>*Organization*</u>

Organization of the research work, i.e. involves extensive cooperation, is used to indicate that the nature of the work done in the research groups does indeed require extensive cooperation, and can thus be used to test portions of flock theory, which is modeling specifically cooperative situations. This item was answered on a 1 (*X applies*) to 5 (*Y applies*) response scale where the *X* and *Y* were opposite statements that required the staff scientists to evaluate their perception that the nature of *their* units' work requires extensive cooperation (*X –The nature of research work in the unit* *requires extensive cooperation among its members; Y –The nature of research work in the unit is organized mainly on an individual basis*).

<u>Cooperation</u>

Cooperation amongst scientists and engineers is used to indicate the amount of cooperation the group members perceive within their groups, which is one of the central constructs to flock theory. This item was answered on a 1 (*X applies*) to 5 (*Y applies*) response scale where the *X* and *Y* were opposite statements that required the staff scientists to evaluate their perception of the degree of cooperation within the group (*X –There is a very high degree of cooperation among the scientists and engineers; Y –There is very little or no cooperation among the scientists and engineers of the unit*).

Table 2 clarifies the hypothesized relationships between the variables, and how each of the above variables relates to the theory covered in Chapter 2.

Table 2 – Hypothesized relationships and Related Theory for Variables in Study 1

	1.	2.	3.	4.	Flock Construct
1. Atmosphere					C
2. Influence					C, D
3. Information	H7: +	H6: +			C, R
4. Value of work	H3: +	H4: +	H8: +		(Outcome)
5. Organization	H1: +		H5: +	H2: +	SD, C, D

SD=Structural Distance, C=Collaboration, D=Decentralization, R=Roadmap

Results

Statistical testing for hypotheses 1-8 consisted of Person product moment correlations using SPSS (see Table 2 for complete correlation matrix), revealing slight to moderate relationships.

The amount of information received on research and planning was positively related to; the amount of influence on managerial decisions, $r = .333$, $p < .001$, and the general atmosphere and supportiveness, $r = .522$, $p < .001$, supporting hypotheses 6 and 7.

The value of the research units' work was positively related to; the general atmosphere and supportiveness, $r = .456$, $p < .001$, the amount of influence on managerial decisions, $r = .201$, $p < .001$, and the amount of information received on research and planning, $r = .282$, $p < .001$, supporting hypotheses 3, 4, and 8.

The level of extensive cooperation required for research work was positively related to; the general atmosphere and supportiveness, $r = .152$, $p < .001$, the value of the research units' work, $r = .158$, $p < .001$, and the amount of information received on research and planning, $r = .151$, $p < .001$, marginally supporting hypotheses 1, 2, and 5.

Table 3 – Correlation table for Study 1

	1	2	3	4	5	6
1. Atmosphere	1.00 N=1172					
2. Influence	.282*** N=1161	1.00 N=1162				
3. Information	.522*** N=1166	.333*** N=1158	1.00 N=1167			
4. Value of work	.456*** N=1165	.201*** N=1157	.282*** N=1161	1.00 N=1166		
5. Organization	.152*** N=1161	.125*** N=1152	.151*** N=1156	.158*** N=1156	1.00 N=1120	
6. Cooperation	.669*** N=1115	.185*** N=1108	.414*** N=1111	.333*** N=1109	.162*** N=1105	1.00 N=1072

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

Cooperation was tested against all of the other variables to explore the direct correlation of that item, revealing a mix of statistically significant relationships ranging from negligible to moderate. The degree of cooperation among the scientists and engineers of the unit was positively related to; the level of involvement in research, $r = .052$, $p < .05$, the general atmosphere and supportiveness, $r = .669$, $p < .001$, the amount of influence on managerial decisions, $r = .185$, $p < .001$, the amount of information received on research and planning, $r = .414$, $p < .001$, the value of the research units' work, $r = .333$, $p < .001$, the level of extensive cooperation required for research work, $r = .162$, $p < .001$, and the significance of brainstorming to the units work, $r = .126$, $p < .001$.

Statistical testing for hypothesis 9 (Group members perceived value of their units work is predicted by their involvement in research, influence on decision making within the research unit, and general atmosphere of the unit) consisted of multiple regression analysis, with the dependent variables *involvement*, *information*, and *influence*, and the independent variable *value of work*. The regression formula used was:

$V = b_o + b_1I + b_2D + b_3A_3 + e$, where

V = Value of unit work

I = Involvement in research

D = Influence on decision making

A = Atmosphere of the unit

b = Regression weight

e = Residual

The regression fit was moderate but the overall relationship was significant, $R^2_{adj} = .222$, $F_{3, 1149} = 109.2$, $p < .001$, supporting hypothesis 9. There was a statistically significant effect for *involvement*, $\beta = .10$, $t = 3.65$, $p < .001$, as well as *influence*, $\beta = .07$, $t = 2.377$, $p < .05$, but *atmosphere* was the best predictor of *value of work*, $\beta = .43$,

$t = 15.67$, $p < .001$. Checks for collinearity, kurtosis, and skewness revealed no problems.

Discussion

The objective of this study was to test various constructs introduced in Chapter 2, while extending decentralization research into research based organizations. It was expected that the variables tested would be positively related to each other, as the individual constructs in flock theory are all presented as mutually necessary to maintain a cooperative, decentralized group/organization. Further, it was expected that combining the three main constructs of flock theory (structural distance, decentralization, and collaboration) would together predict the overall value of group work.

Although many significant positive relationships were found and all hypotheses were confirmed, many relationships were negligible. However, there were several moderate relationships that confirm some of the theory proposed in the previous chapter. The strongest relationship was between the degree of cooperation and the atmosphere of the unit. Based on the literature presented from corporate organizations, this is to be expected but was confirmatory of theory proposed that cooperation and a positive atmosphere go hand in hand.

Group atmosphere had moderate relationships with two other variables, value of work and amount of information received. Likewise, cooperation had a moderate relationship with both the value of work and amount of information received. These findings come together to paint a picture of groups that shows the more information group members have, the more they cooperate, and the more positive the atmosphere, the better they feel their work is. Relating these findings to the roadmap-based flocking and the bipartite model, it is expected that the more information that group members have and the more they cooperate, the better they will know where they are going as a group, and where to go for information within the group. Thus, more cooperation and a better product will be the outcome, as flock theory proposes.

Another interesting finding is the positive relationship between the amount of information received and the value of work. Although the relationship is not very strong, is it significant, and suggests that the more that group members are included in what is happening within the organization, the better the outcome. Additionally, the more influence that the group members had over managerial decisions the better the value of the work was. This is a very important finding because it confirms the earlier research (Cummings & Cross, 2003; Shaw, 1964; Sparrowe et al., 2001) and the portion of flock theory that proposes that the more decentralized the group structure and access to information, the better the group works.

Three variables were combined in hypothesis 9 to represent the three core constructs of flock theory (structural distance, decentralization, and collaboration) and to test the main tangible outcome of flock theory, the quality and value of the work (e.g. of less tangible outcomes are satisfaction, egalitarianism, etc.). Hypothesis 9 stated that the perceived value of work should be predicted by a combination of the involvement in research, representing structural distance not being too distant, influence on decision-making within the research unit, representing decentralization, and the general atmosphere and supportiveness of the group, representing collaboration. The findings in support of hypothesis 9 suggest that the multiple constructs of flock theory do indeed work together to model the nature of quality work coming from a decentralized, collaborative group. The positive relationship of performance (as measured by the value of work) with several variables, including cooperation and influence over decision-making, highlights the association of decentralization and performance.

Earlier research on decentralization (see decentralization discussion in Chapter 2) confirms that decentralized groups do indeed work better, but these findings extend that research to include a supportive atmosphere and the involvement in research. Further, atmosphere was the best predictor of the value of work, suggesting that it is may be particularly important to combine a cooperative, collaborative group atmosphere with decentralized group structure.

Flock theory was largely created to model decentralized groups, but specifically to promote egalitarianism and cooperation within groups and organizations, and the findings of this case study provide initial confirmation of the propositions and goals of flock theory. Additionally, these findings extend the related decentralization findings to research based organizations, which have been shown to be similar in some ways, but may perhaps differ in others, as is explored in the next chapter.

Limitations

There are several limitations associated with this case study. The entire study utilized secondary level data, from which several limitations occur. First, there was no control or input possible regarding the construction of the instrument and selection of subjects. Second, there was control over methods of data collection and data entry. As a result of the secondary nature of the data, the quality of the data can not be guaranteed, and thus the findings in this case study are subject to those quality issues. The respectable source of the data and the extent that the initial researchers went to ensure quality data (see Andrews, 1979) provides some reliability, but is still a major limitation of the study.

Another limitation of this case study is the notion that it is only illustrating theoretical concepts discussed in Chapter 2 instead of testing these concepts.

Illustrating concepts helps in clarifying and discussing the theory, but empirical testing will be needed for theoretical validation.

Finally, the complexity of the methods used on this case study is a limiting factor. More complex methods will be need in the future for empirical validation. Additionally, the possibility of the findings being caught in causal chains is a limitation that will also need to be addressed in future studies.

CHAPTER IV – STUDY 2

Introduction

This chapter presents the second study illustrating flock theory and related concepts. Similar to Chapter 3, the current study extends the existing decentralization research to research-focused organizations, specifically a large Mid-Western university in the United States. Using data collected by Schwartz (1968), this study provides the opportunity to use the individual as the unit of analysis (similar to Sparrowe et al., 2001, reviewed in Chapter 2), where the previous chapter used the group as the unit of analysis. The benefit of this approach is that it allows for perspective of how structure and performance are related on a person-by-person basis, i.e. does an individual's structural role affect their performance. However, the network data represents an entire organization, similar to Baron and Hannan's (2002) research reviewed in Chapter 2, so the individual data represents access to the entire network.

First, background on the data is provided along with rationale of fit with the theory. Next, related variables and hypotheses are explicated followed by statistical results. Finally, findings are presented followed by some initial discussion and limitations of the study.

Data, Rationale, and Fit

The data used in this study was obtained from Donald Schwartz with permission for use. The initial study done by Schwartz in 1968 is now seen as the first communication network analysis performed in the field of communication (Rogers, 1994). Schwartz based his study largely on the work of Jacobson and Seashore (1951) and Weiss and Jacobson (1955), which postulated that the structure of an organization could be conceptualized and described by the interpersonal and group work related communication patterns. Schwartz then revisited these notions in a study that reported on the liaison role in complex organizations and how they represented an elaboration of the descriptive analysis of complex organizations (Schwartz & Jacobson, 1977). The data provides for a multi-level evaluation of productivity and effectiveness of professors/researchers in a research based environment.

The population from which samples were drawn consists of all the professional faculty and staff of a single college, situated in a single building on a university campus, with a sample size of 142. The questionnaires incorporated a contact checklist for network data, perceived characteristics of the personal contacts, and demographic data such as number of publications and academic rank.

The data from the Schwartz study is of particular interest because it was collected specifically to investigate the relationship of network structure, communication, and performance. Whereas the initial study was specifically looking at liaison roles, which act as “gatekeepers” between otherwise unconnected parts of the network, the data that was collected lends itself extremely well to investigating several variables in line with this thesis. Specifically, structural holes, degree centrality, research performance (publications), and organizational performance (academic rank) can be investigated. These variables extend the decentralization research by Cummings and Cross (2003), presented in detail in Chapter 2, to research organizations while still focusing on the relationship between structural holes and performance. One additional variable was added to this study that has not yet been covered, Simmelian ties.

The notion of Simmelian ties stems largely from the work of David Krackhardt (see Krackhardt 1992, 1996). This work is a combination of Granovetter’s (1973, 1982) notions of long ties and Simmel’s (1950) contributions concerning triads as the fundamental unit of analysis. Long ties within a network provide a greater motivation to assist and are typically more available that weak ties are (Granovetter, 1982). These long ties can be comprised of four main elements (Granovetter 1973, p. 1361):

1) Amounts of time interacting

2) Emotional intensity during the interaction

3) Extent of mutual confiding in the relationship

4) The degree of reciprocal services enacted

Similarly, Simmel (1950) focused on the relationships that form between actors as being integral in the understanding of behavior. He visited the notion that social triads are fundamentally different than dyads and should be studied accordingly. Simmel's model visited three main ways that groups of three (triads) or larger could be distinguished from dyads in the way that the participants interact.

First, groups preserve a smaller amount of individual power gain than dyads. In a group of three or larger, a majority can be derived and thus an individual can be outvoted, resulting in the likely suppression of individual interests and centralized control; regardless of an individuals strength of preference, majority still wins.

Second, actors have less ability to dominate a bargaining or brainstorming situation in a group that a dyad. A dyadic group can be destroyed if the demands of an individual are not accommodated, where as in a triad the demanding, non-cooperative actor can leave and thus has the most to lose; departing individuals would thus be isolating themselves while the group still remains intact.

Third, groups are more able to deal with conflict than dyads. The presence of the third party allows for hardened positions to be moderated and reformulated. This action is not necessarily intentional, just the presence of other parties can alleviate tensions. Simmel (1950, p.145) states,

> The appearance of the third party indicates transition, conciliation, and abandonment of absolute contrast. Such mediations need not occur in words: a gesture, a way of listening, the quality of feeling which proceeds from a

person, suffices to give this dissent between two others a direction toward consensus.

Based largely on the work of Simmel, Krackhardt (1996) defines a Simmelian tie as, “Two people are ‘Simmelian Tied’ to one another if they are reciprocally and strongly tied to each other and if they are each reciprocally and strongly tied to *at least* one third party in common” (p. 8). He goes on to point out that Simmelian ties are best thought of as long ties that add durability and power above that found in strong dyads, thus making Simmelian ties longer lasting.

Applying a Simmelian tie measure to the Schwartz dataset allows for a level of analysis that utilizes the richness of long tie information. Applying Simmelian ties to flock theory allows for the testing of long, cohesive, ties amongst groups within an organization. As notes above, a group that contains Simmelian ties is morel likely to be self-mediating and moderate individual power seeking.

Overall, the data used in this study allow for continued testing of theoretical constructs presented in Chapter 2, while further extending existing literature into research based organizations.

Hypotheses

Combining the theory proposed in chapter 2 with the parallel findings of Sparrowe et al. (2001) and Cummings and Cross (2003), it is expected that the more structural holes one has around them, the worse their performance will be, regarding both the form of research output, career advancement (rank), and organizational service (committee work).

H1: Research performance is negatively associated with structural holes.

H2: Organizational rank is negatively associated with structural holes.

H3: Committee service is negatively associated with structural holes.

Additionally, individuals with a higher degree centrality, i.e. more people connected to them, will also characterize superior performance and advancement.

H4: Organizational rank is positively associated with degree centrality.

H5: Committee service is positively associated with degree centrality.

Centrality is also expected to be negatively associated with structural holes, as they represent opposite measures.

H6: Degree centrality is negatively associated with structural holes.

Expected results regarding Simmelian ties stem mostly from the notion that the measure is indicating a cohesive group of individuals. Thus, based on the constructs of flock theory, is anticipated that individuals with more Simmelian ties will be more likely to participate in cooperative practices, such as sit on committees, and have a higher degree centrality.

H7: The number of Simmelian ties an individual has is positively associated with degree centrality.

H8: Committee service is positively associated with Simmelian ties.

Table 4 – Hypothesized relationships and Related Theory for Variables in for Study 2

	Performance	Rank	Servi ce	Str. Holes	Simmelian	Flock Construct
Str. Holes	H1: -	H2: -	H3: -			D
Deg. centrality		H4: +	H5: +	H6: -	H7: +	SD, D
Simmelian			H8: +			C

SD = Structural Distance, C = Collaboration, D = Decentralization

Method

Structural holes were measured using the constraint measure in Ucinet V (Borgatti, Everett, & Freeman, 1998). Constraint is the most applicable structural holes indicator for the Schwartz dataset because of the nature of the organizational context; educational ties are generally distributed to limited actors within the overall network. For example, departmental units in an educational context would tend to cluster around functional linkages. By its very nature, pockets of clusters would seemingly reflect intra-departmental communication within departmental cliques. Constraint, as dependency among actors, can be viewed in a negative characteristic in oligarchical, or diffused, organizational structures.

Measures of degree centrality were derived from Ucinet V (Borgatti, Everett, & Freeman, 1998). The centralities were then normalized which entails dividing the simple degree (or number of links) of an actor by the maximum degree possible, n*(n-1) and dividing this by 2 (bi-directionally) (see Wasserman & Faust, 1994). As covered in Chapter 2, Degree centrality is calculated by counting the number of adjacent links to or from an actor in a network. Degree centrality, representing the number of alternatives available to an individual in the network, makes it a viable centrality to use in conjuncture with structural holes. Likewise, degree centrality is appropriate for capturing such power-enhancing behaviors that happen via direct interaction, such as integration and reciprocation, direct interactions such as coalitions, and the avoidance of relying on mediating actors for indirect access to resources (Brass & Burkhardt, 1992).

While a relatively straightforward measure, degree centrality provides insight into individual contributions to the interconnectedness of the overall network (Rogers & Kincaid, 1981). In the Schwartz dataset degree centrality can be used in comparison with structural holes, and is related to structural holes in the sense that the number of connections an individual may have within a network is related to the constrains that they have. If someone has few social connections their access to resources will in turn be limited, and the number of structural holes will likely reflect this limitation.

The method to build a Simmelian tie matrix is a five-step process developed specifically for this data, and relies upon tie-length data.

Step1: Symmetrize the original strength tie matrix with average values of tie length with two actors (e.g., if actor 1→2 & tie length = 3; actor 2→1 & tie length = 5, the symmetrized length of the tie between actors 1 and 2 is (3+5)/2 = 4).

Step2: Construct a long tie matrix by dichotomizing the ties into long and short ties

Step3: Perform a clique analysis to identify a co-clique member; with Ucinet 5, Tool: Clique overlap; (see Borgatti, Everett, & Freeman, 1998).

Step4: Dichotomize the ties if A and B have a same clique membership; if members of the same clique, then Simmelian tie value = 1, else = 0.

Step5: In above co-clique matrix, diagonal elements reflect the total number of individual membership cliques; diagonal elements are the sum of Simmelian ties of each actor.

Research performance was measured by the number of articles the researcher reported having had published at the time of data collection (see Appendix B for all items used). Organizational performance was measured by the academic rank of the individual, i.e. Lecturer, Assistant Professor, Associate Professor, and Full Professor. Committee service was measured by totaling the number of committees served on at the departmental, college, and university level. Taken together, the publication record academic rank, and committee service is used to measure the performance of an individual in this case study.

Statistical testing for hypotheses 1, 2, and 5-9 consisted of Person product moment correlations using SPSS (see Table 2 for complete correlation matrix), revealing slight to moderate relationships. Testing for hypotheses 3 and 4 consisted of a multiple comparison ANOVA.

Results

Academic performance, i.e. research publication, was negatively associated with structural holes, $r = -.213$, $p < .05$, confirming hypothesis 1. As academic rank increased, structural holes decreased, $F = 5.584$, $p < 0.001$, confirming hypotheses 2. The constraints went from a mean of 0.53 for a lecturer down to a 0.22 for a professor with decreasing intervals through instructor, 0.42, assistant professor, 0.36, and associate professor, 0.24. As academic rank increased, degree centrality increased, $F = 4.096$, $p < 0.001$, confirming hypotheses 4. Lecturers had a mean degree centrality of 10.85 going up to a 29.38 for professors, with increasing intervals through instructor, 13.81, assistant professor, 19.99, and associate professor, 23.84.

Committee service was negatively associated with structural holes, $r = -.213$, $p < .05$, confirming hypothesis 3. Committee service was with positively associated with degree centrality, $r = .383$, $p < .01$, and Simmelian ties, $r = .286$, $p < .01$, supporting hypotheses 5 and 8.

Structural holes was negatively associated with degree centrality, $r = .687$, $p < .01$, supporting hypotheses 6. Finally, there was a positive relationship between Simmelian ties and degree centrality, $r = .464$, $p < .01$, supporting hypothesis 7.

Discussion

The finding that the more tenured and successful an individual is the organization the fewer structural hole they have is particularly interesting, as it echoes the findings by Cummings and Cross (2003) that structural holes were negatively associated with performance in an organizational context. While the greater the amount of structural holes an actor experiences the fewer committees they will sit on. These results provide more evidence of the nature of constraints as indicative of disproportionate power relations, as degree centrality had a negative correlation with constraints.

The findings in this study also illustrate one of the main propositions of flock theory; that increased collaboration and contact will lead to better performance, and centralized, fragmented groups and organizations will hinder performance. In addition, this finding also alludes to the notion that as an actor is more central in a research based organizational network there will be fewer structural holes around them, a finding that has been previously associated with research organizations (see Schwartz & Jacobson, 1977). The more prominent faculty members and central administrators will be likely to have fewer roles not filled around them, including committee work, which is reflected in the data. The previous case study, discussed in Chapter 3, also found that decentralized groups were positively associated with performance. Combining the findings of the two case studies in the current research with previous findings from decentralization research done on more traditional organizations illustrates the relationship of decentralization with superior performance.

The findings are contrary to Burts' (1992a, 1992b) findings, which resulted from analyses of traditional, corporate organizations; in which the more prominent an actor was, the more structural holes they were surrounded by. The inverse nature of the two sets of findings adds to the rationale to continue to investigate the structural characteristics of research organizations.

Simmelian ties and degree centrality both being positively related to committee service is an intuitive finding, as the more committees one sits on the more contacts and strong ties one will have with others who are strongly ties to one another. The Simmelian tie measure is of particular use in the context of groups, as it is inherently a group measure, and this finding is an initial confirmation of the measures validity. Further investigation is needed in this context.

In summary, the findings of this study confirm several of the theoretical notions proposed in Chapter 2 regarding decentralization and performance. Further, the findings represent an interesting comparison of traditional, corporate organizations and academic, research focused ones.

Limitations

There are several limitations associated with this case study, and echo the limitations covered in the previous case study. Much like the first case study, this study utilized secondary level data, from which similar limitations occur. There was no control or input possible regarding the construction of the instrument and selection of subjects. Additionally, there was no control over methods of data collection. The data for this study was entered with oversight by the researcher from the original research materials. As a result of the secondary nature of the data, the quality of the data collection cannot be guaranteed, and thus the findings in this case study are subject to those quality issues. The relationship between the author and the original researcher provides some reliability but does not alleviate some of the major limitations of the study.

Similar to the previous case study, a limitation of this case study is the notion that it is only illustrating theoretical concepts discussed in Chapter 2 instead of testing these concepts. Illustrating concepts helps in clarifying and discussing the theory, but empirical testing will be needed for theoretical validation.

CHAPTER V – SUMMARY AND CONCLUSION

Previous research on decentralization in groups and organizations has found that decentralization and cooperation leads to superior performance and satisfaction on every level of organization. From early laboratory studies to recent field studies, findings point to the need for more decentralization when solving complex tasks or when creativity is desired. The primary objective of this program of research was to develop a theoretical framework from which to explore the means that an organization or group can promote decentralization while maintaining coordination and cooperation. Social network theory provides the tools and measures to explore and elaborate this investigation, yet does not provide the story, just the means by which to tell it.

Decentralization is discussed here as a social structure where there is minimal control from a specific person or source, allowing the individuals in the group to offer their own talents and potential without bureaucratic constrains. Organizational literature and theory all to often looses sight that the organization is made up of individuals who have ideas, creative input, and endless value. There is a chorus of research to support the idea that people are happier, more productive, and more creative when they are given the freedom of control over their relations and communication with fellow group members.

The review of research provided substantial evidence that decentralized organizational forms were indeed superior, but does not offer much guidance of how that structure is created or maintained. Flock theory was offered as a means by which cooperative groups can be fostered, primarily through a combination of optimizing structural distance, collaboration, and decentralization. Research on roadmap-based flocking was then covered as a means by which decentralized networks can have global information while still having local organization. The roadmap model was extended to social networks via navigation in small world research and bipartite networks, rounding out flock theory as a theory of cooperation, coordination, and navigation within decentralized networks.

The first case study in the present research explored the notion that groups in research-focused organization will be more satisfied with the quality of their work when they are afforded the opportunity to have a more decentralized decision-making structure, and more information on the research. Similarly, that the general atmosphere of the groups will be better when there is more information sharing and mutual influence on decisions. The use of cooperation and brainstorming were also explored in relation to decentralization, atmosphere, information, and performance.

The results from the first study suggest that decentralized decision-making and the value of the work are positively related, similar to traditional corporate originations. Some unique findings were that the general atmosphere and supportiveness also improved with cooperation and decentralized decision-making, providing some initial confirmation of flock theory. Likewise, the results showing information sharing as being positively related to decentralized decision-making, general atmosphere and the value of the work provides a cursory confirmation of the roadmap and model. Finally, the results from the regression including the three main flock variables revealed that the value of the work was indeed a factor of all three variables together. The results from the first case study provide validation of prior research and initial support for the proposed theory.

Case study 2 extended the empirical testing to another research-based organization. In this study specific network measures, i.e. structural holes, degree centrality, and Simmelian ties, were investigated to test the theory. Findings indicated that structural holes inhibited performance, similar to parallel organizational research (see Cummings and Cross, 2003). Structural holes were found to also inhibit organizational advancement, contrary to some parallel organizational research (see Burt 1992a), indicating that research based organizations may need to be more collaborative by nature as the organizational tasks require a particularly high level of creativity and cooperation.

Overall, the results from the two studies indicate that the propositions of flock theory have merit. And when combined with previous research, provide for initial confirmation of flock theory.

Limitations

One of the main limitations of this research is the use of secondary data analysis. The data did provide for initial testing of the theory, but it is not sufficient for a full analytical verification of flock theory. Many aspects of the data were a good fit with the theory, but without control over the instruments used and methods of collection variable development is sacrificed. Additionally, the quality of the data is in question. The sources of the data are respectable, and all data was checked for quality, but that does not guarantee the integrity of the data.

An additional methodological limitation is that the two case studies in the current research do not utilize enough network analytic measures. One of the main theoretical foundations on which this research is built is that of social networks. Future research should gather data that allows for increased use of network analytic methods, and theoretical validation of decentralization should increase the utilization of network structure.

Another limitation of this research is the wide scope of the theoretical background used in developing flock theory. Integrating so many different areas of existing theory for new theory development can make it difficult to thread them together using common vernacular, as different areas of science tend to use different language. Efforts were made to provide a common thread through the theory, but concepts that may have erroneously come across as disjoint.

Finally, because a large portion of this research is new theory development there are many claims that are not well substantiated. Parallel research was reviewed whenever possible, and indeed most of the theory was substantiated with the literature review and case studies, but there are still portions that remain claims until further empirical testing.

Future Research

Methodologically, future research must focus on collecting data that can more directly test the claims made in flock theory. Specifically, longitudinal network data would allow for exploration of how decentralized networks actually self-organize and coordinate. Demographic data would be helpful as well, but data on the perception of the quality of the network links and ability to complete tasks in a range of network structures would greatly augment the current line of research.

Additionally, integrating the roadmap-based coordination into specific problem solving and creative situations is important to develop a model where a group can be locally organized but globally informed. Research on knowledge networks (see Monge and Contractor, 2003) has begun to test related concepts, but lacks the presence of a specifically decentralized organizational structure.

Similar to the current line of research, more data collection and theory testing needs to be conducted in organizations that are specifically and uniquely research-based. Organizations that have a primary goal of knowledge creation and research (e.g. university research groups and government think-tanks) pose a particularly important are of research, as many of the cures for societal wounds, both social and medical, are generated from these organizations. As some of the findings in this research have indicated, along with parallel research, it may not be wise to map research organizations onto bureaucratic corporate models, as these models have been found to hinder creativity and problem solving. If indeed models in line with flock theory are superior in promoting group creativity, coordination, and problem solving, future research needs to provide these findings to those individuals running research organizations.

Future research should also embrace the rapidly developing world of communication technology. Technology like instant messaging, mobile communication, spatially aware mobile devices, intelligent structures that can provide information to residents, and the plethora of technology that will soon come all provide an increased ability for groups of individuals to coordinate, self-organize, and create in the absence of a centralized structure.

The advent of the Internet and exponential increase of its applications and uses has created many exciting venues to explore self-organizing systems like the ones discussed in the current research. Self-organizing online communities is an important context for research on flock theory. Such communities are frequently decentralized in structure, are very collaborative, and use the Internet as a roadmap for navigation and coordination.

A specific self-organizing online community that would be very interesting to research is open-source programming communities. Many individual programmers working together, often geographically isolated, to write and update computer programs, typify open source programming (see Dempsey, Weiss, Jones, & Greenberg, 1999). The organization of the group is decentralized, yet they coordinate their efforts very efficiently and are able to work towards a goal that is constantly changing. Open source online communities use an Internet based roadmap to share what parts of the program they are working on, how close they are to their goal, and what activities they are engaging in that may couple with the work that others are completing. Groups of programmers are able to structurally change, as individuals join and leave, while remaining organizationally closed. It is in this sense that open-source programming is akin to autopoietic systems that use roadmap based navigation to self-organize. The interaction is recorded in such a way that data analysis is feasible, and outcome variables, such as program success, are attainable.

Another online community that would be interesting to investigate is online gaming communities. Online games frequently require groups of individuals who, much like open-source programmers, are frequently not co-located and use their online interaction to coordinate their activities. Such online gaming represents a potentially close fit with flock theory, as the group of individuals must improvise their interaction, utilize each other's skills, communicate openly, cooperate in avoiding enemies, and seek a clear goal. Similar to open source community data, online gaming data is feasible to collect as spatial movements and communicative interaction is recorded. Success can be measured by how successful the group was at completing missions and avoiding termination.

Social phenomena exist that extend to on and off-line contexts, and should be studied to compare how self-organization differs in the two contexts. Grass-roots political organization is an example of such a phenomena. Much recent political activity has utilized decentralized online organization to augment traditional face-to-face and mass media campaigning (see Boyd, 2003; Castells, 1999). Organizations such as MoveOn.Org (2007) utilize a decentralized group of locally organized teams to rapidly coordinate large-scale protests, messages to lawmakers, and financial support for politicians. Grass-roots political organizations are increasingly using Internet websites that act as roadmaps that elaborate what the goals of the group are, who is doing what, how one groups efforts couple with other groups, and how close the group is to reaching the goal. In recent years, such self-organizing political groups have, in many cases, been more successful that traditional political groups (Boyd, 2003). Thus, it would be helpful to research how such groups as MoveOn.Org self-organize and maintain a decentralized structure.

Communication and information technology is providing us with the tools and means to increase the decentralized nature of our interactions. Future research should embrace the new social structures that result from new technology and help us better understand how we can utilize new technologies, and how that use can catalyze egalitarian social interaction.

Conclusion

Organizational communication texts generally begin with an introduction to the history of organizational theory, from the "dark ages" of organizations when production was the only consideration, through the human resources "post-Hawthorne[19]" era when peoples welfare started to matter to the organization, ending with the modern organization and its attention to health care and employee feedback. Perhaps it is time to consider another shift in how organizations and groups structure themselves and their employee interaction.

Research has presented us with findings leading to the conclusion that decentralization leads to happier people and superior performance, and the current line if research proposes a model of how that decentralization can be fostered and utilized. One of the main motivations for this line of research is to promote more egalitarian organizations and, hopefully, societies.

We have seen an era begin where decentralized and self-organizing groups of individuals can overcome centralized, autocratic rule. Utilizing an influx of communication technology, phenomena like *smart mobs* can form (see Rheingold,

[19] The Hawthorne Electric Plant studies are attributed for starting the human resources movement in organizations, where employees' feelings and welfare were increasingly considered.

2003), allowing groups of people to become embowered around a specific cause and use self-organized, decentralized communication to organize and overthrow autocratic regimes. Democratized societies are promoted in the age of decentralized information and grassroots movements. Likewise, democratized groups and organizations are promoted through decentralized information and self-directed movement.

Similarly, we are seeing an era come where decentralized and self-organizing organizations can outperform and overcome centralized, autocratic ones. What the decentralized organizations realize is that every individual contains a massive amount of potential and the desire to contribute that potential, and to let them control that contribution. What the centralized, autocratic organizations don't realize is that motivation and contribution cannot be forced, bribed, or kicked out; motivation is internal (see Hertzberg, 1987). The way to turn the potential into kinetic is to allow people to collaborate and cooperate.

Human interaction may *at times* be more like a classical symphony than a jazz improvisation, but the jazz improvisation is where creativity and imagination flourish. The classical symphony will never create something new, and the musicians will never contribute their own individual potential of creativity; that is unless they take their own course and create something innovative. And, perhaps, get other birds to flock and jam with them on the journey.

APPENDICES

Appendix A – Survey Items and Variables from Study 1

Variable: Atmosphere (scale ∝ = .85)
Instructions: This question aims to obtain your views on the climate of the unit, such as attitudes on technical and non-technical matters, personal attitudes and perceptions, personal involvement in the work, and atmosphere of the unit. Please indicate, for each of the following pairs of extreme statements, the column which most accurately describes your views by selecting one number for each pair below and writing it in the space provided
(Items were answered on a 1 (*X applies*), 2 (*Tend. To X*), 3 (*Intermediate*), 4 (*Tend. To Y*), and 5 (*Y applies*) scale)

1. X – There is generally a very innovative spirit and sense of pioneering in he unit
   Y – There is a very traditional spirit and stultifying atmosphere in the unit
2. X – There is an atmosphere of great dedication to work in the unit
   Y – There is a feeling that everyone in the unit only works to make a living
3. X – Nearly all new ideas for research or other technical matters are given adequate consideration
   Y – Very few new ideas for research or other technical matters are given adequate consideration
4. X – Nearly all new ideas for improvement in non-technical matters are given serious consideration
   Y – Nearly all new ideas for non-technical matters are ignored and existing practices are generally maintained
5. X – New ideas on all matters from junior staff or technicians are as readily considered as if they originate from the senior staff
   Y – Any new ideas considered at all levels are only taken seriously if they come from senior staff
6. X – There is a very high degree of cooperation among the scientists and engineers of the unit
   Y – There is very little or no cooperation among the scientists or engineers of the unit

Variable: Influence (scale ∝ = 0.86)
Instructions: Please indicate how much influence each of the following has on the research and management decisions relevant to the unit by selecting one number from below and writing it in the space provided according to the amount of influence.
(Items were answered on a 1 (*high influence*) to 5 (*low influence*) response scale)

1. Choice of the specific research tasks
2. Choice of the methods used
3. Publication and circulation of research results

4. Allocation of work within the unit
5. Coordination and/or cooperation with other units

Variable: Information (scale ∝ = 0.88)
Instructions: Please indicate, for each of the following pairs of extreme statements, the column which most accurately describes your views and/or degree of satisfaction about the research planning and the execution of the work in the unit by selecting one number for each pair of statements below and writing it in the space provided
(Items were answered on a 1 (*X applies*), 2 (*Tend. To X*), 3 (*Intermediate*), 4 (*Tend. To Y*), and 5 (*Y applies*) scale)
1. X – I am kept very well informed of all aspects of the research carried out by the unit
   Y – I am kept in ignorance of most aspects of the on-going research
2. X – I am kept very well informed of all aspects of the research planning of the unit
   Y – I am kept in ignorance of most of the research planning in the unit
3. X – I participate at every stage in the planning of the research
   Y – I am kept right out of the planning of the research

Variable: Value of work (scale ∝ = 0.84)
Instructions: Please indicate, for each of the following pairs of extreme statements, the column which most accurately describes your views about the value of the work of the research unit covering the LAST THREE YEARS by selecting ONE number for each pair of statements below and writing it in the space provided
(Items were answered on a 1 (*X applies*), 2 (*Tend. To X*), 3 (*Intermediate*), 4 (*Tend. To Y*), and 5 (*Y applies*) scale)
1. X – The unit has been highly productive in the sense of adding knowledge, methods or inventions in its field of work
   Y – The unit's productivity has been very low in the sense defined
2. X – The unit has been highly innovative in generating useful new ideas, approaches, methods, inventions or applications in its field o work
   Y – The unit has been very uninnovative in the sense described
3. X – The work of the unit has been extremely useful in helping the organization to which it belongs to carry out its responsibilities with regard to research and experimental development
   Y – The work of the unit has been largely ineffective in furthering the objectives of the organization to which it belongs to with regard to research and experimental development
4. X – The unit has made an outstanding contribution to scientific or technical development in its field
   Y – The unit has made an little or no contribution to scientific or technical development in its field

Variable: Organization

Instructions: Please characterize the organization and planning of the research work in the unit by selecting one number from below and writing it in the space provided. (Items were answered on a 1 (*X applies*), 2 (*Tend. To X*), 3 (*Intermediate*), 4 (*Tend. To Y*), and 5 (*Y applies*) scale)

1. X – The nature of research work in the unit involves extensive cooperation among its members
   Y – The nature of the research work in the unit is organized mainly on an individual basis

Variable: Cooperation

Instructions: This question aims to obtain your views on the climate of the unit, such as attitudes on technical and non-technical matters, personal attitudes and perceptions, personal involvement in the work, and atmosphere of the unit. Please indicate, for each of the following pairs of extreme statements, the column which most accurately describes your views by selecting one number for each pair below and writing it in the space provided

(Item was answered on a 1 (*X applies*), 2 (*Tend. To X*), 3 (*Intermediate*), 4 (*Tend. To Y*), and 5 (*Y applies*) scale)

1. X – There is a very high degree of cooperation among the scientists and engineers of the unit

Y – There is very little or no cooperation among the scientists or engineers of the unit

Appendix B – Survey Items from Study 2

Academic Rank
What is your academic rank?
1. Instructor, 2. Assistant Professor, 3. Associate Professor, 4. Professor
5. Other (Please specify)________

Committee Service
How many faculty or administrative committees do you belong to including both standing and ad hoc committees?
___1. Departmental (or Institute) level committees
___2. College level committees
___3. University level committees

Publications
How many professional journal articles have you published (or had accepted for publication) and how many papers have you presented at professional meetings since 1965? ____ (combined total)

Personal contact checklist
Now go back over the past two or three months and think of the professional people in the College of (--) with whom you worked most closely. We would like to have you list below the names of the people in the college with whom you work most closely. By "work with most closely" we mean the professional people with whom you usually have at least one contact per week on matter related to programs or activities of the College, or in teaching, research, or consulting in which you or the other person is engaged. You need to only list people who are officed in (---) Hall. By "professional people" we mean faculty with academic rank of instructor or higher and/or administrators.

For each of the individuals you list below, check how frequently in an "average" week you have contact with (talk to in person or on the phone, write) each of them. Name as many or as few people as accurately describe your usual contacts

(A) List the name of each person in the College with whom you work most closely.
(B) For each person listed, check the appropriate frequency column.

Name_________
Frequency of contact:
1) Several times daily __
2) About once per day __
3) 2 or 3 times per week __
4) About once per week __

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