NETWORK STRUCTURE IN VIRTUAL ORGANIZATIONS

March 23, 1998

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Abstract

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Virtual organizations, that use email to communicate and coordinate their work toward a common goal, are becoming ubiquitous. However, little is known about how these organizations work. In this paper, we examine the behavior of one such group and in particular the relationship among task routineness, organizational structure, and performance within this group. Much prior research suggests that virtual organizations, largely due to the fact that they use information technology to communicate, will be decentralized and non-hierarchical. We empirically measured the structure of a virtual organization and found evidence of hierarchy. Our analysis is based on a case study of the communication structure and content of communications among members of a virtual organization during a four-month period. Results indicate that the fit between structure and task routineness affects the perception of performance, but may not affect the actual performance of the group. The findings of this study imply that the structure of virtual organizations is similar to traditional organizations in so far as fit predicted perceived performance. However, virtual organizations are dissimilar from traditional organizations in so far as fit did not predict objective performance. To the extent that virtual organizations are similar to traditional organizations, we can build on existing theories to study the structure and perceived performance of virtual organizations. New theories must be developed that explain objective performance in virtual groups.

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Introduction

Today's organizations are faced with a dynamic and turbulent environment that requires flexible and fast responses to changing business needs. The literature suggests that many organizations have responded by becoming decentralized, team-based and distributed (DeSanctis and Jackson, 1994; Drucker, 1988). These distributed organizations have also been described as virtual, network, self-managing teams, cluster organizations and autonomous business units in the recent literature (Goldman, Nagel, and Preiss, 1995; Beyerlein and Johnson, 1994; Camillus, 1993; Mills, 1991; Drucker, 1988). Advances in communication technologies have enabled organizations to acquire and retain such distributed structure by supporting interaction among people coordinating their efforts from different locations. Despite the rapid increase in the number of organizations that are becoming distribute, little is known about the nature or performance of such organizations. This research examines network structure in a virtual design group by using a social network approach (Tichy and Fombrun, 1979; Tushman, 1978; Brass, 1985; Burkhardt and Brass, 1990).

The purpose of this research is to conceptually clarify and empirically examine the emergent network structure of a virtual organization. A second purpose is to consider whether the emergent structure that has evolved is suitable for the task being performed. Specifically, we examine linkages among task characteristics, emergent network structure and network performance (of communication networks formed to perform the given task or task-related networks) in virtual organizations. Our hypothesis here is that in a virtual organization, the fit between task routineness and network structure is associated with superior network performance.

The rest of the paper is organized as follows. The next section defines and describes virtual organizations. This is followed by a description of the research context in which this study was conducted. In section three, we discuss the research model. A description of the data and methodology can be found in section four. The results are presented in section five and discussed in section six. Finally, contributions and limitations of the study are presented.

Virtual Organizations

Lipnack and Stamps (1997) have identified elements of virtuality in teams and organizations. They define a virtual team as "a group of people who interact through interdependent tasks guided by common purpose" that "works across space, time, and organizational boundaries with links strengthened by webs of communication technologies (p. 7)”. However, they emphasize that they are most definitely teams or organizations, not electronic representations of the real thing. We define a virtual organization as a geographically distributed organization whose members are bound by a long-term common interest or goal, and who communicate and coordinate through information technology. Our focus is on a particular type of virtual organization, the virtual research organization, in which members of various corporate and academic research units voluntarily come together to advance a technology and which is an on-going group (as opposed to a short-lived or ad-hoc team) of people.

A key feature of virtual organizations is a high degree of informal interaction. Due to a lack of formal rules, procedures, and norms, more extensive communication is required (Monge and Contractor, 1997). Also, a lack of formal and clear reporting relationships warrants an increase in communication regarding tasks and problem solving (Monge and Contractor, 1997). While formal communication is non-interactive and impersonal involving media use such as reports, structured meetings, informal interaction is personal, peer oriented, and interactive involving media such as face-to-face meetings and email. Formal interaction is a function of the formal hierarchy embedded in the system while informal interaction is associated with emergent structure.

Researchers in the area of social networks have found that if interactions of informal groups are tracked over a period of time, they exhibit a pattern of communication and reveal what has been referred to as network structure (Krackhardt, 1991; Krackhardt and Porter, 1985; Brass, 1985; Burkhardt and Brass, 1990). In social network theory, network structure has been defined as “the arrangement of the differentiated elements that can be recognized as the patterned flows of information in a communication network” (Rogers and Kincaid, 1981; p. 21).

Formal, imposed or mandated networks (Aldrich, 1976) represent the legitimate authority of the organization reflected in the organizational chart. They are also representative of the communication channels that facilitated downward transmission of orders and upward transmission of information (Monge and Contractor, 1997; Weber, 1947). Researchers have found that formal structures do not adequately explain organizational behavior and that emergent structures not only add considerable explanatory power to the organizational behavior models but also explain behavior better than formal structures (Bacharach and Lawler, 1980; Krackhardt and Hanson, 1993; Monge and Contractor, 1997). According to Monge and Contractor (1997), the distinction between formal and informal structures may blur in coming decades as the new forms of organizations become prevalent. These new organizational forms may be based on emergent structures that result from communication through information technologies that facilitate lateral communication without regard for traditional hierarchy.

Historically, virtual groups have used electronic mail (email) to share information and coordinate their work. Use of email allows these groups to call on expertise whenever needed regardless of where it resides. This use of email facilitates creation and sustenance of a group identity without a shared physical setting in which the communication occurs and enables existence of a group without visible participants (Finholt and Sproull, 1990). Participants can send or receive messages regardless of their location. Thus, at least in principle, they are less reminded of the shared context of the virtual group (Finholt and Sproull, 1990).

Literature suggests that virtual organizations tend to be non-hierarchical (Goldman *et. al.*, 1995; Beyerlein and Johnson, 1994; Camillus, 1993; Mills, 1991; Drucker, 1988) and decentralized (Baker, 1992). For example, Baker (1992) suggests that "at least in metaphor, the network organization is a market mechanism that allocates people and resources to problems and projects in a decentralized manner (p398)." However, researchers have yet to empirically examine the nature of structure in virtual organizations. Further, since the research on virtual organizations is still evolving, there is still a lack of precision in the terminology used to describe them, particularly with respect to structure. Conceptual clarification regarding the network structure evolving in these new forms of organization has not been achieved. For example, the terms decentralized and non-hierarchical are used interchangeably to describe the structure of virtual organizations. This research analyzes different dimensions of structure (degree of hierarchy, centralization, and hierarchical levels) to gain an in-depth understanding of a single group (Yin, 1984). An attempt is made to conceptually distinguish among these structural dimensions. We also examine the effect of the fit between task and structure on performance in virtual groups.

A Virtual Organization – The Soar Group

Drucker (1988) in discussing the new forms of organization enabled by information technology has suggested that this transformation is most evident in the area of research and development. Since the empirical research in the area of virtual organizations and their structure is in its infancy, the next logical step in developing an understanding of this new form of organization is to study in depth one such existing research and development team.

We examined a virtual organization engaged in research and design of a general purpose artificial intelligence architecture - Soar. This virtual organization, the Soar group is involved in basic research and software development. In the sections that follow, we describe the Soar architecture, the Soar group (as it is commonly referred to), and the nature of tasks performed by the Soar group.

Soar

Soar was initially developed in 1982 at Carnegie Mellon University and was originally defined as "State Operator And Result" (Carley & Wendt, 1991). Soar is an architecture for a general intelligence system which learns about possible solutions to problems as it solves them and thus improves its capability to solve similar problems in the future. As this system was being developed, , Soar also became a tool for studying the theoretical construct of cognition (Newell, 1990). According to Laird *et al.* (1987), "Soar is to be able to: work on the full range of tasks from highly routine to extremely difficult open-ended problems; employ a full range of problem solving methods and representations required for these tasks; and learn about all aspects of the tasks and its performance on them." (p.2). In congruence with this mission, Soar has been used for a wide range of tasks - from creating music to problem-solving in space-related projects by NASA.

Soar Group

A simple definition of a group found in the literature describes it as "two or more individuals who influence each other through social interaction" (Forsyth, 1983, p. 81). This definition reflects one school of thought on group research. Others have suggested that the existence of communication and mutual influence is not a sufficient condition for a collection of individuals to be viewed as a group (Baron *et al.*, 1992). They contend that groups must have some permanence, structure and a sense of belonging. The Soar group fits both definitions of group. It is comprised of researchers and developers who through email interaction influence each other's work involving Soar. The group arose in an unplanned manner from voluntary participation of academic and corporate researchers. Yet, members have a shared sense of belonging which is enhanced by participation in semi-annual workshops. At these meetings members have an opportunity to interact face-to-face and update their knowledge of recent activities of the group as a whole. Recently, there have also been European Soar workshops.

As is the case with other virtual organizations, the Soar group has no single shared physical setting (Finholt and Sproull, 1990). Since its inception in 1982, the Soar group has spread to several universities and corporations nationally and internationally. The key participants are researchers and developers at Carnegie Mellon, Michigan and Southern California Universities. Researchers from several corporations such as Xerox and Digital Equipment Corporation are also involved.

Members are bound by a common interest in Soar. For some, the Soar architecture itself is the main research interest while others use Soar for research in artificial intelligence and cognition on topics ranging from sentence formation to music. Both researchers and developers alike are interested in advancement of Soar as an architecture. For a developer, this is clearly the main objective but researchers also benefit from a more effective and friendly system. Thus, the goal of advancing Soar as an architecture is common to all members regardless of their role.

Like many virtual organizations, the Soar group communicates extensively by email to share information and coordinate tasks. Members view and use the Soar group for ideas, feedback, support, and stimulation. Information exchange through email can take various forms. For example, a member can inform the group through email when he or she finds a bug or discovers new requirements. Additionally, members can post a problem on a bulletin board with the expectation of receiving feedback from other members.

Members collaborate in research using Soar, in a variety of domains including cognition, natural language understanding, and robotics. Most collaborated projects include corporate as well as academic participants. Since most of the Soar members are academic or corporate researchers, they are interested in producing results of their work in the form of publications. Therefore, one indicator of the effectiveness of the Soar group's research and design efforts is the number of Soar-related publications of its members.

Tasks in Soar group

In principle, virtual organizations may face either routine or non-routine tasks. In fact, the Soar group faces both. Prior research has demonstrated that formal interaction is useful for some structured activities but it is ineffective when the situation lacks certainty and structure (Kraut and Streeter, 1995). Software development is typically considered an unstructured and non-routine task (Kraut and Streeter, 1995) and therefore needs informal interaction for coordination (Van de Ven *et* *al.*, 1976). The main task of the Soar group is research and design of the Soar architecture. However, group maintenance and resource management are also important to long-term survival of the group. Thus, we consider three main tasks of the Soar group - design, group maintenance and resource management. These three tasks vary in the degree to which they are routine.

This first task, design, refers to the task of research and development involving the Soar architecture. In Soar, the design process is collaborative in the sense that members, who are all highly specialized in their own areas, benefit from each others' insights on various design issues. For example, a member struggling with a bug or a conceptual problem might post a message to the group asking for help. Someone else who may have encountered this bug or problem may respond with a solution. All known bugs and fixes are also recorded in Soar archives that are available to all members. Archives of all group emails are kept. Enhancements over a period are compiled in new versions of the architecture which is made available to all group members.

The second task, group maintenance, refers to tasks concerning day to day operations of the group. Organizing meetings and maintaining distribution lists are examples of group maintenance tasks. In the Soar group, members meet twice a year to share their work with the rest of the group. Distribution lists, which are used to disseminate information, are maintained. Coordination of these functions is related to the maintenance of the group. For a group to operate smoothly toward its common goal, the members need to feel a sense of belongingness. Even though group maintenance can be thought of as overhead of the primary goal of the group, its importance cannot be underestimated. Without group cohesiveness, identity, and ego-involvement on the part of its members, the primary goal of the group will not be accomplished effectively.

The third task, resource management, is a challenge to every group or organization's effectiveness. Decisions must be made as to how to best use these resources towards the group goals. The main source of resources in the Soar group is the umbrella grant obtained by the three main universities involved in the group. The members of these three sites take turns in writing the umbrella grants and acting as principle investigators. Money is only one of several resources the Soar group uses; group members must also manage other resources such personnel[i], machines, disk space, computer time etc.

Development of the model

Network Structure in virtual organizations

This research is grounded in the view of organizations as information processing systems (March and Simon, 1958; Galbraith, 1977). Organizations design their structure, processes, and information technologies for the purpose of processing, exchanging, and distributing the information required for their functions (Duncan, 1972; March and Simon, 1958). Researchers have examined network structures based on verbal communication as an important determinant of an organization's information processing capacity (Tushman, 1979; Bavelas, 1950; Connoly, 1977) and distributed intelligence (Carley, 1992; Carley and Svoboda, 1996). In electronically mediated groups, the information processing capacity may be a function of the emergent network structure formed by e-mail exchange (Carley with Wendt, 1991).

Considerable theory-based research on network structures has emerged in recent years (Cook, 1977; Burt, 1980; Granovetter, 1985; Williamson, 1991; Carley, 1991; Monge and Contractor, 1997). Monge and Contractor (1997) have reviewed eleven sets of theories that have been used to explain emergent networks. These theoretical perspectives include resource dependence and related exchange theories, contagion theories, cognitive theories, and theories of network and organizational forms. These diverse theories are unified in part through the use of network analysis which is based on graph theory (Scott, 1991) and by an interest in structure which has been defined as a "overall system, network or pattern of relations" (Nadel, 1957, p.12) which can be derived from observable actions of individuals.. This paper draws on the network and organizational forms perspective which defines network forms as network patterns that recur in multiple settings (Monge and Contractor, 1997). In our networks, the nodes are indivudals and the relationship between individuals is the "tie" or "link." Although these links are the unit of analysis, the focus is on the whole structure within which the communication occurs.

Within organizations, structural patterns of communication become institutionalized over time and contribute towards group stability (Burkhardt and Brass, 1990; Carley, 1991). But what form should this pattern of ties take on in a virtual organization? What type of structure will emerge? Traditional organizations have a tendency, at least in their authority structure to be hierarchical and centralized. However, researchers have argued that in virtual organizations the structure that will emerge will be a more amorphous web of connections (i.e., a network). Baker (1992) has claimed that "the network form is designed to handle tasks and environments that demand flexibility and adaptability" and that "unlike a bureaucracy, which is a fixed set of relationships for processing all problems, the network organization molds itself to each problem" (p. 398). In a virtual organization, where there is no imposed or assigned structure, ad-hoc groups or networks emerge through informal interaction in response to particular situations or to perform certain tasks (Finholt, Sproull, and Kiesler, 1990). These informal task-based ad-hoc groups (networks) are voluntary and can develop within or across formal groups (Finholt and Sproull, 1990).

In the literature on groups, structure has thus far been referred to in terms of centralization and hierarchy. However, as previously indicated, this literature has used the terms "hierarchical" and "centralized" loosely and sometimes, interchangeably. The conflicting predictions in the literature regarding the structure of virtual groups may well be due to this confusion in terminology. In the literature on structure of co-located groups, hierarchy has been measured in terms of organizational levels. Also, a centralized structure has been defined as one in which interactions are mediated by a supervisor. A decentralized structure, on the other extreme, is one that is fully connected and allows immediate feedback and error-correction (Tushman, 1979). We have used network measures of centralization and hierarchical levels to measure these structural properties. Centralization reflects the extent to which a network or group is organized around its focal point (Freeman, 1979). It is a measure of integration or cohesion of the group. A centralized network may reflect an uneven distribution of knowledge such that knowledge is concentrated in the focal points of the network. Finally, hierarchical levels (Hummon and Fararo, 1995) reflect the number of levels one must go through in order to obtain information. An existence of hierarchical levels indicates that members must go through someone rather than directly obtain information from the source.

In co-located groups, an exchange of favors relies on the assumption of stability of the community or group cohesiveness. A member of the community may provide information needed by another member due to a sense of community. There may be an inherent expectation in this exchange that since the relationships within the community are likely to be long lasting, sooner or later the favor is likely to be returned. In a virtual group with relatively high fluidity, exchange of favors is likely to be based on reciprocity in a relatively short time-span. Therefore, one additional structural property we consider addresses reciprocity of relationships or communication links.

This construct of degree-hierarchy (Krackhardt, 1994) suggests that a decentralized network may exhibit predominantly reciprocal links or unidirectional links. If the links are reciprocal, it may allow quick feedback and error-correction whereas a decentralized network without reciprocal links may not exhibit these properties. Degree of hierarchy (Krackhardt, 1994) is an indication of the extent to which it is possible to directly or indirectly reach people in the network. This is reflected by the degree to which relationships in a network are directly or indirectly reciprocal. Reciprocal relationships reflect teamwork while an abundance of unreciprocated relationships are seen in more hierarchical networks.

In using social network constructs, it becomes apparent that a network that is centralized does not necessarily have to be hierarchical. That is, relationships may be reciprocal but they may be organized around a central person. Similarly, a network can be hierarchical in the sense that the relationships among its members are not reciprocal, but it may exhibit few levels of influence or command. On the other hand, relationships may be reciprocal, but only indirectly (i.e., through other people), indicating a low degree of hierarchy but with high number of hierarchical levels. A virtual organization can develop in different ways in response to the different internal and external uncertainties (such as turnover, change in leadership) and exhibit any combination of these structural dimensions. For conceptual clarity we will distinguish among these three structural dimensions of centralization, degree of hierarchy, and hierarchical levels in the context of a virtual organization. We will empirically demonstrate that they are distinct.

Task characteristics, network structure and network performance

Several studies have supported the argument that the fit between information processing needs (which is a function of the task being performed) and information processing capabilities (which is a function of the emergent network structure) determines performance (e.g., Galbraith, 1977; Aiken and Hage, 1968; Woodward, 1961)[ii]. Keller (1994) examined the effect of the fit between routineness and information processing needs on project performance and found support for this relationship. David *et. al.,* examined linkages between technology and structure at the group level of analysis as predictors of group performance. Tushman (1979) found that task characteristics and interdependence influence the degree of decentralization in communication structure and that these effects are accentuated for high-performing subunits. Several researchers have found that centralized organizations were more efficient for routine tasks (see Shaw, 1964 and Monge and Contractor, 1997 for reviews on this topic). Second, people in the decentralized organizations were more satisfied with the work processes than people in centralized organizations. However, the relationship between task and structure and its effect on performance has not been studied at all in the context of the virtual organizations.

In general, different types of structure are better suited for different tasks (Lin and Carley, 1997). Baker (1992) has claimed that “the network form is designed to handle tasks and environments that demand flexibility and adaptability” and that “unlike a bureaucracy, which is a fixed set of relationships for processing all problems, the network organization molds itself to each problem” (p. 398). This implies that the emergent network structure should vary by the nature of the task being performed. If the emergent network structure is suitable for the task characteristics, it should enhance the task performance. A network structure unsuitable for the task may hinder task performance. The general hypothesis of this study is that the fit between task characteristics and network structure is associated with superior network performance. In the context of section, we discuss concepts of task characteristics, network structure, and network performance.

----- Figure 1 about here -----

Task characteristics

By determining the information processing requirements of the group, the task routineness influences the group’s communication structure (Galbraith, 1977). Degree of routineness is a function of the extent to which the task contains variety and is analyzable (Perrow, 1967). Routine tasks are characterized by low variety or a small number of exceptions and high analyzability in terms of alternative courses of action, cost, benefits, and outcomes (Daft and Macintosh, 1981). Non-routine tasks are less predictable and require creativity. Perrow (1970) has suggested that routine tasks benefit from the bureaucratic structures of hierarchies in that they can get the tasks done without delay and errors. A flexible group structure provided by teams is required when the task is complex and demands innovativeness (nonroutine) (Baron, Kerr, and Miller, 1992). The fit between the task of a unit and the ability of its structure to process the information required to perform the task (Galbraith 1977, Daft and Macintosh, 1981; Tushman and Nadler, 1978) determines task performance.

Organizational theory has identified task analyzability and task variety as two components of task routineness, (Perrow, 1970).

Task analyzability is a measure of the extent to which a task can be broken down into small well-defined components. Conceptually, it is similar to Thompson's knowledge of cause-effect relationships (1967) or Cyert and March's search procedures (1963) which make a decision routine.

Task Variety indicates to what extent there is variation in the task over time. A large number of exceptions lead to high task variety. This concept is similar to task variability (Pugh *et al.* 1969; Van de Van and Delbecq, 1974); predictability (Galbraith, 1977; March and Simon, 1958), complexity (Duncan, 1972), and sameness (Hall, 1962).

Network Performance

Most organizational researchers have concerned themselves with organizational level measures of performance. However, in the context of a virtual organization, where task-related networks are formed by individuals across organizational boundaries, a focus on organizational outcomes is inadequate because such an outcome only reflects how well the individual organizations are performing and not how well the virtual organization is performing. For virtual organizations, performance metrics must cross organizational boundaries and take into account the collaboration. Therefore, measures of collective effectiveness are needed. In situations where several separate organizations collaborate, it is conceivable that each individual organization is effective on its own, yet the collaborative effort among them is not effective (e.g., Provan and Milward, 1995). As information technology enables collaborative work across organizations, there is a clear need for further research employing network level outcomes. One of the attempted contributions of this study is to demonstrate the use of network effectiveness as an outcome in virtual organizations.

Ad-hoc networks formed by email exchanged regarding different tasks and their relative performance are examined. Both perceptual and "objective" data are used to measure the performance of these collectives. This was done to overcome limitations of using any one type of performance data alone. Perceptual data is liable to subjective bias whereas "objective" measures of performance may not reflect the satisfaction of the group members with the tasks. Satisfaction of group members with the process is an important indication of effectiveness.

Hypothesis

An objective of this study is to examine the effect of fit between task routineness and network structure on network performance. In light of the above discussion, we expect that if the network structure of a group performing a routine task is hierarchical, then the task should be performed effectively. Similarly, if a nonroutine task is performed by a non-hierarchical or team-oriented group, it should be performed effectively. Thus, it is expected that network performance will be influenced by the fit between task and structure.

Similarly, a high level of centralization in a group attempting to accomplish a non-routine task will adversely affect the performance. If the information regarding a non-routine task was centralized in relatively few people, it should result in the group being less productive as a large amount of group's creativity will remain untapped. Such creativity is not required in a routine task, and having someone in-charge of the task, while others follow instructions, is efficient. Therefore, if the structure of a network performing a routine function is centralized, the network should perform better.

Further, existence of few levels in a network may allow it to be flexible while performing a non-routine tasks. Overall, we expect that when routine tasks are performed in a highly structured network and non-routine tasks are performed in a less structured (loose) network, superior performance will result.

Hypothesis: In a virtual organization, high (low) organizational task routineness coupled with a high (low) degree of hierarchy, centralization, and hierarchical levels will be correlated with high network performance.

Data and Method

In this study, we analyzed email interaction among members in a virtual organization to determine the network structure associated with the three tasks. Email data was collected at two points of time using identical procedures. Multiple measures of network structure were used to determine which, if any, dimensions of structure needed to fit the task characteristics for effective network performance. Both objective and perceived performance measures were utilized. Questionnaire and interview data were used to determine task routineness and perceptions of performance.

Data

Data consisted of all email messages exchanged among the Soar members from summers (June, July and August) of 1989 and 1993. Summers were considered appropriate because in the academic world, most of the research is performed during this period when the teaching load is either low or non-existent. We confirmed this by comparing the summer and non-summer volume of email messages. The senior members of Soar approved use of these email archives for research. All members were notified that any mail sent to distribution lists was being archived and may be used for research purposes.

We wanted to include email messages from all Soar members but not the casual inquirers in this study. Therefore, we decided to include messages from all individuals who sent more than one message to the group and received more than two responses from the group. These selection criteria were chosen because a typical casual exchange consists of one message of inquiry and two responses from one of the Soar administrators. One response contains an acknowledgment and the other consists of a description of the Soar architecture and participants. By using the above selection criteria, we were able to ensure that only the members with more than a casual contact with the Soar group were included in the study. Since our concern was with the informal structure, we did not include messages sent to distribution lists (such as bug reports) in our analysis.

Measurement

Measurement of variables is discussed in the following paragraphs.

Task routineness

Relative routineness of the three tasks was measured based on perceptions of the Soar members. This was assessed using questionnaires. To determine the perceptions of task characteristic in terms of routineness, the instrument developed and validated by Daft and Macintosh (1981) was utilized. Withey, Daft, and Cooper (1983) evaluated six instruments that assess Perrow's dimensions of work unit technology. They found Daft and Macintosh (1981) as well a Van de Ven and Delbecq (1974) to be better instruments than other instruments they reviewed. We used the Daft and Macintosh instrument because it scored well on most convergent criteria and provided better discrimination across subunits.

The Daft and Macintosh instrument is based on the routine-nonroutine continuum described by Perrow (1970), derived by aggregating task analyzability and task variety. Their instrument consists of a 5-item scale each for task analyzability and task variety. The items used in the questionnaire are shown in Appendix 1. We asked the respondents to indicate the extent to which each of these items applied to the given tasks on a five-point scale ranging from "very little extent" to "very great extent". We broke down the tasks into subcategories similar to those shown in Appendix 2.

Reliability

The internal reliability of the analyzability and variety constructs was computed using Cronbach's coefficient alpha. In their paper, Daft and Macintosh reported a coefficient of .86 for analyzability and .77 for variety. The coefficients computed in this study were slightly higher at .92 for analyzability and .79 for variety, both of which are well above the .70 required for acceptable scale reliability (Nunnally, 1978). The alpha coefficient for the combined scale for routineness was .93.

Network structure

A variety of measures of network structure based on the distribution of units and positions have been proposed (see Lin, 1994 for a review). Measures which are considered to be important in the context of email communication are degree of graph hierarchy, centralization, and hierarchical levels. These measures of structures are used because they apply to directed graphs (graph which show direction of the communication through arrows) depicting communication taking place among different points in a graph.

Graph hierarchy

The notion of graph hierarchy is grounded in the idea that all complex systems, including informal organizations have a certain level of hierarchy (Simon, 1977). Krackhardt (1994) developed the measure of graph hierarchy which indicates the extent to which relations among the individuals in the organization are "ordered" and there is little, if any reciprocity. Krackhardt's measure of graph hierarchy is defined as follows:

$$\text{Graph hierarchy} = 1 - \left[\frac{V}{\text{Max}V}\right]$$

where V is the number of unordered or reciprocated links in the organization (A is linked to B and B is linked to A), and Max V is the number of unordered pairs of points (A is linked to B or B is linked to A). A graph that is completely hierarchical will have no "reciprocated" or symmetrical links. Graph hierarchy in a completely hierarchical network graph will be 1 whereas a completely non-hierarchical graph will be indicated by a score of 0.

Centralization

Another measure of structure is centralization. Centralization refers to overall integration or cohesion of a network graph. Centralization indicates the extent to which a graph is organized around its most central point (Freeman, 1979). We use the measure degree centralization. The degree of a point is shown by the number of arrows coming in or going out of the point in a graph (Freeman, 1979). Conceptually, the degree of a point in the graph is the size of its neighborhood. Naturally, this measure is sensitive to the local dominance of points (Scott, 1992). This is measured by the aggregate difference between the centrality scores of the most central point and those of all other points. It is the ratio of the actual sum of differences to the maximum possible sum of differences. Degree centrality scores can range from 0 to 1, 0 being the score for a completely decentralized network.

Hierarchical levels

The hierarchical levels measure (Hummon and Fararo, 1995) is based on an examination of the whole structure. This measure is based upon the notion of cycles of connected nodes. A cycle is a path which returns to its own starting point (Scott, 1991). To compute hierarchy, first a directed graph is condensed using the following steps (Harry, Norman and Cartwright, 1965, p.60):

1. The graph is partitioned into exclusive cycles or subsets Si.
2. Define a tie from subset Si to Sj if and only if there is a tie from a node in subset Si to a node in Sj.

The simplified graph that results from this process of condensation is a new graph that is a directed acyclic graph or DAG. The measure of hierarchical levels is based on the DAG properties of a graph.

Figure 3 illustrates the process of condensation of a directed graph with cycles. Nodes 1, 2, and 3 are connected by a cyclical pattern and form a subset S2. The nodes 4 and 5 do not form any cycles and form subsets S1 and S3. Thus the condensed graph has three ties - S2-S1, S3-S1, and S3-S1.

The next step is to count the number of nodes in the longest path through the condensed graph. In the example here, there are three nodes and two ties in the longest path S2-S1-S3. This indicates that there are three levels in the network graph.

Finally, the number of levels are normalized in terms of the number of nodes in the graph so that the measure will range from 0 for a single level graph and 1 for a completely ordered graph. This is done using the following formula

$$H_L = \frac{L-1}{N-1}$$

where L is number of levels and N is the number of nodes. The H_L in this case is:

$$H_L = \frac{3-1}{2-1} = .50$$

----- Figure 3 about here ------

The notion of fit

The concept of fit used in this study follows the general congruency type of fit used by David *et al.* (1989). This notion of fit is consistent with general congruency concept proposed by Joyce, *et. al.*, (1982). The general congruency concept is also consistent with the ideas of Van de Ven and Drazin (1985), and Alexander and Randolph (1985) which suggest that for each value of routineness, there exists a best value of group structural variable to yield highest performance.

David *et al.* (1989) as well as Alexander and Randolph (1985) defined the congruence fit as the absolute difference between the value of a pair of structure (Si) and task routineness (Ti) variables. The closer the group structure value is to the task routineness value, the better the fit. Therefore, fit approaching 0 reflects the best possible fit. We hypothesize an inverse relationship between the fit value and (network) performance.

$$\text{Fit} = |Si - Ti|$$

The group structure value close to the task routineness value indicates a good fit. Fit approaching 0 reflects the best possible fit. In the current study, routineness was measured on a 1 to 5 scale and network structure (e.g., degree of hierarchy -HD) on a 0 to 1 scale. In order to convert graph hierarchy into a measure which is directly comparable to routineness, a hierarchy index as suggested by Provan and Milward (1995) was computed (Si = (HD * 4) + 1). The difference between routineness value and hierarchy index provides task-structure fit value. Centralization and hierarchical levels were the two other structural measures used in this study and they were also measured and converted in the same manner as degree of hierarchy.

Performance

Objective as well as perceived measures were utilized. Using objective as well as perceptual measure of productivity also assures us a more complete understanding than either one of the measures would afford us if used alone.

The nature of the group and its members is such that rewards are generated in advancement of knowledge which is represented in the form of publications. Since most of the Soar members are academic or corporate researchers, they are interested in producing results of their work in the form of publications. Therefore, one measure of the effectiveness of research and design can be provided by the number of Soar-related publications of its members. The fit of the task and structure should result in member perceptions of effectiveness as well as productivity of the individual members as represented by the output or publications

Therefore, objective performance was examined using the number of publications during the two-year period following the data collection. The two years following the study period were included to account for the time lag between research work and publication of that research. The network performance data was obtained by averaging the publications of all the members of the network.

Data on the perceptions of the group members on effectiveness of the various tasks performed by the group was collected using a questionnaire. The three tasks of research and design, group maintenance, and resource management were broken down into subtasks as shown in Appendix 2. The respondents were asked to rate on a 5-point scale how effectively they thought the group performed each of the listed subtasks.

Procedures

A total of 928 messages from the summer of 1993 were read individually and classified based on the content of the message. Each message was classified in terms of task categories (design, group maintenance, and resource management). Although these task categories were conceptually distinct, a single message could belong to multiple categories if it contains distinct content referring to different tasks. Thus, theoretically it is possible for a message to belong to all three categories simultaneously. For example, if a member sent a message letting someone know of a design feature issue, and sought to meet with him or her regarding the same, we included this message in the design category as well as group maintenance category.

Members receiving carbon copies of messages were considered in a similar fashion as the primary receiver of the message. This is because each message type indicates a communication between the sender and each of the receivers. Thus, if a message was sent to one person and carbon copied to three others, we coded this information as four separate messages.

The number of messages exchanged regarding the three tasks are shown in Table 1. As can be seen from this table, the percentages of messages referring to the three tasks do not sum up to one hundred. The above procedures provide an explanation for this observation.

------ Table 1 about here ------

Inter-coder reliability

Messages were read and coded by one of the authors and one other coder. The coder was asked to refer to the sub-categories listed in Appendix 2 and classify the message to the appropriate task categories. A given message could contain content referring to more than one task and therefore could belong to more than one task category. For example, if a message referred to a meeting, the coder was asked to classify that message under group maintenance. Every two weeks, for a total of fifteen times, we randomly selected thirty messages each week from each coder's database and matched them. The inter-coder reliability was calculated using Scott's *pi* (Scott, 1955), which corrects the possibility of chance agreement. The inter-coder reliability was consistently higher than 90 percent and well within the accepted standards (Lasswell, et al., 1952; Thorndike, 1950).

Questionnaire administration

The questionnaire measuring perceptions of routineness as well as performance of different tasks was administered at a semiannual Soar workshop in March 1994. The questionnaire was distributed to 57 participants. The principal researcher attended the workshop and provided the group members with a brief description of the study. She then solicited their cooperation in completing the questionnaire during the workshop. Most members attending the workshop completed the questionnaire and returned it to the researcher at the workshop. The remaining questionnaires were returned through mail after the workshop. A total of 43 usable questionnaires were returned resulting in a response rate of 75%.

Results

Evidence of Network Structure

This section examines the nature of the structure in the Soar group.

As can be seen from Table 2, considerable evidence of hierarchy and centralization is present in the Soar group. This is interesting in light of the claims that virtual organizations in general tend to be non-hierarchical (Goldman *et. al.*, 1995; Beyerlein and Johnson, 1994; Camillus, 1993; Mills, 1991; Drucker, 1988) and decentralized (Baker, 1992). However, it is important to remember here that the researchers on virtual organizations have thus far used the terms "hierarchical" and "centralization" interchangeably and loosely (for example, by confounding degree of hierarchy and levels of hierarchy). It may well be that by using the precise definitions, it is possible to observe some aspects of structure that could be overlooked otherwise. The hierarchical levels indices, which is consistent with the traditional definitions of hierarchy, are relatively low indicating existence of flexibility in the group.

----- Table 2 about here -----

Task characteristics, network structure and network performance

??? Remove..?{{{PERSONALLY I WOULD KEEP THIS IN}}} An analysis of variance was performed to determine whether the three tasks (group maintenance, resource management, and design) were significantly different in their routineness. The means for each task are shown in Table .

-----Table about here -----

The routineness values in the above table provide a basis for hypothesis testing discussed in the following section.

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Hypothesis testing

We used Pearson's correlation to test whether there is a linear relationship between the task and structure fit and performance. The results indicate that organizational task routineness and structure fit is significantly correlated perceived performance (*r= -.77, p < .001; n=9).* This correlation is based on the fit value derived by subtracting the routineness value from the particular structural index and the perceived performance value for a particular task (Table 3). Figures 4a through 4c show the linear relationship between fit and perceived performance for organizational task in terms the three structural measures for both 1989 and 1993. The correlation of structural index values with objective performance was not significant (*r= ??? ; n=9).*

----- Table 3 about here -----

----- Figures 4a through 4c about here -----

Discussion

This research provided empirical evidence of existence of degree hierarchy, centralization, and hierarchical levels in a virtual group. The results suggest that when structure of a network performing a task is consistent with routineness of the task (e.g. when a network performing a non-routine task is team-oriented), the members are satisfied with the process regardless of the actual performance of the group but do not necessarily perform better in objective terms.

Nature of Structure

The results of this study indicate that considerable hierarchy and centralization were evident in the virtual organization studied. This finding appears to be contrary to the predictions of non-hierarchical and decentralized structure in virtual organizations. However, hierarchies have been associated with efficiency. For example, Simon (1977) instructed that hierarchies should not be thought of as necessarily harmful. He argued that among systems of a given size and complexity, hierarchies require less information exchange among their parts than do teams. Dispersed groups may rely on hierarchies for efficiency in communication and coordination. We also note that virtual organizations operate in an environment of high uncertainty. The type of uncertainty faced by the virtual organization at any given time may be a factor in the emergence of its structure.

High levels of centralization indicate uneven distribution of knowledge such that knowledge may be centered in a few individuals. While it may be true that in virtual groups expertise can be called upon regardless of where it resides, if the expertise resides in a small number of individuals, then all the inquiries will be directed at these individuals. Further, although obtaining access may be easy, considerable individual or collective effort may be involved in identifying the “right” people as sources for a given type of information or knowledge. We observed that in the Soar group, once certain people had been identified for specific types of information or knowledge, the group members had a tendency to direct suitable inquiries to those individuals directly. This is an example of the manner in which structure can solidify at least in the short run.

Our findings regarding presence of hierarchy in virtual organizations are also consistent with the findings of Applegate (1995). Applegate studied three major corporations in depth and concluded that hierarchy is present in today’s new forms of organization but that features of hierarchy are being uniquely combined with features of traditional organizational models of matrix and adhocracy. Based on the findings of these studies, claims regarding the lack of hierarchy in virtual organizations may need to be reviewed. At the very least, structure of other virtual organizations in different contexts should be empirically examined to assess the presence of hierarchy in them.

> According to Simon (1977), as decision processes become more explicit with organizational learning and growth, decisions become more transportable. Therefore, participation in information providing broadens but only a few people can take responsibility for the decisions. This will result in increased centralization. As seen in this research, this pattern of increased centralization over time may not hold true for virtual organizations. Stability in centralization in Soar group implies that the group has been able to retain a structure that allows a wide range of people to participate in decision-making and benefits from their varied expertise. One possible way virtual organizations may be able to retain and enhance their decentralization lies in the fluid composition of virtual organizations. Members in virtual organizations enter and exit more freely than the members of localized groups. This fluidity of membership may limit the transportability of decisions. Also, the ease of communication through information technology may allow many more individuals to participate in decision making in virtual organizations than in localized groups.

We observed several mechanisms in the Soar group that may help achieve and maintain its hierarchical structure. The group is funded by umbrella grants written jointly by the three most senior faculty members at the universities involved. The resources are allocated in a predetermined manner. High-level planning regarding resource allocation takes place among the few key members of the group. A small full-time paid staff is hired that is responsible for taking care of resources and group maintenance at the lower level. While most design discussions are decentralized and take place over email, resolution of issues often takes place at a higher level (involving the senior faculty). A typical research or design-related discussion over email follows this pattern - an issue is brought up usually by one member, if there is enough interest, an explosive discussion takes place that ends with a rejoinder by one of the senior members. Separate distribution lists and archival sites have been set up for specific purposes. For example, distribution lists exist for information dissemination regarding documentation, natural languages, bugs, patches, etc.. All Soar-related publications must be reported to the archives. All bug reports and patches are archived. All communications including casual inquiries are archived. All developments in the architecture are organized and members of paid staff use them to develop different versions of the system. These versions are released and made available through File Transfer Protocols or the World Wide Web.

The observation that the Soar group was found to be hierarchical is consistent with Simon's (1977) prediction that hierarchical structures are the most likely to appear through the evolutionary process of natural selection as the size and complexity grows. Soar has evolved from 3 locations soon after its inception to 27 locations in 1993. Tighter controls and efficient communication are needed to coordinate among members at a much larger number of geographical locations. Another explanation of this phenomenon can be found in the efficiency of hierarchies. While virtual organizations allow relatively easy access to people in the know by making it easy to obtain information from experts, the communication patterns also tend to establish such that efficient use of this expertise can be made.

At the same time, the Soar group on the whole as well as its design network have retained the advantages of decentralization by allowing a large number of people with diverse expertise to participate in decision-making.

Task and Structure fit

The relationship of task routineness and structure has been well established in literature and was also supported in this paper for virtual organizations. However, researchers have cautioned that the relationship between routineness and structure is a complex one and depends upon feedback from the environment, leadership, and particular sources of uncertainty. While some researchers have found that certain dimensions of uncertainty are associated with less formalized structures (Argote, 1982; Lawrence and Lorsch, 1967), others have suggested a contradictory relationship. For example, Bourgeois *et. al.* (1978), and Huber *et. al.* (1975) found that routineness is associated with tightening of organizational structure. Our findings in terms of hierarchy and centralization in the Soar group are consistent with tightening of the structure. In the Soar group, as in other virtual organizations, turnover is a source of uncertainty. Passing of the founder and leader of Soar group in 1991 can be viewed as a crisis that may have lead to a heightened sense of uncertainty. Hamblin (1958), too, has found that groups became more centralized in situations of crisis.

We found that the fit between positive association between organizational task and network structure, is associated with perceived performance but not with objective performance. This indicates that such fit makes members feel more satisfied with the process but does not necessarily lead to objective performance. One explanation of this finding may be that there are other factors at play that determine objective performance. An example of this may be the type of communication taking place (discussions versus telling someone what to do). If these findings hold in future studies, then other factors determining objective performance in virtual organizations should be examined. One example of such a factor may be the type of interaction taking place in order to accomplish a task. Discussions may be more suitable for certain tasks while other tasks can be performed best by a knowledgeable person giving instructions.

While it is interesting that the actual performance was not found to be associated with the organizational task-structure fit, the possibility that the performance measure based on publications alone does not fully capture the performance of the group needs to be considered. Although publications are a reasonable measure of an individual's performance given the nature of the group, the number of publications does not reflect the quality or impact of the publications. Thus, if a small number of publications by the individuals in one network had a higher impact than the larger number of publications by the members of another network, the measure of objective performance used would have missed it. The fact that we did not find a link between objective performance and task-structure fit may also be attributable to the possibility that publications were an individual effort and not an output of any of the three tasks considered in this study. However, we observed that most publications were a collaborative effort of two or three individuals. Future studies can consider an alternative objective performance measure of co-authored (as opposed to all) publications in virtual organizations. Future studies should also try to include quality as well as quantity produced in "objective" measures of performance. However, in order to judge the quality of work, the measure will have to include some amount of judgment or perception that then renders it less than factual. Clearly, it remains a challenge to find objective measures of performance that are free of limitations.

Overall, the results of this study indicate that considerable hierarchy exists in the virtual organization studied. Results also indicate that the perceived performance of a virtual organization is linked with the fit between organizational task routineness and network structure.

Contributions and limitations

The above discussion leads us to a fundamental question - to what extent do these virtual organizations resemble traditional organizations? To the extent that they have properties similar to traditional organizations, we may be able to build upon existing organizational theories to understand virtual organizations. If virtual organizations are a truly revolutionary form of organization as has been claimed, then we may need new paradigms to study virtual organizations. In this study, we found that at least in terms of structure, virtual organizations share some properties of traditional organizations. Specifically, they rely on centralized and hierarchical structure to maintain efficiency and stability. We also found that the emergent structures had a similar relationship with task characteristics as the one found in traditional organizations. However, our findings were different from those based on traditional organizations to the extent that the fit between task characteristics and structure did not explain objective performance. If these findings hold in future studies, we may be able to build upon some of the existing organizational theories of structure and performance by examining other determinants of objective performance in virtual organizations.

This study extends the research in the area of virtual organizations. Earlier claims related to structure of virtual organizations have been at worst speculative and at best theoretical. This study empirically examines the structure of an actual virtual organization. The findings can be used to build a theory of network structure and its relationship with different sources of uncertainty in this increasingly popular type of work environment.

Another contribution of this study is in providing a useful framework for examining virtual organizations. Virtual organizations like Soar are becoming increasingly common due to advancements in communication technology. The framework provided here can be used to examine other such groups in other contexts where organizational tasks may be different but communication tasks are likely to be similar. Finally, this study has provided insight into the relationship among of task, structure and performance of such groups.

The study has implications for design group support systems for localized as well as virtual organizations. The findings of this study might support some normative statements regarding the design of group support systems. If designed with that intention, these systems can be used to influence the group structure to fit the task being performed. For example, the systems can be designed to keep the coordination costs of group maintenance and resource management to a minimum without disturbing the cohesiveness of the group.

Limitations

Single group studies are limited in generalizing their findings to their particular contexts. This study is no exception. The above conclusions are based only on the observations in the group investigated in this study. Other studies will have to examine other settings to see if the findings can be applied to all virtual organizations. To a certain extent, the group studied here can be viewed as a prototype of the virtual organizations we can expect to see commonly in the near future. It is composed of individuals who have come together because of their common interest in a large-scale project. They work individually and the reward systems (publications and individual evaluations in their respective workplaces) are based on individual performance. Individual progress is dependent upon group progress and the group effort is coordinated toward a common goal of developing the Soar architecture. The characteristics of virtual organizations, i.e., geographical dispersion, commonality of goals, status differential and limited heterogeneity, apply to the Soar group. However, replication of this study in different settings is necessary and important before meaningful generalizations can be made.

Field studies are also limited by the fact that they have no control over the factors that might interfere with the phenomena under investigation. Further the findings of this study are limited to structures formed by email communication. It is possible the communication network formed by media other than email are substantially less hierarchical and centralized than that implied in this study and may off-set the higher degree of hierarchy and centralization observed in the email network. It remains to be seen whether other media or even a more structured electronic environment will render similar results. It is conceivable that face-to-face interaction in this group is less hierarchical and can offset the results based on examination of email interaction alone[iii]. However, our preliminary assessment based on the interviews indicates that the face-to-face interaction may be even more hierarchical than the email interaction. Similar studies examining other media can assess the task-structure fit and its impact on performance in groups of different sizes performing other types of tasks, using other media and in other settings.

The measure of email communication ignored volume and focused only on whether or not communication existed between two individuals. Although the volume of messages is an important factor in the communication patterns, it played no role in the investigation of structure. In a similar vein, the objective performance measurement included only one type of productivity. In a research and design group, other performance measures assessing the quantity and quality of software generated can be important.

In conclusion, the relationship between task characteristics and structure is a complex one and may depend on specific contexts. We examined only one type of virtual group involving a limited number of tasks. Different contexts and tasks need to be examined separately to determine how they affect structure. This relationship may also vary among different contexts. Future studies of structure in virtual organizations should examine different contexts and sources of uncertainty.

This study extends the research in the areas of virtual organizations and the impact of task-structure fit on effectiveness of research and development organizations. It empirically examines the structure of an actual virtual organization and provides a foundation for theory building regarding this increasingly popular type of work environment. The study also introduces network analysis as a methodology for studying virtual organizations. By building on this study, researchers can begin to address some of the issues related to virtual organizations, and increase their effectiveness and performance. Researchers can also potentially build on this research to design specifications for computer support facilitating communication in virtual organizations.

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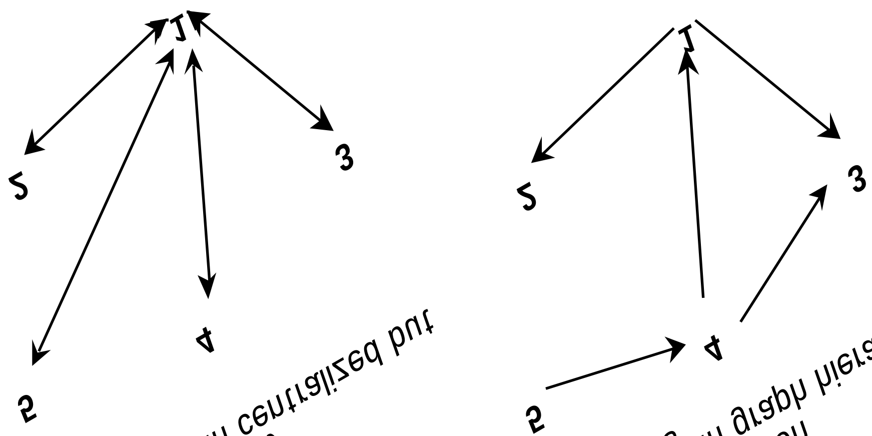

A network high in centralized but low in graph hierarchy

A network high in graph hierarchy but low in centralization

Figure 1: Centralized and hierarchical networks

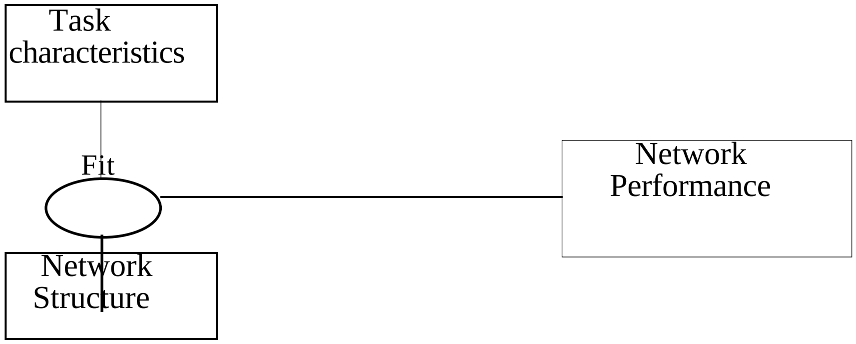

Figure 2: A model of network performance in virtual organizations

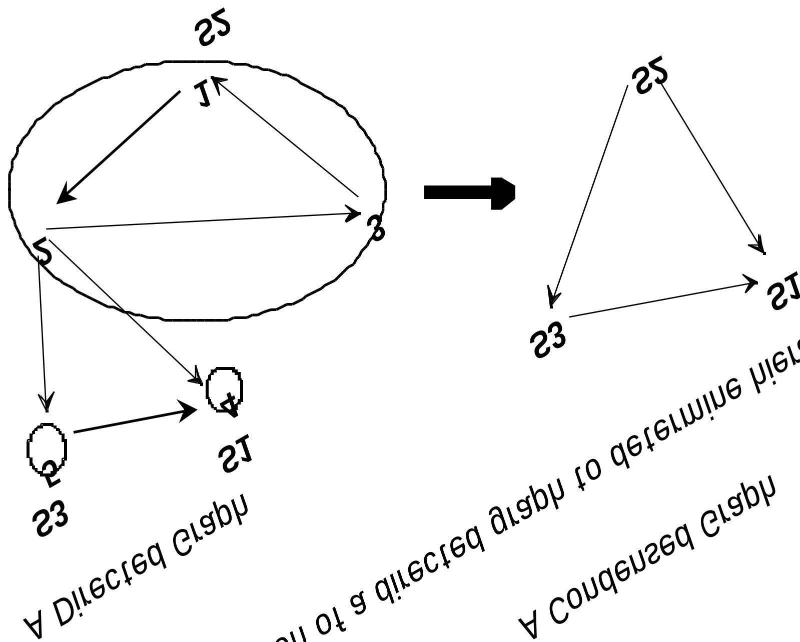

Figure 3: Condensation of a directed graph to determine hierarchical levels

Source: Hummon and Fararo, 1995

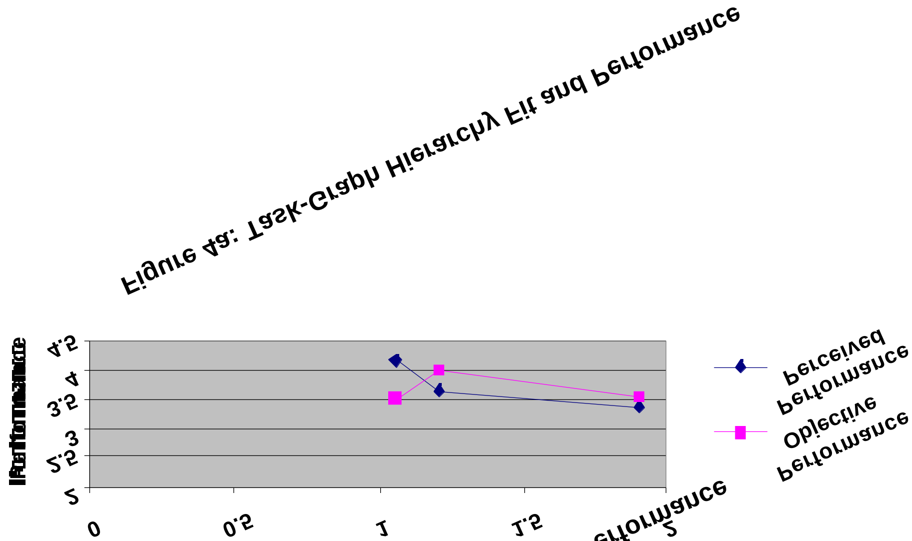
Figure 4a: Task-Graph Hierarchy Fit and Performance
Performance
Fit
Perceived Performance
Objective Performance

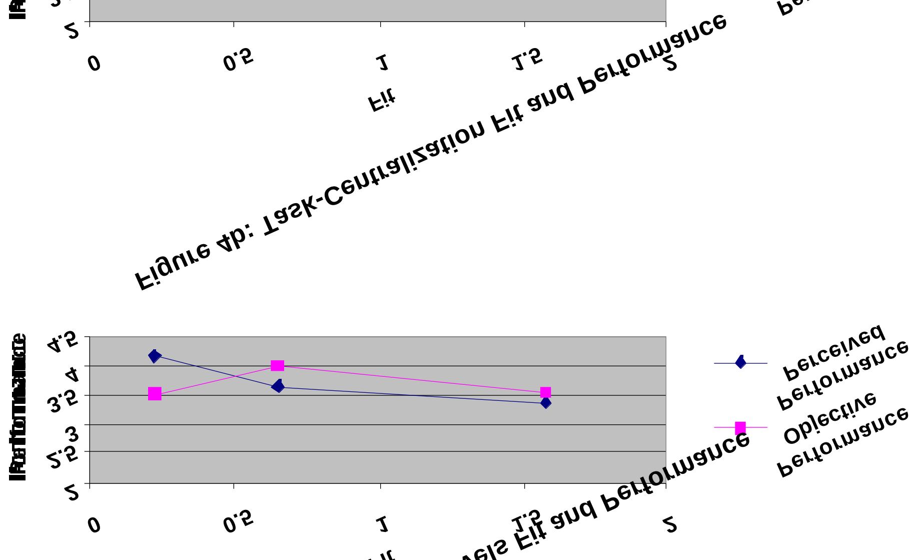
Figure 4b: Task-Centralization Fit and Performance
Performance
Fit
Perceived Performance
Objective Performance

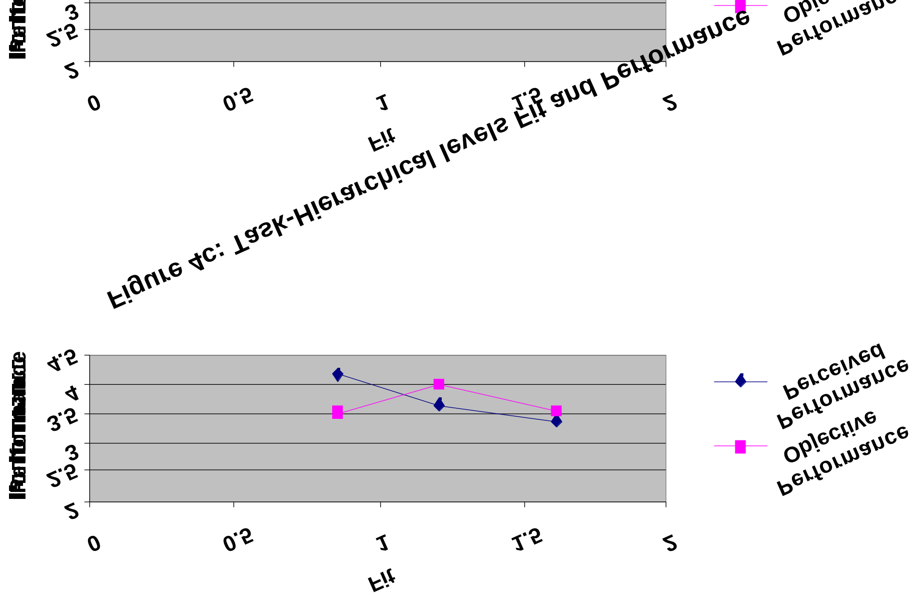
Figure 4c: Task-Hierarchical levels Fit and Performance
Performance
Fit
Perceived Performance
Objective Performance

Table 1: Number of messages sent for each task			
Task	Number of messages	Percentage	Number of people
Design	629	68%	61
Group Maintenance	559	60%	50
Resource Management	512	55%	55
Total	928		66

Not:The percentages do not sum up to one hundred because each message could contain content relating to more than one task categories.

Table 2: Degree of hierarchy, centrality, and hierarchical levels of organizational tasks			
Organizational Task	Degree of hierarchy	Centrality	Hierarchical levels
Design	0.88	0.81	0.80
Resource Management	0.87	0.82	0.66
Group Maintenance	0.84	0.84	0.70

Table 3: Organizational task routineness, centralization, and network performance			
	Design	Resource Management	Group Maintenance
Perceived Performance	**3.36**	**4.17**	**3.63**
Objective Performance	**3.54**	**3.52**	**4.0**
Routineness (Ti)	2.62	3.42	3.15
Degree of Hierarchy	0.88	0.87	0.84
Structure Index (Si)	4.52	4.48	4.36
Fit (Si - Ti)	**1.90**	**1.06**	**1.21**
Centralization	0.81	0.82	0.84
Structure Index (Si)	2.62	3.42	3.15
Fit (Si - Ti)	**1.62**	**0.86**	**1.21**
Hierarchical Levels	0.80	0.66	0.70
Structure Index (Si)	4.20	3.64	3.80
Fit (Si - Ti)	**1.58**	**0.22**	**0.65**

Add in text describing the Soar group

Member type	**1993**
Faculty	11
Students	25
Paid Staff	8
Senior Researchers	18
Others	4
Total	66

Appendix 1: Items used to measure organizational task routineness

Analyzability

1. Normal work activities guided by standard procedures, directives, rules, etc.
2. Know a lot of procedures and standard practices to do the work well.
3. Understandable sequence of steps that can be followed in carrying out the work.
4. People actually rely on established procedures and practices.
5. Established materials (manuals, standards, directives, statutes, technical and professional books, and the like) cover the work.

Variety

1. Variety in the events that cause the work.
2. Describe the work as routine.
3. Work decisions are similar from one day to the next.
4. Takes a lot of experience and training to know what to do and when a problem arises.
5. Tasks require an extensive and demanding search for a solution.

Appendix 2: Subtasks listed on the questionnaire to measure perceptions of performance

Research and Design
Designing Soar software modules
Using Soar for designing other Soar productions

Design - Patches and Bugs
Finding and solving bugs
Making members aware of bugs

Design - Implementation
Getting newer versions of Soar to members
Assisting members in getting started with the new versions

Design - Planning and Analysis
Planning the general direction of Soar architecture
Analysis of individual Soar productions

Design - Documentation
Writing and maintaining manuals
Getting the documentation to members

Resource Management - Hardware
Installing and maintaining user work stations and other hardware

Resource Management - File management
Maintaining archives, backups
Naming and maintaining directories, etc.

Resource Management - Disk space
Allocating and maintaining disk space

Resource Management - Security
Coordinating and monitoring access to software
Licensing, etc.

Resource Management - Operating System/environment
Maintaining the systems
Assisting with problems and features

Group maintenance - Distribution lists
Maintaining distribution lists
Adding new members to mailing lists

Group maintenance - Events and workshops
Scheduling meetings, organizing workshops, organize rides

Group maintenance - Publications

Adding new publications to library
Maintaining publication archives

End-notes

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[i] The Soar group generally hires one full-time systems administrator for each of the three main sites - Carnegie Mellon, Michigan, and Southern California. These employees are supported by joint umbrella grants written by these institutions.

[ii] For a meta-analytic theory testing on the relationship between task technology and structure, see Miller, *et.al.*.

[iii] We are grateful to an anonymous reviewer for this comment.