Network Structure in Virtual Organizations

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Abstract

Virtual organizations that use e-mail to communicate and coordinate their work toward a common goal are becoming ubiquitous. However, little is known about how these organizations work. Much prior research suggests that virtual organizations, for the most part because they use information technology to communicate, will be decentralized and nonhierarchical. This paper examines the behavior of one such organization. The 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. We empirically measure the structure of a virtual organization and find evidence of hierarchy. The findings imply that the communication structure of a virtual organization may exhibit different properties on different dimensions of structure. We also examine the relationship among task routineness, organizational structure, and performance. Results indicate that the fit between structure and task routineness affects the perception of performance, but may not affect the actual performance of the organization. Thus, this virtual organization is similar to traditional organizations in some ways and dissimilar in other ways. It was similar to traditional organizations in so far as task-structure fit predicted perceived performance. However, it was dissimilar to traditional organizations in so far as fit did not predict objective performance. To the extent that the virtual organizations may be similar to traditional organizations, existing theories can be expanded to study the structure and perceived performance of virtual organizations. New theories may need to be developed to explain objective performance in virtual organizations.

(*Virtual Organizations*; *Network Structure*; *Task Routineness*)

Introduction

Today's organizations are faced with a dynamic and turbulent environment that requires flexible and fast responses to changing business needs. Many organizations have responded by adopting decentralized, team-based, and distributed structures (DeSanctis and Jackson 1994, Drucker 1988) variously described in the literature as virtual, network, and cluster organizations (Beyerlein and Johnson 1994, Camillus 1993, Goldman et al. 1995, Mills 1991). Advances in communication technologies have enabled organizations to acquire and retain such distributed structures by supporting coordination among people working from different locations. Despite the rapid increase in the number of organizations that are becoming distributed, little is known about the structure or performance of such organizations. This research examines network structure of a virtual design organization using a social network approach (Tichy and Fombrun 1979, Tushman 1978, Brass 1985, Burkhardt and Brass 1990).

Specifically, this research has two objectives. First, it conceptually clarifies and empirically examines three distinct dimensions of emergent network structure in virtual organizations. Second, following the literature on traditional forms of organization, we posit that in a virtual organization, the fit between task routineness and network structure is associated with superior network performance. This contributes by extending the literature on task-structure fit to virtual organizations.

In discussing the new forms of organization enabled by information technology, Drucker (1988) suggests that this transformation is most evident in the area of research and development. Since 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 organization (Eisenhardt 1989). This study represents one such attempt and examines a virtual organization engaged in research and development.

The paper is organized as follows. First, virtual organizations are discussed in general, and the specific research context in which this study was conducted is described. The research model is then presented, followed by a description of the data and methodology. Finally, results are reported and limitations and contributions of the study are offered.

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Virtual Organizations

Lipnack and Stamps (1997) 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). 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 their work 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 on an ongoing basis. These members assume well-defined roles and status relationships within the context of the virtual group that may be independent of their role and status in the organization employing them.

A key feature of virtual organizations is a high degree of informal communication. Because of a lack of formal rules, procedures, clear reporting relationships, and norms, more extensive informal communication is required (Monge and Contractor 1998). Formal communication, which is noninteractive and impersonal involves use of media such as reports and structured meetings. It is a function of the formal hierarchy embedded in the system. 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 facilitate downward transmission of orders and upward transmission of information (Monge and Contractor 1998, Weber 1947).

By contrast, informal communication is personal, peer oriented, and interactive; it involves media such as face-to-face meetings and e-mail. Informal interaction determines a network's structure, which emerges as the members perform the organizational tasks (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. 82). Researchers have found that network structures explain organizational behavior better than formal structures (Bacharach and Lawler 1980, Krackhardt and Hanson 1993, Monge and Contractor 1998).

Historically, virtual organizations have used electronic mail (e-mail) to share information and coordinate their work. Use of e-mail allows these groups to call on expertise whenever needed, regardless of where it resides. This use of e-mail enables a group to create and sustain its identity without a shared physical setting and enables existence of a group without visible participants (Finholt and Sproull 1990).

The new organizational forms may exhibit emergent structures that result from communication through information technologies that facilitate lateral communication and have little regard for traditional hierarchy. Research on computer-mediated communication suggests that individual characteristics such as role and status are less influential in such communication (Sproull and Kiesler 1986). However, the information-processing needs of individuals varies based on their role and status in the virtual organization, resulting in different e-mail communication patterns. Indeed, more recent research has found that these individual characteristics can influence communication patterns (Saunders et al. 1994, Cohen and Zhou 1991, Zack and McKinney 1995), and therefore may affect communication structure.

Previous research suggests that virtual organizations tend to be nonhierarchical (Beyerlein and Johnson 1994, Camillus 1993, Goldman et al. 1995, Mills 1991) and decentralized (Baker 1992). For example, Baker (1992) suggests ". . . at least in metaphor, the network organization is a market mechanism that allocates people and resources to problems and projects in a decentralized manner" (p. 398). However, there is little empirical research on structure of virtual organizations. Further, since the research on virtual organizations is still evolving, the literature still lacks precision on the terminology used to describe them, particularly with respect to structure. For example, the terms decentralized and nonhierarchical are used interchangeably to describe the structure of virtual organizations. This research suggests that structure of virtual organizations needs to be analyzed along three distinct dimensions (degree of hierarchy, centralization, and hierarchical levels). An attempt is made to conceptually distinguish among these structural dimensions.

A Virtual Organization—The Soar Group

A virtual organization engaged in research and design of a general purpose artificial intelligence architecture (Soar) was examined. The following paragraphs describe the Soar architecture, the Soar group (as it is commonly referred to), and the nature of tasks performed by the Soar group.

The Soar Architecture. Soar was initially developed in 1982 at Carnegie Mellon University and was originally defined as "State Operator And Result" (Carley and Wendt 1991). Soar is an architecture for a general intelligence system that learns about possible solutions to problems as it solves them and thus continuously improves its capability to solve similar problems. As this system was being developed, Soar also became a tool for studying the theoretical construct of cognition (Newell 1990). 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 from one school of thought is, "Two or more individuals who influence each other through social interaction" (Forsyth 1983, p. 81). Another school of thought suggests that the existence of interaction and mutual influence is not a sufficient condition for a collection of individuals to be viewed as a group (Baron et al. 1992). Furthermore, groups must have some permanence, structure, and a sense of belonging. The Soar group fits both these definitions. Soar members, through e-mail interaction, influence each other's work involving Soar. The group arose in an unplanned manner from voluntary participation of academic and corporate researchers. The members of the Soar group have a sense of belonging that is fostered and maintained by participation in semiannual 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 academic researchers and developers at Carnegie Mellon University, University of Michigan, and University of Southern California. Researchers from several corporations such as Xerox and Digital Equipment Corporation are also involved.

The Soar group is comprised of researchers acting as users (those who use Soar for developing applications) and developers (those who develop the Soar architecture) The members are faculty, corporate researchers, graduate students, and paid staff responsible for day-to-day operations of the group. Soar members are bound by a common interest in Soar. 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. Members collaborate in a variety of research domains including cognition, natural language understanding, and robotics. Most collaborated projects include corporate as well as academic participants.

Like many virtual organizations, the Soar group communicates extensively by e-mail to share information and coordinate tasks. Members use the Soar group for ideas, feedback, support, and stimulation. Information exchange through e-mail can take various forms. For example, a member can inform the group through e-mail 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. Someone else who may have encountered this bug or problem may respond with a solution. The Soar group holds workshops twice a year, where the 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.

Tasks in Soar Group. In principle, virtual organizations may face either routine or nonroutine tasks. In fact, the Soar group faces both. Prior research has demonstrated that formal interaction is useful for structured activities but is ineffective when the situation lacks certainty and structure (Kraut and Streeter 1995). Software development is typically considered an unstructured and nonroutine task (Kraut and Streeter 1995). Software development is typically considered an unstructured and nonroutine 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 design, including research and development, of the Soar architecture. In addition, group maintenance and resource management tasks are also important for the long-term survival of the group. 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. All known bugs and fixes are recorded in Soar archives that are available to all members. Archives of all group e-mails 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, such as organizing meetings and workshops and maintaining distribution lists. 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 belonging. 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.

Resource management is a challenge to every group or organization's effectiveness. The main supply 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 universities take turns in writing the umbrella grants and acting as principal investigators. Money is only one of several resources the Soar group uses; group members must also manage others, such as personnel, machines, disk space, computer time, etc. Decisions must be made on how best to use these resources toward the organizational goals.

Since most of the Soar members are academic or corporate researchers, their reward structure centers around advancement of knowledge in the form of publications. Therefore, one measure of the effectiveness of the Soar group can be provided by the number of Soar-related publications of its members.

Development of the Model

Network Structure in Virtual Organizations

This research is grounded in the view that organizations are information-processing systems (Galbraith 1977, March and Simon 1958). Organizations design their structure, processes, and information technologies for the purpose of processing, exchanging, and distributing the information required for their functions (Duncan 1973, March and Simon 1958). Researchers have examined network structures based on verbal communication as an important determinant of an organization's information-processing capacity (Bavelas 1950, Connoly 1977, Tushman 1979) 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.

Considerable theory-based research on network structures has emerged over the last 25 years (Burt 1980, Carley 1992, Cook 1977, Granovetter 1985, Monge and Contractor 1998, Williamson 1991). Monge and Contractor (1998) have comprehensively reviewed several 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 social network analysis that is based on graph theory (Scott 1991) and by an interest in structure derived from observable actions of individuals (Nadel 1957). 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 1998). In this research, the nodes are individuals 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 (Burkhardt and Brass 1990, Carley 1992). But what form should this pattern of ties take 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. While traditional organizations are capable of changing their structure (DiMaggio and Powell 1983) and often do so as they adapt to changes in the environment or the available technology (Finne 1991), these changes may be mandated by top management. Researchers have argued that in virtual organizations the structure that will emerge will be a more amorphous web of connections (i.e., a network), changing constantly in response to information-processing needs.

In the literature on virtual organizations, structure has thus far been referred to in terms of centralization and hierarchy. However, as previously indicated, the literature on virtual and colocated (traditional) organizations has used the terms "hierarchical" and "centralized" loosely and, sometimes, interchangeably (Tushman 1979). In the literature on structure of colocated organizations, conceptualization and measurement of hierarchy reflects organizational levels. A centralized structure has been defined as one in which interactions are mediated by a supervisor. A decentralized structure, at the extreme, is one that is fully connected and allows immediate feedback and error correction (Tushman 1979). In this research, we have used network measures of hierarchical levels and centralization to measure these structural properties. These measures allow us to distinguish between these two structural properties of hierarchical levels and centralization and thereby add precision to the concept of network structure in virtual organizations.

One additional structural property we consider is reciprocity of relationships or communication links. In colocated 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 because of a sense of community. There may be an inherent expectation that since the relationships within the community are typically long lasting, sooner or later the favor is likely to be returned. In a virtual organization, although the common goal binding the members remains long-term, the membership itself may be relatively fluid, with members entering and exiting as their research needs evolve. In this scenario, exchange of favors is likely to be based on reciprocity in a relatively short time span. The recently developed construct of degree of hierarchy addresses this reciprocity (Krackhardt 1994). This construct suggests that hierarchy exists to the extent that members in a network can not directly or indirectly reach each other in a reciprocal manner (that is, A can reach B, but B can not reach A). A decentralized network may exhibit predominantly reciprocal links or predominantly nonreciprocal 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.

Thus, degree of hierarchy, centralization, and hierarchical levels are the three distinct dimensions of structure employed in this study. Degree of hierarchy (Krackhardt 1994) is reflected by the degree to which relationships in a network are directly or indirectly reciprocal. Reciprocal relationships indicate teamwork, while an abundance of unreciprocated relationships are seen in more hierarchical networks. 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. The existence of hierarchical levels indicates that members must go through someone rather than directly obtain information from the source.

In using social network constructs, it becomes apparent that a network that is centralized does not necessarily have to be hierarchical in terms of degree or levels (Figure 1a). That is, relationships may be reciprocal, but they may be organized around a central person. Conversely, a network can be hierarchical in the terms of reciprocity and levels but may only be low or moderate in centralization (Figure 1b). This can happen if the relationships are nonreciprocal but the power is distributed among several individuals. On the other hand, relationships may be reciprocal, but only indirectly (i.e., through other people), indicating a low degree of hierarchy but with moderate or high number of hierarchical levels (Figure 1c). 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. Therefore, it is important to distinguish among these three dimensions of network structure in virtual organizations.

Task Characteristics, Network Structure, and Network Performance

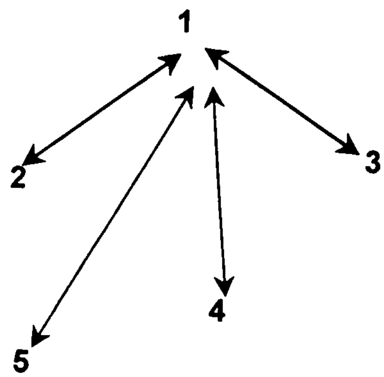
Several studies have supported the argument that the fit between information-processing needs (a function of the task) and information-processing capabilities (a function of the emergent network structure) determines performance (e.g., Aiken and Hage 1971, Galbraith 1977, Woodward 1961). Keller (1994) examined the effect of the fit between routineness and information-processing needs on project performance and found support for this relationship. David et al. (1989) examined linkages between technology and structure at the group level of analysis that predicts 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 are more efficient for routine tasks (see Shaw 1964 and Monge and Contractor 1998 for reviews on this topic). People in decentralized organizations are 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 virtual organizations.

In general, different types of structures are better suited for different tasks (Lin and Carley 1997). Baker (1992) suggests that all known virtual organizations either evolved in an unplanned manner or resulted from the redesign of nonnetwork organizations. If the virtual organization emerges unplanned, absence of prior structure allows the members to develop new structures through informal interaction in response to particular tasks (Finholt et al. 1990). These informal task-based ad hoc groups (networks) are voluntary and can develop within or across formal organizations (Finholt and Sproull 1990). Baker (1992) claims "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 (Figure 2). A network structure unsuitable for the task should hinder task performance.

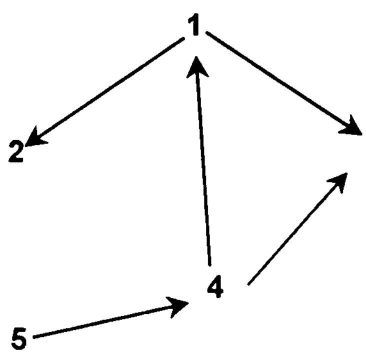
Task Characteristics and Network Structure. By determining the information processing requirements of the group, the task routineness influences the group's communication structure (Galbraith 1977). Degree of routineness is a function of the extent to which the task contains variety and is analyzable (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

Figure 1 Centralization, Degree of Hierarchy, and Hierarchical Levels in Networks

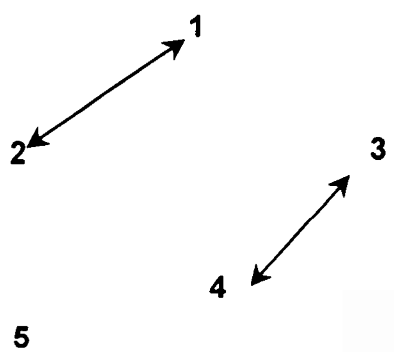
(a.) Centralization = 1.0, Degree of Hierarchy = 0, Hierarchical Levels = 0



(b.) Centralization = 0.4, Degree of Hierarchy = 1, Hierarchical Levels = 1



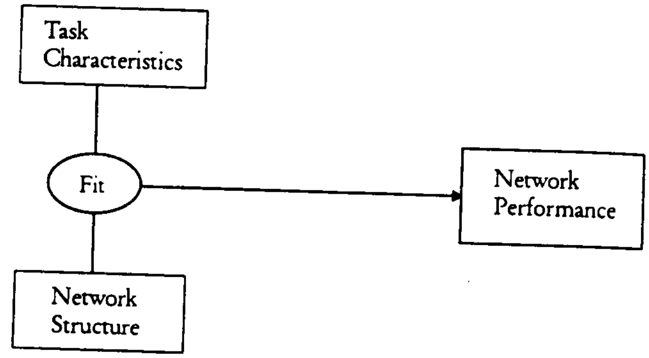
(c.) Centralization = 0.08, Degree of Hierarchy = 0, Hierarchical Levels = 0.5



and Macintosh 1981). Nonroutine tasks are less predictable and require creativity. Perrow (1970) suggests that routine tasks benefit from the bureaucratic structures of hierarchies because 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 et al. 1992).

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 (1967) knowledge of cause-effect relationships or Cyert and March's (1963) search procedures which make a decision routine. *Task variety* indicates the extent to which 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 1973), and sameness (Hall et al. 1967).

Figure 2 A Model of Network Performance in Virtual Organizations



Network Performance. Most organizational researchers have concerned themselves with organizational-level measures of performance. However, in the context of a virtual organization, in which 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 collaboration into account. 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.

This research examines ad hoc networks formed by e-mail exchange of their participants on different tasks and their relative performance. Both perceptual and objective outcomes were used to assess performance of these collectives. This was done to overcome limitations of using any one type of performance outcome alone. Perceptual outcome measures are 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

Based on the above discussion, network performance is expected to be influenced by the fit between task and structure. In addition, 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 nonhierachical or team-oriented group, it should be performed effectively.

A high level of centralization in a group attempting to accomplish a nonroutine task will adversely affect the performance. If the information regarding a nonroutine task is centralized among relatively few people, the group should be less productive since a large amount of the 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 more efficient. Therefore, if the structure of a network performing a routine function is centralized, the network should perform better.

Furthermore, existence of few levels in a network may allow it to be flexible while performing nonroutine tasks. Overall, we expect that when routine tasks are performed in a highly structured network and nonroutine 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 associated with high network performance.*

Method

This study analyzed e-mail interaction among members of a virtual organization to determine the network structure associated with three tasks. Questionnaire and interview data were used to determine task routineness and perceptions of performance. Publication archives were utilized for obtaining information on objective performance of group members.

Data

Data consisted of all e-mail messages exchanged among the Soar members from the summer months of June through August 1993. Summer was considered appropriate because most academic research is performed during this period when the teaching load is either low or nonexistent. This was confirmed by comparing the summer and nonsummer volume of e-mail messages. The senior members of Soar approved use of these e-mail archives for research. All members were notified that any mail sent to distribution lists was being archived and might be used for research purposes.

We wanted to include e-mail 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. Using the above selection criteria ensured that only the members with more than a casual contact with the Soar group were included in the study. This produced e-mail exchanges by 66 Soar members for the analysis (11 faculty, 25 students, eight paid staff members, 18 senior researchers, and four "others"). Since our concern was with the informal structure, messages sent to distribution lists (such as bug reports) were not included in the analysis.

Measurement of Variables

Task Categories. Task categories were derived from a content analysis of 300 randomly selected e-mail messages. These messages were coded based on the type of task to which they referred. The content analysis resulted in subtasks listed in Appendix A. These subtasks were then grouped into three broad categories—design, resource management, and group maintenance.

Task Routineness. The 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 characteristics in terms of routineness, the instrument developed and validated by Daft and Macintosh (1981) was utilized. Withey et al. (1983) evaluated six instruments that assess Perrow's (1970) dimensions of work unit technology. They found Daft and Macintosh (1981) and Van de Ven and Delbecq (1974) to be better 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) and is derived by aggregating task analyzability and task variety. Their instrument consists of five-item scales for both task analyzability and task variety. The items used in the questionnaire are shown in Appendix B. The respondents were asked 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." The tasks were broken down into subcategories similar to those shown in Appendix A.

The internal reliability of the analyzability and variety constructs was computed using Cronbach's coefficient alpha. Daft and Macintosh reported a coefficient of 0.86 for analyzability and 0.77 for variety. The coefficients computed in this study were slightly higher at 0.92 for analyzability and 0.79 for variety, both of which are well above the 0.70 required for acceptable scale reliability (Nunnally 1978). The alpha coefficient for the combined scale for routineness was 0.93.

Network Structure. Measures that were considered important in the context of e-mail communication are degree of hierarchy, centralization, and hierarchical levels. These measures of structures were used because they apply to directed graphs (graphs that show direction of the communication through arrows), depicting communication taking place among different points in a graph.

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

$$D_H = 1 - \left[\frac{V}{MaxV}\right],$$

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. Degree of hierarchy in a completely hierarchical network graph will be 1, whereas a completely nonhierarchical 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. 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 derived from the notion of cycles of connected nodes. A cycle is a path that returns to its own starting point (Scott 1991). To compute hierarchy, first a directed graph is condensed using the following steps (Harary et al. 1965, p. 60):

1. The graph is partitioned into exclusive cycles or subsets S_i.

2. Define a tie from subset S_i to S_j if and only if there is a tie from a node in subset S_i to a node in S_j.

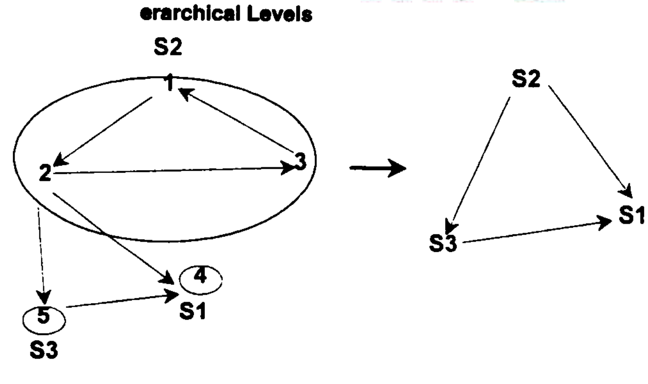
The simplified graph that results from this process of condensation is a new graph that is a directed acydic graph or DAG. The measure of hierarchical levels is based on the DAG properties of a graph.

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 S_2. Nodes 4 and 5 do not form any cycles and form subsets S_1 and S_3. Thus, the condensed graph has three ties—S_2-S_1, S_2-Si3, and S_3-S_1.

The next step is to count the number of nodes in the longest path through the condensed graph. In the example, there are three nodes and two ties in the longest path S_2-S_3-S_1. This indicates that there are three levels in the network graph.

Finally, the number of levels is normalized in terms of

Figure 3 Condensation of a Directed Graph to Determine Hierarchical Levels



A Directed Graph

A Condensed Graph

Source: Hummon and Fararo 1995

the number of nodes in the graph so that the measure will range from 0 for a single level graph to 1 for a completely ordered graph. This is done using the formula, $H_L = L - 1/N - 1$, where L is the number of levels in the condensed graph and N is the number of nodes in the directed graph. The H_L in this case is: $3 - 1/5 - 1 = 0.5$.

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) and is consistent with the 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), define the congruence fit as the absolute difference between the value of a pair of structure (S_i) and task routineness (T_i) variables. The closer the group structure value is to the task routineness value, the better the fit.

$$\text{Fit} = |S_i - T_i|.$$

In this study, routineness was measured on a 1 to 5 scale and network structure (e.g., degree of hierarchy, H_D on a 0 to 1 scale. In order to convert degree of hierarchy into a measure that is directly comparable to routineness, a hierarchy index (as suggested by Provan and Milward 1995) was computed ($Si = H_D * 4) + 1$). The difference between routineness value and hierarchy index provides task-structure fit value. In using this approach suggested by David et al. (1989) and Alexander and Randolph (1985), fit approaching 0 reflects the best possible fit and a fit value of 5 reflects the worst fit. This fit value was transformed so that a higher value represented better fit by subtracting it from 5. This was done to facilitate testing of a positive association between fit and performance as hypothesized. Centralization and hierarchical levels were the two other structural measures used in this study, and they were treated in a similar manner.

Performance. Objective performance was examined using the number of publications during the two-year period following the data collection. This period was 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 respondents were asked to rate on a five-point scale how effectively they thought the group performed each of the listed subtasks (Appendix A).

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, contained distinct content referring to different tasks. Thus, it is theoretically 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, that message was included in the design category as well as the 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, this information was coded as four separate messages.

The number of messages exchanged regarding the three tasks is 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 100. The above procedures provide an explanation for this observation.

Intercoder Reliability. Messages were read and coded by one of the authors and one other coder. The coder was asked to refer to the subcategories listed in Appendix A and classify the message to the appropriate task categories. The coder was instructed that 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 15 times, 30 messages were randomly selected from each coder's database. The intercoder reliability was calculated using

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

Note: The percentages do not sum up to 100 because each message could contain content relating to more than one task categories.

Scott's *pi* (Scott 1955), which corrects the possibility of chance agreement. The intercoder reliability of the coded message contents was consistently higher than 90% 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 the mail afterwards. A total of 43 usable questionnaires were returned, resulting in a response rate of 75%.

Analysis
E-mail messages were coded into a binary matrix, with rows representing message senders, and columns representing message receivers. A value of "1" in the intersection of row A and column B indicates a communication link between A and B, whereas a "0" indicates lack of such a link. These matrices were utilized as input to the Social Network Analysis software package UCINET (Borgatti et al. 1992) which was used to compute Centralization values. The matrices were also used to analyze Degree of Hierarchy and Hierarchical Levels. Degree of Hierarchy was analyzed using the software package Krackplot (Krackhardt et al. 1994), and Hierarchical Levels were computed using a C++ program provided to us by the authors of this measure.

Results

Evidence of Network Structure
As can be seen from the figures approaching 1 in Table 2, evidence of hierarchy and centralization is present in the Soar group. This is interesting given the claims that virtual organizations in general tend to be nonhierarchical (Beyerlein and Johnson 1994, Camillus 1993, Goldman et al. 1995, Mills 1991) and decentralized (Baker 1992). However, it is important to remember that the researchers of 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.

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

Task Characteristics, Network Structure, and Network Performance
The means[1] and standard deviations for perceptions of routineness levels of each task are shown in the first row of Table 3. Members perceived the task of resource management to be the most routine, followed by group maintenance and design tasks. Table 3 also exhibits the perceived and objective performance values for each task. The next three rows in the table show computations of structure index and fit values for degree of hierarchy using the procedure described previously in this paper. The same is presented for centralization and hierarchical levels measures.

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

Hypothesis Testing. We used Regression Analysis to test the relationship between the task and structure fit and performance. This analysis represents the relationship of the fit transformed as described above and as presented

Table 3 **Organizational Task Routineness, Centralization, and Network Performance**

	Design	Resource Management	Group Maintenance
Routineness (T_i)	2.62 (0.48)	3.42 (0.65)	3.15 (0.94)
Perceived Performance	**3.36**	**4.17**	**3.63**
Objective Performance	**3.54**	**3.52**	**4.00**
Degree of Hierarchy	0.88	0.87	0.84
Structure Index (S_i)	4.52	4.48	4.36
Fit ($5 - (S_i - T_i)$)	**3.10**	**3.94**	**3.79**
Centralization	0.81	0.82	0.84
Structure Index (S_i)	2.62	3.42	3.15
Fit ($5 - (S_i - T_i)$)	**3.38**	**4.14**	**3.79**
Hierarchical Levels	0.80	0.66	0.70
Structure Index (S_i)	4.20	3.64	3.80
Fit ($5 - (S_i - T_i)$)	**3.42**	**4.78**	**4.35**

in Table 3 with perceived performance value (also presented in Table 3) for a particular task. The regression analysis yielded an adjusted R^2 of 0.54 (F-statistic $=$ 10.20 $p < 0.01$ $n =$ nine). These results provide support for the notion that a linear relationship exists between organizational task routineness and structure fit and perceived performance. Fit between task and structure significantly contributed ($b = 0.77$, $t = 3.19$, $p < 0.05$) to the explanation of perceived performance.

Figures 4a through 4c are graphs that provide a visual representation of the relationship between fit and perceived performance for organizational task in terms of the three structural measures. For example, Figure 4c plots the relationship of the task-structure fit for hierarchical levels (X-axis) with perceived and objective performance separately (Y-axis). Each point in the graph represents the fit and performance value for a particular type of task. The graph shows that perceived performance increases with fit value. Figures 4a and 4c can be interpreted in a similar manner.

The link between the structural index values with objective performance was not supported (adjusted R^2 $=$ 0.12, F-statistic $=$ 0.15, not significant, $n = 9$). There is no support for the notion that the task-structure fit predicts objective performance ($b = 0.15$, $t = 0.39$, not significant). Since results of the linear regression suggest lack of a linear relationship between fit and objective performance, this relationship was tested for curvilinearity by using curve fitting in regression analysis.[2,3] This analysis attempts to fit the data using several curvilinear models. No support was found for a curvilinear relationship between fit and objective performance.

Figure 4a **Task-Degree of Hierarchy Fit and Performance**

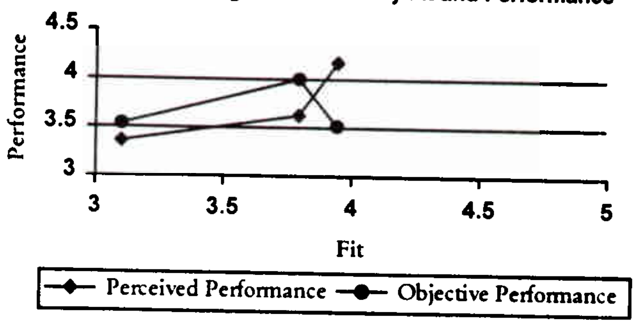


Figure 4b **Task-Centralization Fit and Performance**

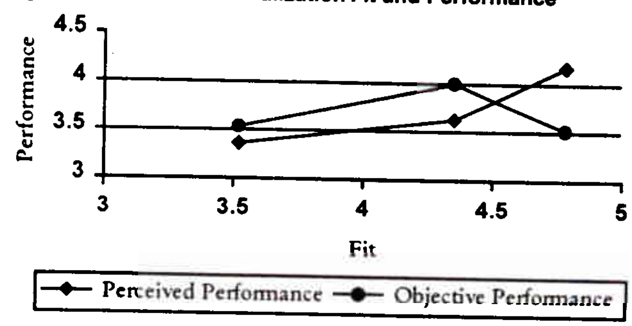
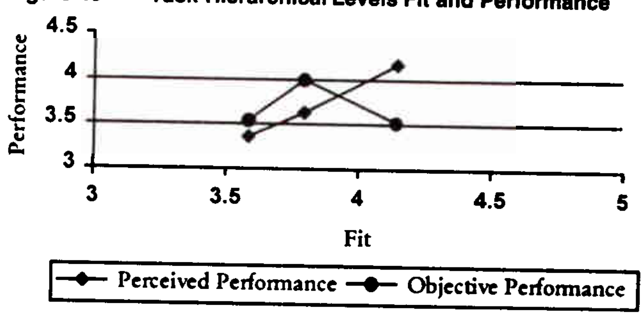


Figure 4c **Task-Hierarchical Levels Fit and Performance**



Discussion

This research provides empirical evidence of the existence of three distinct structural dimensions (degree hierarchy, centralization, and hierarchical levels) in a virtual organization. It also shows that the fit between emergent structure and routineness of the task performed by its members is positively associated with member perceptions of performance but not with objective performance. In the following paragraphs, we discuss the results in more detail.

Nature of Structure

The results of this study indicate that virtual organizations can exhibit considerable hierarchical tendencies (degree, centralization, and multiple levels). This finding appears to contradict the predictions of nonhierarchical and decentralized structure in virtual organizations. Ours is not the only study to find hierarchy in virtual organizations. Applegate (1995) studied three major corporations in depth and concluded that hierarchy is present in today's new forms of organization but those features of hierarchy are being uniquely combined with features of traditional organizational models of matrix and adhocracy. Our observation of hierarchy in the Soar group is consistent with Simon's (1977) prediction that hierarchical structures are the most likely to appear through the evolutionary process of natural selection as size and complexity in the organization grows. The Soar group evolved from three locations soon after its inception to 27 locations by 1993. Collectively, these studies suggest that claims regarding the lack of hierarchy in virtual organizations may need to be revisited.

Our results suggest that virtual organizations may well be nonhierarchical and decentralized from an authority standpoint; however, from a communication standpoint they may still be hierarchical and somewhat centralized.

The reason for this rests in the communicative efficiency and robustness of the hierarchical form and in the benefits of role specialization.

Simon (1977) argues that hierarchies should not be thought of as necessarily harmful. He claims that among systems of a given size and complexity, hierarchies require less information exchange among their parts than do teams. Hierarchies tend to be more robust in the face of various communication errors (Carley and Lin 1995) and under situations in which membership changes (Carley 1992). Dispersed groups may rely on communication hierarchies for efficiency in communication and coordination. Tighter controls are needed to coordinate among members at a large number of geographical locations.

Virtual organizations allow relatively easy access to people in the know by making it easy to obtain information from experts, regardless of where they are located. The communication patterns evolve such that efficient use of this expertise can be made. If the expertise resides in a small number of specialists, then all inquiries will be directed at these individuals. In an area where there are high knowledge barriers to entry because of the high level of technical expertise required, centralization can play an important role in overcoming these barriers. Specialists who can be relied on so that all participants do not have to share in all the knowledge can reduce startup costs for the average participant. Centralization of communication to these specialists can increase group efficiency. We observed this in the Soar group—once certain people had been identified as possessing specific types of information or knowledge, the group members had a tendency to direct suitable inquiries to those individuals directly. In other words, as new members become socialized into the group, general communications about "who knows about xyz" begin to be replaced by specific inquiries to a particular person about "xyz."

There are two consequences of this communication and interaction pattern. First, task-related knowledge is less distributed than is transactive knowledge about who knows what. Second, through this movement in communication, the informal structure of the virtual organization becomes stabilized with respect to roles, thus stratified and centralized.

We observed several mechanisms in the Soar group that facilitated the maintenance of such structures. The underlying authority structure in terms of faculty-student/staff relations and the funding structure all are consistent with the emergence of a more hierarchical form. For example, 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 e-mail, resolution of issues often takes place at a higher level (involving the senior faculty). A typical research or design-related discussion over e-mail follows this pattern—an issue is brought up, usually by one member. If there is enough interest, a lively 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. Although these mechanisms supported and were supported by the emergent hierarchy and centralization in the communication structure, it is not clear that they were necessary to the emergence of that structure. Future work should examine whether these types of support mechanisms are necessary.

Task and Structure Fit

The relationship between task routineness and structure has been well established in the literature and was also supported in this paper for virtual organizations. Researchers, have cautioned however, 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 et al. 1989, Lawrence and Lorsch 1967) others have suggested a contradictory relationship. Our findings in terms of hierarchy and centralization in the Soar group are consistent with Bourgeois et al. (1978) and Huber et al. (1975) who found that routineness is associated with tightening of organizational structure (increased hierarchy and centralization).

We found that the fit 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 better objective performance. One explanation of this finding may be that there are other factors at play that determine objective performance. 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. Future studies should examine these additional factors that may determine objective performance in virtual organizations.

We must also consider the possibility that the performance measure based on publications alone does not fully capture the performance of the group needs to be considered. Other suitable performance measures may have included the number of Soar modules designed in a given period of time, the dollar amount of grants generated, or the number of licenses and patents awarded. In addition, although publications are a reasonable measure of an individual's performance given the nature of the group, the number of publications may not reflect the quality or impact of the publications. Unfortunately, these measures were not available to us in this research. Future studies should also try to include quality as well as quantity produced in objective measures of performance.

One limitation of using publications as a measure of objective performance is that they may represent individual effort and may not be a direct output of any of the three tasks considered in this study.[4] In this context, 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 coauthored (as opposed to all) publications in virtual organizations.

Limitations

Single group studies are limited in generalizing their findings to their particular contexts. This study is no exception. Future studies will have to examine other settings to see if the findings can be applied to other virtual organizations. In some respects, the Soar group is unique in that it operates in an academic setting and contains clearly defined status and role relationships. In other respects, the group studied here can be viewed as a prototype of the virtual organizations we can expect to commonly see 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 workplace) 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.

Field studies are also limited because that they have no control over the factors that might interfere with the phenomena under investigation. Furthermore, the findings of this study are limited to structures formed by e-mail communication. It is possible the communication network formed by media other than e-mail is substantially less hierarchical and centralized than implied in this study and may offset the higher degree of hierarchy and centralization observed in the e-mail 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 e-mail interaction alone.[5] Our preliminary assessment based on the interviews, however, indicates that the face-to-face interaction may be even more hierarchical than the e-mail 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 e-mail communication ignored volume and focused only on whether 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.

Implications for Research

This study tests the impact of task-structure fit on effectiveness of 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. For example, we found that this fit did not explain objective performance. In accordance with our previous discussion, researchers need to develop performance measures that take collaboration into account. A second avenue for future research is to explore other determinants of objective performance in virtual organizations. Some possible determinants of virtual organization performance may include group size, level of communication, type of information being exchanged, and communication patterns and behaviors. Also, mechanisms for reducing information loss and retaining organizational memory in the face of fluidity need to be explored.

Implications for Management

In this section, we address several considerations and suggestions for managers that fall out of this research. One major implication is that in addition to managing formal reporting relationships, it is important to monitor and manage communication structures. Managers responsible for virtual project teams should not assume that nonhierarchical communication structures are necessarily more effective than hierarchical structures. Rather, managers need to align the communication structure to the task characteristics. For routine tasks, hierarchical structure may indeed be preferable, because hierarchies provide efficiency and economy of communication. Managers can foster a hierarchical communication structure by promoting specialization in knowledge areas so that all communication regarding a particular area is directed through a single individual. On the other hand, complex tasks should be managed to promote plenty of discussion and decentralized decision making. This should lead to enhanced innovativeness and creative solutions. Such task-directed hierarchical (or nonhierarchical) structures can also be promoted through specially designed computer-supported communication systems.

Once managers have determined an optimum structure for a particular task, it is still a challenge to achieve this structure repeatedly in similar situations because these communication structures are emergent in nature. Perhaps practitioners need to consider information exchange positions or roles in addition to formal authority roles in virtual organizations that can promote and sustain the desired communication structures.

An additional challenge is to preserve organizational memory by retaining individuals who are at the center of information exchange networks. Perhaps managers can monitor communication structures and design reward structures so that individuals acting as knowledge centers on specific topics can be retained and promoted. Reward structures should also include incentives for these individuals to share their expertise with other members of the organization. Furthermore, it is critical to develop and train other individuals who can assume the network positions vacated due to promotions from within, so that the communication structures can remain stable despite the turnover.

Finally, we found that objective performance was not influenced by task and structure fit. One plausible explanation for this is that not all tasks are equally suitable for being performed in virtual settings. Therefore, managers must consider which tasks can benefit from virtual forms before they launch reorganization. Tasks that are expertise- and competence-based, information and communication intensive, and use distributed resources may be particularly suitable.

Conclusions

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 a virtual organization and provides a foundation for theory building regarding this increasingly popular type of work environment.

The discussion presented in the previous section leads us to a fundamental question—to what extent do virtual organizations resemble traditional organizations? Previous researchers have argued that the difference is largely one of decentralization versus centralization, nonhierarchical versus hierarchical. We find that this distinction is misleading. We found evidence of both centralization and hierarchy in a virtual organization. However, this structural form emerged in the communication structure and was not equivalent to an authority structure based on status or tenure differences. In many traditional organizations the centralization or hierarchy is in the authority structure and is related to status and tenure differences. In other words, we found no evidence that the formal and informal structures in the virtual organization were indistinguishable. Rather, this work suggests that in virtual organizations the decoupling of the authority structure and the communication structures results in a decoupling of power and information. Consequently, the issue is not simply whether it should be centralized and/or hierarchical, but rather, for what types of tasks is centralization or hierarchy in authority and/or centralization or hierarchy in information beneficial.

We also found evidence that in this virtual organization, as in traditional organizations, the structure was matched to the task characteristics. However, unlike traditional organizations, this fit between communication structure and task improved the perception of performance but did not appear to improve objective performance. This suggests that the decoupling of the authority structure and the communication structures in the virtual organization may also result in decoupling subjective and objective performance. Whether such decoupling is beneficial to the organization remains an empirical question.

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Appendix A. Subtasks Listed on the Questionnaire to Measure Routineness and Perceptions of Performance

1. Design
Research and Design
Designing Soar software modules
Using Soar for designing other Soar productions
Patches and Bugs
Finding and solving bugs
Making members aware of bugs
Implementation
Getting newer versions of Soar to members
Assisting members in getting started with the new versions
Planning and Analysis
Planning the general direction of Soar architecture
Analysis of individual Soar productions
Documentation
Writing and maintaining manuals
Getting the documentation to members

2. Resource Management
Hardware
Installing and maintaining user workstations and other hardware
File Management
Maintaining archives, backups
Naming and maintaining directories, etc.
Disk Space
Allocating and maintaining disk space
Security
Coordinating and monitoring access to software
Licensing, etc.
Operating System/Environment
Maintaining the systems
Assisting with problems and features

3. Group Maintenance
Distribution Lists
Maintaining distribution lists
Adding new members to mailing lists
Events and Workshops
Scheduling meetings, organizing workshops, organizing rides
Publications
Adding new publications to library
Maintaining publication archives

Appendix B. 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.

Endnotes

[1]An analysis of variance (ANOVA) was performed to determine whether the three tasks (group maintenance, resource management, and design) were significantly different in their routineness. This was done because it was considered important to test whether the Soar members perceived these task categories as being distinct in their routineness levels. The ANOVA revealed that all three means are significantly different from each other ($f.$ = 10.66, $p < 0.01$). Even considering adjustments to a group significance level of 0.05, all three comparisons still show significance.

[2]We analyzed this data for logistic, exponential, growth, S, power, compound, cubic, quadratic, inverse, and logarithm curvilinear models.

[3]We are grateful to the editors, Peter Monge and Gerardine DeSanctis, for this suggestion.

[4,5]We are grateful to anonymous reviewers for these comments.

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