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Dissertation

COORDINATING EXPERTISE IN SOFTWARE DEVELOPMENT TEAMS

by

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The completion of a dissertation is a momentous occasion for its author. The task that started out as daunting and never-ending is finally complete. It is time for reflection and acknowledgment. Each doctoral journey is unique but they all have in common this arduous process through which the doctoral student undergoes a metamorphosis from being a knowledge consumer to becoming a knowledge producer. The whole saga of germinating interesting ideas, growing them into interesting research questions, and convincing a skeptical committee of the value of your hazy views is only the first part of the challenge. You need to also find a research site interested in supporting a study that may seem far from relevant from a practitioner point of view. Once the site has been swayed into accepting your data collection effort, one has to toil with the data in the hope of finding nuggets of results and write them up in coherent and readable document. Even harder yet, is to emerge from this process with an original intellectual contribution. I speculate that few people who have not gone through the process of completing a doctoral program can fully appreciate the hard work, sorrow, loneliness, and joy of writing a dissertation.

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COORDINATING EXPERTISE

IN SOFTWARE DEVELOPMENT TEAMS

(Order No.)

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Abstract

An essential task faced by knowledge teams is expertise coordination, which is defined as the management of skill and knowledge interdependencies. In order to perform well, teams need to develop cognitive and collaborative processes for achieving expertise coordination, which encompasses three essential components: knowing the location of expertise, knowing where expertise is needed, and accessing the needed expertise. This thesis investigates the importance of expertise coordination in software development teams through a cross-sectional investigation of 69 teams that are developing business application software. The analysis reveals that expertise coordination shows a strong relationship with team effectiveness. The relationship remains significant over and above presence of expertise, administrative coordination, and team input characteristics. This thesis thus provides empirical support to the proposition that a key aspect of effective teamwork is expertise coordination.

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1. Chapter One: Introduction

Software in the US is a $100 billion industry and is experiencing growth at a pace 9 times higher than the rest of the economy (Leebaert, 95). This high rate of growth is leading to heightened interest in ways to improve the performance of software development teams. Organizations face a continuing software crisis due to their inability to manage the complexity of software development. Industry surveys consistently find that the majority of large software projects are not completed on time or on budget and do not function as intended (Gibbs, 1994; Moller and Paulish, 1993). Failures are common with a quarter of large software development projects never completed (DeMarco, 1982; Jones, 1991).

Organizations differ in terms of the type of software they produce. Vendors of application software products have as a highest priority the development of new and innovative applications. They eschew bureaucratic controls and structure their processes to support the innovativeness of the team (Zachary, 1994). Other specialized organizations, such as military or space agencies, are focused on achieving the highest reliability for mission critical solutions. Such software requires costly management systems that emphasize quality control and documentation. A third distinct area of software is custom application software. Such applications are the ones that most organizations require, develop, manage, and support. Customized application software is growing at 7% a year, it is today a $70 billion industry and is expected to reach the $100 billion mark by the year 2001 (United States International Trade Commission, 1995).

Most research and advice on how to build high quality software approaches the question from one of three different perspectives: training, tools, or organizing. Individual training is a perennial focus of all software development organizations. Training is provided by specialized institutions and universities through a variety of degree programs, certification programs, and short courses. The importance of worker training is reflected in the rise in earning of 3 to 11% for people who complete training programs (such as a 4 to 10 weeks training course) compared to those who do not (Gaertner & Nollen, 1989). Continuous training of developers is deemed necessary because of the rapid pace of technology change in the computer industry and thus is driven by the need to keep up with new hardware and software technologies. Further, training can have major productivity impact: teams using a highly familiar computer language require 20% less time than teams with no familiarity with the language; similarly teams made up of highly capable developers outperform their less capable counterparts by a factor of up to four[1] (Boehm, 1981, 1987; Walston & Felix, 1977). Organizations thus use training as a way to increase developers' familiarity with specific languages, methodologies, and technologies. The amount and frequency of training provided by organizations has been identified as a key differentiator between exemplary "world-class" organizations (10 or more days of training/year) and average organizations (1 to 2 days of training/year) (Yourdon, 1993).

A second priority for organizations has been the use of modern software development tools. Since the 1960's developers have been sold an ever changing variety of technological solutions that are touted to increase productivity by an order of magnitude or more (Gibbs, 1994). These "silver bullet" solutions have included tools as varied as: structured methodologies, fourth-generation languages, CASE, Object-Oriented tools, and Java development environments. While the empirical record shows a marginal improvement in performance due to the use of new technologies such as: structured methods (Schneiderman, 1980), fourth-generation languages (Harel & McLean, 1985; Lehner, 1990), and CASE (Iivari, 1996; Norman & Nunamaker, 1989), the actual results seldom match the benefits touted in the trade literature. Brooks (1987: 10) summarizes the field's experience with technological solutions masterfully: "But as we look to the

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[1] At the individual level of analysis, differences between the best and worst developers are even more pronounced reaching the level of 20 to 1 (Dunsmore, 1983; Schneiderman, 1980).

horizon of a decade hence, we see no silver bullet. There is no single development, in either technology or in management technique, that by itself promises even one order-of-magnitude improvement in productivity, in reliability, in simplicity."

The third approach is organizational in nature. IS managers are struggling with issues such as: whether to outsource the software function or to build it up internally, whether to use self-managed teams instead of chief-programmer led teams, and whether to reward the performance of individual programmers or that of a team as a whole. Trade publications frankly acknowledge that the software crisis is more of a managerial problem than a technical one (Gibbs, 1994; Schlender, 1989). The issue of how to select, motivate, and manage people is often identified as an essential element of improving software productivity (Boehm, 1987; Yourdon, 1993). Software development researchers call on the field to focus on "project sociology" (DeMarco & Lister, 1987) or "software psychology" (Basili & Musa, 1991) as areas in need of immediate research progress. This thesis takes an organizational perspective and focuses on organizational issues faced by software development teams working on custom application development.

Why organizational issues are so critical in software development is not difficult to comprehend. Software development is representative of intellectual activities that are highly complex, interdependent, and long lasting.[2] As a result, software is overwhelmingly built by teams. Software is difficult to develop because it integrates two mainly separate classes of skills: computer science expertise and application knowledge (Royce, 1993). A team structure is used in order to include requisite variety of skills and knowledge to meet the demand of the task. The challenge for the team is to transform often vague and ill-defined requirements into thousands, often millions, of lines of very specific commands. These commands must be built into intricate logical structures with complex patterns of procedural interrelationships and data exchange. The work is divided among individual team members, but must be integrated into a consistent whole. Compounding these difficulties is the invisible nature of software structures.

The need for effective coordination among team members has recently emerged as an essential issue in studies of software development teams. Software developers spend more than 70% of their time working with others (DeMarco & Lister, 1987; Jones, 1986). They do so because the sharing of requirement details between team members is one of the difficult areas of software development (Brooks, 1975; Fox, 1982). Team members

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[2] Software development is considered by some as "the most complex craft ever practiced" (Birnbaum, 1982). Software differs qualitatively from other technologies due to its infinitely programmable nature (Sproull and Goodman, 1990). A programmable technology is open-ended and does not allow the development of an a priori explicit enumeration of instructions. Because of software's unique customizability and flexibility, automation is limited and the development of new software remains the domain of craftsmen who built applications one statement at a time.

need to develop a common framing of the system that is being developed because they have to meet an often fluid set of requirements, interface with each others individual modules or existing systems, and integrate their various efforts into a coherent whole. Effective coordination of the team's effort is thus crucial for achieving a successful software system.

Successful teams are the ones which are able to manage conflicting requirements, as well as overcome communication and coordination breakdowns (Curtis, Krasner, and Iscoe, 1988). Researchers studying actual teamwork in software development teams have found that team performance is linked with team-level knowledge acquisition, sharing, and integration (Walz, Elam, and Curtis, 1993), the effecting of necessary horizontal and vertical coordination (Nidumolu, 1995), and the implementation of coordination strategies (Kraut and Streeter, 1995; Wholey, Kiesler, & Karley, 1996). Overall, these studies indicate that in software development teams, coordination processes are crucial aspects of teamwork and that coordination problems negatively affect team performance.

This dissertation takes the perspective that two different coordination processes are key to effective teams: *administrative coordination* and *expertise coordination*. Both are necessary but their importance varies with the nature of the task. For simple routine tasks, administrative coordination is needed to assign tasks, allocate resources, and integrate outputs. However, for complex non-routine intellectual tasks, administrative coordination is not sufficient. For such tasks, I propose that expertise coordination is crucial and is needed during teamwork so that the team can recognize where expertise is located, needed, and accessed. Therefore, team performance is not just a function of having the "right" expertise on the team. Rather, expertise must be coordinated among team members.

This thesis addresses the following research questions:

1. What is expertise coordination?
2. What is the relationship between expertise coordination and team performance?
3. Does expertise coordination contribute to team performance above and beyond traditional factors such as group resources and the use of administrative coordination?
4. Under what task contingencies is expertise coordination most effective in affecting team performance?
5. What are the determinants of expertise coordination?

Chapter two builds on existing research on team performance and coordination to develop a theoretical framework for the study of expertise coordination and proposes a set of hypotheses. Chapter three presents the study's methodology. Chapter four presents the results from the empirical data collection and statistical analysis and additional analysis related to determinants and outcomes of expertise coordination. Chapter five discusses the results and their implications in view of the existing literature. A final chapter discusses the study's limitations and its potential contribution.

2. Chapter Two: Theoretical Framework

This chapter presents the theoretical framework guiding this research. The focus is on the literature on team effectiveness but with an emphasis on the role of *expertise* and its *coordination*. I propose that *knowledge team effectiveness* can best be promoted by the inclusion of expertise on the team and on the coordination of expertise. The first section discusses the role of coordination in team effectiveness. The second section reviews the importance of expertise as an essential input to team performance. The third section presents recent work on teams based on a socio-cognitive or distributed cognition perspective. These studies are unique in their focus on expertise and form the theoretical base of my study. The fourth section presents a discussion of how ontological assumptions affect our views of expertise and its coordination. The final section develops the theoretical model. In the next paragraphs starting below, I provide a detailed definition of expertise coordination and propose a model and a set of hypotheses.

Due to the large number of terms and varying definitions present in the literature, I will start by defining a number of key concepts. A <u>team</u> is a set of interdependent individuals with specialized skills who are pursuing a shared objective. A team differs from a group, or an aggregate of individuals, in that team members share jointly in the outcome of their task. A person's expertise consists of the specialized *skills and knowledge* that he/she possesses and can bring to bear to further team goals. Teamwork refers to the work of the team, and to the collective behaviors of team members interacting in order to accomplish the task. Team members alternate between working alone and interacting with others. Coordination refers to team-situated interactions aimed at managing resource and expertise dependencies.[3]

I differentiate between two kinds of coordination: administrative and expertise. Administrative coordination refers to the management of resource and workflow interdependencies. These interdependencies are managed through organizationally-specified processes to organize teamwork and allocate resources (personnel, time, and artifacts). Administrative coordination is achieved through mechanisms such as: division of labor, task decomposition, task allocation, activities integration, rules and procedures, and tools for facilitating workflow. On the other hand, expertise coordination refers to the management of knowledge and skill interdependencies. These interdependencies are emergent during teamwork and generally cannot be specified or valued ex ante. Expertise

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[3] These definitions are consonant with Malone and Crowston's (1994) definition of coordination as the management of dependencies between activities, or alternatively, as the additional information processing that has to be performed because individuals are working in a group rather than alone (Malone, 1988).

coordination relies on team-level processes to know where expertise resides, where it is needed, and how to access it where needed. Expertise coordination is achieved through mechanisms as varied as: querying specialized databases, posting questions on computer-based discussion groups, questioning experts, and interacting reciprocally with team members to generate problem solutions.[4]

Expertise is not equally distributed on a team and members have varying levels of expertise, even when they share the same disciplinary background. Experts differ from novices in several aspects of cognitive functioning. In chess, for example, they perceive patterns of play more effectively and recall more play position. In problem-solving, they are more conceptually-driven, reason backward from the unknowns, and develop more complex mental representations of the problem (see Chase & Simon, 1973; Chi, Glaser, & Farr, 1988; Druckman & Bjork, 1991 for a fuller discussion). However, experts are not superior to others outside their specific domain (Anderson, 1990). Becoming an expert requires time and a diligent focus. Irrespective of domain, a period of 10 years of professional training may be necessary to achieve such a level of proficiency (Simon, 1991, 1996). During that learning period, the person passes through identifiable stages of development that have been mapped into hierarchies of increasing levels of proficiency

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[4] Although it might be possible to view expertise as simply another resource to be coordinated administratively, this thesis develops the view that expertise has properties that differentiate it from other resources.

(Benner, 1984; Dreyfus & Dreyfus, 1986). How to recognize experts remains a tricky question since expertise is often not reflected in a person's title or organizational position. The simplest way to identify experts is to rely on formal or informal recognition mechanisms that every group or profession bestows on those few individuals that are recognized by their peers as the best at what they do (Shanteau, 1992).

In knowledge teams, much of the knowledge and skills that need to be accessed is tacit and cannot be externalized or shared in formal ways. Each team member is a specialist in a functional area and yields a set of discipline-specific tools and methods as well as his/her experience from having faced analogous situations before. The work of each specialist is primarily intellectual , embedded in the person's mental frames, and difficult to describe. People from other disciplinary areas, even when working on the same project, are often unable to comprehend its internal intricacies or specific workings. For instance, in software development, team members see each others' work often as completed specifications, modules, data structures, or interfaces. How these pieces of the overall task get done is through individual work that is not visible to the others. Each piece reflects its author's unique set of assumptions, problem conceptualization, thinking strategies, disciplinary tools and methods, and adaptation of previous experiences to this new situation.

Further, the knowledge team, as a whole, faces tasks that often are: complex and uncertain, do not have easy answers, are situated in specific context, and require a focused process of expertise application. Task completion does not proceed in a direct and orderly fashion. It depends on complex and unpredictable reciprocal interactions among team members. Task progress occurs through a process of mutual adjustment and interaction through which divergent perspectives, requirements, and assumptions are readjusted and synthesized.

Administrative coordination views the management of expertise as an issue of decomposition and integration in the face of complexity. It assumes that an appropriate division of labor, task decomposition, and integration can be properly designed and are the main conduits through which expertise is managed. Administrative means of coordination may be most effective when within-team tasks are routine, decomposable, and their interdependence is sequential. Using administrative coordination effectively presumes that: 1) the expertise resources within the team are easily recognizable, and 2) that the expertise interdependences among team members are visible and can be specified a priori. Both of these assumptions do not hold well for cognitively complex tasks: expertise interdependences are not explicit, and even if they were, there is no assurance that their management can be planned and performed well using administrative means. Thus, expertise coordination is needed and refers to team processes that manage complex and situated knowledge and skill interdependencies. The nature and role of coordination in team performance is investigated in the next section.

2.1 Coordination in teams

Coordination involves the integration of organizational work due to task uncertainty and interdependence. Coordination has been at the center of organization theory ever since March & Simon (1958) suggested that work in organizations can be coordinated by ways of programming or by feedback. The essential distinction rests on the extent to which activities can be pre-specified in advance (programs) or developed on the spot (feedback). Much of that early work focused at the organizational level and examined the ways by which different organizational units link together and integrate their workflows (Galbraith, 1977; Lawrence & Lorsh, 1967; Thompson, 1967). Researchers have only recently focused at the team-level. The idea that teams develop and use *coordination processes* is a recent conceptualization in organization theory that remains relatively unstudied.

Recent qualitative studies of knowledge team have concluded that coordination is at the heart of the process of teamwork. For example, Curtis, Krasner, and Iscoe (1988), in a large field study, using in-depth interviews of members of 19 software teams, found that successful teams were the ones who not only understood the domain and managed changing requirements, but were able to overcome communication and coordination breakdowns. In an in-depth ethnographic evaluation of a single team, Walz, Elam, and Curtis (1993) found that the essential teamwork activities revolved around knowledge acquisition, knowledge sharing, and knowledge integration.

2.1.1 Coordination Processes

A first perspective on coordination is provided by the social psychological research on teams. From that point of view, task functions, defined as regular activities that directly support and guide the achievement of the team's task,[5] implicitly incorporate coordination. Hackman and his colleagues (Hackman, 1987; Hackman & Morris, 1975, 1983) define task functions broadly as task performance strategies and interventions that support process gain in teams. Team performance is viewed as a function of the ability of the team to reduce its process losses and increase its process gains. Factors such as cohesiveness, open communication, supportiveness, rational decision making, performance strategies, and boundary management are all examples of important team processes (Ancona, 1989; Hackman & Morris, 1975; Steiner, 1972). Coordination is assumed to occur as long as

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[5] Team processes can be divided into internal team processes and external ones. The external function refers to activities that a team engages in to influence stakeholders, acquire resources and generate support. As shown by the work of Ancona & Caldwell, (1990; 1992) the external function may be important for team success. However, the external perspective is most relevant for multifunctional R&D teams or for software project teams at the requirements stage. Thus, it is not addressed here in this thesis.

these processes are executed well. While the importance of "smooth coordination of member effort" (Ancona, 1989: 108) is implicitly recognized, it is only viewed as an aspect of the task function and thus is not measured separately. Thus, from an expertise coordination perspective, the social psychological perspective of teams is relatively limited. While these models of team processes have been the mainstay of social psychology studies of groups, they may not be rich enough to explain the complex set of interactions and real-world complexities faced by knowledge teams. At best they offer general guidelines for process intervention but with limited relevance for long duration, complex and interdependent tasks such as software development.

Two more focused but interrelated conceptualizations have been the focus of most coordination research. The first one, by Van de Ven and his associates (e.g., Van de Ven & Delbecq, 1974; Van de Ven, Delbecq, & Koenig, 1976; Drazin & Van de Ven, 1985) identified three coordination modes (impersonal, personal, and group) which may be used to coordinate work within a workunit. An impersonal coordination mode refers to rules, procedures, plans, and schedules. A personal coordination mode refers to mutual adjustment achieved through horizontal or vertical channels of communication. And a group coordination mode corresponds to scheduled and unscheduled staff or committee meetings. Using empirical data from surveys of administrative units in a state bureaucracy, Van de Ven and his colleagues found that a congruence relationship existed between the task environment of a workunit and its form of coordination: the more uncertain and difficult the task environment, the more the workunit resorted to group mode of coordination. The second conceptualization was developed by Argote (1982) in the context of hospital emergency units. She distinguishes between programmed and non-programmed coordination based on which activities can be specified in advance. Examples of programmed coordination include: rules, scheduled meetings, and authority arrangements. Non-programmed coordination refers to activities not specified in advance and developed on the spot. Examples include: autonomy, general policies, and mutual adjustment. The Van de Ven and Argote conceptualizations are actually very close to each other with the key difference that Van de Ven separates the non-programmed coordination into a personal mode and a group mode.

Coordination has been linked to team performance in a variety of contexts. Using the mode of coordination approach a number of studies have investigated coordination in workunits or teams in a variety of settings: nursing units (Argote, 1982), software teams (Kraut & Streeter, 1995; Nidumolu, 1995), state employment units (Drazin & Van de Ven, 1985; Gresov, 1989), R&D teams (Tushman, 1979), and GAO audit teams (Gupta, Dirsmith, & Fogarty, 1994). Coordination is frequently framed within an information processing view of coordination where the information processing requirements due to the task environment need to be matched by information processing mechanisms (Tushman & Nadler, 1988). The basic focus of these studies is on showing how environmental (primarily task) uncertainties lead to higher level modes of coordination. More recent work has focused on empirically substantiating the idea that the fit between task and coordination leads to better performance. For example, Keller (1994), in a study of 98 R&D teams, found that the fit between the task's non-routineness and information processing capacity predicted project performance.[6]

Some of the empirical studies of mode of coordination have shown results that diverge significantly from the expected results. Results have varied mainly due to differences in the task type. Tushman (1979) studied 58 R&D projects in one organization. Using frequency of communication measures of coordination, he found no link between task environment and intra-project communication as well as outside-project communication. He explained his findings in terms of the possible mediating role of boundary spanners. Nidumolu (1995) measured coordination as consisting of the frequency of use of the following two dimensions: vertical coordination (through the manager, a steering committee, or through senior management), and horizontal coordination, a mixture of formal and informal mechanisms connecting the user to the team (oral or written communication, scheduled and unscheduled meetings). Reporting on a data set of 64 teams developing software, he found that high-performing teams rated high on both types

[6] The work of Daft & Lengel (1986) has been especially influential in extending the information processing approach to include media richness. The authors recommend that when information is equivocal (lacks clarity) and cannot be resolved with more data, there is a need to use information rich channels of communication. These issues of information richness of a channel and the related

of coordination. This finding is in contradiction with the Van de Ven and associates stream of research which views different types of task environment as determining different modes of coordination. Finally, in a similar study of 65 software development teams in a single organization, Kraut & Streeter (1995) used a formal/informal communication lens to study coordination. They found that the frequent use of formal procedures was not associated with coordination success once they controlled for project characteristics such as size. I view these findings to be indicative of a larger problem of how coordination is theoretically conceived. These issues may not be resolvable at present due to the way coordination is operationalized. The problem may lie with the focus on the *mode* of coordination rather than on the content of, and actual occurrence of, coordination. In some settings, such as in team engaged in complex knowledge tasks, the mode may be the least important aspect of coordination. Instead, the fact that coordination occurred and resolved a certain interdependence is the key link to performance.

2.1.2 Coordination Theory

Coordination theory is a recent formalism that refreshingly goes beyond the mode of coordination and takes a systems view of how coordination occurs. It is a body of principles pertaining to the representation and coordination of activities and the

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issue of social influence regarding its use (Fulk & Boyd, 1991) are beyond the scope of this thesis and will not be addressed.

harmonizing of the activities of various actors (Crowston, 1997; Malone, 1988; Malone and Crowston, 1994; Malone, Crowston, Lee, and Pentland, 1993). Coordination is defined as the management of dependencies between activities.[7] Progress in coordination theory is achieved "by characterizing different kind of dependencies and identifying the coordination processes that can be used to manage them" (Malone & Crowston, 1994: 91). The basic building blocks of coordination theory are: actors, activity, and resources. Actors perform interdependent activities and use resources to achieve goals. Actors need to use coordination mechanisms in order to overcome dependencies that constrain task performance.

In recent years, coordination theory has evolved toward the elaboration of a large set of pre-defined *coordination mechanisms*. These can be used to provide solutions to coordination problems in organizations or to design new organization processes (Malone et al., 1993; Crowston, 1997). These coordination mechanisms are generally *administrative* in nature. They tend to be explicit pre-defined organizational ways to solve interdependence problems. For example, Crowston (1997) in his analysis of the software problem fixing process at a minicomputer manufacturer focused on the following

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[7] Coordination theory is broader in scope than organizational theories. It is interdisciplinary in nature and claims to bridge between computer science, organization theory, operations research, economics, linguistics, and psychology. Coordination theory research has so far focused on the development of cooperative work tools, and on the specification of a set of coordination mechanisms to be used as design blocks for new organizational routines.

activities: refer hardware problem to field engineer, attempt to reproduce the problem, set priority for problem, determine affected module, forward bug to appropriate manager, test the proposed fix. All these activities represent the active management of task-task, task-resource, and resource-resource dependencies. Crowston's findings can be viewed as a successful application of the coordination theory framework to represent an actual organizational process and model its dependencies.

In its present state of development, coordination theory represents a major development in the study of coordination. Its use allows the identification and analysis of multiple dependencies between various actors and resources. This is a significant step forward in improving our understanding of coordination beyond the mode model. However, coordination theory does not differentiate expertise dependencies from other kinds of dependencies. It merely identifies the *type* of dependency and does not focus on its *content*. This thesis extends coordination theory by focusing on inter-actor expertise dependencies, particularly within a knowledge team context. Coordination theory can be used to generate a repertoire of coordination processes that provide ways to manage knowledge and skill interdependencies. However, coordination theory is limited by its assumption that organizational mechanism need to be pre-specified and formalized. I extend coordination theory's scope to include the non-formal or emergent aspect of coordination that are so essential in knowledge teams.

2.1.3 Reframing Coordination

In a recent review of the team effectiveness literature, Zalesny, Salas, & Prince (1995) concluded that coordination "is a critical and unifying construct for defining, researching, and achieving effective team performance" (p. 81). They define coordination as: "the complementary temporal sequencing (or synchronicity) of behavior among team members in the accomplishment of their goal" (p. 102) and conclude by suggesting that any coordination measurement system must capture the how, what, and when of coordination.

In my opinion, much of the theoretical difficulty and measurement problems associated with the study of coordination are due to a lack of understanding of the *what*, and *when*, and an unnecessary focus on the *how*. Much of what has slowed progress in the area of coordination over the last two decades (since Van de Ven et al., 1976 seminal work) has been the focus on the *mode* of coordination rather than on the *content* of coordination. The predominant view of coordination is based on the work of organizational units or workunits. In most of these units work is routine and of low intellectual complexity. Under such circumstance, Van de Ven et al. (1976) focus on impersonal, personal, and group modes of coordination were useful measures of *how* coordination took place.

If one focuses on the content (the what) of coordination, then one needs to deal with the importance of expertise coordination, especially in knowledge teams. Expertise is an important resource in a team and needs to be coordinated. If, as was developed in previous sections, expertise coordination in knowledge teams cannot be pre-specified ex ante, then measuring the mode of coordination may be of little relevance. A major weakness of the mode of coordination approach has to do with its focus on frequency of use of each mode. Whether it is meetings, plans, rules, vertical or horizontal communication, or informal meetings, they are all measured as a frequency. This leads to analyses that attempt to link high levels of (modes of) coordination with positive outcomes including performance.

The lack of findings in several studies of a link between coordination and performance may be due to this lack of focus on content of coordination. For example, Wholey, Kiesler, & Carley (1996) have conceptualized team-level coordination as occurring through two mechanisms: structure and communication. Structure refers to organizational ways of coordinating such as division of labor, rules and operating procedure, task and role specialization, and formal authority structure. Communication refers to coordination occurring through direct communication among team members. Each set of mechanisms has costs associated with its use and thus neither can be used as exclusive coordination mechanisms but rather as complementary ones. They found no direct relationship between structure and communication on one hand, and performance on the other. This lack of finding may be caused by the overuse of either of these sets of mechanisms which are not costless. It is quite possible that a team where expertise is shared effectively may score lower on frequency of communication or meetings than one where the expertise is not being shared. In the former case there would be no need for further coordination if the necessary expertise were quickly identified and applied as needed. In the latter case, high levels of coordination may reflect a scramble for finding and applying said expertise.

This view of expertise coordination can be used to illuminate the unresolved debate within the IS field on team structure, and how a chief-programmer led team structure compares with an "egoless" (self-managing) team structure (Baker, 1972; Mantei, 1981; Weinberg, 1971). These different team structures can be seen as stylized solutions to deal with expertise access and coordination problems. So far the debate about what is the best team structure remains unsettled and evidence tends to be anecdotal in nature.[8] However, it is important to note that the chief-programmer team structure views expertise as scarce and primarily embedded in the chief-programmer. In such a team, coordination is likely to occur through formal meetings, reviews, and task assignments initiated by the chief-programmer since he is the source of expertise. In contrast, the self-managed team structure views expertise as more equally distributed among team members. In such a

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[8] This debate about how to structure a software team is still ongoing today in organizations. JCN, the organization that is my research site, underwent major changes in team structure during the life of this project. At the beginning of the study, a significant portion of sites in the South and the West were experimenting with self-managed teams. My study was initially supposed to focus on a comparative assessment of the two team structures. However, a few months after the study began, the organization's management decided to drop the self-managed team structure and to shift back to the chief-programmer model. During phone interviews, several managers in the affected regions expressed their support for the self-managed team structure and their disappointment with the change back.

team expertise needs to be coordinated interpersonally through informal channels of communication. This team structure uses open and frequent communication to meet the coordination demands associated with complex tasks. Thus, the lack of findings about the superiority of one of the two team structures may be due to the task effect. For complex tasks where team expertise is distributed the self-managed team may be superior, while for simpler tasks, or for tasks where the team leader has a much higher level of expertise, the chief-programmer structure is best.

Favoring an expertise view of coordination does not negate the need of frequent communication to occur in a team. Communication is essential at the beginning of a project when team members learn to understand their task and know each other (Galegher & Kraut, 1990). Communication is especially important for technical R&D teams and software teams (Allen, 1984; Kraut & Streeter, 1995; Tushman, 1977, 1979). However, it is possible that spending too much time communicating is detrimental to productivity due to information overload (O'Reilly, 1980) or over reliance on communication as a coordination strategy (Wholey, Kiesler, & Carley, 1996). Critically for our purpose, much of the empirical literature on communication has focused exclusively on issues surrounding the *choice of medium* for a specific communication (Daft & Lengel, 1986) or more generally on the *frequency of communication* (Allen, 1984; Tushman, 1977). In the context of knowledge teams, I argue that what matters is not medium or frequency of communication but *content* of communication. In such a context, the task demands are such that few problems faced by the team are amenable to a simple one way sharing of codified knowledge, rather the focus is on knowledge that is situated and emerges from the unfolding of activity in a real setting.

2.2 The Role of Expertise in Teams

Within organizational psychology, expertise has long been recognized as an essential input for team performance within the dominant input-process-output model of team/group performance (Gladstein, 1984; Guzzo & Shea, 1992; Hackman, 1987). Inputs refer to characteristics of the group or of their organizational context. Processes refer to the interaction among group members as well as to their boundary activities. Outcomes refer to team performance and psychological results. The model assumes that we can improve/predict performance by changing the group's inputs and processes. Because the group input-process-output model is based in psychology, coordination is believed to occur implicitly if the team develops effective inter-personal processes to manage the task-generated technical and social demands. Expertise is viewed as an essential input for a work team to operate successfully. It affects both processes and outcomes. A limitation of such models is their lack of focus on actual teamwork processes. The perspective is narrowly psychological: a team that interacts well and exchanges information well will be characterized by a positive group process. Expertise is viewed narrowly in terms of skills, training, and experience. This perspective may be limited due to its focus on psychological aspects of teamwork and its limited applicability to knowledge tasks.

In spite of their theoretical prominence in input-process-outcome models, inputs have often not been studied empirically with regards to their impact on team performance, and when they were studied, the empirical record is mixed (Guzzo & Shea, 1992).[9] Studies of teams composition have offered a wide variety of inputs that may affect team processes and performance. Among the expertise-type inputs, team member skill has systematically been identified as the essential input for team effectiveness (Gladstein, 1984; Hackman, 1987; McGrath, 1984; Steiner, 1972). However, what type or what combination of member skills and abilities are more effective is still an open question[10]. The few field studies that have focused on measures of expertise have found mixed results.

Gladstein (1984) in a field study of 100 sales teams, found a link between organizational and job tenure on one hand, and self-rated measures of team performance and actual sales revenues on the other. However, self-rated measures of team skill adequacy did not relate to either outcome variables. One reason for these results may be the domain of the teams

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[9] At the individual level, there exists considerable evidence that that general cognitive ability is a clear predictor of task performance, especially for complex tasks (Glynn, 1996; Gottfredson, 1986). This thesis does not address individual performance and its relation with individual ability.

as they are all in sales. In such an environment, task demands may not be as high as in other technical domains, and thus most of the teams probably had the minimal level of required skills.

In a survey-based study of 661 employees at a single Fortune 100 site, Gaertner & Nollen (1989) measured both the input and process factors that affect work unit effectiveness. They paid special attention to the three dimensions of skills: education, training, and experience measured as organizational tenure. They found that team effectiveness, measured using Van de Ven & Ferry's (1980) operationalization, was related only to the receipt of job-related training. No link was found between experience and education on one hand and effectiveness on the other. Here too, the domain (a manufacturing plant) may have affected results, since in such an environment formal education may not be crucial and the impact of experience may plateau after a short phase.

How the abilities of team members combine together and affect team performance has long been investigated in the teams literature. The traditional view is that abilities of team members combine simply in an additive manner: the more competent the members are, the higher their team performance (Hill, 1982; Shaw, 1981). However, how differences

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[10] One reason may be "the near exclusive attachment to laboratory methods" and the failure of most of the research to reflect "concerns either with real world problems or with theoretical developments." (McGrath, 1984: 22).

among individual abilities affect team level combination is a thorny and unsettled issue. Do teams made up of members homogeneous in terms of abilities perform better than teams made up of more heterogeneous members? In an influential study, Goldman (1965) rated subjects from a college population based on an intelligence test. The subjects formed pairs based on a combination of high-medium-low intelligence levels and worked together on another version of the same intelligence test. The results indicated that heterogeneous pairs gained significantly more than the homogeneous pairs. The study was replicated by Laughlin, Branch, & Johnson (1969) but using triads instead of dyads. Here too, the heterogeneous groups were clearly superior to the homogeneous groups. A possible limitation of these findings may be the use of students on a simple short-duration test-taking task. The tasks also require little coordination and communication among team members.

Other more recent field-based research found that teams of homogenous ability can outperform heterogeneous teams if the individuals in the team are all of high ability. Tziner & Eden (1985) studied 224 three-member tank crews in a field experiment where they controlled ex ante crew composition. They measured individual ability through a composite of: level of education, score on an intelligence test, language proficiency, and an assessment of adaptability to army life. Performance rankings were made by the unit commanders. The results went beyond the traditional view of team performance as an additive function of ability and motivation and showed a strong interaction effect for member ability. They found that teams made up of all high-ability members significantly outperformed other teams to a degree higher than expected based on a linear combination of their individual abilities. Similarly, low-ability teams performed much worse than expected based on their abilities. The authors concluded that "talent is used more effectively when concentrated than when spread around" (p. 91).

Is ability an additive factor or is it multiplicative? It is important to note that these conflicting effects of composition may be due to the difference in tasks and context. In the studies by Goldman (1965) and Laughlin et al. (1969), the task is a simple intellective one taking place in an experiment among people without required, long-lasting organizational ties. In the Tziner and Eden (1985) field study, the teams worked and lived together as a tank crew over a period of several weeks. An important issue that has not been addressed in both sets of studies is the role of coordination and specifically the coordination of skills and knowledge of expertise. All these studies focused on individual traits such as ability and motivation and did not investigate team level variables such as cohesion or coordination. For example, in his attempt to provide a theoretical explanation for the tank crews results, Tziner (1985) relies exclusively on two social psychological theories, similarity theory and equity theory, both of which provide explanations in terms of meeting members socio-psychological needs rather than in terms of teamwork and how members combined their knowledge.

This multiplicative impact of skill has also been found to be important for software development. Several researchers have focused on individual-level human factors that may affect team outcomes. Most of these studies are laboratory-based investigations of how people generate, understand, and debug small programs, and have formed the basis for much of the human side of software engineering (see Curtis, 1985; Schneiderman, 1980 for a review of this literature). The key finding of these type of studies is that large differences (up to a factor of 100) in performance can occur between programmers with different ability levels working on the same task. These results are based on experiments where programmers are given a program to develop and their performance is assessed in terms of time to completion.

Two large IS field studies comparing the productivity of teams have found significant performance differences due to team-level expertise differences. Walston & Felix (1976) collected factors and productivity data on 60 software projects in a single organization. They found that teams that rated themselves as having above-average personnel experience and qualification outperformed those who rated themselves as below-average by a factor ratio of 3.1 in terms of lines-of-code per person-month productivity. Using similar productivity measures, Boehm (1981) studied 63 commercial projects and found that teams that were rated in the 15th-percentile in terms of personnel capability were outperformed by teams rated at the 90th-percentile by a factor ratio of 4.2. These findings have led several authors to take an implicitly multiplicative view of the impact of expertise and to suggest that software project performance is mainly a function of using individuals with superior programming abilities and little else (Brooks, 1987; Boehm, 1981, 1987; Yourdon, 1993).

Other organizational researchers have studied the impact of team composition under the heading of organizational demography. These researchers view differences within a team as alternative, and often better, predictors of team outcomes than hard to measure variables such as values, cognition, and attitude (Pfeffer, 1983). In several reviews of demography studies, researchers have found that teams homogeneous on demographic variable such as age, gender, organizational tenure, background, or experience, and engaged in complex tasks seem to perform better than teams that are heterogeneous on those variables (Argote & McGrath, 1993; Bettenhausen, 1991; Keck, 1997). In a field study of R&D teams, Zenger & Lawrence (1989) found that high variation[11] in organizational tenure within a team led to reduced performance. Ancona & Caldwell (1992) found a similar negative relationship between variation in organizational tenure and performance in their survey of R&D teams. In a recent field study of software teams, Guinan, Cooprider, & Faraj (forthcoming) found a negative and direct impact of heterogeneity of within-team work experience on performance.

How demography variables, such as work experience or organizational tenure, affect performance is an open question. The nature of the task matters: homogeneous teams have the advantage for tasks requiring consensus-reaching and common framing. High variation in organizational tenure may lead to widened environmental scanning activities and the generation of more complex and complete solutions. Heterogeneous groups have the advantage in tasks requiring a varied range of skills and abilities. Heterogeneous teams may also be more innovative in creative or alternative generation tasks (Guzzo & Dickson, 1996).

Since expertise is such a crucial input variable, expertise variation may be a key factor being indirectly measured by demographic variables. Current explanations offered for why heterogeneous teams perform worse include: a lack of shared understanding of events (Zenger & Lawrence, 1989), lack of social integration (O'Reilly, Caldwell, & Barnett, 1989), increased group conflict (Wagner, Pfeffer, & O'Reilly, 1984), reduced communication frequency (Smith et al., 1994), and ineffective communication (Pfeffer & O'Reilly, 1987). All these factors may actually reflect difficulties in coordinating expertise. Teams made up of very different people, who have not historically been member of the same organizational cohorts, and thus lack social integration, are likely to

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[11] Generally measured using the coefficient of variation (standard deviation/mean) which is the most direct and scale invariant measure of variation within the team.

be less apt to know what expertise is present in a team, where it may be needed, and how to share it.

How does expertise relate to measures of experience? Several studies have attempted to measure the impact of experience on performance and have produced weak results. In a study of university administrators, Nass (1994) found that work experience linked to knowledge rather than skills. Empirical research on software maintenance productivity found support for the role of skill (measured as management rating) on productivity (Banker, Datar, Kemerer, & Zweig, 1993). In other settings, the evidence has been contrary. Work experience has not been found to be a good predictor of performance in the domains of data base conceptual representation (Villeneuve & Strong, 1993) and corporate strategy (Barr, Stimpert, & Huff, 1992). These conflicting findings are not surprising in view of the general practice of operationalizing experience in terms of years of work experience or of organizational tenure. Years of experience does not adequately reflect expertise because years could be spent focused on a narrow specialization, or inversely, working in a high-level but non-productive capacity. Thus, experience measured as a single indicator of work experience is unlikely to accurately reflect expertise.

To summarize, this section has addressed the role and importance of expertise as an input for team performance. Expertise is viewed mainly through its impact on socio-psychological outcomes. Much of the literature on team inputs acknowledges the importance of expertise for team performance and views its impact as an additive combination of individual expertise. However, field studies seem to indicate that, for complex tasks such as software development, the impact of expertise is more than linear. I view much of the research on the impact of demography on team performance as indirectly measuring variation in expertise. Thus, demographic variability is likely to reflect expertise variability. Much of the literature is based on experimental tasks and on non-demanding simple tasks. The implication for field studies of software team performance are two fold: first, expertise is critical due to the nature of the task, and two, how expertise is coordinated is crucial for performance. In the next section, I address these coordination issues.

2.3 Ontological Dimensions of Expertise Coordination

Two views of expertise exist in the organizational literature. The first one views knowledge as *abstract representation* and expertise as the possession of such knowledge (Rorty, 1979). This approach has been used to explore cognition in a multitude of domains, especially managerial cognition (Walsh, 1994). It is deeply rooted in the rationalist tradition and views knowledge as a mental representation of an objective world.

Knowledge is perceived as something that can be abstracted, explicitly represented, codified, and accessed.

Traditional theories of teams have implicitly favored this first view of expertise. The team is a way to bring together experts from different domains. A team's expertise is defined as the aggregation of individual skills, knowledge, behaviors, and roles. A team maximizes its collective know-how by incorporating highly skilled members and their specific knowledge and skills to the task in an efficient and effective manner. From this perspective, and mainly for additive tasks, team performance is a function of some combination of the ability of team members (Jackson, 1992; Shaw, 1981).

Researchers studying software teams have privileged this individualistic view of expertise because of the complexity inherent in the software development task. Studies comparing team productivity support this focus by showing marked differences between high-ability teams and their less capable counterparts. Currently, practitioners and researchers alike focus on individual programmer technical competence as the essential element affecting team performance (Boehm, 1987; Brooks, 1975; Jones, 1991; Schneiderman, 1980; Yourdon, 1993). However, this focus on the role of individual skills on team performance, while important, may miss the importance of team-level coordination. The assumption that team performance is based on a simple combination of member abilities may not hold for complex and highly interdependent tasks. In such tasks, where outcome is dependent on the effective synchronization and meshing of activities, performance may be non-additive.

This first view of team expertise is most appropriate if skills and knowledge in teams are partitioned among team members in non-overlapping and distinct sets, and the task is disjunctive or additive. The coordination necessary for team performance can be met by administrative procedures such as formal plans, clear division of labor, and specific schedules. However, knowledge teams face complex and highly interdependent tasks. Such teams have to rely on a redundant distribution of knowledge, communication, and expertise sharing in order to overcome possible failures of one individual so the whole team effort does not fail. Such teams develop a robust system of distributed knowledge where a redundant (and overlapping) distribution of expertise allows team members to access and monitor each other's activities, and provide occasional help (Hutchins, 1993).

The second, and alternative, perspective views expertise as embodied in *situated practice*. Based on practice theory (Bourdieu, 1977; 1990; Lave, 1988; Pentland, 1992), this perspective reconceptualizes people as knowledgeable agents who are embedded in social situations. It emphasizes "the relational interdependency of agent and world, activity, meaning, cognition, learning, and knowing" (Lave & Wenger, 1991: 50). Knowledge is thus socially mediated and as a result, emerges from patterned interactions (Winograd & Flores, 1986).

Recent research on work expertise in the field, as opposed to the laboratory, has provided support for a more situated and socially interactive view of expertise sharing and coordination. For complex tasks, working, learning, and innovating is dependent on a *situated view of expertise coordination*. Processes of expertise coordination form the basis for noncanonical practices (Brown & Duguid, 1991) and learning through legitimate peripheral participation (Lave, 1988; Lave & Wenger, 1991). More recently, Weick & Roberts (1993) have proposed that the performance of highly reliable systems is mediated by mental processes at the level of a "collective mind." For them, teams in high pressure and highly interdependent environments develop heedful interrelations of actions among team members in order to achieve performance goals.

Another reason why a situated perspective that privileges expertise coordination is critical has to do with the ill-defined and constantly changing nature of the task. In many teams, the information necessary to comprehend and solve the problem is unequally distributed and can be intrinsically equivocal and amenable to multiple interpretations (Daft & Macintosh, 1981; Weick, 1979). Variations in technical specialization, past experience, and domain knowledge often leads to different representations of the problem (Larson & Christensen, 1993). Within-team differences may emerge in how to assess the relevance of various kinds of information, requiring more complex coordination, and making it more difficult for the team to agree on a solution.

2.4 A Distributed Cognition Foundation for Expertise Coordination

Cognitive aspects of coordination are important because of the overwhelmingly mental nature of the work of knowledge teams. A key point of contention in the literature is whether the knowledge structure discussed by socio-cognition researchers is an aggregation of individual knowledge structures or something different. The issue is important due to its level of analysis implication (individual or group) and remains hotly debated (Klimoski & Mohammed, 1994). Today, the majority of organizational researchers are still preoccupied by cognition in the small (one brain at a time) and take the position that group-level knowledge structures are aggregate structures (Walsh, 1995). These group-level mental structures act as a template to be imposed on a specific information environment in order to generate meaning. Empirical research seems to be focused on how these cognitive maps develop and how best to test for their existence (see Meindl, Stubbart, & Porac, 1994, for a recent review).

While the cognitive "revolution" has affected organizational research in major ways, organizational researchers are ill-served by narrowly following the individual cognition perspective while most of their phenomena of interest occur at the group level. The mainstream approach assumes the existence of a cognitive core that is independent of context and intention. This perspective leaves much to be desired in the context of knowledge teams whose members are brought together to work on an often ill-defined, changing, and complex task. Much of what goes on in the project is *situated* and depends on interaction within the team, with clients, with users, and with stakeholders. Even traditional factors of task understanding, of making plans, and implementing those plans are essentially emergent, and social.

Several authors have proposed a retargeting of cognition toward a more social perspective, where cognition is socially constructed, shared, and based on interaction (Lave, 1988, 1991; Levine, Resnick, & Higgins, 1993; Winograd and Flores, 1986). Social cognition, which used to focus on thinking about social objects (Fiske & Taylor, 1991), can be refocused as primarily a group-level social phenomenon "that relates to the acquisition, storage, transmission, manipulation, and use of information for the purpose of creating a group-level intellective product" (Larson & Christensen, 1993). Taking such a perspective situates cognition away from an exclusive *mental activity* and more toward a *set of behaviors and interactions*. What is gained is a deeper understanding of inter-subjective phenomena and a blurring of the line between cognition and interaction.

The distributed cognitive approach can provide a useful perspective for the study of knowledge teams. Several researchers have proposed theoretical conceptualizations that link socio-cognitive factors and team performance. Factors as diverse as shared definition of the situation (Bettenhausen & Murnighan, 1985), teamwork schema similarity (Rentsh & Hall, 1994), shared knowledge about the group and work (Levine & Moreland, 1990), team mental model (Klimoski & Mohammed, 1994), and collective mind (Weick & Roberts, 1993) have been proposed as useful conceptual constructs that may link to team performance. The key aspect here is the commonality in understanding the situation, the team, and nature of teamwork.

Three distinct research contributions provide a foundation for understanding expertise coordination from a distributed cognition perspective. The first perspective is premised on the realization that when tasks exceed individual abilities, distributed cognition is socially organized. Hutchins (1991) used a computer simulation to show how the cognitive properties of teams are different from those of individual members. Using neural networks made up of nodes and links, he showed that depending on how communication is structured, the group will display different cognitive properties. An important implication here is the importance of redundant representations and how the group-level cognition emerges from the foundation of between-nodes distributed processing. Hutchins also studied navigation teams aboard ocean-going vessels. Using observational methods, he found that in teams engaged in complex, high-stakes tasks an overlap of task skill and knowledge was essential for the smooth operation of the team (Hutchins, 1995).

Such findings provide support for the contention that the intersubjective nature of cognition, and its situatedness, are important for knowledge teams.

The second perspective, that of Weick and Roberts (1993), is based on an observational study of high reliability systems on aircraft carriers. Weick and Roberts use "collective mind," defined as disposition to act with heed, as a metaphor for organizational teams that operate as highly-reliable smart system. They propose that the collective mind begins with individual actions, emerges from the ongoing activity stream, and is manifested by the process of heedful interrelating. Specifically, members of a team reach a high-level comprehension of the process in which their individual know-how and skill become linked together. The team is then able to respond as a complete system in order to meet situational demands even though the complexity of the task is actually beyond the cognitive capabilities of individuals. Theoretically, Weick & Roberts (1993) flip the traditional causality between mind and action on its head by focusing on how actions construct mental processes rather than the other way around.[12]

The third perspective focuses on within-team cognitive interdependences. Recently, Wegner (1987) has proposed transactive memory as a way to understand how a group

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[12] Weick & Roberts do not, however, provide operational characteristics or specific processes that may lead a team to operate heedfully.

processes and stores information. A transactive memory system is defined as the set of knowledge possessed by group members coupled with an awareness of who knows what. A transactive memory exists when people in close relationships use other people as memory storage locations. Thus, people can depend on communication with each other in order to enhance their memory stores. They know the location rather than the content of what is being stored and rely on each other to furnish necessary detail. These cognitive dependencies lead to the creation of a group-level knowledge system where each individual knows some knowledge items and knows the location of other knowledge items.

The operation of a transactive memory system brings out the importance of communication processes among group members. These processes develop naturally depending on group activities and individual inclinations. A recent experiment that compared natural and artificially-imposed transactive memory systems, using dating couples and strangers couples respectively, found that dating couples, if left to themselves, develop transactive memory systems that correspond to their inherent expertise areas and thus outperform couples who are assigned an artificial transactive memory system (Wegner, Erber, & Raymond, 1991). More recently, Liang, Moreland, & Argote (1995) studied the impact of a transactive memory system on performance in a complex assembly task. In an experiment consisting of 30 three-member teams, they found that teams that trained together, as opposed to individually, developed a transactive memory system, which in turn led to higher performance. The transactive memory system is defined operationally by measuring the extent to which the team demonstrates effective differentiation, smooth coordination, and trusting each other's expertise. In addition to showing a link between transactive memory and performance, this study is important because it conceives and measures transactive memory as an aspect of teamwork processes.

These three distributed cognition conceptualizations of team processes allow us to focus on shared cognition, heedful activities, and distributed memory systems -- all key elements for knowledge teams. Expertise coordination, conceptualized as interactions aimed at managing skill and knowledge dependencies, is in tune with Malone & Crowston's (1994) definition of coordination theory. It is supported by recent findings that team members that are unaware of each others' expertise may be unable to take advantage of it (Stasser, 1992). By using this conceptualization, we avoid the limiting perspective that expertise resides primarily in the head of team members (Chi, Glasser, & Farr, 1988).

2.5 Theoretical Model

2.5.1 Defining Expertise Coordination

Using the theoretical anchors of practice theory and distributed cognition, this section provides a theoretical exposition of the *process* of expertise coordination by integrating:

group-level cognition (Hutchins, 1991; 1993), heedful interrelations (Weick & Roberts, 1993), and transactive memory systems (Liang, Moreland, & Argote, 1995; Wegner, 1987; Wegner, Erber, & Raymond, 1991). Expertise coordination occurs when a team engaged in a long-duration, complex and highly interdependent task develops mechanisms for accessing and applying expertise when and where it is needed. The processes are based on interpersonal activities and exchanges but are manifested at the team level.

Expertise coordination processes are mainly social in nature and evolve in order to meet the demands of task-based skill and knowledge dependencies. Each specific individual-level expertise coordination activity need not be overtly visible. However, teams where members undertake formal or informal actions to share expertise and help each other meet the demand of task are *activating and constantly reinforcing expertise coordination processes*. The concept of expertise coordination extends the Wegner et al. transactive memory system beyond their narrow focus on distributed memory storage and recall of information to the broader issue of expertise sharing. Expertise coordination processes require a combination of the differentiated knowledge and skills possessed by team members, and patterns of heedful interactions that support the application of these skills and knowledge where needed. Such processes facilitate coordination by integrating cognitive interdependencies with communication and sharing of expertise. What matters is not the medium of communication nor the mode of coordination but the fact that these expertise coordination processes are present.

Thus, expertise coordination can be modeled as entailing a series of processes that have to occur for coordination to be effective. These team processes are *distributed* since expertise is distributed on the team. They are *heedful* because overlapping task knowledge allows flexibility and robustness of action. Finally, they are *emergent* because answers are not specified but are generated through interactions. These attributes of the team processes translate into: knowing where expertise is located, recognizing where it is needed, and accessing expertise. These processes are not rigid steps, nor need to occur in a preset temporal progression. They represent general processes, or patterns of activities, that need to exist and that a team needs to manage in order to be effective.

2.5.1.1 Knowing Expertise Location

Expertise coordination depends on the team's developing an understanding of how information and expertise are distributed among its members and its environment. Teams that know how knowledge is distributed among its members and how to effectively share it have been shown to increase their performance (Liang, Moreland, & Argote, 1995; Stasser, 1992). Knowing what others on a team know and do not know is critical for team performance. Team members need to develop a common language for describing tasks, assignments, roles, and location of expertise. Knowing the area of expertise of other team members serves an important integrative and coordinative function by stressing meta-knowledge about expertise location.[13]

Knowing expertise location[14] requires using any source of potentially useful expertise. These sources could include: specialized documents, corporate Q&A files, and most important for knowledge work, knowing who has what knowledge/skill on the team as well as outside the team. A large amount of expertise is situated in knowledge tasks such as software development. Obscure technical solutions may be documented in an organizational database or reside with fellow team members who may have encountered a similar problem on a prior project, or have advanced theoretical knowledge related to the problem. Often, a short informal discussion with an "expert" can save an individual programmer large amounts of time and can help in the identification of technically superior solutions. However, if the location of expertise is not clear, then the individual developer is faced with the prospect of time consuming searches of codified sources, or asking too many questions to too many others. Both of these strategies have high costs. The individual search is expensive in terms of wasted time and effort, and may lead to

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[13] This kind of meta-knowledge does not need to be limited to the confines of the team: much of the importance of boundary individuals in teams can be linked to their ability to know where external expertise and information are located (Allen, 1984; Ancona & Caldwell, 1988, 1992; Tushman, 1977). It is, however, outside the scope of this thesis.

[14] Only in the simplest situation does knowing expertise location refer to knowing where an answer to a problem is located. In non-trivial cases, expertise refers to knowledge and skills that

information overload, a situation associated with decreased performance (O'Reilly, 1980). Similarly, there is a social cost associated with not knowing how information is distributed on the team. Interrupting others to learn where things are is detrimental since it undermines the askers' social standing in the team. As Allen (1984: 192) states: "an engineer who very frequently seeks consultation will soon wear out his welcome."

2.5.1.2 Recognizing the Need for Expertise

The second step relates to recognizing when and where expertise is needed. If a team cannot recognize the need for expertise, expertise cannot be applied. For example, if a team member is having difficulty due to a lack of information, knowledge, or specific skill, others on the team cannot step in and offer help unless they are aware of the need. Awareness of the need for expertise thus needs to be supported by processes operating at the team level.

Just as a transactive memory system can help identify where expertise is located, it can also point to where and when expertise is needed. The essence of a transactive memory system is a combination of the knowledge possessed by individual team members and an awareness of who knows what (Liang, Moreland, & Argote, 1995). Such knowledge

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need to be applied onto a situated problem. The answer is not there to be found but needs to be developed by interacting with the appropriate expertise.

implies that assessments of individual strengths, as well as weaknesses, are available to other team members. Thus, team members should be able to identify substantive as well as situational areas of low expertise and react accordingly to provide needed expertise.

The context of the team work is likely to be an important factor affecting the recognition of where expertise is needed. The need for a certain kind of expertise will not remain constant over the life of the project. The need will vary depending on where the project is in its lifecycle. For instance, the need for domain knowledge is likely to be higher at the requirements stage than at the coding stage. Similarly, the need for technical expertise will peak during coding compared to other phases. Thus, as the project progresses, there will be variation in what kind of expertise is needed and who needs it the most.

2.5.1.3 Accessing Expertise

The third step relates to arranging for expertise access. It is not sufficient to recognize where expertise is located or where it is needed; a team needs to develop ways by which expertise is brought to bear in a timely manner on the problem. Teams do so by developing heedful interactions and activities that facilitate expertise access as well as support the actual application of expertise. Teams that develop the ability to work together smoothly face less need for planning, greater cooperation, fewer misunderstandings, and lower confusion (Liang, Moreland, & Argote, 1995). The processes of accessing expertise can be either formal or informal. Formal processes include actions such as the assignment of (expert) team members to help others and the discussion of expertise-related issues in formal meetings. Informal processes may occur in unscheduled meetings or one-on-one discussion among team members.

Formal processes of arranging for expertise access are not likely to be sufficient for complex and interdependent tasks. Under such conditions, formal procedures cannot pre-define the type of expertise needed, cannot pre-specify the most appropriate mode of coordination, and may be limited because members may be unwilling to share information (Kmetz, 1984; Orlikowski, 1992). They may be insufficient for tasks with equivocal information (Daft & Macintosh, 1981) or where tasks are non-routine (Kraut & Streeter, 1995).

Thus, effective sharing and coordination of expertise requires an environment supportive of interpersonal interactions. People in intellectual work settings need to develop a common understanding and thus rich interactions with colleagues are critical. They have to communicate using a common language and social knowledge, in order to facilitate the understanding of personal codes (Katz & Kahn, 1978); and to permit the sharing of personal knowledge due to shared values (Berger and Luckman, 1967). The ability of an individual to function in a work situation is inevitably based on "coordinated cognitive interactions with others" (Levine, Resnick, & Higgins, 1993: 399). Knowing informally who has knowledge and how to access it is a powerful factor in the effective work of knowledge teams: "the informal network is a much more powerful--and much more efficient--means by which the individual, but not the organization, can acquire information" (MacDonald, 1995: 564). A recent study of Lotus Notes support analysts supports the importance of the social interaction: "while an individual can query the system, *making use of that information is essentially a collaborative activity* (emphasis in the original) (Ehrlich & Cash, 1994, p. 4).

2.5.2 Proposed Model and Hypothesis

The proposed research model is described in this section. This model represents an expertise coordination view of team performance. In this model, expertise coordination is the principal set of processes that affect team effectiveness. Three sets of constructs are of import: (a) traditional team factors; (b) expertise coordination, (c) task uncertainty. Figure 1 presents the research model along with a set of hypothesis.

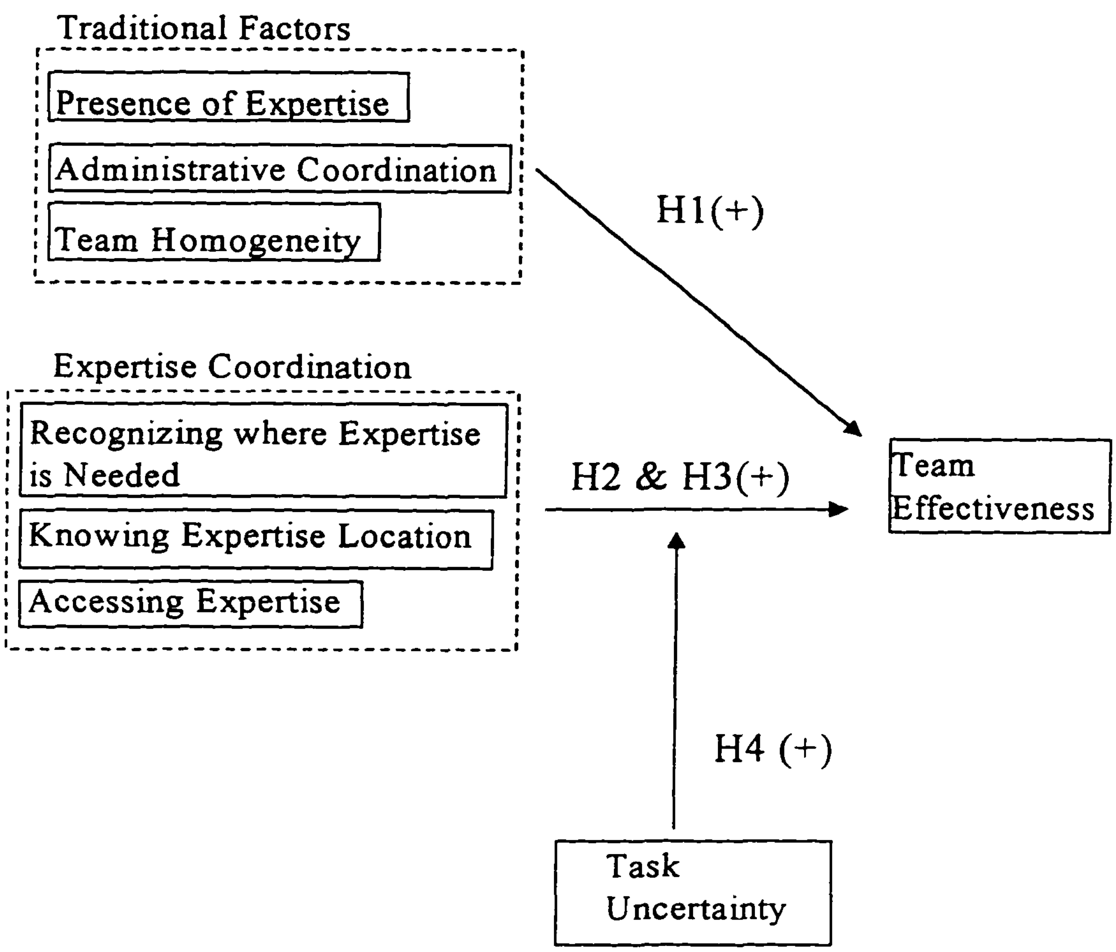

Figure 1. Theoretical Model

2.5.2.1 Traditional Factors

A large number of factors have been used previously in studies of team performance. Because this thesis focuses on expertise and its coordination in software development, a number of constructs related to motivation are not considered here. Similarly, issues of leadership and culture are not included either since the field site is a single organization with a strong culture and managerial culture. Based on the theoretical discussion in the previous sections, I propose three factors that have been shown to be particularly relevant for software team performance. They are: 1) the presence of expertise on the team, 2) the use of administrative coordination mechanisms, and 3) homogeneous team composition.

In order for a team to perform well in a knowledge task, it must include among its members the necessary expertise to perform the task. A widely accepted claim in organizations is that teams with highly trained or expert members tend to perform better than other teams. In software development, the use of the most knowledgeable and skilled people has been recommended as a preferred strategy to ensure software development success (Brooks, 1975; Jones, 1991; Yourdon, 1993).

The use of administrative coordination mechanisms has been shown to relate to performance in work units. In software development, lack of effective administrative coordination has been identified as a key predictor of software project problems. Higher levels of administrative coordination bring about better integration of teamwork, allow better sharing of knowledge, and maintain cultural norms. The effective structuring of administrative issues can facilitate teamwork by breaking down tasks into smaller components and clarifying responsibilities.

Team composition refers to the distribution of basic individual attributes such as age, gender, tenure, education, etc.. Team heterogeneity has been linked to increased turnover and a lack of social integration (Pfeffer & O'Reilly, 1987; Tsui & O'Reilly, 1989; Wagner, Pfeffer, & O'Reilly, 1984). In certain situations such as when solving a decision task that requires a variety of perspectives, heterogeneous teams are more likely to be innovative, creative, and make effective decisions (Jackson, 1992; Jackson, May, & Whitney, 1995). However, for situations where the task requires high interdependence, teams that are composed of similar members performed better than those made up of dissimilar members (Murnighan and Conlon, 1991). For teams engaged in complex and interdependent knowledge work, demographic heterogeneity seems to increase conflict, complicate communication, reduce cohesion, and limit coordination thus impeding performance (Ancona & Caldwell, 1992; Bettenhausen, 1991; Guinan, Cooprider, & Faraj, forthcoming; Shaw, 1981; Smith et al., 1994). Thus, I propose the following hypothesis:

H1: Conventional team factors (presence of expertise, administrative coordination, team homogeneity) are positively related to team effectiveness.

2.5.2.2 Expertise Coordination Factors

As has been suggested in the discussion on expertise coordination, the presence of expertise on the team *may be necessary but is not sufficient* for team performance to occur. The team needs to develop effective procedures and tactics to identify and apply this expertise where and when needed. Thus, I propose the following hypothesis:

H2: Expertise coordination processes (recognizing where expertise is needed, knowing where expertise is located, and accessing expertise) are positively related to team effectiveness.

One important question is: can the expertise coordination processes explain team effectiveness *above and beyond* the traditional factors? Thus, I propose the following hypothesis:

H3: Expertise coordination processes (recognizing where expertise is needed, knowing where expertise is located, and accessing expertise) are positively related to team effectiveness above and beyond traditional factors (presence of expertise, administrative coordination, team homogeneity).

2.5.2.3 Additional Exploratory Hypothesis[15]

I also propose an exploratory hypothesis focusing on the impact of task characteristics. Several authors have suggested that task type moderates the relationship between group processes and performance (Gladstein, 1984; Jehn, 1995; Van de Ven & Ferry, 1980). This might be especially true for software development. There often exists wide variation between software projects. Walston and Felix (1977) found team productivity differences of 300% between teams assigned complex tasks versus those assigned easy ones. The information processing framework indicates that as the task information processing requirements go up, so do the benefits associated with higher levels of coordination. This is mainly due to the fact that nonroutine tasks (those requiring complex problem solving) are highly uncertain and have few preset procedures (Galbraith, 1977; Tushman & Nadler, 1978; Van de Ven, Delbecq, & Koenig, 1976).

Task uncertainty is generally recognized as having two dimensions: analyzability and number of exceptions (Perrow, 1970). The number of exceptions dimension reflects how variable is the task input while the analyzability dimension reflects the extent to which there are known and available ways to solve the task. The number of exception dimension is of little use here since the team members are assessing a single as opposed to several

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[15] The impact of determinants of expertise coordination are not part of the theoretical model and thus are not posited as hypotheses. They will be analyzed and discussed only as post hoc research questions.

projects and thus face little variability in task. I will use uncertainty here in the analyzability sense. Based on the findings of structural contingency theory, I suggest that the relationship between expertise coordination and team performance will be moderated by task uncertainty. Thus, I propose the following hypothesis:

H4: Expertise coordination will make a greater contribution to team effectiveness when the task is uncertain compared to when the task is certain.

Table 2.1 below provides a summary of the hypotheses.

Number	Type of effect	Relationship between constructs
H1	Direct	(+) Traditional team factors → team effectiveness
H2	Direct	(+) Expertise coordination → team effectiveness
H3	Direct	(+) above and beyond traditional factors Expertise coordination → team effectiveness
H4	Moderated	Task uncertainty ↓(+) Expertise coordination → team effectiveness

Table 2.1. Summary of Hypotheses

3. Chapter Three: Methodology

The research strategy used to test the proposed model of expertise coordination combines qualitative research in the form of in-depth interviews, instrument development and testing in the form of creating and testing new measures, and finally, undertaking a hypothesis-testing quantitative field study. The first section of this chapter describes the study design. The second section covers the measures and their development. The third section describes the research site while the fourth section examines questionnaire administration. The fifth and final section describes the power analysis used to assess sample size adequacy.

3.1 Study Design

In order to test the proposed research questions, a study of expertise coordination and its impact on team effectiveness needs to incorporate a number of methodological characteristics. First, since expertise coordination is a new conceptualization, there is the need to develop measures of it. Second, this research requires access to software development teams in a real organizational setting, engaged in long term complex tasks, as well as access to organizational stakeholders to assess team effectiveness. Third, the study needs to focus its data collection and analysis on the team level since this is the level at which the proposed expertise coordination processes operate. Fourth, the study should use a large enough sample of teams in order to be able to generate reliable statistical results and provide confidence in the generalizability of the results. The current study was developed with these issues in mind.

3.2 Measures[16]

3.2.1 Development of Expertise Coordination Measures

The first phase of the field work involved conducting unstructured interviews with 23 software developers about coordination in software development teams. The interviews were done by phone or in person and lasted 20-50 minutes each. About half of these people were from a convenience sample of developers in the Boston area while the rest were working for the multinational firm that became the site of the survey research. The site is described in more detail below. The primary objective of these semi-structured interviews with developers was to understand how coordination occurs in teams and how it affects performance. I used as a guide the general issues that Hackman (1990) had

16 A list of measures with definitions, theoretical links, and items is provided in Appendix A.

identified for team effectiveness, and focused on coordination processes (using Van de Ven, Delbecq, & Koenig, 1976 and Weick & Roberts, 1993 as a guide).

The goal of this qualitative phase of the research was to develop my theoretical sensitivity to the phenomena as experienced in specific organizational settings. A major way to increase a researcher's theoretical sensitivity is to be first well grounded in the theoretical literature and to bring into the research project a significant amount of personal and professional experience (Strauss & Corbin, 1990). I did bring to the project 7 years experience in software development and a familiarity with the literature. The interviews then provided the anecdotal evidence and in-depth description to support the expertise coordination perspective. Further, these interviews supported the breaking down of expertise coordination into recognizable constituent dimensions that I had developed from theory. The result of the in-depth interviews was two-fold. First, I developed an understanding of expertise coordination as a recognizable and differentiable process separate from administrative coordination. The stories overwhelmingly showed the importance of expertise coordination as it related to project outcomes. Second, the stories provided specific anchoring of what expertise coordination means in the domain of team-based software development.

The second phase involved the development of a set of survey items related to expertise coordination. In order to measure various dimensions of the expertise coordination process, a number of new constructs were developed. The process and the results are described below. Based on an extensive search of the literature, I found that issues of a team's distributed cognition were openly discussed in a large number of articles but empirical evidence was scant (Larson & Christensen, 1993; Levine, Resnick, & Higgins, 1993; Resnick, Levine, & Teasley, 1991; Klimoski & Mohammed, 1994; Liang, Moreland, & Argote, 1995, Rentsch, 1990; Rentsch & Hall, 1994). Very few studies have attempted to assess team distributed cognition processes. Those who did, relied on developing causal maps of small managerial or professional teams (Bougon, Weick, & Binkhorst, 1977; Thomas & McDaniel, 1990).

Thus, I proceeded to develop my own measures of team expertise coordination processes. A list of questions was drawn based on theoretical sources in the literature (Hackman, 1982; Liang, Moreland, & Argote, 1995; Kraut & Streeter, 1995; Weick & Roberts, 1993) and adapted to focus on team level expertise coordination. A total of 44 questionnaire items were initially generated. Following reviews of the scales by 6 experts (3 at the site and 3 academicians), I rewrote some questions and dropped others. A test instrument of 39 items was created based on that process. I pre-tested the instrument on 61 MBA and undergraduate students, all of whom were enrolled in IS courses and were involved in a total of 19 semester-long projects developing software. Preliminary analysis indicates reasonable convergent validity for the instrument. Table 3.1 presents the results of the preliminary analysis:

Construct	**Definition**	**Theoretical Links and Sources**	**Pre-Test Cronbach Alpha and Number of Items**
knowing expertise location	The degree to which members of the team know where expertise necessary for the task is located	• Memory differentiation (Liang, Moreland, & Argote, 1995) • Transactional memory system (Wegner, 1986; Wegner, Eber & Raymond, 1991)	Alpha = .69 (7 items)
recognition of needed expertise	The degree to which there exist a team level recognition of the need of certain team members to access specialized knowledge and skill	• Communities of practice (Brown & Duguid, 1991) • Situated learning (Lave & Wenger, 1991)	Alpha = .64 (8 items)
accessing expertise	The extent to which team members have access to needed knowledge and skill	• Task coordination (Liang, Moreland, & Argote, 1995) • Informal coordination (Kraut & Streeter, 1995)	Alpha = .72 (8 items)

Table 3.1: Construct development

Following the pre-test, the instrument was reviewed again for theoretical clarity, conceptual focus, and ease of reading. Two faculty members helped in a final reworking of the questionnaire. Several items were removed from the instrument or reworded in order to improve clarity. The final set of questions were then incorporated in the final version of the survey.

3.2.2 Other Independent Measures

3.2.2.1 Presence of Expertise

Before expertise can be coordinated, it must exist on a team. Additionally, a researcher must control for the presence of expertise before being able to claim an impact of expertise coordination on performance. Expertise is a multi-dimensional construct and varies depending on the domain (Shanteau, 1992). In order to measure the presence of expertise on the team, one must define dimensions of expertise that are relevant to the application software development domain. Three dimensions of expertise are relevant for software development: 1) technical expertise, 2) design expertise, and 3) domain expertise. I have developed a measure of the presence of expertise on the team by asking respondents to evaluate, for each dimension of expertise, the percentage of necessary expertise that is located inside the team (range 0-100%). The construct *presence of expertise* is the mean percentage response to the three dimensions.

3.2.2.2 Administrative Coordination

Administrative coordination refers to formal mechanisms of an administrative nature that the team engages in order to accomplish its task. A number of previous studies have linked the use of proper coordination mechanisms to team performance (Argote, 1982; Van de Ven, Delbecq, & Koenig, 1976; Gupta, Dirsmith, & Fogarty, 1994). From my perspective, administrative modes of coordination are important ways by which a team manager/leader is able to assign tasks, control work progress, follow individual outcomes, integrate work outcomes, and deal with exceptions. An effective team relies on both formal mechanisms such as: project documentation and memos, project milestones and delivery schedules, as well as more interpersonal coordination mechanisms such as regularly scheduled meetings, and design review meetings. I chose to use the Kraut & Streeter (1995) adaptation of administrative coordination measures (both formal and interpersonal) to the study of software development. Their questions form a succinct and coherent set of administrative coordination measures (6 items).

3.2.2.3 Team Heterogeneity

Team heterogeneity measures how varied team composition is. This construct is important because teams that have a high degree of heterogeneity are likely to lack social integration, face problems in communication, and face lowered cohesion (Pfeffer & O'Reilly, 1987; Smith et al., 1994; Tsui & O'Reilly, 1989). Team heterogeneity has been measured in terms of variation in the level of education, experience, and functional background. The measure of heterogeneity, also called coefficient of variation, takes the following form:

$$\text{coefficient of variation} = S.D._x / Mean_x$$

The importance of professional experience in affecting software development outcomes is a consistent finding in software development studies (Boehm, 1987; Brooks, 1975, 1987; Schneiderman, 1980; Yourdon, 1993). Thus, I chose to derive a coefficient of variation for professional experience, a factor that is already well established in the team literature (Ancona & Caldwell, 1992; Guinan, Cooprider, & Faraj, forthcoming; Tsui & O'Reilly, 1989).

3.2.3 Moderating Measure: Task Uncertainty

Task uncertainty has been long recognized as an important measure of how effectively the work (transformation of inputs into outputs) can be reduced to pre-defined steps or objective procedures (Whithey, Daft, & Cooper, 1983). Uncertainty is an essential characteristic of task and has been posited to moderate process to outcome relations in team models. The instrument developed by Whithey et al., has been used in a large number of studies and its reliability and validity have been confirmed. I used the version developed by Nidumolu (1985) specifically for the software development environment. The four item instrument demonstrated a high degree of reliability in a similar setting to this one.

3.2.4 Dependent Measure: Team Effectiveness

Team performance is a multidimensional concept. A variety of dimensions of team performance have been presented in the literature including actual output (Cheng, 1984; Goodman, 1986; Goodman & Leyden, 1991), managerial measures of efficiency and effectiveness (Argote, 1982; Fry & Slocum, 1984; Gupta, Dirsmith, & Fogarty, 1994), and job satisfaction and organizational commitment (Campion, Medsker, & Higgs, 1993; Gaertner, & Nollen, 1989; Van de Ven & Ferry, 1980). The importance of each dimension of team performance will vary depending on the study's theoretical emphasis; measures of performance that are valid for one domain may not be appropriate for another. Further, certain performance measures, such as effectiveness and efficiency, may vary in opposite directions: an increase in one may be associated with a decrease in the other. I focus on team effectiveness due to its clearer theoretical linkage with expertise coordination.

I propose to use subjective measures of effectiveness because there are substantial problems associated with the use of objective measures in the IS field (Ives, Olson, & Baroudi, 1983; Henderson and Lee, 1992; Kemerer, 1989). First, objective measures are often unavailable since not all teams or sites collect such data or are willing to provide it. Second, objective measures such as productivity per Function Point and actual/initial budget ratios are often subject to manipulations, both deliberate and inadvertent, and may reflect the specific accounting practices of a site rather than an "actual" performance.[17] Third, using objective measures assumes comparability across projects and does not control for idiosyncratic differences between projects or unique situational constraints, and thus raise a new set of methodological and measurement issues. Thus, I preferred to rely on expert judgment as a better source of performance data.

A key issue in team performance measurement is the problem of response bias. Tsui (1984) has found that constituent groups have different interests, different responses and understanding of performance. Team members seem to provide markedly different assessments of team performance than is supported by either managers' rating or outcome data (Ancona & Caldwell, 1992; Gladstein, 1984; Guinan, Cooprider, & Faraj, forthcoming). I decided to use stakeholder ratings as my primary means to assess team effectiveness. A stakeholder is an individual, knowledgeable about the team, who is not a formal member of the team but who is affected by the outcome of the project or is capable of affecting the team's performance. Previous research has shown that subjective assessments of effectiveness provided by knowledgeable managers have a high level of

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[17] I did manage to collect estimates of Function Point (FP) for about 32 projects. The data was provided by the team leader. Prior to analysis, I was told by the study's project manager that FP data on most projects was available at headquarters. As expected I requested the data and provided the names for the projects in the study, expecting a gold mine of FP data to suddenly materialize. However, it was not to be. After two weeks of search at headquarters, the study manager was able to find some of the FP data, but the numbers did not match those provided by

convergence with other objective measures of performance (Bourgeois, 1980; Venkatraman and Ramanujan, 1987). Other research has demonstrated that private performance ratings generated for research purposes may be freer from bias and have better validity and reliability than official administrative ratings (Tsui & O'Reilly, 1989).

For IS development, a key issue is whom to choose as a stakeholder. Because application software teams have to meet the requirements of both a client and those of their internal organization, I chose to survey two stakeholders, one from IS and the other from the client side in order to rate the team. Measures of effectiveness are based on a validated (5 items) instrument previously used in the IS context (Henderson and Lee, 1992 and Guinan et al. forthcoming).

3.3 Research Site and Project Development

This research investigates software development teams at a large high-technology firm specializing in software development. The firm, a Fortune 50 multinational with over 100,000 employees, is one of the largest players in the outsourcing business and is involved in a large variety of software development projects. As one of the oldest and

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the teams, and often differed by wide margins. By mutual agreement, the study manager and I stopped all attempts to gather "objective" data.

largest software developers, the company has long been interested in procedures on how to measure, motivate, improve, and support the software development process. The specific organizational sponsor of this study was the applications development division of the firm. The division (a de facto independent organization) develops application software for other divisions of the firm as well as for commercial clients. Teams developing software for a variety of industries and types of application were provided. Most key sites of the firm were involved in the study, including sites in 13 states: Connecticut, New York, New Jersey, Maryland, Georgia, North Carolina, Alabama, Ohio, Illinois, Texas, Colorado, Kentucky, and California.

A project coordinator from the firm's headquarters assisted in the development of the study and the selection of teams to participate in this study. For each region, the project coordinator contacted senior managers, presented the study's goals, and asked them to allow their site to participate in the study. Once a site senior manager agreed to participate in the study, I contacted him directly and generally ended up working the details through a less senior manager who was given the assignment to coordinate the study. I gave the site's study manager the criteria list of what kind of teams were appropriate for the study (see Table 3-2) and the manager generated a list of 78 teams that met the criteria. At that point I contacted each team leader separately and mailed him/her a survey package or sent the site manager a number of packages to distribute to the teams.[18]

[18] This study's unfolding, while by no means unusual, can be informative for those attempting to study teams in real organizational settings. The study was funded by a senior Vice President from headquarters and data collection looked promising with a target sample of over 100 teams. The study started in earnest in February of 1995 and was due to be completed within a year. The chief sponsor of the study and his right hand senior manager both took on other jobs midway through the life of the project. The new senior manager turned out to be a person who did not believe in academic studies (too theoretical) and no longer championed our research. Data collection suddenly became much more difficult. The study was completed only because we were already so far along and we agreed to continue the work at no cost to the firm. Over a period of a year and a half, the study had 3 different project managers.

Criterion	Explanation
• Sites are selected so as to maximize geographic diversity with no single site being over-represented.	• Since this study is not based on a random sample but rather on a convenience sample, steps need to be taken to ensure that the sample is representative. • Because the organization is so large, there may be differences in organizational culture and experience in developing software that may make certain sites more effective than others. Thus the need for a careful selection of teams (emphasis on breadth and representativeness).
• Teams are selected so as to maximize representation of teams with a diversity in previous performance or reputation.	• I specifically asked for either a random sample, or if not possible, a broad diversity of teams, especially with regard to performance and reputation in order to avoid any tendency from site managers to provide only their best teams.
• Team must be developing application software.	• In addition to application software, the organization develops packaged software and systems software. I view these domains to be significantly different and thus representing a very different task. I chose to control for the task type by limiting the sample to application software.
• Teams are to be staffed almost exclusively by company employees rather than by external consultants.	• The presence of part-time employees, off site workers, and external consultants can significantly affect the team dynamics and work processes. I chose to exclude teams with high levels of part-timers and consultants.

Criterion	Explanation
• This project is the primary project for most team members.	• A team made up primarily of part-time team members is not equivalent to a team staffed by full time members.
• Teams need to have completed the requirements phase of the lifecycle.	• Teams that are in the early phase of a project are still forming internally, are facing changing requirements, and are struggling to define their task. • Teams that are at a later stage of the lifecycle have already "gelled" as a team and are facing a stable set of requirements.
• Teams are required to be of average size, ranging from 4 to 15 people.	• I believe that large teams (and very small teams) have different dynamics than medium sized teams. The sheer number of team members on large projects forces the development of significantly different coordination modes than on medium teams.
• Project duration is required to be at least 6 months but no more than 18 months.	• Because of the need to collect effectiveness data from stakeholders at the end of the project, pragmatic considerations of data collection practicality led me to choose projects that were of medium duration. • Multi-year projects may face different pressures and develop different dynamics than shorter projects.

Table 3.2: Description of study criteria for team selection

At the level of the team, participation was voluntary as the team had to agree to participate in the study before being included in our sample. Within a team, individuals had the option of not participating as well as the option to remain anonymous.

In view of the number of sites represented in the study and the stringent requirements for team participation, I am confident that the sampling plan allowed me to control for a significant amount of exogenous variance in team behaviors and performance.

The teams were not informed of the theoretical framework and hypotheses guiding the study. The teams basically committed to participate in a university study of software development that was supported by management. The study was described as a general study to investigate software development teams. The firm's project coordinator and several within-firm researchers reviewed the survey instrument prior to its distribution. Their comments, mainly language change, were helpful in focusing the instrument and making it palatable to the typical developer.

3.4 Questionnaire Administration

Each team participating in the study was sent a number of surveys equivalent to the number of members of the team. The team leader was my point of contact with the team and distributed the surveys to team members. Each team member filled out the same survey. The team leader, on the other hand, received a modified version of the same survey. The main difference is that team member surveys included a section on leadership, while the team leader survey had that section replaced with questions about the nature of the project, its stage of the lifecycle, size in function points and additional project metrics. The survey took approximately 30 minutes to complete.

Included in each individual package were instructions as well as a set of stamped pre-addressed envelopes for mailing back the survey once it was completed. Once surveys were received at BU, I coded each survey with a unique identifier. The next step entailed checking data integrity (do the answers make sense?) and completeness (are all the sections filled out?). A research assistant (experienced graduate student) and I checked the returned surveys for lapses, missing data, and misunderstood questions. If any problem was found, respondents were called for confirmation or correction. Surveys with major sections missing (or misunderstood) were faxed back to the author (with their approval) for completion. Next, a coding scheme was developed and the surveys were sent out for data coding. The resulting computerized data was then checked for accuracy and completeness against the actual physical instruments. Only at that point was statistical data analysis initiated.

An important feature of this study was the use of stakeholders to assess team effectiveness. The team leader was asked for the names and email addresses of two stakeholders (generally managers), one from IS and one from the client side. Each stakeholder was sent either a paper or an electronic version of the outcome survey. The use of electronic communication for data collection was very effective. The firm operates a sophisticated internal electronic communication system that I used to communicate with both the team leaders and the stakeholders. A few outside client stakeholders were not reachable by electronic mail and thus received an identical paper survey. The stakeholder survey is a very short set of questions measuring aspects of team performance. The received stakeholder surveys were checked, assigned an identification number, and coded prior to data analysis. Table 3.2 below details the various data collection instruments

Type of Respondent	**Number per team**	**Instrument**
Team member	N - 1	Paper survey focuses on team processes
Team leader	1	Paper survey, similar to team member surveys but asks for project level information
Stakeholder (IS)	1	short electronic survey
Stakeholder (Client)	1	short electronic or paper survey

Table 3.2: Data collection instruments

3.5 Power Analysis

Support for the hypothesized model depends on our ability to muster a sample size sufficient to detect non-random increases in R^2. The power of a statistical procedure is the probability that it will yield statistically significant results (Cohen, 1988). More formally, it is the probability of rejecting H0 given that H0 is false. It can also be thought of as the likelihood that the study will detect a deviation from the null hypothesis given that such a deviation exists. Power analysis is necessary in order to identify the confidence we can place in the study's findings.

This is done by testing whether the proportion of variance in the dependent variable is accounted for by the independent variables in the study. Using a power level of .8 and an alpha value of .05,[19] we can derive a required sample size that matches the pre-identified level of effect size.[20] Table 3.4 below provides the sample size required for different population effect sizes.

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[19] Power analysis requires the specification of levels of type 1 and type 2 errors. Type 1 error (alpha) deals with the problem of finding an effect when there is not one, i.e. mistakenly rejecting the null hypothesis when it is true. Type 2 error (beta) refers to the probability of failing to reject the null hypothesis when it is false. Power is calculated as: 1 - beta. Commonly accepted levels of alpha and beta are .05 and .2 respectively (Cohen, 1992: 156).

[20] The actual procedure for calculating required sample size requires the specification of an effect size and the use of several equations and lookup tables. The interested reader is referred to Cohen (1988) pp. 407-465.

Number of Independent Variables	Effect Size: Small (.02)	Effect Size: Medium (.15)	Effect Size: Large (.35)
2	481	67	30
3	547	76	34
4	599	84	38
5	645	91	42
6	686	97	45
7	726	102	48
8	757	107	50

Note: A small effect size corresponds to an equation R^2 of .02; a medium effect size corresponds to an equation R^2 of .13; A large effect size corresponds to an equation R^2 of .26.

Table 3.4: Power Analysis: N required for a power level of .8 in regression type studies (at $\alpha = .05$)

A more specific evaluation of the R^2 level that we expect to find can provide an accurate calculation of the required sample size. I will assume that the theoretical model will generate a R^2 level of .2, which is reasonable for organizational and social psychological studies (Cohen, 1988: 414) and in line with similar team level studies.[21] Thus for the same

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[21] Recent team level studies based on similar theoretical approaches have developed R^2 levels of: .27-.4 (Kraut & Streeter, 1995), .26 (Guinan, Cooprider, & Faraj, forthcoming), and .17 (Ancona & Caldwell, 1992).

power level of .8, α level of .05, and for our largest model consisting of 6 independent variables, we derive a required sample size of 61 teams. Since the response set contains 69 teams, the appropriate sample size requirement has been exceeded.

4. Chapter Four: Results

This chapter summarizes the results of data analysis. The first section presents preliminary analyses: response analysis, individual to team aggregation analysis, and measurement issues related to convergent and discriminant analysis. The second section presents the descriptive results including sample sites and demographics. The third section reports on hypotheses and model tests. The fourth and final section reports on additional analysis focusing on the link between expertise coordination and other variables.

4.1 Preliminary Analyses

4.1.1 Response Analysis

The team level focus of this study requires response analysis at both the team level and at the within-team level. Nine out of 78 teams in the sample did not participate or complete the study, for a team-level response rate of 88%. The reasons for dropping out included: two team leaders going on maternity leave, two team leader leaving the job, and a customer abruptly ending the project. In four of the teams, people complained about the lack of available time to fill out the survey and reminded the manager (and the researcher) that participation in the study was voluntary.

Within each team, response rate varied. At an aggregate level, the mean size of a team is 10 people. We received a mean of 5 responses per team, or a 50 percent mean within team response rate. During data collection, I undertook a focused email and phone campaign in order to increase the response rate. I contacted every team leader to stress the importance of having as many team members as possible fill out the survey. In almost all the cases the team leaders reported that core team members were responding to the survey. On the other hand, marginal team members, such as consultants or part-time team members were often no longer part of the team or had less interest in the project. Based on the phone interaction with every team leader, I believe that most core team members responded to the survey.

Further, statistical analysis to determine the (within-team) response rate required to ensure representative responses from the team was undertaken. Results indicate that for an average team size of 10 the average number of respondents needed was approximately 4 (see Campion, Medsker & Higgs, 1993; Warwick & Lininger, 1975 for more details on the statistical derivation). Since this study generated (on average) 5 responses per team, confidence is warranted in the statistical representativeness of the within-team sample.

4.1.2 Aggregation Analysis

Before aggregating individual responses to the team level, it is necessary to test the homogeneity, independence, and heterogeneity of measures. Two classes of statistical tests have been suggested in the literature to answer the question of whether the variability within teams differs from what would be expected by chance. The first class of tests compares within and between team variance using Intra-Class Correlation (ICC). The second class of procedures assesses within team agreement of each team separately using a new procedure called Inter-Rater Agreement (IRA). Both tests are performed because they are based on different statistical assumptions and thus provide methodological and statistical triangulation.

The ICC is based on a nested ANOVA test that tests whether membership in the same team leads to more similar answers. If the ICC is one then all the team members have the same score; if the ICC is zero, then people within a team are no more similar than people from different teams. According to Kenny & Lavoie (1985) and Florin et al. (1990), a question is meaningful at the team level if the question is conceptually meaningful at that level (the question matches the level of the theory) and the ICC is greater than zero. Statistically, the ICC indicates the proportion of variance in the dependent variable that is determined by team membership. There is no agreed upon guideline on the cutoff value for acceptable ICCs. James (1982) reviewed the previously published studies and found that the mean reported ICC was .12. Table 4.1 provides the ICC values for this study's variables. As can be seen by the range of ICCs (.32 to .61) these results suggest a substantial level of agreement within all the teams.

While variance techniques can suggest when it is inappropriate to perform analysis at the aggregate level, they tend to suffer from false negative error. Muthen (1991) demonstrated that "ANOVA substantially underestimates the intraclass correlation, or the proportion of between-class variation" (p. 352). Therefore in the context of organizational research, where organizations tend to have homogeneous groups of individuals, ANOVA and WABA techniques have limitations.

The second class of methods focus on Inter Rater Agreement (IRA), and is best represented by the R_{wg} procedure which assesses the amount of agreement among respondents (James, Demaree, & Wolf, 1984, 1993; Kozlowski & Hattrup, 1992). The technique uses the proportion of non-error variance in the ratings to assesses agreement among the judgments made by a single group of judges on a single variable.

The IRA is appropriate for team research because it compares the convergence of the responses from multiple respondents evaluating a single target. In short, the IRA assesses reliability across informants. A strength of this method is that it compares the responses within a team without including any information from the other teams. Thus it is unaffected by situations where distribution properties that underlie ANOVA, such as restriction of range, are violated. For example, in many organizations institutional forces (such as culture) may restrict variance and make team responses overtly similar. In such situations, the IRA method effectively uncovers within-team agreement in cases where means may not differ across teams. Thus agreement within a team is not conditional on disagreement between teams (see George & James, 1992 for a fuller discussion). Table 4.1 presents the results of the IRA tests for this study's variables. The values range from .59 to .88. There are no commonly agreed upon required levels for IRA in the literature. The IRA is broadly construed as a test of agreement and is affected by the number of raters. Based on the simulation work of Kozlowski and Hattrup (1992), I propose the conservative cutoff point of .525 which is more than twice the level they have identified as representing moderate agreement for a sample size equivalent to my average team size. All the variables exceed this level and thus reflect a high degree of within team agreement.

Construct	Intra-Class Correlation (ICC)	Inter-Rater Agreement (Rwg)
Expertise Presence	.32	NA[22]
Administrative Coordination	.44	.77
Task Uncertainty	.37	.76
Location of Expertise	.29	.88
Access to Expertise	.32	.85
Need for Expertise	.25	.59
Team Effectiveness	.61	.83

Table 4.1: Aggregation Analysis Results

4.1.3 Measurement Properties

Analysis of the measurement model is a crucial first step before undertaking an analysis of the relationship between measured constructs. This analysis process requires the explicit demonstration that the measures are valid and that they adequately reflect theoretical

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[22] We could not calculate a value for expertise presence because proper application of the Rwg procedure assumes an interval scale of limited breadth (for e.g. scales of 5, 7, or 9 values). Expertise presence was elicited through a percentage range that can take values from 0 to 100.

constructs. In this section, I report the results of different analyses addressing: 1) the internal consistency of measurements, and 2) the convergent and discriminant validity for the three new constructs developed for expertise coordination.

4.1.3.1 Internal Consistency of Measurements

Items that make up a construct must be checked for interitem reliability. This step is important since in addition to aggregating across the team, we need to show support for aggregating within-respondent but across items. The internal consistency of an operationalization refers to the degree of homogeneity of the indicators underlying a theoretical construct. This evaluation of internal consistency requires the presence of multiple indicators for each theoretical construct. The most commonly used measure of internal consistency is Cronbach's coefficient Alpha (Cronbach, 1951). While a pre-specified cutoff level for Cronbach's Alpha is not recommended (Pedhazur & Schmelkin, 1991), acceptable values for perceptual measures are recommended to exceed the value of .7 (Nunnally, 1978).[23] When the level of Alpha is much lower than such a minimum, the implication is that the indicators underlying the construct may be unrelated or measuring more than one construct.

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[23] An Alpha of .7 indicates that 70% of the scale's variance is systematic.

An additional concern regarding the internal consistency of measures is the level of analysis. Cronbach Alpha values need to be derived at both individual and team level of analysis in order to ascertain if the process of aggregation to the team level negatively affects the internal consistency of the measures. Any major change in alpha when going from individual to team level aggregation would indicate a theoretical problem with the construct. Table 4.2 presents the Cronbach Alpha levels of all our variables at both the individual and the team level. The Cronbach Alpha levels are all greater than .8 and thus comfortably demonstrate internal consistency of measurement.

Construct	Number of Items	Cronbach Alpha (individual level data)	Number of Respondents	Cronbach Alpha (team level data)	Number of Teams
Expertise Presence	3	.82	306	.88	69
Administrative Coordination	6	.80	305	.82	69
Task Unanalyzabilitiy	4	.82	314	.89	69
Location of Expertise	4	.87	325	.90	69
Access to Expertise	4	.82	323	.89	69
Need for Expertise	3	.81	324	.86	69
Team Effectiveness	5	.89	124	.86	69

Table 4.2: Cronbach Alpha Levels at Both the Individual and Team Level

4.1.3.2 Convergent and Discriminant Validity

Two complementary procedures can be used to investigate convergent and discriminant validity. First, data analysis using a Multi-Trait Multi-Method (MTMM) matrix has long been proposed to deal with convergent and discriminant analysis issues (Campbell & Fiske, 1959). Second, factor analysis can provide confirmation that different sets of indicators correspond to their theoretical constructs.

While the MTMM approach was initially aimed at measuring the impact of maximally different methods, the procedure can be simplified to analyze single method (i.e. single source) situations. Using an indicator level MTMM correlation table, one can examine if the indicators underlying a theoretical construct have a high degree of correlation among one another compared to their correlation with indicators underlying other constructs. If the majority of the indicators have their highest correlation with their own construct, then convergent and discriminant validity is supported. As seen in table 4.3, all our indicators have a stronger correlation with one another and a lower correlation with the other indicators, thus providing strong support for our convergent and discriminant validity claims.

	Expertise-Location1	Expertise-Location2	Expertise-Location3	Expertise-Location4	Expertise-Need1	Expertise-Need2	Expertise-Need3	Expertise-Access1	Expertise-Access2	Expertise-Access3	Expertise-Access4
Expertise-Location1	1.0000										
Expertise-Location2	.7017**	1.0000									
Expertise-Location3	.6972**	.6978**	1.0000								
Expertise-Location4	.5518**	.5068**	.6245**	1.0000							
Expertise-Need1	-.1560**	-.2689**	-.1822**	-.1609**	1.0000						
Expertise-Need2	-.1850**	-.2726**	-.1959**	-.2223**	.4746**	1.0000					
Expertise-Need3	-.2130**	-.3045**	-.2043**	-.2133**	.6001**	.6632**	1.0000				
Expertise-Access1	.3826**	.3561**	.3476**	.3415**	-.1622**	-.3110**	-.2980**	1.0000			
Expertise-Access2	.3183**	.3430**	.3687**	.2780**	-.1736**	-.3128**	-.3234**	.5070**	1.0000		
Expertise-Access3	.3722**	.3935**	.3715**	.3451**	-.1324*	-.2567**	-.2320**	.5115**	.5131**	1.0000	
Expertise-Access4	.3753**	.4036**	.4029**	.3550**	-.1091*	-.2382**	-.1731**	.4940**	.4718**	.7055**	1.0000

* $p < .05$, ** $p < .01$

Table 4.3: Item Level Correlation Analysis (Individual Level)

The measurement model (represented by the correlation matrix in table 4.3) was further analyzed using a factor analysis with a varimax rotation. These results are shown in table 4.4. Three factors resulted from the analysis and are consistent with our theoretical model. Average communality was .70 which is well above the .6 level recommended by Stevens (1986: 342) for samples of this size and thus supports our 3 factor solution. The 3 factors account for 70.5% of the total variance and had Eigenvalues of 4.6, 1.8, and 1.3.

	Factor 1	Factor 2	Factor 3
Expertise-Location1	.86		
Expertise-Location2	.85		
Expertise-Location3	.81		
Expertise-Location4	.74		
Expertise-Access1		.83	
Expertise-Access2		.81	
Expertise-Access3		.73	
Expertise-Access4		.71	
Expertise-Need1			.87
Expertise-Need2			.83
Expertise-Need3			.80

Note: Loadings smaller than .26 are not shown

Table 4.4: Factor Analysis for Expertise Coordination (individual level of analysis)

4.2 *Descriptive Results, Including Sites and Demographics*

4.2.1 Sample Sites and Demographics

Responses were received from 13 sites across the US. These sites included all key regions and several independent sites. A total of 333 respondents from 69 teams participated in the study. In addition, we collected ratings of these teams from 135 stakeholder respondents (with about half the ratings coming from the IS organization and half coming from the client side).

A little over one third of the team respondents were female. The average age of the respondent was 39 years. They had almost 12 years experience in the software field, with the majority of those years (11 of them) spent at the current firm. Most respondents were highly educated with 84% having completed college. Approximately 23% of the respondents had a masters degree or higher. Approximately a fifth of the responses came from team leaders, 30% of respondents were programmers, 17% called themselves system analysts, while a further 17% identified themselves as specialists or consultants. Figure 4.5 describes the characteristics of the individual respondents in the sample.

Variable	Statistic
Gender:	63.4% male
Age:	Mean: 38.9 years (s.d.: 8.5)
Experience in Software Field:	Mean: 11.8 years (s.d.: 6.6)
Experience with Current Employer:	Mean: 11.1 years (s.d.: 8.3)
Education:	Ph.D.: .3% MS and advanced courses: 8.8% MS: 13.9% BS and advanced courses: 29.7% BS: 31.2% H. S. and advanced courses: 16.1%
Position:	Project leader/manager: 21.7% Systems Analyst: 16.7% Senior Programmer: 23.2% Junior Programmer: 6.5% IS Specialist: 5.5% Business Function Specialist: 2.2% Consultant: 9.9% Other: 14.2%

Table 4.5: Demographic Characteristics of Respondents

We received approximately 5 responses per team. The average size of the team participating in our study was approximately 10 people. Thus we have collected response from half the team members. The average size of project was approximately 11 thousand person-hours. Regional analysis indicates no response bias from any of the key regions. Figure 4.6 provides a summary description of the projects by region.

Region	Number of Participating Teams	Mean Number of Respondents per Team	Overall Mean Size of Team	Project Budgeted Labor (in person-hours)
Site 1	14	5	9	16,857
Site 2	14	5	11	11,151
Site 3	16	4	7	6,974
Site 4	7	5	10	12,559
Site 5	7	5	15	5,354 (only 2 teams reporting)
Site 6	7	6	10	14,650
Other	4	5	10	7,369
Total	**69**	5	**10**	**10,881 (52 teams reporting)**

Table 4.6: Descriptive Project Statistics for Different Regions

4.2.2 Statistical Results

Table 4.7 presents the means and standard deviations and inter-correlations of the variables present in the research model. All the variables with the exception of expertise presence and expertise heterogeneity are measured using a 1-5 Likert scale. The standard deviation of the team aggregated variables are typical of team studies and thus show a reasonable diversity in responses.[24] Expertise presence was measured using a 0-100% range while expertise heterogeneity was measured using a coefficient of variation of tenure. I investigated the distributional properties of the variables: skewness ranged from .089 to 1.116 with a mean of .496; kurtosis ranged from .126 to 2.40 with a mean of .905. These results indicate that the variables are well below the levels requiring transformation of variables: skewness of two and kurtosis of five (Ghiselli, Campbell, & Zedeck, 1981). Before presenting the results of the model of team effectiveness, I investigate the relationships among all predictor variables.

The relationship between administrative coordination with the expertise coordination measures is moderate to low (r =.07 to .25), further indicating conceptual separateness. Administrative coordination is moderately linked to team effectiveness ($r = .20, p < .1$) as expected from the literature (Van de Ven, Delbecq, & Koenig, 1976). There is a strong

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[24] Aggregation to the team level of individual answers always reduces the standard deviation (SD) associated with the mean. In order to ensure that the SD for my measures is adequate, I compared the values to those of similar studies that used 5-item scales. Ancona & Caldwell (1992) used 7

negative relationship between task uncertainty and administrative coordination ($r = -.61$, $p < .001$). While there is no indication of multicollinearity,[25] the strength of the relation shows that teams facing highly uncertain task environments will rely less on administrative means of coordination.

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different variables and had a very similar average SD of .42 (range: .38-.46). My average SD for 7 different variables was .46.

[25] Multicollinearity becomes a problem when the correlation between two variables exceeds .8 (Billings & Wroten, 1978).

Variable	Mean	S. D.	Scale Range	Correlation Coefficients 1	2	3	4	5	6	7
1. Administrative Coordination	3.49	.56	1-5							
2. Expertise Presence	78.3	12.7	0-100%	.18						
3. Experience Heterogeneity	.56	.32	NA[26]	.12	.01					
4. Task Uncertainty	2.55	.54	1-5	-.61	-.3	-.03				
5. Expertise Location	3.94	.39	1-5	.22	.31	.03	-.32			
6. Expertise Needed	2.3	.53	1-5	.07	-.26	-.14	.28	-.34		
7. Expertise Access	4.28	.39	1-5	.25	.17	.11	-.38	.56	-.34	
8. Team Effectiveness	4.07	.48	1-5	.2	.12	.04	-.23	.47	-.2	.48

Note: N = 69. Correlations > .25 are significant at $p < .05$; correlations > .31 are significant at $p < .01$.

Table 4.7: Descriptive results and correlation matrix (team level analysis)

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[26] Expertise presence is measured using a coefficient of variation (S.D./Mean) and thus has no predefined endpoints.

4.3 Hypothesis and Model Testing

4.3.1 Model Testing Approach

Since my key theoretical proposition is that expertise coordination contributes to team effectiveness *above and beyond* traditional factors, I used hierarchical regression analysis to test the theoretical model. Hierarchical regression analysis is a variation of traditional regression analysis that makes it possible to test whether a set of variables (one or more) adds significantly to variance already explained by a prior set of variables. Hierarchical regressions allow the evaluation of the impact of competing sets of variables by entering them as a block in the regression (Cohen & Cohen, 1983). It is important in studies like this one that variables are entered in the equation in the theoretically specified order. This helps improve the interpretation of the impact of each set of variables onto the dependent measure, since the contribution of earlier variables has already been partialled out.

If the R^2 change is significant, then the block of variables is said to contribute to the explanatory power of the model above and beyond the variables previously in the model. The key aspect of the analysis is that the *change* in F associated with each additional set of variables in the equation provides support for the new model. In other words, we are testing a null hypothesis that there is no increase in R^2. If the null hypothesis is rejected, then we can conclude that the set of new variables adds significantly to the variance explained by variables already in the model.[27]

My first regression tests the traditional factors model corresponding to hypothesis 1:

$$\text{Performance} = \beta_0 + \beta_1(\text{presence of expertise}) + \beta_2(\text{administrative coordination}) + \beta_3(\text{team heterogeneity}) + \varepsilon$$

The second regression tests the direct impact on team effectiveness of the expertise coordination model (hypothesis 2):

$$\text{Performance} = \beta_0 + \beta_1(\text{recognition of expertise need}) + \beta_2(\text{knowing expertise location}) + \beta_3(\text{accessing expertise}) + \varepsilon$$

The third regression tests how much the expertise coordination model explains above and beyond the conventional factors (Hypothesis 3):

[27] I also examined the distribution properties of the data to ensure that the assumptions of ordinary least square regressions were met.

Performance = $\beta_0 + \beta_1$(presence of expertise) + β_2(administrative coordination) + β_3(team heterogeneity) + β_4(recognition of expertise need) + β_5(knowing expertise location) + β_6(accessing expertise) + ε

The fourth equation tests the exploratory moderation impact of task uncertainty on the relationship between expertise coordination and team performance, using an interaction term formulation (hypothesis 4):

Performance = $\beta_0 + \beta_1$(presence of expertise) + β_2(administrative coordination) + β_3(team heterogeneity) + β_4(recognition of expertise need) + β_5(knowing expertise location) + β_6(accessing expertise) + β_7 (recognition of expertise need)*(uncertainty) + β_8(knowing expertise location) *(uncertainty) + β_9(accessing expertise) *(uncertainty) + ε

The presence of both the original terms (the expertise coordination variables) as well as multiplicative terms (expertise coordination * task uncertainty) in the regression, may lead to multicollinearity problems. Thus, there is a need to transform these variables by centering them in order to reduce the multicollinearity (see Aiken & West, 1991). I did the analysis both ways in order to obtain a fuller picture of the data results.

4.3.2 Empirical Results

To test the first 3 hypotheses, I used a simple hierarchical regression analysis in order to test whether the expertise coordination dimensions contributed to team effectiveness above and beyond the control variables. In step 1, the three traditional factors (administrative coordination, experience homogeneity, and presence of expertise) were entered in the regression as a set. A significant R^2 and associated F would indicate support for hypothesis 1. In step 2, the three dimensions of expertise coordination were entered in the regression as a set. Similar to step 1 analysis, a significant R^2 and associated F would indicate support for hypothesis 2. In the third step, the three expertise coordination variables are entered in a regression model that already contains the three control variables. If the change in R^2 is significant as indicated by the significance of the F statistic, then hypothesis 3 is supported.

Table 4.8 presents the results of the hierarchical regression analysis. Column 1 presents the regression results associated with the traditional factors model. The R^2 of the model is minor (4.8%) and when adjusted for degrees of freedom tends to disappear ($R^2_{adj.}$ = .4%). Thus, hypothesis 1 is not supported.

Column 2 presents the regression results associated with the expertise coordination dimensions. The model is significant (R^2 = 29.1%, $R^2_{adj.}$ = 25.8%, F = 8.88, p = .000) and provides support for hypothesis 2.

Column 3 assesses the additional impact of expertise coordination above and beyond the control variables. The model is significant (ΔR^2 = 24.8%, F for ΔR^2 =7.27, p = .001) and thus provides support for hypothesis 3.

In addition to the assessment of the impact of variables entered as a block, regression analysis allows the evaluation of the individual contribution of each variable. Administrative coordination (in column 1) has a reasonably high value (.19) which, even though not significant, indicates a weak link with team effectiveness. In contrast, the other two control variables exhibit no link with team effectiveness. Two of the three expertise coordination variables exhibit strong links with team effectiveness: expertise location (b = .29, p <.05) and expertise access (b = .32, p <.05). The third expertise coordination variable, expertise needed was not significant.

	H1	H2	H3
Control Variables β:			
Admin. Coordination	.19		.07
Experience homogeneity	.01		-.01
Presence of expertise	.08		-.04
Expertise Coordination β:			
Expertise Location		.29*	.29*
Expertise Needed		.01	-.02
Expertise Access		.32*	.30*
Model Statistics:			
N	69	69	69
R^2	4.8%	29.1%	29.6%
Adjusted R^2	0.4%	25.8%	22.8%
Model F	1.10	8.88***	4.34**
ΔR^2 from model 1			24.8%
F for ΔR^2			7.27***[28]

$p < .05$, ** $p < .01$, *** $p < .001$

Table 4.8: Hierarchical Regression Results, Tests of Hypotheses 1, 2, and 3, for Team Effectiveness

[28] This statistic (joint F test) represents the impact of the incremental variance accounted by the variables of the model above and beyond the variance of the variables in the base model.

To test whether task uncertainty was a moderator to the relationship between expertise coordination and team effectiveness (hypothesis 4), I used moderated regression analysis. Evidence of moderation exists when the interaction terms explain a significant portion of the variance of the dependent variable.

Several authors have recommended the use of centered variables for the analysis of multiplicative interaction terms in order to reduce the effect of multicollinearity among variables (Aiken & West, 1991; Aguinis, 1995; Cronbach, 1987). Multicollinearity is detrimental to moderated regression analysis because it increases rounding and regression sample error and complicates the interpretation of regression coefficients (Cronbach, 1987). I centered the predictor variables before creating the multiplicative terms and then ran the moderated regression analysis. The result are presented in table 4.9. As shown by looking at the change in R^2 and its associated F for R^2 change, the interaction between task uncertainty and the expertise coordination factors is non-significant. Thus, Hypothesis 4 is not supported.

	Unmoderated Model	Moderated Model
Block 1(main effects):		
Expertise Location (EL)	.32*	.30*
Expertise Needed	.01	.01
Expertise Access	.29*	.33*
Task Uncertainty	-.02	-.22
Block 2 (interaction effects):		
Task Uncertainty X Expertise Location		.02
Task Uncertainty X Expertise Needed		.20
Task Uncertainty X Expertise Access		-.07
Model Statistics:		
N	69	69
R^2	29.1%	29.3%
Adjusted R^2	24.6%	21.1%
Model F	6.57***	3.60**
ΔR^2 from model 1		.2%
F for ΔR^2		.05

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 4.9: Hierarchical Regression Results, Tests of Hypothesis Four

4.4 Additional Analyses

The previous section showed that the traditional factors model did not significantly predict team effectiveness and that the expertise coordination model did significantly predict team effectiveness, even in the presence of the traditional factors model variables. Four key issues need to be addressed in order to better understand the role of expertise coordination in software development teams. First, what is the relationship between the traditional factors model variables and expertise coordination?. Specifically, does expertise coordination mediate between the traditional factors model and team effectiveness. Second, the traditional factors model included only 3 variables which offered potentially competing explanations as sources of expertise and its coordination. Further analysis is needed to investigate the impact of a variety of demographic and input variables on the theoretical model. Third, the measure of team performance used in this study is one of effectiveness. Does the use of an alternative and complementary measure of performance lead to different results? Fourth, the significance of the expertise coordination model leads to an important derivative question: how do we promote expertise coordination on teams? Additional analysis is needed to identify the determinants of expertise coordination.

4.4.1 Relation Between Conventional Factors and Expertise Coordination

Team heterogeneity has been shown to have a direct and negative effect on team performance (Ancona & Caldwell, 1992; Guinan, Cooprider, & Faraj, forthcoming) and less frequently has been shown to have a negative impact on team processes (Pelled, 1996; Smith et al., 1994; Wagner, Pfeffer, & O'Reilly, 1984). While the impact of heterogeneity on affective variables such as cohesion or on communication levels has been documented, it is less clear through what specific work-related processes its influence is operating (Keck, 1997; Lawrence, 1997). Thus, it is difficult to propose any hypothesis on the impact of experience heterogeneity on expertise coordination processes.

The presence of expertise is likely to affect expertise coordination processes directly. If a team includes high levels of design, technical, and domain expertise, then these team members are likely to be specialists who need to share their specialized skills and knowledge. Further, expert team members are likely to develop effective patterns of interaction, cohesion, and ease of communication (Sims, et al. 1994). Teams containing high levels of expertise have been shown to develop superior teamwork processes (Tziner & Eden, 1985). Thus, I expect teams with high degree of expertise to be positively related to expertise coordination processes.

Finally, a team engaged in high levels of administrative coordination is typically one which has focused on structure as a means to achieve coordination (Wholey, Kiesler, & Carley, 1996). While administrative coordination is essential for the management of economic interdependencies, it can also be used to promote expertise coordination processes. Thus, high levels of administrative coordination are likely to be positively related to expertise coordination processes.

I used path analysis (Billings & Wroten, 1978; Cohen & Cohen, 1983; Pedhazur & Schmelkin, 1991) in order to investigate the relationship between the traditional factors model variables and each one of the expertise coordination variables (and team effectiveness). Figure 4.1 presents a graphical summary of the findings. Only significant paths are shown in the figure.

The results indicate that experience heterogeneity, as expected, had no impact on expertise coordination. The presence of expertise on the team was negatively related to expertise needed[29] and positively related to expertise location. Finally, administrative coordination is positively linked (albeit at a $p = .08$ level) to expertise access, thus indicating that administrative measures may support somewhat the sharing of knowledge and skills within the team.

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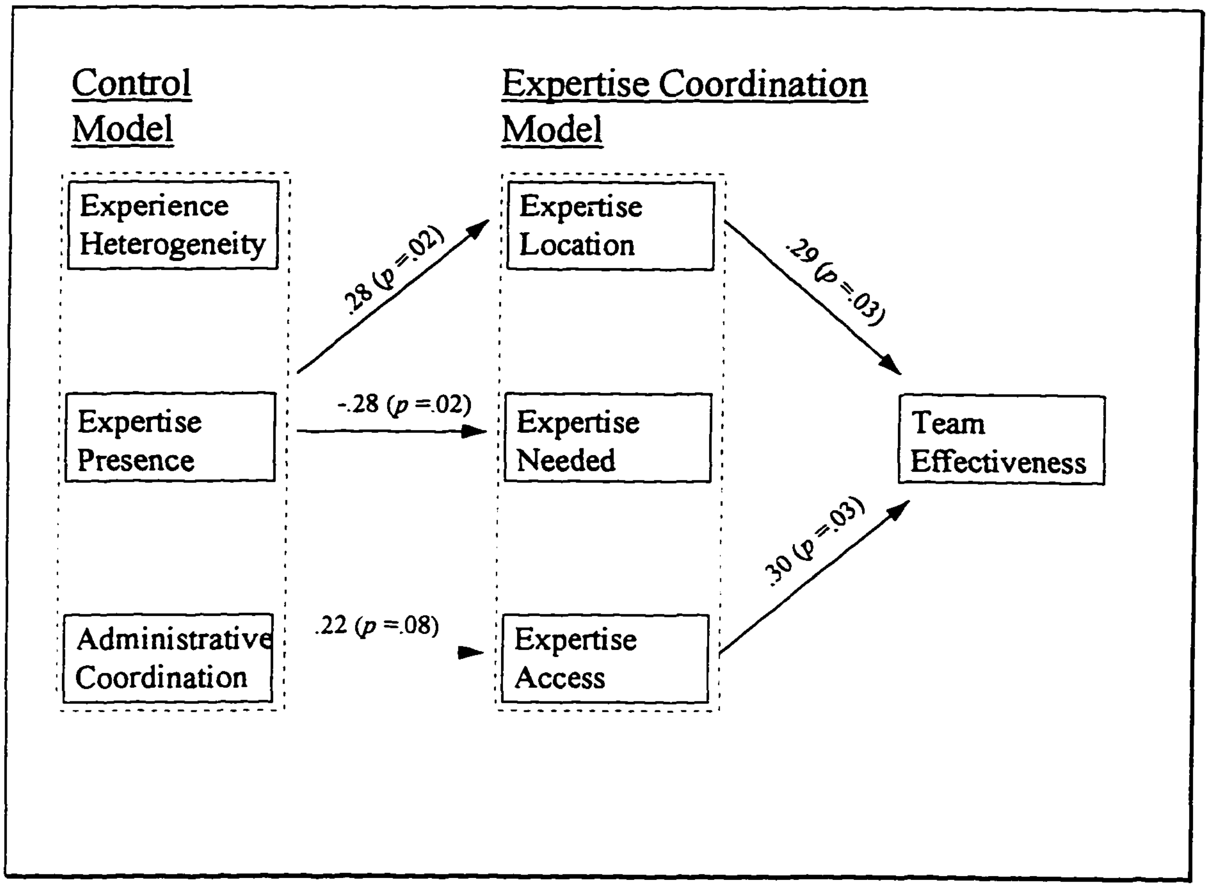
[29] Note that expertise needed, as operationalized, is a negative concept that seems to indicate a need for expertise. Thus, the presence of expertise on the team seems to reduce that need.

Overall, the path analysis provides partial and modest support for the assertion that expertise coordination moderates the link between the traditional factors model and team effectiveness.



Note: Only paths that are significant at a $p < .1$ level are shown.

Figure 4.1: Results of Path Analysis Testing Mediation Between the Control and the Expertise Coordination Models

4.4.2 Additional Control Variables

The traditional factors model as currently specified focuses on variables that can be theoretical alternatives to expertise coordination. As described earlier, we chose to include administrative coordination as the chief theoretical alternative to expertise coordination in the traditional model of coordination. The presence of expertise is included in the traditional factors model because my theoretical model specifies that for expertise coordination to occur, there needs to be some expertise. That is, the presence of expertise is a necessary but not sufficient condition for team effectiveness. Finally, the traditional factors model includes a demography variable, team experience heterogeneity, because the IS literature has always stressed the importance of experience as a link to project success.

While the choice of variables for the traditional factors model is relatively clear from a theoretical point of view, a post hoc exploratory analysis could include a more complete set of variables that have been shown to affect team outcomes. In order to confirm the validity of my theoretical model, I ran the same analysis reported in the previous chapter (the hierarchical regression analysis) but with an additional set of control variables.

I added 5 additional control variables to the analysis. These were: 1) age, operationalized as the mean age of team members; 2) team size, operationalized as the number of team members; 3) experience, operationalized as the mean years of team members' experience;

4) gender, operationalized as the percent of female team members; and 5) education, operationalized as the percent of team members with a masters degree or higher. The use of these variables allows us to control for other factors that may explain variance in team effectiveness. For instance, teams that may have extreme gender ratio, years of experience, age, education levels, or unusual size may develop different interaction and work patterns compared to other teams. This choice of variables is in line with past research that has shown that organizational tenure, team size, team composition, and demographics influence performance (Gladstein, 1984; Jehn, 1995; Pelled, 1996; Tsui & O'Reilly, 1989). The results of the analysis are presented in table 4.10.

	Step1	Step2	Step3
Control Variables β:			
Size of Team	.07	.04	.13
Experience	.20	.19	.24
Age	-.21	-.19	-.27
Education	-.12	-.11	-.08
Gender	.15	.12	.08
Traditional Factors β:			
Admin. Coordination		.13	-.02
Experience homogeneity		.06	.04
Presence of expertise		.04	-.06
Expertise Coordination β:			
Expertise Location			.30*
Expertise Needed			-.03
Expertise Access			.32*
Model Statistics:			
N	69	69	69
R^2	6.7%	9.1%	35.2%
Adjusted R^2	-0.6%	-3.0%	22.6%
Model F	.91	.75	2.81**
ΔR^2 from previous model		2.3%	26.1%
F for ΔR^2		.51	7.64***

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 4.10: Hierarchical Regression Results for Team Effectiveness and including control variables

The analysis was run with the 5 new control variables being entered first (as a block) in the regression. They were followed next by the 3 variables of the previously defined traditional factors model, and finally by the 3 variables of the expertise coordination model. The regression results differed little from the results presented in the previous chapter. The first regression (5 control variables) resulted in the following statistics: *Adj.* $R^2 = 0$; $F = .92$; $p = .48$. The second regression (adding the traditional factors model) resulted in the following statistics: *Adj.* $R^2 = 0$; $F = .75$; $p = .65$. The third regression (adding the expertise coordination model) resulted in the following statistics: *Adj.* $R^2 = .23$; $F = 2.81$; $p < .01$; $\Delta F = 7.65$; $p(\Delta F) < .001$. None of the control variables was significant at any point in the analysis, while the two key aspects of expertise coordination (location of expertise and expertise sharing) were individually significant at the $p < .05$ level. Thus, the theoretical model remains significant even in the presence of 8 other traditional factor or control variables.[30]

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[30] Per recommendation of a committee member, the theoretically interesting proposition that turnover may have a negative impact on team effectiveness was investigated. I added to the hierarchical regression analysis a variable that reflected how many of the original team members at requirements were still present on the team. I expected to find that teams that had remained stable in composition were better performers than teams that had undergone marked changes in composition. The results of that analysis were not significant even though the direction of the regression coefficient supported the theoretical contention.

4.4.3 Outcome of Expertise Coordination: Relationship to Efficiency

4.4.3.1 An Efficiency View of Performance

For teams engaged in knowledge tasks, such as software teams, two dimensions of performance are essential: effectiveness and efficiency (Ancona & Caldwell, 1992; Henderson & Lee, 1992; Leonard-Barton & Sinha, 1993; Pritchard & Watson, 1992). Efficiency is measured by ratios of inputs to outputs, while effectiveness is measured by performance against goals and expectations. Previous analysis used effectiveness as the dependent variable; here I use efficiency. The questions I used were stakeholder ratings of how well the team met its schedule and budget requirements, both outcome measures that software teams are regularly measured on (Boehm, 1981; Jones, 1991).

4.4.3.2 Measurement Issues

The existence of two dimensions of performance was confirmed by principal component analysis. The Oblimin routine converged in 5 iterations and the two factors explained 72 percent of the overall data variance. Communalities were all above .6 (indicating a high proportion of indicator variance that is explained by the factors). I used an oblique (Oblimin) rotation procedure in order to take into account the close relationship between the two dimensions of performance. Indeed, at the team level, the correlation between the effectiveness and efficiency measures of performance was .56 ($p < .001$) indicating that stakeholders perceived a close relationship between the two dimensions. Other researchers have found similar correlations between measures of effectiveness and efficiency[31] Thus, the results of this factor analysis coupled to the correlation result indicate that the two factors, while statistically distinct, are closely related. Table 4.11 provides the results of the factor analysis. The Cronbach Alpha was equal to .77 at the individual stakeholder level, and equal to .74 after the measures were aggregated to the team level. These values indicate good internal consistency.

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[31] Ancona and Caldwell (1992) used similar measures of effectiveness and efficiency. The factor analysis yielded two separate measures even though the correlation was .42. They supported their decision to keep the two dimensions separate by noting that discussions with managers suggested that these dimensions represent conceptually distinct definitions of performance.

	Factor 1	Factor 2
EFFECTIVENESS1	.91	
EFFECTIVENESS2	.84	
EFFECTIVENESS3	.81	
EFFECTIVENESS4	.67	
EFFECTIVENESS5	.56	
EFFICIENCY1		.92
EFFICIENCY2		.83
Eigenvalue[32]	4.1	.91

Note: Loadings smaller than .32 are not shown

Table 4.11: Factor Analysis for Team Performance Measures (Oblimin rotation, individual stakeholder level of analysis)

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[32] The Eigenvalue of the efficiency dimension is slightly lower than the usual value of 1. This is due to the correlation between the two variables. An examination of the Scree plot shows that these two are the only essential dimensions in the data.

4.4.3.3 Relation Between the Theoretical Model and Efficiency

Table 4.12 provides the results of the hierarchical regression analysis for team efficiency. The traditional factors model had an Adjusted R^2 of 8.3% and thus was a significant predictor of team efficiency. Among the specific variables, only administrative coordination had a statistically significant impact and is strongly related to stakeholder ratings of team efficiency. In addition, the relationship remains significant in the presence of expertise coordination variables, thus confirming the importance of administrative coordination as a unique predictor of team efficiency.

Similarly to the findings for the effectiveness dependent variable, the expertise coordination model was highly significant, either by itself (Adjusted R^2 of 15.2%; $p < .01$) or in the presence of the traditional factors model (Adjusted R^2 of 18.5%; $p < .01$; F for $\Delta R^2 = 3.72$*).[33] Among the individual variables, only expertise location was consistently related to team efficiency.

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[33] This statistic (joint F test) represents the impact of the incremental variance accounted by the variables of the model above and beyond the variance of the variables in the base model.

	Traditional Factors Model	Expertise Coordination	Joint Model
Traditional Variables β:			
Admin. Coordination	.28*		.27*
Experience homogeneity	.05		.01
Presence of expertise	.16		.02
Expertise Coordination β:			
Expertise Location		.34*	.29*
Expertise Needed		-.17	-.22
Expertise Access		.0	-.06
Model Statistics:			
N	69	69	69
R^2	12.4%	20.0%	25.7%
Adjusted R^2	8.3%	15.2%	18.5%
Model F	3.05*	5.08**	3.58**
ΔR^2 from model 1			13.3%
F for ΔR^2			3.72*

+ $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Table 4.12: Hierarchical Regression Results, Test of Hypotheses 1, 2, and 3, for Team Efficiency

4.4.4 Promoting Expertise Coordination: Exploring Potential Determinants

4.4.4.1 Identifying Potential Determinants

This section begins to explore what might produce or promote expertise coordination. These predictors are then tested to investigate their actual relationship with the three variables of expertise coordination. Such an analysis is necessary in order to demonstrate the nomological validity of the constructs and to link it to a set of theoretically meaningful predictors.

Nomological validity refers to the degree to which predictions from a theoretical network of concepts contain the concept under investigation. It is a final test to see how one's own theory, once found empirically valid, is logically related to a wider body of literature. The procedure bridges between validity and theory since theoretical deductions form the base of the expected relationships (Bryman, 1989; Stone, 1978). In earlier parts of this thesis, I have shown an empirical link between expertise coordination and measures of team effectiveness and efficiency. Here, I assess the link with selected predictor variables.

The first variable of interest is goal interdependence. For over 40 years Deutsch has argued that group members' perceptions of how their goals are related affects the outcome and dynamics of interaction (Deutsch, 1949, 1973). Goal interdependence has been shown to positively affect productivity, effectiveness of problem-solving, communication patterns, decision-making approaches, and attitudes toward other members of the group (Johnson & Johnson, 1989, Tjosvold, 1986, 1991). Goal interdependence operates through the impact it has on openness of team members to others' influence and interaction. The more people believe that their goals are positively linked, the more they reckon that they must move together with others toward that goal. This leads to openness, trust, and expectation of mutual assistance (Tjosvold, Andrews, & Struther, 1991) as well as enhanced productivity and learning (Johnson, Johnson, & Smith, 1991). Thus, it follows that goal interdependence is likely to support the development of expertise coordination processes.

A second variable of interest is reciprocal task interdependence. While goal interdependence refers to how the structure of goals and outcomes makes the team positively interdependent, reciprocal task interdependence refers to interdependence that is driven by the demands of the task. Reciprocal interdependence indicates the extent to which team members are dependent on each other to perform the task (Van de Ven, Delbecq, & Koenig, 1976). High levels of reciprocal task interdependence have been shown to raise the level of felt responsibility and lead to increased extra-role behaviors (Kiggundu, 1981; Pearce & Gregersen, 1991). When people work continuously with others, they develop a sense of shared responsibility and can see directly the effects of their own actions. Thus, reciprocal task interdependence is likely to facilitate the development of expertise coordination processes as team members develop empathy and feel responsible for the work of fellow team members.

A third variable of interest is leadership promotion of teamwork. The leader may have a large impact on team work processes. Manz & Sims propose that good leaders "lead others to lead themselves" (1990: 5). They encourage teamwork and take the role of teacher, coach, and model (Cox, 1994). Specifically, the leader promotes behavioral self-management and cognitive behavior modification and thus helps reconceptualize performance obstacles as opportunities for learning. Team members in turn must engage in self-management by exhibiting proactive self-determination and relative autonomy (Manz, 1986). Thus, a team leader recognizes that the presence of expertise on the team is not sufficient and that the expertise needs to be coordinated. He can then encourage teamwork which in turn promotes the development of expertise coordination processes.

4.4.4.2 Measurement Analysis

In this section, I report the results of different analyses addressing: 1) the internal consistency of measurements, and 2) the convergent and discriminant validity for the three determinants of expertise coordination.

The internal consistency of measurement is shown by calculating Cronbach's Alpha for each variable at the individual level (the level of measurement). The results are:

Reciprocal Task Interdependence = .81, Leader Encourages Teamwork = .89, and Goal Interdependence = .88. A factor analysis was also performed in order to test the convergent and discriminant validity of these three variables. The results, shown in table 4.13, are strong and support a clean separation among the three variables.

Overall, the variables exhibit high levels of internal consistency of measurement and show high levels of convergent and discriminant validity.

	Factor 1: Goal Interdependence	Factor 2: Leader Encourages Teamwork	Factor 3: Reciprocal Task Interdependence
Goal-Interdependence1	.81		
Goal-Interdependence2	.79		
Goal-Interdependence3	.77		
Goal-Interdependence4	.75		
Goal-Interdependence5	.74		
Goal-Interdependence6	.62		
Leader-Teamwork1		.85	
Leader-Teamwork2		.82	
Leader-Teamwork3		.80	
Leader-Teamwork4		.80	
Leader-Teamwork5		.72	
Reciprocal-Interdependence1			.80
Reciprocal-Interdependence2			.78
Reciprocal-Interdependence3			.74
Reciprocal-Interdependence4			.71
Reciprocal-Interdependence5			.67
Eigenvalues	6.24	2.43	1.64

Note: Loadings smaller than .4 are not shown

Table 4.13: Factor Analysis for Some Potential Determinants of Expertise Coordination (individual level of analysis)

4.4.4.3 Results

I used simple regression analysis to assess the relationship between the determinants and each of the three dimensions of expertise coordination. The results are shown in table 4.14. In addition, Appendix C contains the correlations of all the variables that appear in this study. There is a strong link between the determinants and expertise coordination as shown by the model R^2 for each regression. All of the individual determinant variables are also linked to at least one dimension of expertise coordination, thus suggesting a more fine grained analysis. Expertise location is weakly promoted by leader promotion of teamwork and strongly promoted by goal interdependence. Expertise needed shows a negative link to leader promotion of teamwork, thus indicating that such leadership behavior reduces the identification of people lacking in expertise. Expertise needed is also negatively linked to task interdependence, thus indicating that the more the task is interdependent the less the team faces situations where expertise is lacking. Finally, expertise access is very strongly linked to both leader promotion of teamwork and goal interdependence. Expertise access is not linked to task interdependence.

Overall the results are quite strong and show a consistent influence of leadership promotion of teamwork and goal interdependence on the two key dimensions of expertise coordination (location and access). Reciprocal task interdependence was not linked to these two dimensions.

In spite of the strong association between the antecedents and the dimensions of expertise coordination, a note of caution is needed about the implication of these results. First, the results are based on cross-sectional data and thus are of limited use in establishing causality. A longitudinal design and a more developed theoretical argument would be necessary to establish a causal rather than a mere correlational link. Second, this analysis is based on an ex post argument and not on an ex ante argument. Thus, these results must clearly be seen as exploratory rather than confirmatory.

	Expertise Location	Expertise Needed	Expertise Access
Leader Promotion of Teamwork	.25+	-.37*	.28**
Goal Interdependence	.40**	-.03	.59***
Reciprocal Task Interdependence	-.05	-.28*	-.12
Model Statistics:			
N	69	69	69
R^2	32.4%	18.0%	58.4%
Adjusted R^2	29.3%	14.2%	56.5%
Model F	10.4***	4.75**	30.45***

+ $p < .1$, * $p < .05$, ** $p < .01$, *** $p < .001$

Table 4.14: Hierarchical Regression Results, Determinants of Expertise Coordination

5. Chapter Five: Discussion

This chapter discusses the results reported in the previous chapter. The first section provides a summary of the research questions and the overall findings. The second section presents an interpretation of the study findings and discusses how these results fit with existing literature. The third section discusses a number of limitations inherent in this study.

5.1 Overall Findings

The results of the analysis covered in the results chapter are listed below in table 5.1 along with the motivating research question and a summary of the analysis approach. These specific findings are then discussed in depth.

Research Question	Analysis Approach	Summary of Results
What is expertise coordination?	• Used in-depth interviews to understand phenomena • Developed, tested, and validated new measures of expertise coordination	• Measures internally consistent. • Convergent and discriminant validity supported

Research Question	Analysis Approach	Summary of Results
What is the relationship between expertise coordination and team performance?	• Evaluated correlations • Performed a regression analysis	• Expertise coordination model is significant • Two out of three dimensions of expertise coordination have independent effects
Does expertise coordination contribute to team performance above and beyond traditional factors such as group resources and the use of administrative coordination?	• Traditional factors variables first entered as a block in the regression. The expertise coordination variables entered second as a block in order to evaluate their additional impact	• Regression results indicate that expertise coordination contributes significantly to team effectiveness above and beyond the presence of the traditional factors
Under what task contingencies is expertise coordination most effective in affecting team performance?	• Ran a ordered hierarchical regression analysis with the following sets of variables: first, the traditional factors variables, second, the expertise coordination variables, and third, interaction terms of technology and expertise coordination	• Results indicate no moderating effect for task uncertainty (complexity)

Research Question	Analysis Approach	Summary of Results
Does expertise coordination processes mediate between the traditional factors model and team effectiveness?	• Used path analysis to test the mediation possibility	• Weak support for mediation. • Some traditional model variables are linked to expertise coordination
Do additional control variables affect the stability of the expertise coordination model?	• Tested the impact of 6 variables: team size, mean age, mean experience, gender ratio, mean education level, within team turnover	• None of the additional control variables affected the stability of the results
Does the overall model and analysis hold when performance is measured by efficiency?	• Used Cronbach Alpha and factor analysis to check convergent and discriminant validity. • Ran the same hierarchical regression analysis with a stakeholder based efficiency measure of team performance.	• Measurement model analysis confirmed the presence of two differentiated dimensions of performance. • Regression results indicate that expertise coordination contributes significantly to team efficiency. • Administrative coordination is a strong predictor of team efficiency

Research Question	Analysis Approach	Summary of Results
Are there theoretically grounded determinants of expertise coordination? Specifically: leader promotion of teamwork, goal interdependence, and task interdependence	• Used Cronbach Alpha and factor analysis to check convergent and discriminant validity • Used regression analysis to test the relationship between the determinants and expertise coordination	• Determinants exhibited clean factors and high reliability. • Leader promotion of teamwork and goal interdependence were effective predictors of expertise coordination. Required task interdependence did not predict expertise coordination.

Table 5.1: Summary Of Research Questions, Methods, And Results

This study's primary goal was to assess the relationship of expertise coordination to team effectiveness. I tested four different hypothesis that correspond to the primary research question 2, 3, and 4. The statistical results indicate the following: Hypothesis 1 (link between traditional factors model and effectiveness) is not supported; Hypothesis 2 is supported (link between expertise coordination and effectiveness); Hypothesis 3 is supported (link between expertise coordination and effectiveness in the presence of the traditional factors model); and Hypothesis 4 (moderation impact of task uncertainty) is not supported.

Supporting the central theme of this research, the results suggest that expertise coordination plays a crucial role in explaining team effectiveness. To the extent that the study's findings are generalizable, then expertise coordination emerges as a key aspect of teamwork for teams engaged in complex, interdependent, and long duration tasks.

The four exploratory research questions present a complex set of results that improve our understanding of expertise coordination. The first finding, a weak mediation effect of expertise coordination confirms the analysis presented in the previous chapter about the uniqueness of the contribution of expertise coordination. The second finding, that a variety of control variables did not affect the stability of the results confirms the strength of the relationship between expertise coordination and effectiveness.

The third finding, related to strength of the relationship between expertise coordination and team efficiency, is interesting and requires a more detailed discussion. Team efficiency is a complementary and often a favored measure of team performance in software development. The fact that the regression result shows the impact of expertise coordination, above and beyond the traditional factors model, indicates the breadth of impact of the expertise coordination constructs. Thus teams that engage in expertise coordination processes are likely to be perceived to be efficient, as well as effective, by stakeholders.

5.2 *Interpretation of Findings*

5.2.1 Coordination: Dimensions and Issues

The separation in this study of coordination into its administrative and expertise component provides a conceptually different lens with which to view how teamwork actually occurs in a team. Previous conceptualizations had favored an administrative view of coordination, and differentiated between the (formal and informal) modes of coordination (Kraut & Streeter, 1995; Van de Ven, Delbecq, & Koenig, 1976;). Other conceptualizations have focused on differentiating between structure and communication (Wholey, Kiesler, & Carley, 1996). Both these approaches focus on frequencies of team events, be they meetings, code reviews, memos, or formal/informal communications. However, such a focus on frequencies misses the content of the team event. High levels of administrative coordination activities have organizational costs associated with their use. Ancona & Caldwell (1992) found a negative relationship between communication frequency and self-rated performance in new product development teams. Sims et al. (1994) have argued that communication and meeting frequency are more a reflection of task-detracting conflict and disagreement in the group than they are of effective team functioning. The focus in this thesis on expertise coordination as a separate dimension from administrative coordination allows a richer understanding of the content of coordination as it takes place.

An important finding in this analysis is the different relationship between administrative coordination on one hand, and the two dimensions of team performance. In the analysis reported in the previous chapter, administrative coordination did not significantly relate to team effectiveness, even without the inclusion of expertise coordination variables. This finding confirms previous research on coordination in software teams which found that managers, focusing on budget and schedule issues, rate highly teams that follow formal administrative coordination and reporting procedures (Ancona & Caldwell, 1992; Kraut & Streeter, 1995). Administrative coordination does show a strong relation to team efficiency (measured as meeting budget and schedule requirements), which remains significant even after expertise coordination is incorporated in the analysis. This finding is consonant with Kraut & Streeter's (1995) finding that the use of formal impersonal procedures linked to management's evaluation of the team and Gupta, Dirsmith, & Fogarty's (1994) similar finding in GAO audit teams[34]. Since my study presents a more fine-grained separation of performance into the two dimensions of efficiency and effectiveness, it allows a more specific investigation of whether team administrative coordination activities have a differential impact on performance. In this study, teams that engage in high levels of administrative coordination tend to meet their budget and schedule requirements. Interestingly, the lack of relationship between administrative coordination and effectiveness suggests that while they may be doing things right, they may not be doing the right thing. Doing the right thing is clearly associated with expertise coordination processes.

Previous research on coordination has indicated that coordination is *additive* at high levels of interdependence (Van de Ven, Delbecq, & Koenig, 1976). Our findings do not provide support for the additivity thesis. Our findings do replicate the differentiation between efficiency and effectiveness found by Henderson and Lee (1992).[35] They also enrich traditional models of coordination (Van de Ven, Delbecq, & Koenig, 1976) by finding differentiated impacts of coordination methods on efficiency and effectiveness. As a result, future models of coordination will need to more clearly define their performance measure.

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[34] Both these studies measured performance as consisting of meeting budget and schedule requirements.

[35] IS researchers have often not been careful in defining performance. Nidumolu (1995) for instance, merges four separate dimensions of outcomes into a single measure of team performance.

5.2.2 Inputs, Traditional Factors, and Antecedents

This study found little impact for the demographic variables on team performance. It was the coordination process variables that had the largest impact on performance. Sims et al. (1994) found similar support for the importance of team process variables relative to demographic variables. Our results support such an emphasis and contradict Pfeffer's (1983) contention that demographic variables account for more of the variation of team outcomes than process variables.

The study's results provided no support for the proposed relationship between the traditional factors and input variables on one hand, and team effectiveness on the other. The presence of expertise was specifically incorporated in the model in order to avoid interpretation problems regarding whether it is the *presence of* expertise or the *coordination of* expertise that actually affects team effectiveness. Several IS researchers have previously stressed the importance of putting the "best" people on the team (Boehm, 1987; Brooks, 1987; Yourdon, 1993). The logic of putting the "best" people on the team is based on measurable differences that appeared in laboratory studies of individual programmers. These findings may have less relevance for actual organizational projects where programmers are assigned to projects based on pragmatic rather than optimal concerns conditions (who is available when, etc.). In the results reported here, the mere presence of expertise on the team is *not sufficient* to affect performance. In other words, a team may include superior experts, but if these same experts do not communicate and share knowledge their expertise does not link to measurable outcomes.

A similar logic has guided the use of the variable experience heterogeneity. I used the coefficient of variation as a measure of team experience heterogeneity because it provides the most direct and scale invariant measure of dispersion for interval data (Allison, 1978; Pfeffer & O'Reilly, 1987). Recent research has shown that team heterogeneity in tenure is negatively related to team performance (Ancona & Caldwell, 1992; Guinan, Cooprider, & Faraj, forthcoming; Tsui & O'Reilly, 1989). The finding here of no significant link between team heterogeneity and team effectiveness does not provide support for the "homogeneity is good" thesis.

Control variables such as average years of experience, age, or education level turned out not to be related to team performance. Previous studies had found that work experience contributed to knowledge (ready-made information) but not to skills (Nass, 1994). Other studies had found that individuals took about 10 years to acquire the 50,000 or so chunks of specialized knowledge required to become an expert (Simon, 1991) and thus age, years of experience, and education level have often been used as proxies for expertise. The higher the level of these variables, the more likely the individual is an expert. Our findings did not find an association between these demographic variables and team performance, and thus raise the question of how appropriate they are as surrogate measures of expertise. Age, work experience, and education level do not seem to translate into an ability to produce superior performance and thus imply that even if they were appropriate measures of expertise[36], the management and coordination of said expertise is the key issue for achieving performance.

The findings also illustrate how managerial intervention can potentially promote expertise coordination. I found a strong association between team leader activities (promoting teamwork) and goal interdependence on one hand and expertise coordination on the other hand. The leadership finding is in tune with the burgeoning literature on team leadership, especially with transformational, super, and empowering leadership (Cox, 1994; Manz & Sims, 1980; 1987; Sims & Lorenzi, 1992). Similarly, the association between goal interdependence and expertise coordination provides strong evidence for the importance to design team level goal structures that promote team level goals. Our strong finding seems to indicate that teams with individualistic, as opposed to team oriented, goals do not develop strong expertise coordination processes. Thus, their effectiveness is much lower than that of teams that share the same team oriented goals. Here too, my findings are aligned with the findings of previous studies on the performance impact of cooperative goals (Deutsch, 1949, 1973; Johnson & Johnson, 1989; Tjosvold, 1989; 1991).

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[36] The correlational analysis shows that age is highly correlated with experience. However, education and sex (ratio) are not correlated with either of these two variables (or with each other).

5.3 Study Limitations

A number of limitations inherent in the study need to be recognized. These include threats to internal and external validity, methods limitations, and operationalization problems. They are discussed in turn below.

5.3.1 Threats to Internal Validity

It is important to note that the use of subjective rather than objective performance measures is a potential limitation of this study. Stakeholders were asked to assess the team's task performance in terms of conceptualizations of effectiveness and efficiency. I consciously tried to avoid subjective bias by using multi-item measures and by targeting both IS and client stakeholders. In spite of this triangulation by using two complementary and external to the team sources, the use of subjective measures, may need to be reconsidered by future researcher with access to better data. However, "objective" measures are by no means always superior to "subjective" measures. As my experience with trying to collect "objective" data from the team shows, there is nothing objective about measures such as Function Points and ratios of initial-versus-current budget and schedule. Productivity measured in Function Points/person-month is often an organizationally negotiated number rather than a hard invariable measurement. For instance, the productivity numbers can significantly vary depending on how the team incorporates scope changes, and whether ancillary activities, such as systems testing or implementation, are included in the calculation or left out. Similarly, the extent to which a budget overrun is due to teamwork problems versus client-induced change in requirements is often a subjective judgment call made by the manager providing the performance data. As a result, I concur with previous warnings about the dangers of over-relying on quantitative information without understanding the process through which such numbers are chosen or derived (Ives, Olson, & Baroudi, 1983; Henderson & Lee, 1992; Kemerer, 1989). Nevertheless, the use of exclusively subjective measures of performance is one of the study's limitations.

Another threat to internal validity in this study is the issue of within-team response rate. As discussed in section 4.1, the within-team response rate was 50%. Phone interviews with all the team leaders indicated that 1) core team members were overwhelmingly responding, and 2) that most non-respondents were either people who had moved on to other projects/sites or were peripheral members of the team (part-timers or consultants). While participation in the study was voluntary at the individual level, and a within-team response rate of 50% was shown to be more than adequate to be statistically representative, a possibility still exists that the study results would have changed if the response rate was closer to the theoretical maximum of 100%.

5.3.2 Limitations on Generalizability

An important question that must be addressed is whether the study's findings are generalizable to other settings. This issue requires the consideration of the study along four related dimensions: 1) generalizability to other software teams at JCN, 2) generalizability to software teams outside JCN, 3) generalizability to teams engaged in other types of software activities, and 4) generalizability to teams working on intellective interdependent knowledge tasks other than software development.

The first limit on generalizability requires the evaluation of whether the teams that participated in the study are representative of the teams at JCN; in other words, did the specific study design and sample choice affect the generalizability of the findings? The issue is important since the sampling plan was relatively strict. In order to emphasize theoretical clarity and reduce random variability, teams were selected into the study if: 1) they were beyond the requirements stage, 2) the team was made up primarily of full-time employees, and 3) this project was the primary project of most team members. Such a sample design was deemed necessary in order to preclude having to deal with teams that are extremely different in terms of their task, membership, and project stage. However, this sampling plan can conceivably limit the generalizability of our findings. For instance, teams that have a significant number of outsiders (consultants, part-timers) may rely to a higher degree on administrative coordination than the teams in our sample. Similarly, teams that are at requirements would contain a number of user representatives. This would affect expertise coordination processes and may imply a greater reliance on expertise outside the team.

The study had limited variability in task type (application software development), project size (small to medium), project stage (past requirements), and team membership (majority of core team members). However, the sample is characterized by a large variability in task domain and geographic diversity. Application software development is the largest software business area at JCN. The sheer size of the data set, 69 teams, the largest team-level data set assembled in IS research, points to possible diversity through the relatively large sample size. Geographic diversity was evident as the teams were located across the continental US and included teams from all the key regions and cities where JCN develops software.[37] They represent a wide spectrum of tasks and environments within JCN.

The second limitation on generalizability is whether the teams studied here are representative of teams engaged in software development. All the teams in the study are part of a single, albeit very large, organization and thus may not be sufficiently representative of teams developing software. There may be certain characteristics in the culture, work environment, and type of projects that may affect our findings and thus reduce our ability to generalize from the JCN context to other environments. For example, certain characteristics of projects such as turnover rates, composition of teams, availability of resources, reward structure, nature of relationship to client, will differ in other organizations. Further studies using our same constructs but in other contexts are necessary before dispelling this threat.

A third threat to generalizability exists due to the task focus on application software development. There are at least two major classes of software development activities that differ from application development. They are systems integration projects and new software products. Systems integration projects may differ by being characterized by unambiguous project goals but may require the presence on the team of a large number of narrow specialists, each working on a small aspect of the integration project. New software products also differ markedly due to 1) a fluid development approach that emphasizes synchronization of smaller sub-teams to develop evolving components, and 2) the use of stringent, often daily, stabilization and testing procedures as coordination and control methods (see Cusumano & Selby, 1997). Such teams, while representing a small minority of all software team, will differ markedly from those working in application software development.

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[37] Teams in the study came from 13 different states: CA, CT, CO, GA, IL, KY, NC, MD, MN, NJ, NY, OH, and TX.

A fourth dimension where generalization should be especially cautious has to do with the relevance of expertise coordination outside the domain of software development. The issue is of importance due to the emergent conceptualization of teams (or groups) as information processors that increasingly perform cognitive tasks (Galegher, Kraut, & Egido, 1990; Hinsz, Tindale, & Vollrath, 1997). If software teams are actually representative of knowledge teams engaged in complex, interdependent, and intellectual task, then the management and coordination of expertise may be essential. However, it is an open question as to whether these teams need to develop the same expertise coordination processes found here, or whether they may be better served through simple information sharing or high degrees of administrative coordination. Thus, little can be advanced at this stage as to the generalizability of this study's findings to other knowledge tasks. Future research needs to explicitly investigate expertise coordination processes in other knowledge domain.

5.3.3 Methodological Threats to Validity

This study has the limitations inherent in cross-sectional data collection. I am making a tradeoff between in depth understanding (a thick description) of the process of software development and breadth and relevance (reaching several hundred people on dozens of teams). The methodology I chose permitted group level analysis as well as model testing. All the limitations inherent in cross-sectional research do however apply.

An essential limitation of self-report survey research, as applied in this study, is the lack of in-depth understanding of the phenomena of interest. Even though I used multiple items to measure the constructs of interest, it is possible that indicators as they appear in a questionnaire do not capture the richness of the actual phenomenon. Little interpretation and minimal attention to context is possible when using survey research. More critically, such analysis tells us little about the dynamics of teamwork, such as, how the process of expertise coordination unfolds over time.

Another limitation of the cross-sectional survey methodology is its inability to demonstrate strong causality because as a method it has limited ability to control or manipulate independent variables. A laboratory experiment or a field experiment would provide stronger support for testing causal hypothesis and permit a higher degree of control against confounding variables. In survey research, the problem of inferring causal directions is tackled by the post hoc imposition of statistical control using techniques such as regression. This limits the researcher's ability to conceive of alternative ordering of variables or the development of more interesting causal chains. Even though in this study the use of theoretically guided hierarchical regression analysis provided some support for our causal ordering, we cannot be fully certain about the actual causality.

5.3.4 Threat to Validity Due to Operationalization Problems

The third dimension of expertise coordination, expertise needed, was found to be unrelated to team effectiveness. As such, this finding is contrary to the hypothesis and deserves comment. First, expertise needed correlated negatively with the other two dimensions of expertise coordination and the stakeholder rating of team effectiveness. While these correlations were not high, their direction is nonetheless puzzling. Second, expertise needed correlates negatively with the presence of expertise control variable (r = -.26, p = .029). This indicates that expertise needed operates in an opposite direction from the other expertise coordination measures and that its level increases as the level of expertise present in the team decreases.

An explanation of this unexpected result may have to do with the wording of the questions. While the intent of the construct is to tap cognitive aspects of whether the team recognizes where expertise is needed, the actual questions may have been understood to mean more than that. An examination of the expertise needed scales indicates that the essential focus of the questions was on whether team members did *not have* the necessary skills and knowledge to perform their task. This style of wording seems to have led respondents to focus on whether some team members are *unable* to get their work done. If so, then the negative correlation with the other two dimensions of expertise coordination is explainable: it is hard for expertise coordination processes to develop on a team when there are team members who are limited in their basic abilities.

This also explains the negative correlation with presence of expertise. If the team contains a lower level of expertise than is necessary for the task, then the expertise needed scale will be higher to reflect the increased demand for expertise coordination. Future operationalizations of expertise needed will need to be more focused on *the recognition* of situations that require expertise access. Or alternatively, that the team has processes in place to help members who happen to need special expertise that they do not possess. This would avoid the problem of social desirability bias since most team members are conflicted about questions that single out certain team members as needing help.[38]

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[38] See Sudman & Bradburn (1982) for a more detailed discussion of social desirability bias.

6. Chapter Six: Implications and Future Directions

This final chapter presents the implications of this thesis and suggests avenues for future work. The first section considers methodological implications. The second section discusses the theoretical contribution of the thesis. The third section evaluates the implications for practice. The fourth section proposes directions for future work. These include: replication in other settings, identification of antecedents of expertise coordination, evaluation of how these results can be of use for managers, and possible linkage between expertise coordination and collaborative tools. The sixth and last section concludes with an evaluative summary of the study.

6.1 Methodological Implications

From a narrow methodological perspective, this thesis is based on a cross-sectional survey coupled with traditional regression analysis, and thus does not claim methodological novelty. However, the development of measures of expertise coordination has methodological implications. Previous research on cognitive or distributed cognition aspects of teamwork had not used surveys. Hutchins (1993, 1995) relied on field observations as well as computer simulations; Weick & Roberts (1993) used direct field observations and interviews on aircraft carriers; Liang, Moreland, & Argote (1995) performed an experiment but relied on the coding of video tapes in order to measure team processes; Wegner et al. (1991) also relied on an experiment and measured levels of recall.[39] Thus, a contribution of this study is to demonstrate the possibility of assessing the presence of expertise coordination processes using a survey instrument. In addition, future socio-psychological studies of teams may benefit from controlling for expertise coordination factors as separate from the traditional group processes factors such as cohesion or social integration.

6.2 *Theoretical Implications*

Expertise coordination, as defined in this thesis, differs from traditional conceptions of coordination by stressing the socio-cognitive and distributed cognition aspects of teamwork. Historically-accepted conceptions of coordination have long stressed the two dimensions of coordination by programming and coordination by feedback (March & Simon, 1958). While the dimension of coordination by programming has been well

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[39] In contrast, researchers studying coordination have used survey measures before, but the focus was primarily on the coordination mode (Gupta, Dirsmith, & Fogarty, 1994; Kraut & Streeter, 1995; Van de Ven, Delbecq, & Koenig, 1976) or the frequency of communication (Allen, 1984; Wholey, Kiesler, & Carley, 1995; Tushman, 1977, 1979).

understood and accepted, the dimension of coordination by feedback has always been problematic for researchers. A variety of more specific conceptions have been offered including: coordination by mutual adjustment (Thompson, 1967), coordination by personal and group mode (Van de Ven, Delbecq, & Koenig, 1976), coordination through formal and informal procedures (Kraut & Streeter, 1995), and coordination through communication (Allen, 1984; Tushman, 1979; Wholey, Kiesler, & Carley, 1996). Yet, most of these conceptions have been operationalized as content-free measures of frequency.[40] While the amount of communication tends to increase along with task demands, there are costs to associated with unbridled communication (Wholey, Kiesler, & Carley, 1996).

By separating coordination into two distinct dimensions (administrative and expertise) this study is able to extend beyond the mode of coordination perspective predominant in previous research (see for e.g.: Cheng, 1983, 1984; Gupta, Dirsmith, & Fogarty, 1994; Kraut & Streeter, 1995; Lawrence and Lorsh, 1967; Van de Ven, Delbecq, & Koenig, 1976). In most of these studies, higher levels of uncertainty and interdependence lead to

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[40] For example, Van de Ven, Delbecq, & Koenig (1976) whose measures have widely been reused formulate their questions the following way: "indicate the extent to which each of the following mechanisms were used to coordinate the work among unit personnel within the unit" (p. 327). Similarly Allen (1984) influential study followed a similar approach: "levels of communication was measured in terms of the number of time over the course of a project that each project member reported having communicated with a colleague on a technical or scientific subject" (p. 111).

higher coordination demands and the use of more "group" modes or informal communication modes of coordination. However, the question remains about the weak link between coordination mode and team performance. For instance, Kraut & Streeter (1995) found that formal impersonal coordination modes affected stakeholder ratings of teams while informal interpersonal coordination modes did not. Similarly, in their study of learning in software teams, Wholey, Kiesler, & Carley (1996) also found that teams can overlearn communication and that levels of communication were not related to performance. My findings suggest that the weak empirical link between coordination and performance may be due to the lack of differentiation in the existing literature between efficiency and effectiveness dimensions of performance. Measures that narrowly focus on efficiency outcomes (rather than effectiveness) may be a possible cause for the lack of consistent linkage between coordination and performance.

A major implication of this study has to do with how it informs research on team (or group) performance. Expertise coordination was found to be a critical aspect of teamwork. I extend the traditional socio-psychological perspective by bringing to the fore issues of distributed cognition in general and expertise coordination in particular. At least for teams engaged in complex tasks such as software development, previous research seems to have neglected the importance of expertise coordination as an essential component of teamwork. The essential aspect of teamwork is not one of social integration or cohesion (such as in Sims et al., 1994), or boundary activities (Ancona &

Caldwell, 1992), or about the frequency of communication -- content unknown (Allen, 1984; Tushman, 1977, 1979). Rather, it is about task specific interaction: identifying and accessing needed knowledge and skills. Recent field studies of distributed cognition have identified the importance of having effective sharing of expertise as well as overlapping knowledge among team members (Hutchins, 1993). Teams where members have knowledge and skills that are too compartmentalized may find it more difficult to share expertise. Thus, research on team performance and team socio-psychological processes may benefit from considering expertise coordination.

The conception of expertise coordination offered here is in tune with recent studies of distributed cognition systems (Hutchins, 1995; Liang, Moreland, & Argote, 1995; Weick & Roberts, 1993). The cognitive importance of knowing who has what knowledge and skill on the team taps into the literature of team development, especially the need to have the team form and norm at the early stages of the project. Such a need to have people on the team be familiar enough with each others' experiences, skills, and specialized knowledge may represent a challenge for the new organizational forms such as the networked organization (Davidow & Malone, 1992; Malone & Rockart, 1991) where teams are created just-in-time and just-in-place with specialists brought in from a variety of settings. This study's findings are in agreement with recent laboratory studies of teams made up of members with varying degrees of interpersonal knowledge. Faced with the same task and information set, teams whose members had previous interpersonal interactions were more effective at information sharing than teams made up of strangers (Gruenfeld, Mannix, Williams, & Neale, 1996; Stasser, 1992; Stasser, Stewart, & Wittenbaum, 1995). At the very least, this study points to the need to support newly created teams in their attempt to figure out who-is-who and who-knows-what on the team.

It may be important to address at this point a theoretical point that may impact future research on expertise coordination. While much of the previous literature on coordination does not differentiate between a coordination process and a coordination mechanism, it is important to do so for expertise coordination. This study has focused principally on measuring the existence of three types of coordination processes and how their existence related positively to team performance. A process may be enabled, sustained, or augmented by the usage of a variety of mechanisms. For example, electronic mail is a coordination mechanism that supports one or all of the three expertise coordination processes (as well as administrative coordination). Such a focus on coordination processes is a mixed blessing. On one hand, since expertise coordination is an emergent process that is often not clearly articulated, measuring the existence of the three expertise coordination processes allowed us to successfully develop usable survey measures. On the other hand, keeping the measurement at the level of existence of processes leaves this research unable to specify a set of specific mechanisms that lead to high levels of coordination processes and in turn high levels of team performance. I view this study as a first attempt to identify, measure, and test the key processes of expertise coordination. Future research may need to focus on identifying and measuring the sets of mechanisms that support such processes.

This research contributes to the literature by suggesting expertise coordination as a moderator between leadership and goal setting and team performance. Such variables along with demographic variables are often viewed as input factors and the process through which they affect performance is still not well established (Lawrence, 1997). In recent years, several respected researchers have called for more research on: the development of shared understanding in teams (Bettenhausen, 1991), on socially shared knowledge about the group, its members, and its work (Levine & Moreland, 1991), on how shared cognitive structures emerge from and are affected by social processes (Walsh, 1995), and on the need to develop appropriate construct systems and explore the relationship between individual and collective belief systems (Meindl, Stubbard, & Porac, 1994). The research reported here focuses on the distributed cognition aspects of coordination and thus is a first effort to answer these calls.

6.3 *Implication for Practice*

This research also contributes to software development practice and the management of teams. From a software development perspective, this research addresses the acute problem of how to build high quality software and supports an organizational perspective for solving that problem. By showing the impact of expertise coordination above and beyond that of expertise presence on a team, this research has identified predictors of team effectiveness in the context of software development. It has also clarified the relative importance of the presence of experts on a team and the use of administrative coordination mechanisms, both of which are currently predominant strategies to ensure software team performance.

The results support the contentions of several IS researchers that improvements in the social process of software development is a fruitful area for increasing software development performance (Basili & Musa, 1991; Elam et al., 1991; Kraut & Streeter, 1995). The study suggests specific dimensions of expertise coordination that team managers can use to measure expertise coordination and intervene to improve it, thus affecting team outcomes. This suggests that project managers, experts, and team members should be made aware of the importance of engaging in expertise coordination. Another implication for practice is the careful consideration that needs to be given as to how to facilitate expertise coordination. Vendors selling groupware tools, such as Lotus

Notes, are focusing on the tools' abilities to support workflow, task automation, integrated email, discussion groups, and other mechanisms to share knowledge and information within and outside the team. My findings agree with Orlikowski's (1992) findings about the introduction of Lotus Notes in a large organization. She had found that the technology, by itself, is unlikely to engender collaboration and that issues of workplace norms, individually-oriented reward systems, and lack of incentives for cooperation were blocking the effective use of the technology as a collaborative tool. My analysis of the determinants of expertise coordination indicates that the team leader has an important role to play by directly encouraging teamwork and aligning goals, thus positively affecting expertise coordination processes. Finally, practitioners need to view the two coordination dimensions as both necessary and complementary. Increased use of administrative coordination has been shown, in this study as in others, to link to schedule and budget performance. However, it is not enough to manage teamwork through administrative means of coordination; managers need to encourage expertise coordination which, in addition to independently affecting efficiency, is associated with higher stakeholder ratings of effectiveness.

6.4 Directions for Future Research

This section identifies a number of directions that researchers may want to pursue. First the study should be replicated in a different context beyond the one firm which served as research site. Second, the role of specific antecedents of expertise coordination should be investigated. Third, specific managerial interventions that would support expertise coordination should be developed. Fourth, the design of collaborative work tools should be informed by the need to support expertise coordination.

6.4.1 Replication in Other Organizational and Task Settings

Since one of the major limitations of this study is its narrow focus on teams developing application software in a single organization, there is a clear need to investigate expertise coordination in other settings. Other organizations may have a different environment where norms, leadership roles, use of methodology, reward systems, and even developers' demographics may be significantly different from JCN. A study which includes teams from a variety of organizations and that duplicates my findings will increase confidence in the generalizability of this study's results.

Another set of replications is needed with regard to the dimensions that this study controlled for. For instance, replication is also needed within the software development domain but with a focus on different software tasks. We need to learn if expertise coordination is critical for teams engaged in developing different kinds of software, such as developing systems software, building packaged software, and maintaining existing software. Each of these task may have characteristics that may dampen or stimulate expertise coordination.

We also need to study how expertise coordination occurs in large teams. It is quite plausible that for large teams administrative coordination would play a more critical role than in smaller teams. Teams' organizational composition, a factor that we controlled for, may also be important. Our findings are based on teams that are made up predominantly of full time team members. How generalizable are our findings to the growing phenomenon of including a large number of consultants and part-timers on the team? Such peripheral team members may not want to invest in developing or contributing to team expertise coordination processes. They may view their expertise as a valuable asset that depreciates rapidly as it is shared with others. Further, as outsourcing of the IT function gathers steam in organizations, teams are increasingly made up of members from different organizations. Clearly, new research is needed to evaluate the impact of such compositional aspects on teamwork in general and expertise coordination in particular.

Researchers may also want to replicate this study in populations where the task is significantly different than the one faced by the teams in this study. The essential question here is whether the link between expertise coordination and performance remains in teams engaged in similarly complex and interdependent tasks but that occur in other domains, such as: engineering, new product development, legal or accounting teams. Finally, we may want to investigate teams that are engaged in routine activities and confirm the major assumption of this thesis that teams engaged in non-routine, complex and interdependent tasks are the ones that will develop and rely on expertise coordination processes.

6.4.2 Antecedents of Expertise Coordination

This study's results suggest that team expertise coordination processes contribute to team effectiveness. This finding in turn implies the following research question: what are the factors that promote expertise coordination? This question is important because as discussed earlier, expertise coordination processes are processes that develop through effective team work among team members. As such, expertise coordination emerges through the *process* of team work. Both theoreticians and managers are interested in how to promote such expertise coordination processes. We have investigated in this study the impact of a team leader's behaviors, goal interdependence, and required task interdependence on the development of expertise coordination processes. However, there exists other antecedents that need to be investigated. Performance motivation represent an important set of antecedents. Performance motivation may be viewed as including a variety of theoretical perspectives such as: Vroom's expectancy theory, Adam's equity theory, Locke & Latham's (1990) goal setting theory, and Bandura's (1986) self-efficacy social cognitive theory (see Steers, Porter, & Bigley, 1996, for a balanced assessment of these theories). Finally, do these antecedents link directly to team performance as has been suggested (Campion et al., 1993; 1996) or are they moderated by expertise coordination? Thus, an important new area of research that needs to be undertaken relates to antecedents of expertise coordination and whether expertise coordination moderates the link between these antecedents and team effectiveness.

6.4.3 Managerial Intervention

More research is needed on how to develop or improve team expertise coordination processes. It would seem logical that management or even the team leader could encourage/support the development of such processes. Yet, we do not know if such a specific intervention would be appropriate compared to changes in the team's context. It is quite conceivable that a heavy-handed managerial intervention will have less of an impact than instituting changes in goal/outcome interdependence, reward system, or letting the team self-manage (Manz & Sims, 1980, 1987). Thus more research is needed on the specific intervention that will improve expertise coordination processes.

6.4.4 Tool Design

Finally, my findings have important implications for tool designers. Recent developments in software and communication technology have enabled the development of new collaborative tools that may finally be able to support the work of teams engaged in knowledge tasks. While the nature of cooperative work is still little understood (Olson, 1989), it has long been recognized that knowledge is distributed and requires active cooperation.

While the new generations of tools such as Lotus Notes support improved email connectivity, sharing of documents, version control, and threaded discussions, these tools can be improved by providing support for expertise coordination. For instance, a collaborative tool may need to provide a list of experts or provide a detailed table providing information on who is an expert in what area. This way, team members can find out who is the best person to access as an expert for a specific problem. Without such a feature, the team may need a longer period of "forming" before team members have developed a cognitive map of the expertise distribution in the team. Further, the collaborative tool may not need to be limited to a specific project. Team members may need to identify and access expertise elsewhere in the organization. Thus, a collaborative tool needs to support expertise coordination enterprise wide.

Incorporating features in collaborative tools that support expertise coordination is not sufficient. The tool may support and facilitate expertise coordination if it exists in a team, but it cannot overcome a contextual and organizational environment that hinders it. This brings us back to this thesis's major contribution: software teams need to develop their expertise coordination processes in order to be effective. This simple finding may be a more important "silver bullet" than any set of tools.

6.5 Summary and Conclusion

Coordination is an important and understudied aspect of team work. Previous conceptualizations of coordination have favored an administrative perspective of coordination. This research takes the point of view that the essential interdependence faced by knowledge teams is one of expertise. Expertise coordination is defined as the management of skill and knowledge interdependencies. In order to perform, teams need to develop cognitive and collaborative processes for achieving expertise coordination. Expertise coordination processes encompass three essential components: knowing the location of expertise, recognizing where expertise is needed, and accessing the needed expertise. This research investigated the importance of expertise coordination by performing a cross-sectional investigation of 69 teams that develop business application software. Expertise coordination is shown to be directly related to team effectiveness.

The relationship remains statistically strong in the presence of traditional factors. Thus, this thesis has provided support to the proposition that a key aspect of effective teamwork is expertise coordination. Further, this thesis has found that administrative coordination and expertise coordination have differentiated impacts on performance with expertise coordination relating to both effectiveness and efficiency, and administrative coordination relating to efficiency. Finally, this thesis has identified input variables that may explain how a team develops expertise coordination processes.

This research improves our understanding of teamwork and the importance of coordination among team members. It provides a theoretical argument for an expertise view of team work, and separates coordination into administrative and expertise components. By demonstrating the importance of expertise coordination above and beyond traditional factors, this research has contributed to the literature on team coordination, extended previous conceptualizations of coordination, and shed light on previously contradictory findings in coordination studies. Future studies of coordination in knowledge teams may benefit from a deeper investigation of the expertise coordination processes uncovered in this research.

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Appendix A: Constructs and Operationalization

Expertise Coordination Variables

Construct:	Knowing expertise location
Definition:	The degree to which members of the team know where expertise necessary for the task is located
Theoretical Sources:	• Memory differentiation (Liang, Moreland, & Argote, 1995) • Transactional memory system (Wegner, 1986; Wegner, Eber & Raymond, 1991)
Measures and Response Format:	The following section examines expertise coordination which is the way in which the team shares skills and knowledge about the software development task. Please indicate the extent of your agreement with the following statements: (5 point scale; range: to a very small extent -- to some extent -- to a very great extent) • The team has a good "map" of each others' talents and skills • Team members are assigned to tasks commensurate with their task-relevant knowledge and skill • Team members know what task-related skills and knowledge they each possess • Team members know who on the team has specialized skills and knowledge that is relevant to their work

Construct:	Recognizing Where Expertise is Needed
Definition:	The degree to which there exists a team level recognition of the need of certain team members to access specialized knowledge and skill
Theoretical Sources:	Broadly based on communities of practice and situated learning studies (Brown & Duguid, 1991; Lave & Wenger, 1991)
Measures and Response Format:	The following section examines expertise coordination which is the way in which the team shares skills and knowledge about the software development task. Please indicate the extent of your agreement with the following statements: (5 point scale; range: to a very small extent -- to some extent -- to a very great extent) • Some team members lack certain specialized knowledge that is necessary to do their task • Some team members do not have the necessary knowledge and skill to perform well--regardless of how hard they try • Some people on our team do not have enough knowledge and skill to do their part of the team task

Construct:	Accessing Expertise
Definition:	The extent to which team members do access needed knowledge and skill
Theoretical Sources	• Task coordination (Liang, Moreland, & Argote, 1995) • Informal coordination (Kraut & Streeter, 1995)
Measures and Response Format:	The following section examines expertise coordination which is the way in which the team shares skills and knowledge about the software development task. Please indicate the extent of your agreement with the following statements: (5 point scale; range: to a very small extent -- to some extent -- to a very great extent) • There is virtually no exchange of information, knowledge, or sharing of skills among members • If someone in our team has some special knowledge about how to perform the team task, he or she is not likely to tell the other member about it • People in our team share their special knowledge and expertise with one another • More knowledgeable team members freely provide other members with hard-to-find knowledge or specialized skills

Traditional factors model Variables

Construct:	Presence of Expertise
Definition:	The team members' perception of the location of expertise within their team boundary
Theoretical Sources:	Novel operationalization based on the Importance of expertise domain (Shanteau, 1992)
Measures and Response Format:	The following questions assess whether the team includes the necessary expertise inside its boundaries (for example, if 60% of necessary technical expertise is located inside the team, enter 60 in the first line). For each dimension of expertise, what percentage of the necessary expertise is located inside your team? • technical expertise • design expertise • domain expertise

Construct:	Team Experience Heterogeneity
Definition:	Differences in experience spread between individual team members
Theoretical Sources:	• Importance for IS: Brooks (1987); Boehm (1981) • Demography impact: Pfeffer & O'Reilly (1987); Ancona & Caldwell (1992).
Measures and Response Format:	Measure: Total years of experience in the software development field • Operationalized as one variable: Experience spread = standard deviation/mean for team member work experience.

Construct:	Administrative Coordination
Definition:	Organizationally designed ways to organize teamwork and to manage interdependencies between economic resources
Theoretical Sources:	Van de Ven, Delbecq, & Koenig (1976); Kraut & Streeter (1995)
Measures and Response Format:	Teams can use a variety of techniques to coordinate work. Rate the coordination mechanisms listed below according to the extent of their use on the project. Extent of use on this project: (5 point scale; range: to a small extent -- to a great extent) • Formal policies and procedures for coordinating the team's work • Project milestones and delivery schedules • Project documents and memos • Regularly scheduled team meetings • Requirements/design review meetings • Design inspections

Moderating Variable

Construct:	Task Uncertainty
Definition:	Variability exhibited by work procedures and the extent to which one can predict the problems to be encountered and the procedures that are to be carried out.
Theoretical Sources:	• Theoretical basis: Perrow (1970); • Operationalization: Nidumolu (1995)
Measures and Response Format:	This section attempts to evaluate the task environment that the team operates under. Please characterize the extent to which your project has the following characteristics: (5 point scale; range: to a very small extent -- to some extent -- to a very great extent) • Available knowledge was of great help in developing software that would meet these requirements specifications • Established procedures and practices could be relied upon to develop software to meet these requirements specifications • An understandable sequence of steps could be followed for developing software to meet these requirements specifications • There was a clearly known way to develop software that would meet the requirements specifications

Team Outcome Variables

Construct:	Team Effectiveness
Definition:	Quality of project outcome
Theoretical Sources:	Henderson & Lee, (1992); Ancona & Caldwell (1992); Liang, Moreland, & Argote, (1995)
Measures and Response Format:	Please indicate your assessment of how well the project team performed compared to other software teams you are familiar with. (1-5 scale; range: well below average -- average -- well above average) • Quality of the work the team produces. • The team's ability to meet the goals of the project. • Extent to which the system meets the design objectives. • Team's reputation for work excellence • Efficiency of team operations.

Construct:	Team Efficiency
Definition:	Budget and Schedule outcomes
Theoretical Sources:	Henderson & Lee, (1992); Ancona & Caldwell (1992); Liang, Moreland, & Argote, (1995)
Measures and Response Format:	Please indicate your assessment of how well the project team performed compared to other software teams you are familiar with. (1-5 scale; range: well below average -- average -- well above average) • The team's adherence to schedules • The team's adherence to budgets

Control Variables

Construct:	Age
Definition:	Age is a high-visibility demographic variable
Theoretical Sources:	Demography literature: Lawrence (1997); Pelled (1997); Zenger & Lawrence (1989)
Measures and Response Format:	Indicator: Please write your current age • Operationalized as mean age of team members

Construct:	Team Size
Definition:	Number of members of a team
Theoretical Sources:	Group process literature: Wagner, Pfeffer, & O'Reilly, 1989
Measures and Response Format:	Indicator: What is the total number of people on your project team? • Operationalized as the number of people that are members of the team

Construct:	Experience
Definition:	Experience in software development field
Theoretical Sources:	Demography literature: Lawrence (1997); Pelled (1997); Zenger & Lawrence (1989); Wagner, Pfeffer, & O'Reilly (1989)
Measures and Response Format:	Indicator: Total years of experience in the software development field? • Operationalized as mean experience level of team members

Construct:	Gender
Definition:	gender composition of the team
Theoretical Sources:	Demography literature: Lawrence (1997); Pelled (1997); Zenger & Lawrence (1989)
Measures and Response Format:	Indicator: Please check on space to indicate your gender (range: male, female). • Operationalized as a team-level female/male ratio

Construct:	Education
Definition:	Level of education on team
Theoretical Sources:	Demography literature: Lawrence (1997); Pelled (1997); Zenger & Lawrence (1989); Wagner, Pfeffer, & O'Reilly (1989)
Measures and Response Format:	Indicator: Please check the category that best represents your level of formal education: (range: Ph.D., MS + specialized courses, MS, BS + specialized courses, BS, High School + specialized courses) • Operationalized as the percent of team members with a masters degree or higher

Determinants of Expertise Coordination

Construct:	Goal Interdependence
Definition:	Team members' perception of how their goals and outcomes are interrelated
Theoretical Sources:	Cooperation theory: Deutsch (1973); Johnson & Johnson (1989); Tjosvold et al. (1991)
Measures and Response Format:	The following section focuses on the extent to which team members share the same goals, image, and boundary activities. Please indicate the extent to which your team engages in the following activities: (5 point scale; range: to a very small extent -- to some extent -- to a very great extent) • My team members are interested in the things that I want to accomplish. • My team members try to help me get ahead in the organization. • My team members structure things so that their goals and my goals can be achieved. • My team members share their resources with me • My team members help me grow and develop on the job • My team members show as much concern for what I accomplish as to what they want to accomplish

Construct:	Task Interdependence
Definition:	Required interdependence within the team due to task demands
Theoretical Sources:	Pearce & Gregersen (1991); Van de Ven, Delbecq, & Koenig (1976)
Measures and Response Format:	This section attempts to evaluate the task environment that the team operates under. Please characterize the extent to which your project has the following characteristics: (5 point scale; range: to a very small extent -- to some extent -- to a very great extent) • I work closely with others in doing my work • I frequently must coordinate my efforts with others • My own performance is dependent on receiving accurate information from others • The way I perform my work has a significant impact on others • My work requires me to consult with others fairly frequently

Construct:	Leadership Promotion of Teamwork
Definition:	Leader supports strategies to promotes teamwork
Theoretical Sources:	Empowering leadership: Cox (1994); Manz & Sims (1990)
Measures and Response Format:	The following section focuses on the management actions of the team leader. Using the scale provided, please circle the number that corresponds to your response for each statement. (5 point scale; range: Definitely not true -- Neither true nor untrue -- Definitely true) • My team leader encourages me to work together with other individuals who are part of the team • My team leader emphasizes the importance of working together for a common goal • My team leader urges me to work as a team with other individuals who are part of the team • My team leader advises me to coordinate my efforts with other individuals who are part of the team • My team leader encourages cooperation among members of the team

Appendix B: Supporting Analysis for Expertise Presence

The variable Expertise Presence is an important input factor in this thesis. The distributional properties of the variable need to be investigated in order to ensure that its impact on the model does not vary if it is transformed to make it more normal. The summary statistics for expertise presence are listed in table B1.

Mean	78.33
Std. Dev.	12.69
Kurtosis	.14
Skewness	-.81
Range	43.33 to 100
N	69

Table B1: Summary Statistics

As can be seen from an examination of table B1, the distributional properties of the variable are slightly different from those of a normal distribution. The kurtosis level is negligible, but the skewness statistic is large enough to warrant further investigation of its effects. The variable is biased away from zero and toward the 100 percent mark. This is expected since no team working on a task is likely not to have any expertise relevant for the said task. In this section, I present the results of supplementary analysis in which the main results of this thesis (as presented in table 4.8) are rerun with a transformed expertise presence variable. The transformations are performed in order to change the distribution of the variable in order to reduce skewness.

Figure B1 presents a histogram for the untransformed expertise presence variable. Figure B2 presents a histogram of expertise presence following a natural logarithm (ln) transformation. Table B2 presents the hierarchical regression results using the ln transformed variable. Similarly, figure B3 presents a histogram of expertise presence following a base 10 logarithm (log10) transformation. Table B3 presents its corresponding hierarchical regression results using the log10 transformed variable. Finally, figure B4 presents a histogram of expertise presence following a square-root transformation. Table B4 presents its corresponding hierarchical regression results using the square-root transformed variable.

As seen from these figures and tables, the transformation of the variable in order to reduce its skewness has negligible impact of the model. All our regression results are stable and are not affected by the shape of the initial distribution.

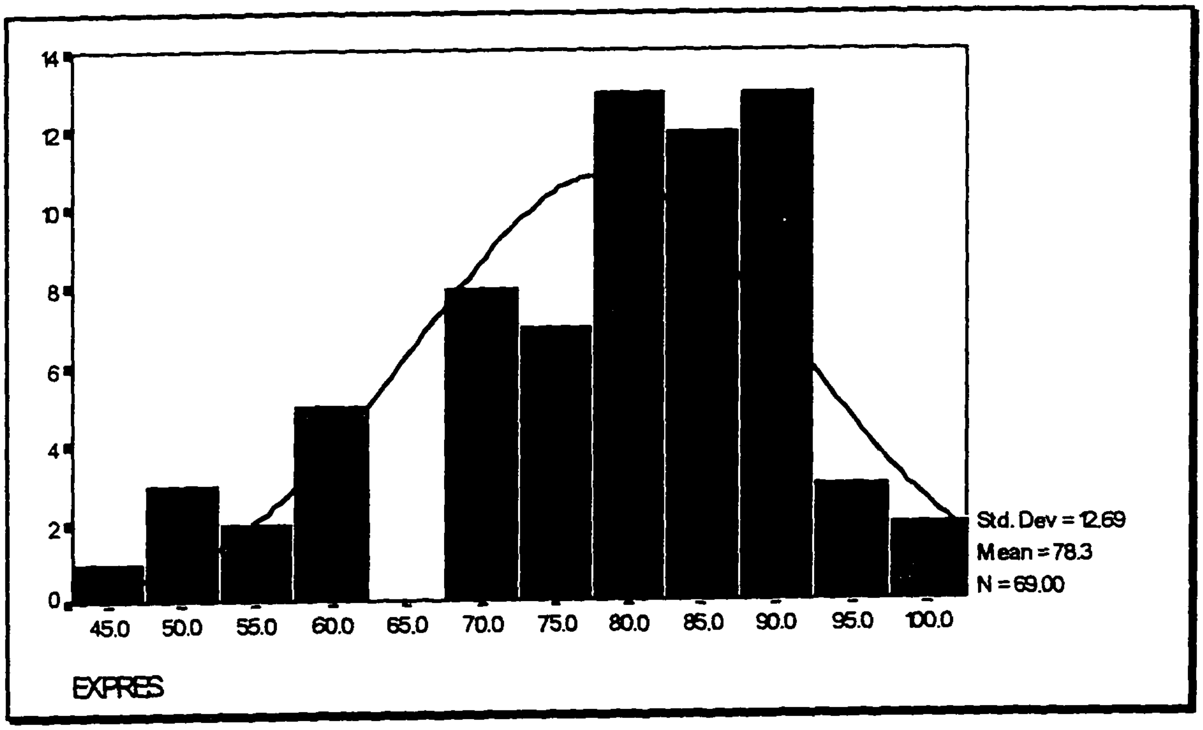

Figure B1: Histogram for Expertise Presence (Untransformed)

Histogram and statistical results: Natural log Transformation

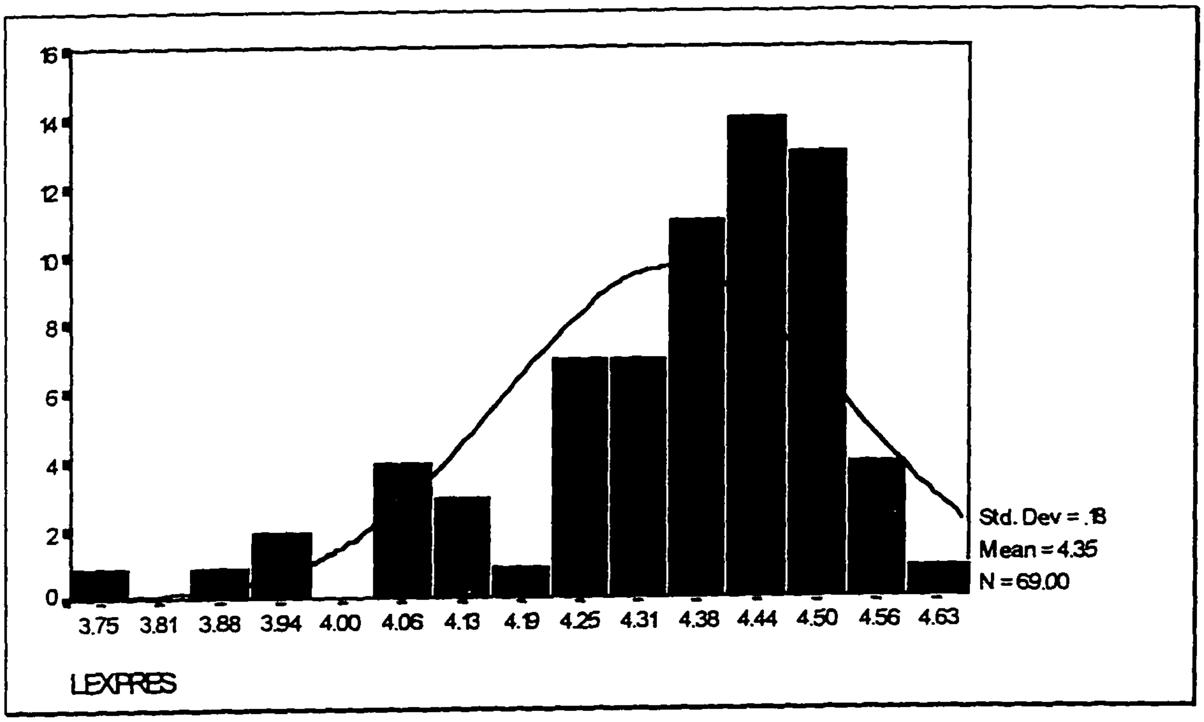

Figure B2: Histogram for Expertise Presence (Natural Log Transformed)

	H1	H2	H3
Control Variables β:			
Admin. Coordination	.19		.07
Experience homogeneity	.02		-.01
Presence of expertise	.07		-.05
Expertise Coordination β:			
Expertise Location		.29*	.29*
Expertise Needed		.01	-.02
Expertise Access		.32*	.30*
Model Statistics:			
N	69	69	69
R^2	4.6%	29.1%	29.6%
Adjusted R^2	0.2%	25.8%	22.8%
Model F	1.05	8.88***	4.35**
ΔR^2 from model 1			25.0%
F for ΔR^2			7.34***

* $p < .05$, ** $p < .01$, *** $p < .001$

Table B2: Hierarchical Regression Results, Tests of Hypotheses 1, 2, and 3 with Natural Log Transformed Expertise Presence

Histogram and statistical results: log10 transformation

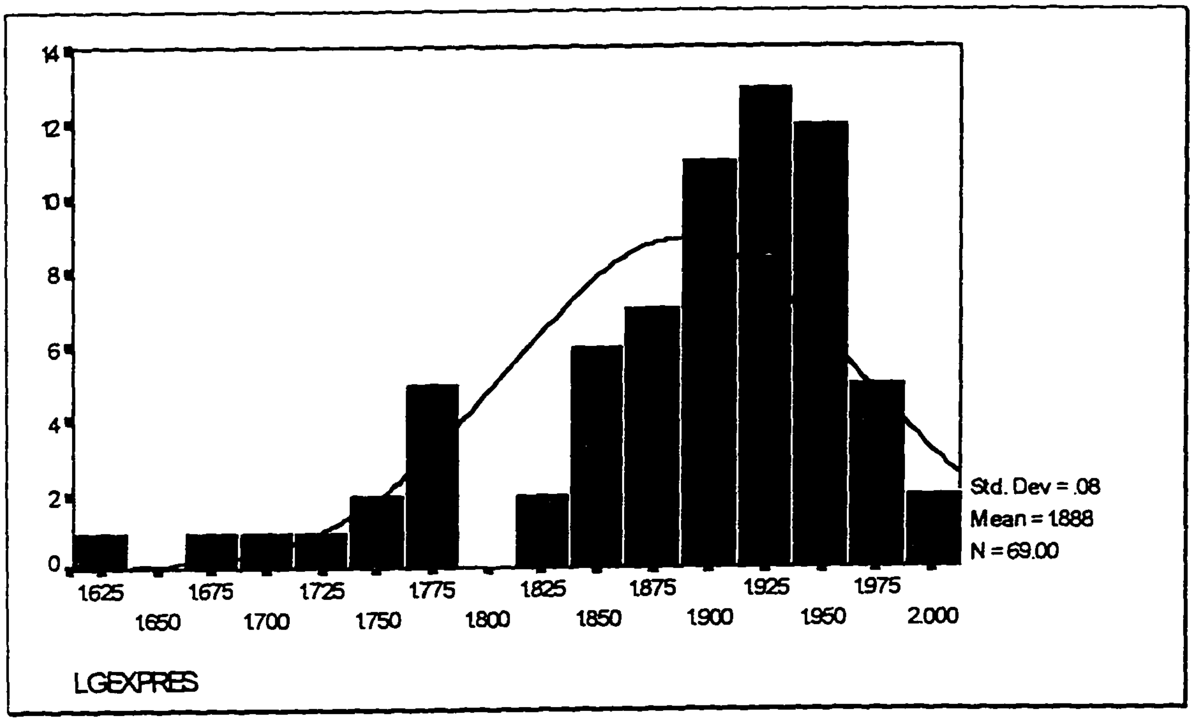

Figure B3: Histogram for Expertise Presence (Log10 Transformed)

	H1	H2	H3
Control Variables β:			
Admin. Coordination	.18		.07
Experience homogeneity	.03		.04
Presence of expertise	.07		-.05
Expertise Coordination β:			
Expertise Location		.29*	.29*
Expertise Needed		.01	-.03
Expertise Access		.32*	.30*
Model Statistics:			
N	69	69	69
R^2	4.7%	29.1%	29.7%
Adjusted R^2	0.3%	25.8%	22.9%
Model F	1.07	8.88***	4.37**
ΔR^2 from model 1			25.0%
F for ΔR^2			7.36***

* $p < .05$, ** $p < .01$, *** $p < .001$

Table B3: Hierarchical Regression Results, Tests of Hypotheses 1, 2, and 3 with Log10 Transformed Expertise Presence

Histogram and statistical results: square root transformation

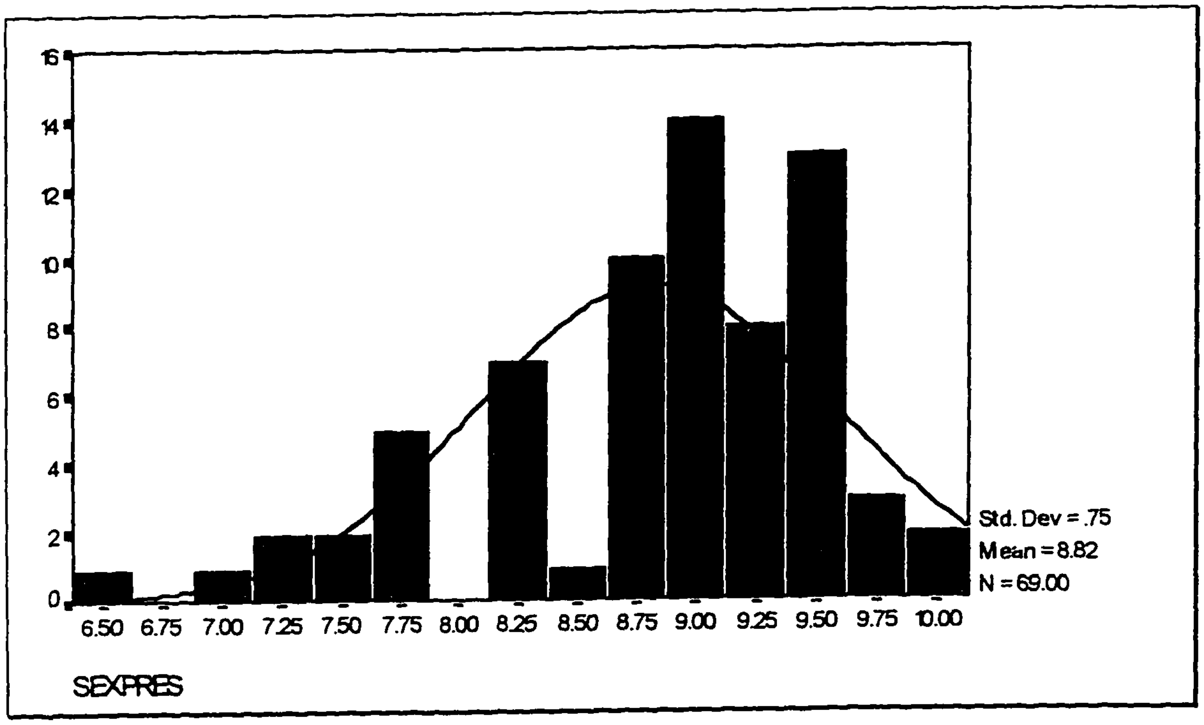

Figure B4: Histogram for Expertise Presence (Square Root Transformed)

	H1	H2	H3
Control Variables β:			
Admin. Coordination	.19		.07
Experience homogeneity	.02		-.01
Presence of expertise	.08		-.04
Expertise Coordination β:			
Expertise Location		.29*	.29*
Expertise Needed		.01	-.02
Expertise Access		.32*	.30*
Model Statistics:			
N	69	69	69
R^2	4.7%	29.1%	29.6%
Adjusted R^2	0.3%	25.8%	22.8%
Model F	1.08	8.88***	4.35**
ΔR^2 from model 1			24.9%
F for ΔR^2			7.31***

* $p < .05$, ** $p < .01$, *** $p < .001$

Table B4: Hierarchical Regression Results, Tests of Hypotheses 1, 2, and 3 with Square Root Transformed Expertise Presence

As can be seen from the results presented in tables B2, B3, and B4, transforming expertise presence statistically in order to remedy its slight skewness has had no impact on the hierarchical regression analysis initially shown in table 4.8. The transformation does reduce the distance between the distance and the mean and thus allows a closer approximation of a normal distribution. However, in this case, and possibly due to the low level of skewness, the transformation, whether in its ln, log10, or square root form has had practically no impact on the results.[41]

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[41] This result brings to mind the warning by statisticians about transformations: "We have also observed cases in which transformed variables behaved no better (and occasionally worse) than the original ones did. So, although there are a number of good theoretical reasons for transformation, in practice the advantages may be slight." (Tabachnick & Fidell, 1984: 84).

Appendix C: Complete Correlation Table

	Correlation Coefficient															
Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Administrative Coordination																
2. Expertise Presence	.18															
3. Experience Heterogeneity	.12	.01														
4. Task Uncertainty	-.61	-.3	-.03													
5. Expertise Location	.22	.31	.03	-.32												
6. Expertise Needed	.07	-.26	-.14	.28	-.34											
7. Expertise Access	.25	.17	.11	-.38	.56	-.34										
8. Team Effectiveness	.2	.12	.04	-.23	.47	-.2	.48									
9. Team Efficiency	.31	.21	.08	-.30	.40	-.29	.25	.56								
10. Team Size	.28	-.26	-.00	-.14	-.11	.04	-.15	.03	.09							
11. Average Experience	.16	.02	-.33	-.07	.02	.14	.04	.06	.24	.09						
12. Average Age	-.02	-.13	-.13	.02	.01	.09	.03	-.09	.10	.08	.68					
13. Education	-.07	.03	.02	-.11	-.12	-.15	-.00	-.10	-.04	.06	.00	.03				
14. Gender (Female Ratio)	.07	.33	.03	.05	.14	.07	.18	.14	.18	-.27	-.00	-.11	.11			
15. Required Task Interdep.	.29	-.17	-.03	-.11	.10	.19	.09	.04	-.09	.05	-.01	.01	.02	-.12		
16. Leader Promote Teamwork	.50	.22	.10	-.64	.50	-.34	.62	.39	.35	.08	.06	-.03	-.03	-.04	.24	
17. Goal Interdependence	.38	.25	.12	-.41	.54	-.19	.72	.30	.18	-.09	.04	-.00	-.09	.04	.24	.59

Note: N = 69. Correlations greater than .25 are significant at $p < .05$; correlations greater than .31 are significant at $p < .01$.

Curriculum Vitae

Samer Faraj holds a Masters of Science degree in Technology and Policy from the Massachusetts Institute of Technology. He received his BS degree in engineering from the University of Wisconsin, Milwaukee. Prior to returning to school for a doctorate, he has worked for several years as an energy analyst, energy economist, and technology planner on AID and World Bank projects supporting energy technology planning in developing countries. He was also president of his own consulting firm and worked as a software developer and software project manager for several organizations.

His research interests include: team processes and performance in the context of software development, the study of electronic collaboration and electronically enabled social groups. In the fall of 1997, he joined the University of Maryland at College Park as an assistant professor of Information Systems.