The Effect of Task Knowledge Similarity and Distribution on Asynchronous Team Coordination and Performance: Empirical Evidence from Decision Teams

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Abstract

There is agreement in the literature, but little empirical evidence, that team mental models positively influence team coordination and performance. However, most of the empirical evidence on the effects of team mental models are from teams working on real-time (i.e., synchronous) tasks and, to the best of our knowledge, none of the prior studies have taken into account task knowledge distribution within teams. However, most organizational teams work asynchronously (i.e., not always at the same time) and task knowledge distribution varies within teams. Consequently, this study proposes a framework for the study of the effect of team mental models on coordination, and uses this framework to more specifically investigate how two aspects aspect of the team mental model construct—i.e., task knowledge similarity and distribution of task knowledge—influence team coordination and performance. Using data from decision teams, our results suggest that task knowledge similarity has a positive effect on activity coordination and strategy coordination, and that the leader's task knowledge centrality has a positive effect on strategy coordination. Strategy coordination, in turn, is associated with superior team performance, both in terms of objective financial performance and external board evaluations.

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INTRODUCTION

Teams are fundamental units of organizational work (Hackman 1987; Sproull and Kiesler 1991). The diversity of knowledge and skills that members bring to a task make teams ideal for tasks that may be too complex for single individuals. This is particularly important for management decision tasks in which different functional, product or regional managers bring individual expertise and knowledge from their respective areas to the team, helping them formulate integrated business strategies. The synergies achieved from pooling complementary knowledge from various members can potentially create team knowledge structures that are greater than the sum of the individual knowledge of its members. Team knowledge can be thought of as having two components: individual knowledge, which is necessary for members to carry out their own task responsibilities; and shared knowledge, which is necessary to coordinate task activities and operate as a consistent unit. Naturally, tasks with more interdependencies among members and subtasks will require more coordination and, therefore benefit more from shared knowledge than tasks in which team members can operate independently. Team knowledge has also been characterized as one consisting of two types of knowledge: team mental models and team situation models (Cooke, Salas et al. 2000). Team mental models are based on shared knowledge team members have about things like the task, each other, goals and strategies. Teams develop these mental models over time through experience with the task and by training and interacting with each other. Team situation models (i.e., team situation awareness) are more dynamic and have to do with shared knowledge about the current task situation, which changes as the task progresses (Wellens 1993; Endsley

1995). This study focuses more specifically on team mental models.

It has been argued in the research literature that team mental models improve coordination and performance (Cannon-Bowers, Salas et al. 1993; Klimoski and Mohammed 1994; Mathieu, Goodwin et al. 2000). However, most of this literature has focused on synchronous (i.e., same-time) dynamic decision tasks and we don't know whether these theories and findings extend to other tasks and to more asynchronous contexts (McGrath 1991). Consequently, more needs to be learned about the potential benefits of team mental models before we can extend these arguments to business teams. Management decision teams typically interact over long periods of time and alternate between synchronous (e.g., meetings, conferences, phone calls, etc.) and asynchronous interaction (e.g., electronic mail, discussion boards, shared databases, etc.). For the purposes of this study, we define asynchronous teams as those that have a substantial amount of asynchronous interaction. We speculate that team mental models are very important for asynchronous teams because their opportunities to interact are more limited than synchronous teams, thus the importance of learning how team mental models influence asynchronous team coordination and performance. To the best of our knowledge, there is very little empirical evidence on the effect of team mental models on asynchronous team coordination and performance.

The paucity of empirical evidence on the effects of team mental models is partly due to two issues that have not been resolved in the literature. The first one is the lack of agreement on the team mental model construct. A recent special journal issue on team mental models presented and discussed a number of studies and reviews of other research on the subject and the issue editors concluded, among other things that there is disagreement about whether the team mental model is based on similarity of knowledge structures or similarity of knowledge content among team members (Cannon-Bowers and Salas 2001), but they argued that team members with similar organization of knowledge will enable them to be more effective at sharing knowledge content. They also suggested that researchers of team cognition need to be specific about which type of shared knowledge is being investigated. There are many types of knowledge that can be shared in a team, but many agree that these fall under one of two main categories. These are shared knowledge about task-work (i.e., knowledge necessary to carry out task activities) and shared knowledge about team-work (i.e., knowledge necessary for members to work with each other) (Cannon-Bowers, Salas et al. 1993; Klimoski and Mohammed 1994; Rentsch and Hall 1994; Cooke, Salas et al. 2000; Mathieu, Goodwin et al. 2000). Because asynchronous decision teams don't interact directly as frequently as synchronous teams, and because management decision tasks take place over longer periods of time, it is speculated that these teams may benefit more from shared knowledge content than from shared knowledge organization. Similarly, it is speculated that these teams may benefit more from having shared knowledge of task-work than shared knowledge of team-work. Consequently, this study focuses more specifically on the effects of task knowledge content similarity within the team.

Finally, while we expect that task knowledge similarity to have positive effects on teams, we also recognize that developing this shared knowledge requires interaction and communication, which can take a substantial amount of time and effort from the task itself. This is particularly the case for newly formed teams in which team members did not have much prior history working together. Therefore, it is possible that certain knowledge distribution patterns may be more efficient than others. For example, a team with weak overall shared task knowledge but with a very knowledgeable leader could outperform teams with stronger shared task knowledge but poor leadership. Thus, it is important that we control for knowledge distribution within the team. To the best of our knowledge, there is no empirical evidence on the effect of team mental models on asynchronous team performance in which knowledge distribution within the team is accounted for.

In sum, this empirical study investigates the effect of task knowledge similarity and task knowledge distribution on asynchronous team coordination and performance in the context of a management decision task. More specifically, our research question is: "*How does task knowledge similarity and task knowledge distribution affect team coordination and performance?*" The next section presents the theoretical foundations and hypotheses of the study. The next section describes the research context, data sources and study variables. The following section presents the results of the study. The final section offers a discussion of results and main conclusions.

THEORETICAL FOUNDATIONS AND HYOPOTHESES

Coordination and Performance in Management Decisions: Activities and Strategies

Coordination is the process of managing dependencies among activities (Malone and Crowston 1994). If there are no dependencies, then there is nothing to coordinate. More importantly, the nature of dependencies among sub-tasks will influence how much coordination affects team performance (Thompson 1967). Different tasks have different types of dependencies that need to be managed, thus requiring different kinds of coordination. Performance in tasks with tightly coupled dependencies among sub-tasks will require more coordination than tasks with relatively independent sub-tasks (VanDeVen, Delbecq et al. 1976). Furthermore, different types of coordination may affect different aspects of performance, depending on which types of interdependencies are being affected. For example, a recent study with global software teams found that there are three main types of coordination that are important for these teams: technical, temporal and process coordination, which are necessary to manage the respective technical, temporal and software process dependencies present in software tasks when multiple developers are working on a single software product in parallel (Espinosa 2002). So, while high temporal coordination in software development may ensure that project schedules are met in a timely manner, it will not ensure that different software parts will work well together (i.e., technical dependencies).

Similarly, managerial decision tasks have different types of dependencies. On the one hand, members of management decision teams need to coordinate their general activities like producing individual documents on time, scheduling meetings, passing information to each other when necessary, and the right hand knowing what the left hand is doing. On the other hand, complex, multidisciplinary management decision tasks require the complex integration of functional strategies, which also need to be coordinated. For example, financial strategies aimed at reducing costs cannot be implemented in isolation without understanding its repercussions on production and marketing strategies. Similarly, a marketing strategy aimed at increasing sales cannot be made in isolation without first figuring out if the planned production capacity can deliver the goods to meet the increased sales volume.

Consequently, while activity coordination may be important for performance in decision tasks, it may not be sufficient. A team with good activity coordination but a poor business strategy will probably not achieve financial success. Therefore, we speculate that strategy coordination will lead to formulation of more effective competitive strategies and superior performance in management decision tasks. Consequently, this study investigates two distinct but related aspects of coordination: activity and strategy coordination. Activity coordination in this study refers to the management of dependencies among general task activities, while strategy coordination refers to the management of dependencies among the different functional strategies formulated by different managers. Activity coordination may be a necessary condition for performance, but it may not be sufficient. If general activities in a team are not well coordinated (e.g., information not ready when needed, the right hand doesn't know what the left hand is doing, team members missing meetings), chances are that the team will not perform well. But the opposite is not necessarily true. In other words, a team with well coordinated activities may not necessarily formulate well integrated and coordinated functional strategies. In order to have well integrated and coordinated functional strategies, the respective functional specialists in the decision team (e.g., financial, marketing, production) need to have some knowledge similarity about each other's work.

Well integrated decisions and effective business strategies generally lead to superior financial performance in the form of greater profits, increased rate of return on investment (ROI), and higher stock price. Profits and ROI are indicators of current financial performance while stock price is an indicator of investors' expectations on future performance. In addition, board members have other information about the company's performance, which is not privy to the general public. Company boards meet regularly with their management teams to get more specific reports on things like operations, marketing, and strategies, placing them in a better position to judge the effectiveness of management teams. Consequently, we use two indicators of performance in this study: firm financial performance and board of director's rating of the management team. We anticipate that strategy coordination in management decision teams will lead to stronger financial performance and better evaluation of the management team by its board of directors.

H_1: a) Strategy coordination has a positive effect on firm financial performance

b) Strategy coordination has a positive effect on board evaluations of the team

Coordinating Explicitly: Task Organization and Team Communication

Reaching a certain state of coordination requires time and effort beyond what is needed for individual task activities (Malone and Crowston 1994). Teams coordinate their work explicitly (i.e., by taking conscious actions to achieve coordination) or implicitly (i.e., unconsciously, from their team knowledge). Teams develop coordination explicitly by task programming and by feedback (March and Simon 1958; Thompson 1967; VanDeVen, Delbecq et al. 1976). Coordination by programming refers to task organization mechanisms like schedules, division of labor, and routine procedures established by the team to deal with routine aspects of the task. Once team members become familiar with programs, this type of coordination becomes mechanized and cost-effective. But coordination by programming is less effective with non-routine situations or when things change because the established programs may no longer apply, thus creating the need for members to communicate (i.e., coordinate by feedback). In sum, teams will generally use coordination by programming in routine situations reducing the need to communicate, but will use coordination by feedback in more unusual or uncertain situations not addressed by the program.

Coordinating Implicitly through Team Cognition: Task Knowledge Similarity

While traditional theories have addressed coordination by focusing on explicit mechanisms, newer theories have looked into other more implicit mechanisms based on team cognition. Implicit coordination has been referred to as the "synchronization of member actions based on unspoken assumptions about what others in the group are likely to do" (Wittenbaum & Stasser 1996). This distinction between explicit and implicit coordination is important because most team coordination studies have explored one or the other. However, in order to truly understand what leads to coordination, we need to consider all coordination mechanisms that the team may be using. For example, as one study with software teams found that co-located team members have frequent opportunities to encounter each other in hallways and water coolers and begin spontaneous conversations, which helps them coordinate their joint activities and bring each other up to date in a very informal manner and without the need to interrupt individual work (Kraut et. al. 1995).

However, if the team interacts more asynchronously (i.e., they have fewer opportunities to interact in real time), then they may resort to task programming mechanisms like weekly debriefing meetings, operational plans, task assignments and schedules. The extent to which team cognition may affect coordination may vary depending on which explicit coordination mechanisms are being used. For example, teams that have many opportunities to communicate may not need benefit as much from having task knowledge similarity because they can always walk to each other's office and coordinate things. On the other hand, members of asynchronous teams may need to plan their individual actions at times when other members are not present, so having shared knowledge of the task can help them anticipate how the task will progress, thus helping them coordinate implicitly.

The team mental model is a team cognition construct that has received substantial attention in recent years (Cannon-Bowers, Salas et al. 1993; Klimoski and Mohammed 1994; Kraiger and Wenzel 1997; Carley 1997; Fussell et al. 1999; Mathieu, Goodwin et al. 2000; Cooke et al. 2000; Levesque, Wilson et al. 2001; Cannon-Bowers and Salas 2001; Espinosa 2002). The mental model concept derives from the cognitive science concept of individual mental models, which are organized knowledge that humans develop about the environment they interact with (Johnson-Laird 1983; Rouse and Morris 1986). Individuals develop mental models for many things, such as driving, using a computer, and playing an instrument. Some have argued that as members interact with each other and gain experience with the joint task, they also develop team mental models, which are organized shared knowledge that team members have about the task, the team, goals, and strategies, among other things. Some empirical studies have found preliminary evidence of this (Levesque, Wilson et al. 2001; Espinosa 2002). Team mental models are perhaps best exemplified in high-paced synchronous activities like sports competitions in which members spend a good amount of time training together, thus developing shared knowledge about the joint, enabling them to act in a coordinated fashion during actual games without much communication. Asynchronous team members, on the other hand, have more limited opportunities to communicate and interact with each other and often have to do it through less rich media (e.g., e-mail, documents, etc.), which not only makes it more difficult to coordinate, but it also hinders the development of team mental models.

It is argued in the team mental model literature that because organized shared knowledge enables members to form accurate expectations about the task and each other's actions, they help teams coordinate implicitly. The effect of team mental models on team coordination has received a lot of attention in the literature in the last few years (Cannon-Bowers, Salas et al. 1993; Klimoski and Mohammed 1994; Kraiger and Wenzel 1997; Mathieu, Goodwin et al. 2000), particularly in the domain of real-time tasks. Recent studies have also begun to show preliminary evidence that shared task knowledge has positive effects on more asynchronous tasks like software development and management decisions (Fussell, Kraut et al. 1999; Espinosa 2002).

Given the strong agreement in the literature that team mental models are important for performance, and given that it is more difficult to develop these models through asynchronous interaction, it is important that we understand what effect does this how shared mental models develop in asynchronous teams and how do these models affect performance.

As discussed in the introduction section, this study focuses more specifically on the effects of task knowledge similarity rather than other aspects of the team mental model construct. The benefits of task knowledge similarity have been explored before in studies that explored the effects of worker familiarity with their working environment. A series of studies conducted several years ago with mining teams found that prior work familiarity reduced accident rates and improved team performance (Goodman & Shah 1992). Familiarity in those studies was defined as the specific knowledge members have about unique aspects of the workplace, such as machinery, materials, the physical environment, people, and task activities. This familiarity is acquired through interaction and work practice. Goodman and colleagues argued that familiar workers have larger bodies of task knowledge, better organization of this knowledge, and better internal representation of problems, and are more aware of when errors occur and have more automated responses to work stimuli, thus making them more productive workers. They also suggested that familiarity has a stronger impact when the task has high levels of uncertainty and complexity (e.g., cross-functional managerial decisions). One of their studies found that high familiarity dyads (i.e., regular workers) had lower accident rates than low familiarity dyads (i.e., replacement workers) and that accident rates increased in both groups with prior absenteeism (Goodman & Garber 1988). Another study investigated the effect of familiarity with jobs, sections (e.g., machinery, physical environment) and other crewmembers (measured as the number of days that a given worker had been in a similar situation as "today") on group productivity and also found strong effects (Goodman & Leyden 1991).

Team members who are very familiar with their task environment are very likely to have substantial amount of task knowledge similarity among each other. Therefore, the notion that familiarity is beneficial is consistent with our argument that task knowledge similarity helps coordination and performance. The concept that task knowledge similarity improves performance has also been explored in other domains. For example, a study of airline pilot dyad crews conducted with flight simulations of emergency situations found that crews that flew together recently performed better than those who did not (Kanki & Foushee 1989). This study found that recent operating experience generated task knowledge similarity between crewmembers, which made their communication better grounded on task-related issues (e.g., less non-task statements, less tension-release speech) and improved information exchange and validation. Such knowledge similarity enabled crewmembers to anticipate and tailor behaviors and interaction to the needs of particular situations, which reduced error rates. This effect became stronger as the severity of errors increased. These studies collectively suggest that task knowledge similarity improves team effectiveness and performance. Another study with teams of large-scale software developers found that knowledge similarity about software modules, software files and prior software projects was associated with shorter software development time (Espinosa 2002).

We argue in this study that task knowledge similarity within a team helps its members coordinate implicitly through their increased ability to anticipate and explain actions and situations, and by having more common ground in their communication, thus making them more coordinated.

H_2: a) Task knowledge similarity has a positive effect on activity coordination

b) Task knowledge similarity has a positive effect on strategy coordination

Task Knowledge Distribution: Leader's Knowledge Centrality

While we argue that task knowledge similarity has a positive effect on team coordination, it is not entirely clear how much task knowledge sharing is efficient or effective. Too much knowledge sharing could potentially create problems of groupthink, cognitive overload and knowledge redundancy. We speculate that some knowledge distribution patterns are more efficient than others for a given task. For example, general knowledge distribution in leaderless teams may affect how effectively teams operate depending on whether there are one or two centrally knowledgeable members that coordinates things and helps the team exchange key information among members. On the other hand, teams with appointed leaders who are accountable to higher authorities, may rely more on the knowledge and coordination capabilities of their leaders. Teams with a formal leader may benefit if the leader has a substantial amount about the task because a knowledgeable team leader is in a better position to pool unshared task information from other members and act as a communication hub through which information can be efficiently filtered, processed and disseminated to appropriate members (Wittenbaum and Stasser 1996). Furthermore, having centrally knowledgeable leaders can help filter the information before is exchanged thus reducing potential inefficiencies and cognitive costs from too much knowledge sharing, which could even lead to other problems such as groupthink and limited external learning (Cohen and Levinthal 1990; Hambrick, Cho et al. 1996; Williams and O'Reilly 1998). Because management decisions are tasks in which strategies are integrated using available information, we anticipate that knowledge distribution will affect team coordination. That is, we anticipate that the team leader's knowledge centrality will have a positive effect on coordination. Conversely, high knowledge concentration on members other than the leader could be dysfunctional, particularly if members lose confidence in the leader.

H_3: a) The leader's knowledge centrality has a positive effect on activity coordination

b) The leader's knowledge centrality has a positive effect on strategy coordination

In sum, we anticipate that task knowledge similarity and task knowledge distribution (i.e., the leader's task knowledge centrality) will affect team coordination (i.e., activity and strategy coordination). Because teams also coordinate explicitly through team communication and task organization, we control for the use of these mechanisms. Since complex managerial decisions have substantial dependencies, we also anticipate that team coordination will affect team performance (i.e., firm financial performance and external board evaluation). This research framework is illustrated in Figure 1.

Place Figure 1 about here

RESEARCH CONTEXT, DATA SOURCES AND STUDY VARIABLES

Research Context

The data for this research comes from a graduate-level management course in which student teams run simulated companies and compete with each other for approximately fourteen weeks. Teams range in size from 4 to 6 members, and more than 75% of them have 5 members. Each team (i.e., firm) reports to an external board of directors composed mostly of business professionals from the local business community. Team members assume management roles (i.e. president, v.p. marketing, v.p. finance, etc.). Firms compete against each other by formulating strategies based on multidisciplinary decisions involving production, distribution, finance, marketing and strategy. There is also a simulated stock market in which company shares are traded among students. The simulation is very representative of competitive business environments in which management teams make routine decisions and handle ad-hoc crises, which are introduced from time to time by instructors to keep teams under pressure and in constant need to share information and make decisions. The simulation is also very real to students who compete with each other for their grades, which are largely based (70%) on firm financial performance and external board evaluations. Students meet in the classroom only once per week, not to receive lectures, but mostly to exchange logistical information with course instructors. Most of the work on this course is done outside of the classroom. Teams formulate functional strategies and make marketing, production and finance decisions, which are integrated into a business strategy. Decisions are entered into a model that simulates firm competition and produces financial performance outputs for all firms. Each team meets with its board of directors three times during the course to report on current performance and obtain advice and consent on actions and strategies. These meetings are long and involved, often lasting several hours.

Data Sources

Data is systematically collected for research purposes during the course. The data used for this study consists primarily of:

- Three voluntary student surveys, conducted at the beginning (T1), middle (T2) and end (T3) of the course. Approximately 70% of the students completed the surveys. We only used data for teams with 3 or more responses, representing approximately 74% of the teams.
- Firm financial performance data (i.e., profits, return on investment, and stock price) recorded for each of the 10 simulated quarters in the course.
- Three team evaluations by external board members completed immediately after each board meeting, roughly coinciding in time with student surveys.

Dependent Variables

Variables were collected at the individual and team levels. Individual level items were aggregated to the team levels as described below. Team level variables aggregated from individual level items were inspected to evaluate the presence of group effects using intra-class correlation (ICC) statistics to ensure that it was appropriate to do the analysis at the team level (Kenny & Voie 1985). The respective ANOVA F-statistics for these tests were all significant at the $p<0.05$ level or less, indicating the presence of group effects, thus suggesting that it is appropriate to do the analysis at the team level. Tables 1 and 2 contain descriptive statistics and the correlation matrix for the variables used in this study.

Place Tables 1 and 2 about here

- *Firm's Financial Performance.* This measure was constructed as an average of standardized z-scores of three key financial performance indicators of the firm: firm price, profits and rates of return on investment (Cronbach-α=0.90). These indicators weight heavily on the course grade. The z-scores were computed to be able to average otherwise dissimilar scales. These scores were centered on the mean for each time period because average firm performance increases substantially over time for most teams, thus creating autocorrelation problems.
- *Board Evaluations of the Team.* Evaluations involve open-ended written assessments of the team and multiple questions on a 1-7 Likert scale. The measure used for this variable is the average response to eleven questions (Cronbach-α=0.97) that asked board members to evaluate different aspects of performance of the team (see Table 4).
- *Activity coordination.* This variable was computed as the average of responses to 9 survey items (Cronbach-α = 0.79) that asked about the teams' state of activity coordination (see Table 4).
- *Strategy Coordination.* This variable is the average of responses to 6 survey items (Cronbach-α = 0.84) that asked about the teams' state of strategy coordination (see Table 4).

Independent Variables of Interest

- *Task Knowledge Similarity.* Some authors have proposed and/or used methods to measure team mental models (Carley 1997, Cooke et al. 2000, Fussell et al. 1999, Levesque et al. 2000, Mathieu et al. 2000). All these measures are based on knowledge similarities among team members. In this study we use measure task knowledge similarity in a manner consistent with prior methods, but we computed them using network analysis tools. The measure was derived from peer ratings of each other's knowledge (including self) in three specific task areas (i.e., finance, production and marketing) regarding their companies. The measure represents the average amount of knowledge overlap between the two members of every dyad in the team, across each of the 3 task areas. This measures is validated and more fully described elsewhere (Espinosa and Carley 2001). A brief description of the measure discussed in that article is reproduced in Appendix 1.

- *Task Knowledge Distribution: Team Leader's Knowledge Centrality.* This variable was computed as the average difference between the team leader's task knowledge and each of the other members' knowledge, across the three task areas. In network analysis terms, this measure is equivalent to the degree centrality of the team's leader in an adjacency matrix of a directed network in which the relationship p → i represents the difference in knowledge between member p and member i (Scott 1991; Wasserman, et. al. 1994). The network is directed (i.e., asymmetric) because if member p is more knowledgeable than i, the relationship is positive and vice-versa. This measure is similar to the concept of distance in network analysis, except that in our case we are interested in the sign of this distance because we want to know if the team's leader is more or less knowledgeable than the rest of the team. A positive aggregate value indicates that, on average, the team's leader has more task knowledge than other team members and vice-versa. The measure was normalized to a [-1, 1] range by dividing the actual difference by the scale range.

Control Variables

- *Task Organization: Division of Labor*. This variable was computed from four questionnaire items in which each member rated the extent to which he/she played a role in each of the four key task areas (i.e., leadership, operations, finance and marketing) by calculating the within-team variances for each area and then taking the square root of the average across all areas.

High variances are indicative of more division of labor. We don't speculate on the effect of this variable because prior studies have shown that the effect of division of labor is mixed, depending on how effective the actual assignments of roles to members are. Other studies have shown that division of labor is only effective when the team has been working together for some time (Wholey, Kiesler et al. 1996).

- *Task Organization: Use of File Sharing System.* This variable was constructed from a questionnaire item on a 1-5 Likert scale that asked about the importance of use of a central facility provided to share files within the team and with course instructors. While this variable measures importance and not actual use, it was significantly correlated with the aggregate number of word processing documents and presentation files stored by each team ($r=0.349$, $p< 0.001$). As previously discussed, we include this variable for control purposes, but do not anticipate noticeable effects because the use of this facility is fairly uniform in this simulation.
- *Team Communication: Communication Frequency*. Team members were asked to rate how frequently they communicated with each member of the team. This variable consists of the average rating across all team members. It was significantly correlated with the number of e-mail messages sent within the team ($r=0.465$, $p< 0.001$). We did not use actual e-mail volume as a measure of communication frequency because only 30% of the students consented to capturing their e-mail. The next two variables were included to measure communication mode.
- *Team Communication: Face-to-Face Communication*. This variable comes from a survey item that asked members to rate on a 1-5 Likert scale the importance of face-to-face communication within the team.
- *Team Communication: Use of Electronic Mail.* This variable comes from a survey item that asked respondents to rate on a 1-5 Likert scale the importance of use of electronic mail within

the team. This measure is also significantly correlated with the number of electronic mail messages sent within the team ($r=0.381$, $p< 0.001$). Again, we did not use e-mail volume for the reasons explained above.

- *Time Effects.* Because there are three time periods, time effects were modeled with three binary variables each taking the value of 1 for Time 1, Time 2 and Time 3 respectively, and 0 otherwise. Because each of these variables is dependent on the other two, the Time 2 variable was eliminated. Thus the Time 1 variable measures time effects between the first and second surveys and the Time 3 variable measures time effects between the second and third surveys.

Data Analysis Method

The survey data was collected at the individual level and then aggregated at the team level. Variables constructed from multiple questionnaire items were first selected based on their theoretical meaning and then grouped using factor analysis. The factors identified were then analyzed for reliability. Items that reduced the reliability of the constructs were removed (only one such case was found). Most of the remaining data analysis was then performed using regression analysis, except where noted. Four regression models were formulated, one for each of the dependent variables of interest: activity coordination, strategy coordination, firm performance and board evaluation. The activity coordination model was regressed on the team communication, task organization, task knowledge similarity, and team leader's task knowledge centrality variables. The strategy coordination model was also regressed on activity coordination since high activity coordination is likely to affect strategy coordination. The financial performance model was regressed on activity and strategy coordination, as hypothesized, and also on all other independent variables. The external board evaluation variable was also regressed on all these variables, but was also regressed on the team financial performance model. Financial performance influences board evaluations because board members receive the team's financial performance report in each of their meetings in which these evaluations take place. In general, each subsequent regression in the path model includes all independent variables used in previous models to evaluate which effects are direct and which ones are mediated by other variables (Baron and Kenny 1986).

The regression models were first analyzed equation by equation using Ordinary Least Squares (OLS). An initial inspection of residuals and results from Breush-Godfrey tests (Kennedy 1992) revealed correlated residuals in all equations, except in the financial performance model. The serial correlation was corrected in the auto-correlated models by lagging the dependent variable, thus reducing the data to only two time periods. We used this method instead of autoregressive models because prior values of most dependent variables of interest are expected to influence their respective future values (e.g., coordinated teams at Time 1 are likely to be coordinated at Time 2). We did not lag the dependent variable in the firm performance model because there is no financial performance data at time 1 when the simulation starts, so we would have been limited to data for only one time period otherwise. Furthermore, because financial data was standardized for each time period the main source of autocorrelation (i.e., financial growth) was eliminated. After lagging all other dependent variables, we re-inspected every model again for serial correlation and found no further problems. We also tested for heteroskedasticity, by regressing squared residuals on all right-hand side variables and their squared values and then conducting White's tests (Greene 1997), and found no problems. We inspected all models for multicollinearity using variance inflation factors (VIF) and condition indices (CI) and comparing them against standard guidelines. All VIFs were smaller than 5 and all CIs were much smaller than 100 indicating no problems with multicollinearity (Montgomery and Peck 1992).

Because we have a panel data set, the final models were run random effects method because group differences are likely to random shifts, rather than parametric shifts (Kennedy 1992; Greene 1997). To obtain some assurance of consistency, the regression models were also estimated equation-by-equation using ordinary least squares (OLS), and jointly as a single block using seemingly unrelated regression (SUR). The results from OLS and SUR regressions were very similar to the random effects regression results, thus providing some indication of consistency of results across methods. For simplicity, only results from random effects regressions are reported and discussed because they are the most suitable for panel data (Kennedy 1992; Greene 1997).

Place Table 3 and Figure 2 about here

Results

Results from random effects regression are presented in Table 3 and illustrated in Figure 2. While results are similar for the three methods, the discussion of results is based on random effects models, unless otherwise indicated. We first inspected the task knowledge similarity variable to see if it increased over time. As discussed above, the literature suggests that teams develop organized shared knowledge as they interact and become familiar with the task. However, prior studies have not found empirical support for this argument (Mathieu, Goodwin et al. 2000; Levesque, Wilson et al. 2001), perhaps because of the short duration of the task. However, results from F-tests in our study do indeed show that task knowledge similarity becomes stronger over time ($F=50.902$, $p<0.001$). To the best of our knowledge, this is the first empirical study supporting the argument that team mental models become stronger over time. Teams will most likely acquire shared knowledge about something to the extent that there is something useful to be learned, and to the extent that such learning is possible within the task timeframe. Because teams need overlapping task knowledge to formulate coherent business strategies, it is natural to expect that their task knowledge will become more similar over time as members learn more about each other's aspects of the task. Also, as the correlation matrix in table 2 shows, task knowledge similarity is correlated with both, frequency of communication ($r=0.263$, $p=0.003$) and face-to-face communication ($r=0.278$, $p=0.002$). The empirical support for the increase in task knowledge similarity overtime, and the concurrent positive correlation between task knowledge similarity and both, communication frequency and face-to-face communication, provide some assurance of convergent and concurrent validity for the task knowledge similarity measure (Ghiselli et al., 1981). Interestingly, the team president's knowledge centrality was correlated with face-to-face communication ($r=0.290$, $p<0.001$) but not with frequency of communication, suggesting that team leaders acquire task knowledge from their teams through few high-quality face-to-face meetings and not necessarily by communicating frequently.

Results from the coordination models support hypotheses H_2.a and H_2.b that task knowledge similarity has a positive effect on both, activity coordination ($\beta=2.455$, $p=0.019$) and strategy coordination ($\beta=2.228$, $p=0.007$). Interestingly, none of the explicit coordination mechanism variables (i.e., communication and team organization) had an effect on coordination. The fact that communication frequency and face-to-face communication were correlated with task knowledge similarity suggests that the effect of communication on coordination in management decision teams is not direct, but indirect by fostering the development of shared task knowledge in the team, which in turn helps teams coordinate (Baron and Kenny 1986). Both lag coefficients in the coordination models were positive and significant for both, activity coordination ($\beta=0.283$, $p=0.015$) and strategy coordination ($\beta=0.137$, $p=0.070$), suggesting that it is important to develop coordination early on in the task. Furthermore, it strengthens the finding that task knowledge similarity improves coordination incrementally over and above prior levels of coordination.

The coordination models also provide strong support for hypothesis H_3.b that the leader's task knowledge centrality has a positive effect on strategy coordination (β=0.969, p=0.005), but fail to provide support for hypothesis H_3.a that it has an effect on activity coordination. In addition, activity coordination has a significant and positive effect on strategy coordination (β=0.493, $p<0.001$). The implication of these findings is that a centrally knowledgeable leader has a strong effect on the team's ability to develop a cohesive strategy, but it does not necessarily influence the team's ability to coordinate its activities. Activity coordination is simply accomplished by having sufficient task knowledge shared among team members, regardless of leadership. On the other hand, the activity coordination does influence the team's ability to coordinate its business strategies. These results support our view that while activity coordination is important, it is not sufficient to ensure high performance in management teams, but that it is also necessary to have consistent strategies.

Finally, the performance models support hypothesis H_1.a that strategy coordination has a positive effect on financial performance (β=0.973, p=0.002) but do not support hypothesis H_1.b that strategy coordination has a positive effect on board evaluations. However, since financial performance has a positive effect on board evaluations (β=0.240, p=0.033) and since firm performance occurs as a consequence of sound business strategies, these results suggest that the effect of coordinated strategy on board evaluations is not direct but that firm performance mediates it. This is an intuitive result since strategy coordination is not necessarily visible to the board of directors, but firm performance is. Consequently, the board of directors is likely to equate sound business strategy formulation with firm financial success, thus evaluating the team accordingly. Task knowledge similarity did not have a significant effect on firm performance or board evaluation, suggesting that strategy coordination mediates the effect of task knowledge similarity on performance. This is consistent with the team mental model literature that suggests that these models affect team processes (e.g., coordination), which in turn affect performance (Cannon-Bowers, Salas et al. 1993; Klimoski and Mohammed 1994; Mathieu, Goodwin et al. 2000).

Surprisingly, activity coordination had a significant but negative effect on financial performance (β=-0.606, p=0.016). However, this result is consistent with the arguments of coordination theory (VanDeVen, Delbecq et al. 1976; Malone and Crowston 1994) that coordination is the management of dependencies and that not all dependencies are equally critical to performance, thus the importance for managers to understand which dependencies to pay close attention to. Effectively managing dependencies among functional strategies (i.e., finance, marketing and operations) is critical to success in the management simulation used in this study. However, activity coordination alone is uncorrelated with financial performance, and too much activity coordination beyond what is necessary to achieve strategy coordination is actually detrimental to the team, most likely because it diverts attention from decision makers from important aspects of their individual tasks.

Interestingly, communication frequency also had a negative effect on financial performance (β=-0.299, p=0.016). While it may seem counterintuitive that frequent communication leads to lower financial performance, we speculate that communication beyond what is necessary to coordinate strategies may be dysfunctional. Furthermore, it is also possible that the effect of this variable is reversed and that, in reality, teams that have poor financial performance need to communicate frequently and actively to re-formulate their strategies and resolve their differences. Finally, face-to-face communication had a positive effect on board evaluations (β=0.366, p=0.046). This is an important finding because, while face-to-face communication did not have a direct effect on any type of coordination, it did have a positive correlation with task knowledge similarity and the leader's task knowledge centrality, as we discussed before, and a positive effect on board evaluations. This highlights the importance of face-to-face communication in management decision teams. Communicating face-to-face not only helps develop shared task knowledge among team members and between team members and their leaders, which helps them coordinate activities and strategies, but it also enables them to convey to their respective boards a better sense of team unity and cohesiveness strategies, thus causing a better impression on them.

DISCUSSION AND CONCLUDING REMARKS

To the best of our knowledge, our study is the first one linking team mental models to different aspects of coordination and performance in asynchronous teams that perform over a moderate period of time (i.e., over fourteen weeks) in which task knowledge distribution within the team is controlled for. The main lessons learned in this study are that the nature of the task does matter when studying shared mental models and teams, and that once key dependencies for performance are identified in a given task context, one can find the link between team mental models and coordination, as well as the link between coordination and performance. Task knowledge similarity in the task context of this study was found to be important because it not only helps team members coordinate task activities, but it also helps them formulate cohesive and better coordinated strategies that lead to superior financial performance and board satisfaction. Similarly, while activity coordination may be an important pre-condition for team performance for tasks in which the management of activity dependencies is intimately linked to performance (e.g., software development, construction projects, production lines, etc.), it is not sufficient in tasks like decision-making and strategy formulation in which other key dependencies (i.e., among functional strategies) also need to be effectively managed. In fact, too much activity coordination beyond what is necessary to formulate coordinated strategies may be detrimental.

Overall, while established theories attribute coordination to the effective use of explicit mechanisms (i.e., communication and team organization), which are necessary for many tasks (i.e., emergencies, large-scale software development, etc.), this study provides some empirical evidence that explicit mechanisms like communication help teams share task knowledge leading to increased similarity in this knowledge, which in turn helps their team members coordinate implicitly, thus indirectly influencing performance. Furthermore, our study suggests that while communication may have a direct effect on coordination in other tasks, it only has an indirect effect in our asynchronous task, which is mediated by the shared mental model of the task.

In conclusion, this study provides empirical evidence that: (1) face-to-face and frequent communication promote the sharing of task knowledge; (2) task knowledge similarity has beneficial effects on coordination and performance; (3) these effects can be complemented (or offset) with effective (or ineffective) knowledge distribution patterns within the team (i.e., centralized on the leader); (4) different types of coordination have different effects on team performance, depending on which dependencies are more critical to performance; and, (5) coordination has different effects on different measures of performance (i.e., financial and board evaluations), depending on how important is the management of the respective dependencies to that particular measure of performance. Once again, these findings highlight the importance of understanding the task, and learning how to promote shared mental model development in asynchronous teams that have less frequent opportunities to interact than synchronous teams.

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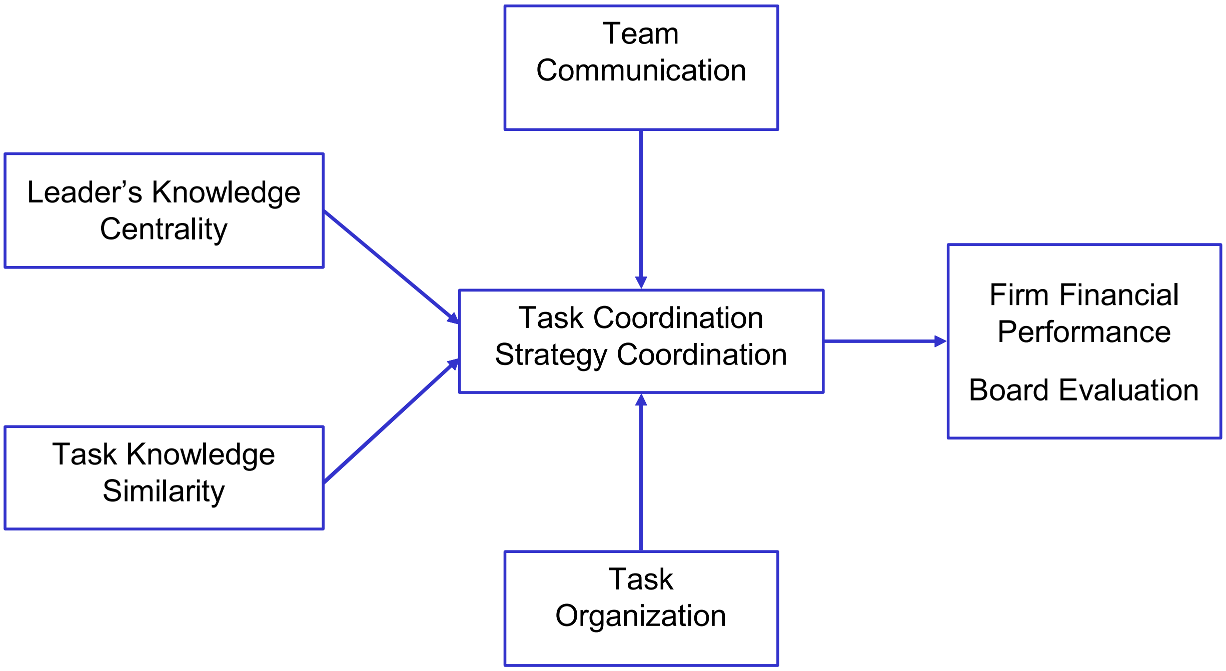

Figure 1: Research Model

Table 1: Descriptive Statistics

Variable	N	Min	Max	Mean	Std. Dev.
Board Evaluation	127	1.97	6.76	4.79	1.060
Firm Performance	79	-1.79	2.98	-0.05	0.962
Strategy Coordination	127	3.56	6.89	5.44	0.673
Activity Coordination	127	3.74	6.63	5.42	0.629
Task Knowledge Sim	127	0.34	0.80	0.54	0.093
Pres Knowl Centrality	127	-0.37	0.43	0.07	0.149
Div of Labor	124	0.53	1.00	0.76	0.080
Use of File Sharing Sys	127	1.67	5.00	3.99	0.702
Comm Frequency	127	-3.30	1.91	0.00	0.960
Face-To-Face Comm	127	2.00	5.00	4.23	0.563
Use of E-Mail	127	2.67	5.00	4.02	0.481

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Table 2: Correlation Matrix

	Variable	1	2	3	4	5	6	7	8	9	10	11
1	Board Evaluation		0.264	0.373	0.228	0.416	0.171	-0.215	0.199	0.000	0.150	0.235
	p-value		0.019	0.000	0.010	0.000	0.055	0.017	0.025	0.996	0.093	0.008
2	Firm Performance	0.264		0.299	0.001	0.020	0.239	-0.130	-0.122	-0.253	0.069	0.012
	p-value	0.019		0.007	0.995	0.861	0.034	0.254	0.284	0.025	0.547	0.913
3	Strategy Coordination	0.373	0.299		0.696	0.586	0.136	-0.026	0.159	0.104	0.221	0.171
	p-value	0.000	0.007		0.000	0.000	0.128	0.774	0.074	0.243	0.013	0.055
4	Activity Coordination	0.228	0.001	0.696		0.393	0.032	0.053	0.190	0.121	0.226	0.271
	p-value	0.010	0.995	0.000		0.000	0.725	0.559	0.032	0.176	0.010	0.002
5	Task Knowledge Sim	0.416	0.020	0.586	0.393		-0.091	-0.023	0.177	0.263	0.278	0.239
	p-value	0.000	0.861	0.000	0.000		0.307	0.800	0.046	0.003	0.002	0.007
6	Pres Knowl Centrality	0.171	0.239	0.136	0.032	-0.091		0.049	0.071	-0.050	0.290	-0.014
	p-value	0.055	0.034	0.128	0.725	0.307		0.587	0.430	0.579	0.001	0.879
7	Div of Labor	-0.215	-0.130	-0.026	0.053	-0.023	0.049		-0.010	0.062	-0.073	-0.018
	p-value	0.017	0.254	0.774	0.559	0.800	0.587		0.915	0.496	0.420	0.839
8	Use of File Sharing Sys	0.199	-0.122	0.159	0.190	0.177	0.071	-0.010		0.081	-0.029	0.389
	p-value	0.025	0.284	0.074	0.032	0.046	0.430	0.915		0.364	0.743	0.000
9	Comm Frequency	0.000	-0.253	0.104	0.121	0.263	-0.050	0.062	0.081		0.196	0.028
	p-value	0.996	0.025	0.243	0.176	0.003	0.579	0.496	0.364		0.027	0.751
10	Face-To-Face Comm	0.150	0.069	0.221	0.226	0.278	0.290	-0.073	-0.029	0.196		-0.032
	p-value	0.093	0.547	0.013	0.010	0.002	0.001	0.420	0.743	0.027		0.723
11	Use of E-Mail	0.235	0.012	0.171	0.271	0.239	-0.014	-0.018	0.389	0.028	-0.032	
	p-value	0.008	0.913	0.055	0.002	0.007	0.879	0.839	0.000	0.751	0.723	

Table 3: Regression Results

	Activity		Strategy		Firm		Board	
Variabl	Coe	p-value	Coe	p-value	Coe	p-value	Coe	p-value
La	0.283	***0.015***	0.137	*0.070*	-	-	0.472	**<0.001**
Time	0.154	0.137	0.146	*0.092*	-0.081	*0.707*	0.131	0.523
Financial	-	-	-	-	-	-	0.240	***0.033***
Strategy	-	-	-	-	0.973	***0.002***	0.064	0.808
Activity	-	-	0.497	**<0.001**	-0.606	***0.016***	-0.119	0.565
Task Knowledge	2.455	***0.019***	2.228	***0.007***	-0.055	0.977	0.461	0.781
Pres Knowl	0.150	0.742	0.969	***0.005***	0.646	0.404	-0.170	0.794
Comm	-0.102	0.159	0.027	0.600	-0.299	***0.016***	0.119	0.254
Face-To-Face	0.105	0.427	-0.098	0.291	-0.002	0.993	0.366	***0.046***
Use of File Sharing	0.070	0.399	-0.051	0.409	-0.184	0.219	0.082	0.522
Use of E-	0.077	0.564	-0.082	0.406	0.353	0.142	0.165	0.433
Div of	-0.669	0.538	-0.179	0.800	-1.997	0.216	0.583	0.666

Figure 2: Regression Results

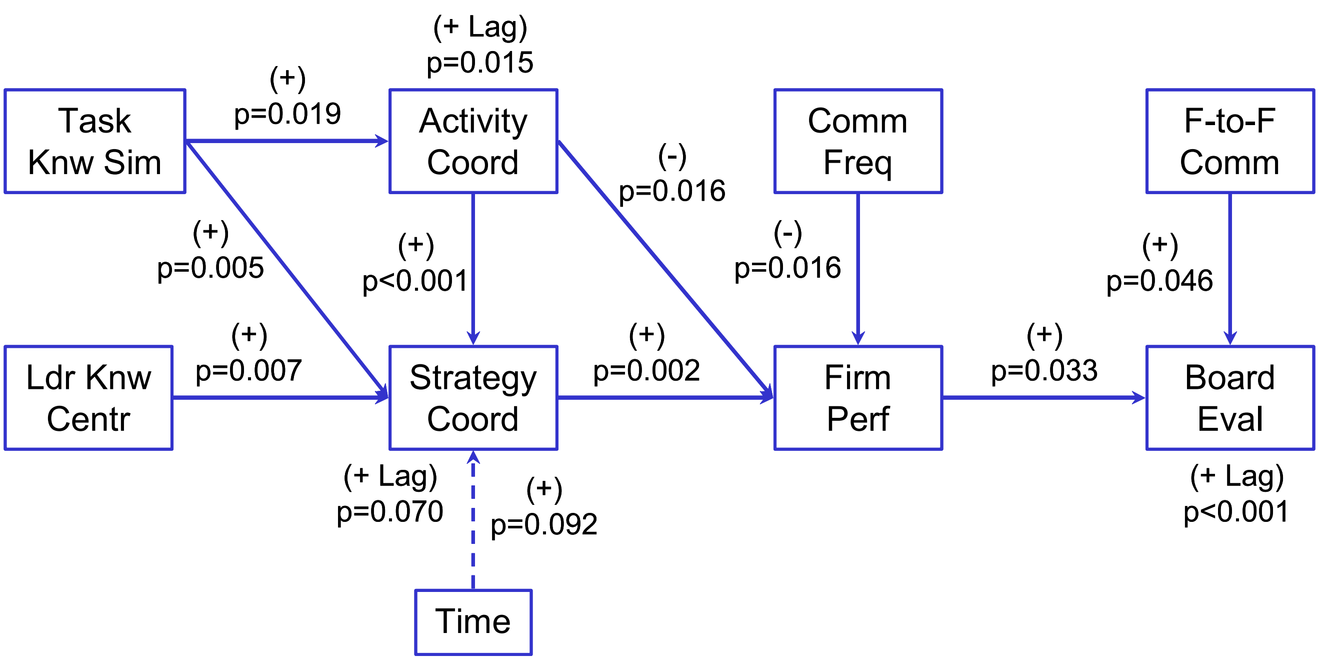

Table 4: Survey Questionnaire Items

Activity coordination

1. Members of my team often disagreed about who should be doing what task
2. Members of my team did their jobs without getting in each others' way
3. Members of my team often duplicated each others' work
4. Tasks were clearly assigned to specific team members
5. My team wasted a lot of time
6. It was very easy for me to get info from other team members when I needed it
7. I always received the info I needed from other team members on time
8. I usually received just the right amount of info I needed in order to do my tasks effectively
9. It was difficult for me to share my work with others and to get feedback from them

Strategy Coordination

1. My team has a clear idea of what our financial strategy should be
2. My team has a clear idea of what our marketing strategy should be
3. My team has a clear idea of what our production strategy should be
4. Members of my team have a clear idea of what our team's goals are
5. My team knew exactly what it had to get done in order to succeed in the Game
6. Members of my team fully understand how competitors' actions will impact our performance

Board Evaluations

1. The team set measurable financial objectives
2. The team is very likely to meet its financial objectives
3. The team set measurable marketing objectives
4. The team is very likely to meet its marketing objectives
5. The team has predicted the reactions of its competitors to its strategy
6. The team's financial proposals are in the best interests of the shareholders
7. The team has viable contingency plans for several likely scenarios
8. The team's plans and proposals are very clear to me
9. The team's plans and proposals are well supported
10. The team's document is complete
11. The team's strategic plans and reports much better than other's I have read

APPENDIX 1

Computation of the Task Knowledge Similarity Measure

This measure was constructed from peer ratings of each other's knowledge (including self) in three specific task areas (i.e., finance, production and marketing) regarding their companies. The measure represents the average amount of knowledge overlap between the two members of every dyad in the team, across each of the 3 task areas. This measures is validated and more fully described elsewhere (Espinosa and Carley 2001). The ratings were used to construct one task knowledge matrix **TK**(nx3) for each team. This matrix has one row for each of the n members and one column for each three task areas. Cells tk_{ij} in this matrix contains the average knowledge rating given by all member for member i with respect to task area. Such aggregation corrects for biases in scale interpretation that may exist within the team (Cronbach 1955). It represents the aggregate assessment by all members of how much knowledge member i has about task area j.

The task knowledge similarity between members i and i' was then computed as $tks_{jii'}=\min(tk_{ij}, tk_{i'j})$. In other words, $tks_{jii'}$ represents the amount of knowledge of the least knowledgeable member in the dyad I, which is the largest amount of knowledge overlap the two dyad members could have. While it is possible that the actual knowledge similarity between the two dyad members may be smaller than this, it is not likely that it will smaller by much because all members are rating each other using the same frame of reference (i.e., their respective knowledge of the financial, marketing and production aspects of the simulated firms they manage). The aggregate task knowledge similarity measure used in the study is the average task dyadic knowledge similarity across all dyads in the teams and across each of the three task areas.