Coordination in Teams:

Evidence from a Simulated Management Game

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Summary

In this paper, we examine the strategies managerial teams use to achieve coordination and the effects of coordination on team performance. We hypothesized that four coordination strategies—frequent communication, evenly distributed communication, shared cognitions about members' expertise, and team history—would lead to greater team coordination. We also hypothesized that there would be tradeoffs between several of these strategies. Greater coordination was expected to lead to better performance outcomes, regardless of the strategies a team used to achieve it. We examined our hypotheses within the context of a 14-week realistic management simulation. Coordination was influenced by evenness of communication, shared cognitions about the distribution of expertise within the team, and time working together. Coordination was also influenced by interactions between shared cognitions and frequency of communication, and between shared cognitions and team history. Contrary to our predictions, however, there was neither a main effect of communication frequency on coordination, nor an interaction of communication frequency with history working together. The level of coordination within a team was directly related to three of four outcome measures.

Coordination in Teams:

Evidence from Simulated Management Teams

Groups are inherently different from individuals performing the same task because of a need to coordinate. Whenever the work of individuals is interdependent, they must coordinate to achieve success (Van de Ven, 1976). Malone and Crowston (1994) defined coordination as the extra work organizations and individuals must complete when individuals are working in concert to accomplish some goal, over and above what they would need to do to accomplish the goal individually. To work together effectively, team members must coordinate their efforts in both broad and detailed ways. At the broad level, for example, managers organizing a new product roll-out must align goals: If the marketing manager is positioning a product as a prestige item, the engineering manager cannot skimp on quality. At a more detailed level, the team must assign tasks to the people most capable of doing them, must phrase documents so that they reflect a common style, and must exchange work products with each other in a timely way.

Although coordination has long been assumed by group and organizational scholars to be a component of group effectiveness, as Argote and McGrath (1993) note, there has been little systematic research examining the way teams achieve coordination or its effects on performance. In this paper, we examine the strategies teams use to achieve coordination and the effects of coordination on team performance with a specific focus on managerial teamwork.

Coordination strategies are methods that groups and organizations can use to align their activities. Classic theories of organizational behavior typically distinguish between mechanistic and organic coordination (March, 1958; Thompson, 1967). Mechanistic coordination or coordination by programming consists of relatively static techniques, such as division of labor, regulations, or standard operating procedures, that align individual actions through structure or

directive. In contrast, organic coordination or coordination by mutual adjustment consists of more informal and unstructured communication, whereby individuals exchange information about their current states and adjust their behavior to others' goals and actions.

Although there are a number of different strategies teams can use to coordinate their activities, we focus in this paper on four that we hypothesize will be especially important for the type of managerial teamwork we examine: frequency of communication, evenness of communication, shared cognition, and reliance on a common history. These strategies are beneficial individually and are likely to compensate for each other. That is, teams can use any of these methods to coordinate, but using more of them might not lead to additional benefit.. In addition, we examine how a team's overall level of coordination, regardless of which strategies it used to achieve it, affects several different performance outcomes.

In the remainder of this introduction, we describe in more detail our specific hypotheses regarding coordination strategies, trade-offs among coordination strategies, and effects of coordination on performance. We then examine these hypotheses in the context of a realistic management simulation, in which teams of MBA students manage a simulated consumer products company over a multi-week time period. We end with a general discussion of the implications of our findings.

Coordination Strategies

In this section we consider four distinct strategies that groups can use to become coordinated: (a) frequent communication among team members; (b) evenness of communication among team members; (c) shared mental models of who knows what within the team; and (d) reliance on a team's history of working together. We next describe the rationale for expecting that these strategies will lead to increased coordination in teams.

Frequent communication. By communication we mean the conversations, meetings, phone calls, electronic mail (email), documents, notes and verbal interactions over other media that teams members use to perform such tasks as negotiating their goals, making decisions, and updating each other about task status. This is a prime example of coordination by mutual adjustment. A large literature in the management and organizational sciences shows that for tasks involving interdependence and uncertainty—characteristic of the management simulation that we describe below—team members must have a substantial amount of interpersonal communication to be successful (Thompson, 1967; Van de Ven, 1976). Pelz and Andrews (1966), in their classic study of scientists in organizations, show the importance of within-team communication for success, and these findings have been replicated often. In a recent study, Cummings (2001) showed that teams in a multi-national corporation were evaluated more highly when the members communicated more with each other. Conversely, Kiesler, Wholey and Carley (Kiesler, Wholey, & Carley, 1994) showed that novice software engineering teams failed when they didn't communicate enough.   Thus, we expect that in general more communication will lead to more coordination.

Hypothesis 1: More frequent communication among team members will lead to better coordination.

Even communication. In addition to the sheer volume of communication, the structure of the communication within the group is also likely to influence how well teams can coordinate their efforts. Research has shown that for relatively simple, information-exchange tasks, communication flow is more efficient when it passes through a small number of individuals who serve as communication hubs than when it is spread evenly among all group members (Leavitt, 1951). However, this centralized structure is not appropriate for typical managerial tasks

involving high uncertainty in a changing and competitive environment. In these circumstances, the centralized communication hub becomes a bottleneck (Shaw, 1964). As a result, research has shown that when task uncertainty is high, people engage in higher levels of informal, peer-to-peer communication to coordinate their work (Van de Ven, 1976), and teams that fail to do so perform less well (Tushman, 1979). This reasoning suggest the following hypothesis:

> *Hypothesis 2: Greater evenness of communication among team members will lead to better coordination.*

Shared cognitions about team expertise. Contemporary theorists have added *shared cognition* or *shared mental models* to the list of strategies that teams use to coordinate (e.g., Cannon-Bowers, Salas, & Converse, 1993; Fiore, Salas, & Cannon-Bowers, 2001; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). By shared cognitions we mean the beliefs in common that team members have about such topics as each other's abilities, the tasks they must perform, team processes, and the team environment (see Mohammed & Dumville, 2001 for a review). In this paper, we concentrate on shared cognitions about the distribution of expertise in a group—others' skills, knowledge, and the like. Shared cognitions about expertise are part of what many researchers call *transactive memory* systems (e.g., Hollingshead, 2000; Moreland, 2000; Moreland, Argote, & Krishnan, 1996; Wegner, 1987).   These shared cognitions allow team members to retrieve a larger amount of material than they would be able to store on their own, by knowing whom to consult about what topics or for what assistance.

There are a number of ways teams can drawn upon shared cognitions about members' expertise to help coordinate their activities. Knowing each person's strengths and weaknesses increases the efficiency and appropriateness of team's task assignments (Argote, 2000; Liang, 1995), allows team members to distribute information more efficiently (Larson, Christensen,

Abbott, & Franz, 1996), and enables people to consult the appropriate individuals for advice and

guidance (Olivera, 1999). Depending on how detailed this knowledge is, shared cognitions

about expertise allow groups members to anticipate the actions of others and to make

adjustments in their own behavior in anticipation of others' reactions (e.g., Blickensderfer,

2000). Under some circumstances, knowledge of the distribution of expertise may also

encourage group members to work harder, if they realize that their unique talents are needed for

a group effort (Karau & Williams, 1993). Finally, this knowledge may be the basis of trust

within the group, especially what McAllister calls cognitive trust, which is based on judgments

of competence (E.g., Gabarro, 1978). Although the mediating mechanisms might vary, this

reasoning suggests the following hypothesis:

> *Hypothesis 3: Shared cognitions about the distribution of expertise within the team will*
>
> *lead to better coordination.*

Team History. By team history we mean the length of time members have worked

together. Team performance typically increases as its members work together for longer periods,

at least up to some limits. In Katz's classic research (1978), research and development teams

reached their peak of performance when the average tenure in the team was three to five years

(See Pelz, 1966, for similar results). Training in an intact group improves later performance in

that group (Hollingshead, 2000; Moreland, Argote, & Krishnan, 1998). Even brief periods of

work history improve performance. For example, (Kanki & Foushee, 1989) demonstrated that

cockpit crews who had flown together for two days before participating in a simulator exercise

performed more successfully and committed fewer serious errors than crews that had not yet

flown together . When intact work groups are disrupted through personnel turnover, change in

the technology they use, or change in their physical environment, the group's performance

declines until it become accustomed to the changes (Goodman & Shah, 1991; McGrath, Arrow, Gruenfeld, Hollingshead, & et al., 1993). Thus, we hypothesize that longer team history will have a positive effect on coordination:

Hypothesis 4: As groups work together longer, they will become better coordinated.

Trade-offs among Coordination Strategies

Although each of the strategies we have discussed—volume of communication, evenness of communication, shared cognitions about expertise, and team history—in and of itself may benefit coordination, it may not be necessary for a team to rely on all four of these strategies in order to achieve a satisfactory level of coordination. Indeed, there is evidence that overuse of coordination strategies when they are not necessary can harm team performance by detracting from the work itself. In this section we consider three trade-offs between coordination strategies: between volume of communication and shared cognition, between volume of communication and team history, and between shared cognition and team history.

Trade-offs between frequency of communication and shared cognition. Communication is essential for coordination, but it is also a time-intensive activity that diverts time and effort from team member's primary tasks. Engineers, for example, frequently believe that coordination-oriented communication is not real work; research too much of it leads to wasted time and missed deadlines (Perlow, 1999). When shared cognition leads to better coordination, it may do so by reducing needs to explicitly communicate for coordination. There are two reasons to expect this interaction of shared cognition and frequency of communication on coordination. First, as suggested previously, knowledge of who knows what allows team members to assign tasks and to anticipate others' actions with minimal communication. For example, they can use their shared beliefs about each other's interpersonal skills or expertise in finance to decide,

without extensive discussion, who to send to a negotiating session with union representatives or to serve as the spokesperson describing a stock buy-back policy to a board of directors. Second, shared knowledge of one another's skills and expertise constitutes a type of mutual knowledge or common ground, which provides the basis for efficient communication (Clark & Brennan, 1991; Cramton, 2001).When team members are aware of each other's expertise, they can formulate easily understood messages to their partners—for example, using the acronym ROI instead of "return on investment" when they know that their communicative partners are familiar with finance. Consequently, we predict that when teams share cognitions about member expertise, they will be able to achieve coordination with a lower volume of communication.

> *Hypothesis 5: Greater shared cognition about the distribution of expertise within a team will lead to better coordination with less frequent communication.*

Trade-offs between frequency of communication and team history. The longer a team has been together, the less communication it may need to coordinate activities. First, early in their histories, managerial groups are setting direction, while later on they are primarily executing plans developed earlier. Therefore, they will need to communicate extensively to set direction early on, when their task is more uncertain, but can reduce their communication later on, when they are executing their plans. Second, over time, teams devise standard operating procedures or routines, such as weekly meeting times or responsibilities for tasks, that could allow them to handle recurrent problems without explicit communication (Gersick & Hackman, 1990). Third, as groups work together they develop common ground that they can draw upon for more efficient communication (E.g., Isaacs & Clark, 1987; Krauss & Weinheimer, 1966). Kanki and her colleagues (Kanki & Foushee, 1989) demonstrated that improvements in communication mediated the impact of work history on performance in natural settings. Because by working

together teams reduce the uncertainty in their tasks, develop standard operating procedures and develop efficient communication over time, we would expect they would need less communication to coordinate later in their histories than they did earlier on.

Hypothesis 6: The influence of frequent communication will have weaker effects on coordination later in a teams history than early .

Trade-offs between shared cognition and team history. Through the observations of each other and through the communication they exchange in the course of working together, team members develop the shared cognitions previously discussed. Salas and his colleagues (E.g., Orasanu & Salas, 1993) have demonstrated that teams that work longer together are likely to develop shared cognitions, including those about each other's competencies. Gabarro (1978) describes how senior managers learn about the competencies of their management team through direct observation.

At the same time, however, as teams develop standard operating procedures over time, the need to rely upon shared models of who knows to coordinate what is also likely to decline. Task assignments and other decisions based on this knowledge are likely to have been made already. The consequences of routinization associated with working together suggests that coordination through shared beliefs will be more important for groups early in their histories than later on.

Hypothesis 7: The effects of shared cognition on coordination will be strongest early in a team's history than later on.

Effects of Coordination on Performance Outcomes

The overall level of coordination achieved by a team, regardless of the strategies used to achieve it, is a component of what Hoegle and Gemeunden (2001) refer to as teamwork quality. One can think of coordination in this sense as an index of group efficiency. When coordination is high, a unit of individual work translates into more or better team output. In contrast, when coordination is low, the same quality and quantity of individual work will result in less or poorer group output because of what Steiner (1972) terms process losses. Teams will be devoting valuable time and attention to solving the problems of how to work together, rather than apply this energy into their primary task. Failures of coordination lead to excess communication, redundant work, delays in production, and incompatibilities between intermediate outputs that need to be redone before they can be integrated. For example, Brooks (Brooks, 1975) writes eloquently about the way that coordination problems undercut productivity in software teams, and Argyes (1999) demonstrated that information technologies that improved coordination among engineers working on the Stealth Bomber improved the timeliness of handoffs and reduced the rework. Of course, successful coordination by itself does not guarantee a successful group. The group needs appropriate goals and strategies, and individual members need to possess sufficient skill and motivation to contribute to the achieving the goal (Larson & Schaumann, 1993). However, all else being equal, one would expect that increased coordination would improve a team's success.

Hypothesis 8: Groups will be more successful in their primary tasks as their coordination increases.

Method

Setting and participants

We examined these hypotheses in the context of a realistic business simulation called the *Management Game* (Cohen, Dill, Kuehn, & Winters, 1964). Participants consisted of 277 MBA students, organized into 50 teams. Students had from zero to 27 years prior work experience (M = 4.62; sd = 3.12). Approximately one-third were women.

Teams of five or six MBA students competed with each other running soap companies over a 14-week period. During the first seven weeks, students organized teams and learned about the simulation, and during the second period they actually played the game. Students were placed on teams through a two-stage draft. First, students exchanged resumes describing skills, task preferences, and work experience. Based on a popular vote, the class as a whole elected 50 team presidents. These presidents subsequently selected members for their teams through a round-robin draft.

Students acted as the senior managers of a consumer product company during a simulated two-year business period. They made decisions regarding the nature, production, distribution, and financing of their products--laundry detergents. For example, they decided what combinations of price, cleaning power, and environmental friendliness their detergents should have, how much to manufacture, which regions of the country to target, what manufacturing capacity they should maintain, and how large their stock dividends should be. During three separate reviews, each team presented its company's strategies and accomplishments to its board of directors, composed of local business executives. As individuals, all students participated in a stock market, trading shares of the simulated companies to amass personal wealth.

Except for the appointment of its president, each team had discretion on how they would be internally organized. Most teams adopted a functional division of labor, with different individuals responsible for research and development, finance, marketing, production and the presidency of the company. Each team member was responsible for finding, analyzing, and drawing conclusions from a large body of information, which had to be integrated with information developed by other roles to make decisions. For example, early in the simulation, Vice Presidents of Marketing typically decided how much money to spend on simulated market research programs about the consumers' preferences; they executed these programs and interpreted the results.

The responsibilities for acquiring and analyzing other information were more diffuse. For example, most team members would be involved in the basic strategic decision to produce a low cost/low quality product or a high cost/premium one. In addition, most team members examined publicly available financial data about other firms and sought out classroom gossip to assess their competitor's strategies. Most business decisions they made were highly interdependent, requiring a high degree of coordination among team members. For example, marketing decisions about consumer preferences had to be integrated with research and development information about product formula and production decisions about plant capacities.

Approximately twice a week each team recorded decisions for that period (e.g., about the pricing of products in different markets, the attributes of products, the level of production in several factories, the sources of financing for their operations, etc.) and received feedback from a computer simulation about their sales, market share, profitability and other key business indicators.

Each team met with a separate board of directors three times over a seven-week period. Each board of directors consisted of four or five local business executives or managers. In preparation for each meeting, the teams wrote 10-25 page strategic plans and operational reviews, and they presented their plans and accomplishments to their board during multi-hour, highly interactive meetings. The boards of directors approved major capital decisions and set compensation for the team. At the end of each meeting, they evaluated the team and its members on several Likert scales. These evaluations were a major component of students' grades.

Team members communicated both synchronously (scheduled face-to-face meetings, telephone calls, impromptu discussions in corridors) and asynchronously (email and file sharing). Because team members had different work and class schedules, teams worked in a distributed manner much of the time.

Measures

Because the teams prepared for and played the simulation over 14 weeks, we were able to collect data over time, allowing us to examine developmental processes and to test causal paths using panel designs and path analysis. Teams are the unit of analysis for this study. Some variables (e.g., a team's profit or the evenness of communication within the team) can only be measured at the team level. Others variables (e.g., coordination or board member's evaluations) represent individuals' assessments of the team as a whole. For these measures, we first determined that teams explained sufficient variance to warrant combining data at the team-level and then averaging data from all who made assessments, as described below. The data came from three sources:

Student Surveys. Participants completed voluntary surveys assessing their teams at three points during the simulation: at the end of the first 7-week period, halfway through the second 7-

week period, and at the end of the simulation. The second and third surveys coincided with

teams' second and third presentations to their boards of directors. Of the 277 students, 74%

completed the first survey, 77% completed the second, and 67% completed the third. We first

conducted one-way analyses of variance to establish that the team explained variance in these

assessments, and then calculated team-level measures by taking the mean of the individual

member's ratings. The effect of teams was significant for all self-reported measures described

below, except for the measure of communication volume.

For each time period, we calculated team-level data from any team where at least 3

members filled out a survey. This represents 49 teams at time 1, 50 teams at time 2 and 47 teams

at time 3. When teams had fewer than three responses, we imputed missing values for teams

within time-period, using the expectation-maximization technique in (SPSS, 1997). Although

significance levels change slightly, none of the results that we present below changed

substantively when we limited the analysis to teams with no missing values or when we included

all teams with at least two non-missing surveys per time period. We included the following

measures, based on self-reported, survey data.

Frequency of communication. Team members indicated the frequency with which they

communicated with the other members of their team using a 6-point scale ranging from never to

multiple times per day. Estimates were averaged across respondents and their partners to first get

an index of the communication between the pair and then averaged across pairs to arrive at a

communication index for the team as a whole. While we did not keep records of electronic mail

exchanges among team members for the simulation reported in this paper, we did record this data

for the subsequent running of the Management Game. During that year, self-reported

communication frequently was moderately correlated with the number of e-mail messages sent within the team (r=.47, p< 0.001), suggesting some validity to this self-reported measure.

Evenness of communication. We used students' estimates of their communication with each other to calculate a measure of the evenness of communication among team members. Our measure of evenness is one minus the Gini coefficient (Alker & Russett, 1964). The Gini coefficient measures the deviation of the actual Lorenz curve, in which the X-axis represents the cumulative percentage of communicators in the team and the Y-axis represents the cumulative percentage of communication, from the straight line of equality. The evenness measure (reversed Gini) could theoretically range from 1, when each member of a team received an equal amount of communication, to 0, when one team member (e.g., the team president) received all communication. The formula for the reversed Gini coefficient $= 1 - \dfrac{\sum_{i=1}^{n}\sum_{j=1}^{n}\left|x_i - x_j\right|}{2n^2 \overline{X}}$, where X_i represents the cumulative percentage of individuals in a group and X_j represents the cumulative percentage of communication that they receive and N represents the number of individuals in the group. In the following year of conducting the Management Game, the measure of communication evenness was moderately correlated with evenness of e-mail messages sent within the team (r=0.316, p= 0.002), suggesting some validity of the self-reported measure.

Shared cognitions about expertise. Each member of a team rated him or herself and every other team member on four dimensions: their knowledge of marketing, strategy, finance, and production. We calculated the average correlation between pairs of respondents judging the same target across the four knowledge dimensions. It is equivalent to estimating the reliability of the judges' assessments (Rosenthal, 1982). This metric represents overlap of beliefs about who knows what, and controls for biases in the use of rating scales (Cronbach, 1955). We used this measure of shared beliefs because we believed coordination in a group would be influenced by

members' agreement about the *relative* expertise of each other on these four dimensions (e.g., who is most knowledgeable about finance or production). It is relative judgments that determine who one would ask for help on a task or who one would assign to a particular activity. We explicitly decided not to use R_{wg} (James, Demaree, & Wolf, 1984), because the R_{wg} compares absolute judgments and penalizes raters who have different mean values when using a scale.

In general these shared beliefs about expertise were moderately accurate, in the sense that the average Pearson correlation between group members' evaluation of a target's knowledge and the target's self assessment was .44 ($p<.001$).

Coordination. The questionnaire included scales that previous research had developed to measure interdependence (Van de Ven, 1976) and coordination (Cammann, Fichman, Jenkins, & Flesh, 1983; Van de Ven, 1976). We also included questions that we had constructed to assess the adequacy of the team's ability to relate tasks and share information needed for decisions.

Principal components analysis of each of the three questionnaires we administered demonstrated non-independence of many of these independently developed scales. In particular, each survey contained a major factor that can be interpreted as how well-coordinated members of a team judged the team to be. This coordination factor included agreement with statements such as "People in this team were able to do their jobs without getting in each other's way," and "I found myself duplicating others' work (reversed)". These were originally designed to measure coordination. This factor also included items such as "It was very easy for me to get information from other team members when I needed it," (reversed)." The reliability of this measure was high at all three time periods (.86, .93, and .90). We therefore constructed a coordination scale by taking the mean of the 15 items loading most highly on this factor. We consider this to be a measure of coordination as outcome.

Board Evaluations. Boards of directors evaluated each team based on its presentations and reports as well as objective performance data, such as market share, profitability, and stock price. Boards made their judgments by indicating their level of agreement/disagreement with statements such as "The team is very likely to meet its financial and marketing objectives," "The team has predicted the reactions of its competitors to its strategy," and "Compared to other strategic plans and reports that I have read, this one is [7-point Likert scale, with endpoints of 'unacceptable' to 'outstanding']." Principal components analysis identified only one dimension, reflecting overall quality of performance, underlying their judgments.

The board evaluation is the mean of multiple evaluation questions, averaged over board members. The average intercorrelation across three time periods between members of a board rating each of the 50 teams was .61 (s.d. = .15). The average reliability of this measure across all judges for a team was high for all three time periods (.80, .84 and .89).

Financial performance. Based on the decisions a team made in relation to those of its competitors, the simulation calculated a number of financial indicators of team success for each quarter. We include Sales and Profits. *Sales* represent the quantity of soap the team sold in the simulation. In the simulation, sales for soap was determined by the price a team set, the extent to which their product had attributes that met the consumer's preferences in different markets, customer loyalty, the team's inventory levels during periods of high demand, and the team's success at competing in government wholesale auctions, all relative to the performance of competing teams. *Profits* represents the gross income the team received from sales (price times sales) minus the cost of goods sold and operating expenses, including salaries, transportation, research and development and marketing. Because profits are contingent on sales, we include sales when predicting profits in the analyses below.

The third financial outcome was the team's stock price. Students traded shares of the

companies in the simulation on a stock market, and a particular company's value was based on

this market. Each student started the simulation with an equal number of shares in all the firms

in Game. Thus, at any time, a firm's stock's price represents the collective judgment of

participating students about how much the firm was worth, based on its past performance and

future prospects.

The financial performance data were collected three times during the 7-week period in

which teams were actively playing the simulation. For the first and second waves, measurement

of the financial performance followed the team's self-reported questionnaires and the evaluations

by their boards of directors. For the third wave, financial performance was measured before the

final board evaluation, at approximately the same time as students were completing their final

surveys. The financial outcome variables were all moderately correlated (see Table 1).

Statistical techniques

The regression analyses we report below use the method recommended by Cohen and

Cohen (1983) for dealing with measurement of change and were analyzed by an equation of the

following form:

$$Y_t = Y_{t-1} + X_{at} + X_{bt} + \_ + X_{nt}$$

This analysis examines the effects of predictor variables $(X_a - X_n)$ measured at one time

period (e.g., team coordination as reported on the second questionnaire) on a dependent variable,

Y_t, measured at approximately the same time (e.g., profits at the time of the second board

evaluation) while holding constant the value of that dependent variable, Y_{t-1}, at the prior time

period (e.g., stock price at the beginning of the game). Because the lagged value of the

dependent variable is included among the regressors, the analysis is equivalent to an analysis of

change scores on Y, controlling for regression towards the mean, unreliability, contemporaneous

co-variation between the outcome and the predictor variables, and other statistical artifacts. In

the example described in this paragraph, one can interpret the regression coefficient associated

with coordination as an estimate of the extent to which variation in a team's current state of

coordination predicts changes to its stock price (or more accurately, variation in its stock price

that was not predictable by its price a few weeks prior).

Each team contributed two observations to this analysis (i.e., when predicting profits at

T_2 and T_3). Since the errors in these observations are not independent of each other, violating

assumptions of ordinary least squares regression, we analyzed data using the cross-sectional,

time series regression procedure (xtreg) in the Stata statistical package (StatCorp, 2001), with a

random effects design that modeled teams as a random variable. This procedure accounts for the

non-independence of observations.

Tables 3-5 present the results of these analyses as a hierarchical regression analysis.

Figure 2 is a path analysis, summarizing the results relevant to our hypotheses. In these

analyses, interaction terms involving an independent variable have been excluded when

calculating that variable's main effect on a dependent variable; main effects, however, are

included when calculating the impact of interaction terms. (i.e., interactions involving amount of

communication, history, and shared cognitions have been excluded when predicting the main

effects of these variables on coordination, stock price, or board evaluation; main effects have

been included when predicting the impact of the interactions on the dependent variables). We

used regression coefficients to estimate a path model rather than a structure equation model, such

as LISREL, because the small sample size of 50 teams did not allow estimation of both

measurement and casual parameters in a single structural equation model.

Results

Preliminary analyses

Table 1 shows the means, standard deviations, and standard errors of the mean for all

variables at the three time periods and the correlations among the variables after being averaged

across the three time periods. Note that frequency of communication was negatively correlated

with evenness of communication ($r = -.51$, $p < .001$). To guard against potential multi-

colinearity in models testing the influence of communication, we conducted additional analyses,

described below.

Insert Table 1 About Here

Coordination Strategies

The major goal in this research was to investigate the way that frequency of

communication, evenness of communication, shared cognitions about team expertise, and time

working together influenced a team's ability to coordinate and, through this path, influenced

performance outcomes. In this section, we consider predictors of coordination; in the next

section we examine the effects of coordination on our performance measures.

The first model in Table 2 shows the results for the main-effects analysis; the second

model adds the theoretically relevant first-order interactions. As one would expect, coordination

at one time period predicted coordination at the next ($\beta = .32$, $p < .01$). That is, teams that were

coordinated at one time period continued to be coordinated.

Hypothesis 1, that more frequent communication would lead to better coordination, was

not supported (β = .04, ns). However, Hypothesis 2, that more even communication would lead

to greater coordination, was supported (β = .17, *p*=.05, 1-tailed). Overall, teams exhibited high

evenness of communication (see Table 1), close to the theoretical maximum on the scale.

Therefore, the association of evenness of communication with coordination means that the

minority of groups that excluded one of their members from their communication networks

performed worse than the majority of teams who included everyone equally in their networks.

Because communication frequency and communication evenness were themselves moderately

correlated (*r*= -.51), we conducted two supplementary analyses to assess whether including both

variables into the models predicting coordination distorted the results. We refit Models 1 and 2 in

Table 2 separately, excluding first communication evenness and then communication frequency.

The results are not substantively different than those presented in Table 2: Communication

evenness still predicted increases in coordination, while communication volume did not.

Hypothesis 3, that shared cognitions about the distribution of expertise within the team

would lead to greater coordination, was also supported (β = 22, p <.01). Coordination increased

more among teams whose judgments of each other's knowledge were more similar.

As predicted by Hypothesis 4, coordination increased as teams worked together longer.

The coefficient of .36 (p. < .05) for Time in Model 1 of Table 2 indicates that, on average, teams

increased their coordination approximately one-third of a scale point in the original measurement

units, or approximately two-thirds of a standard deviation, between administrations of the

questionnaire. This is a moderate effect size.

Model 2 shows the results of the analysis with the three predicted interactions included.

Consistent with Hypothesis 5, shared beliefs and communication seem to be able to substitute for

each other (β = -.21, p < .05). The interaction plot in Figure 1A shows that teams that had both

below-average shared cognitions about others' knowledge and below-average communication

were poorly coordinated, while teams that had either one of these were better coordinated.

Having both above-average communication frequency and above-average shared cognitions

conferred no additional advantage.

There was no support for Hypothesis 6. Communication did not have stronger effects on

coordination early in a team's history. However, consistent with Hypothesis 7, teams gained

more from shared beliefs earlier in their history than they did later on (β = -.42, p =.01). The

interaction plot in Figure 1B indicates that teams with higher shared cognitions improved their

coordination more between time periods one and two than teams with fewer shared cognitions.

However, shared cognitions did not confer a similar advantage between time periods two and

three.

Insert Table 2 and Figure 1 About Here

Effects of Coordination on Performance

Table 3 shows the effects of each coordination strategy, the interactions among these

strategies, and team coordination on the teams' performance outcomes. Common business

practice indicates that the financial performance outcomes for a firm are themselves causally

interrelated. Profits are constrained by a firm's sales. Investors rely upon a firm's current profits

to predict its future performance; therefore stock market price is dependent upon profits. Finally,

boards of directors, representing shareholders interests, are influenced by these financial

performance measures. Therefore we include causally prior financial outcomes in the models of

performance below.

To summarize the major results reported in more detail below, teams' performance outcomes improved more during periods when the teams were more coordinated, holding constant their previous performance outcomes and the financial outcomes during that period.

_____

Insert Table 3 About Here
_____

Sales. Model 1 in Table 3 shows sales as a dependent variable. The only reliable predictor of a team's sales during one time period was its sales in the immediately preceding period ($\beta = .46$, $p < .001$).

Profits. Model 2 in Table 3 shows profits as the dependent variable. Profits declined with time, as the game became more competitive ($\beta = -.31$, $p < .05$). Firms with larger sales were more profitable ($\beta = .67$, $p < .001$). Consistent with Hypothesis 8, teams that were more coordinated had larger profits, even holding constant sales and profits in the prior period ($\beta = .21$, $p < .01$).

Firm Price. Model 3 in Table 3 shows a firm's stock price as the dependent variable. Recall that stock price is the amount that other students in the class were willing to pay for a share of the firm's stock in the Management Game stock market. It represents their assessment of that firm's prior performance and future earnings.

Stock prices increased with time ($\beta = .61$, $p < .001$), in part driven by the law of supply and demand, as the amount of cash in the simulated economy increased while the number of stock shares remained constant. A company's previous stock price was a good predictor of its subsequent stock price ($\beta = .66$, $p < .001$). In addition, firms that were more profitable had larger increases in their stock price ($\beta = .47$, $p < .001$). Holding constant these financial considerations

and consistent with Hypothesis 8, teams that were more coordinated had larger run-ups in their stock prices ($\beta = .20$, $p < .01$).

Board Evaluations. Model 4 in Table 3 shows the boards of directors' evaluation of the team as the dependent variable. Prior evaluations ($\beta = .44$, $p < .001$), current profits ($\beta = .32$, $p < .001$) and current stock price ($\beta = .32$, $p < .10$) predicted the evaluation a team received from its boards. Board evaluations tended to be stable, with teams that received a high evaluation at one time tending to receive high ones at subsequent times. In addition, the boards were sensitive to objective measures of performance: higher profits and stock prices predicted their evaluations.

Although we had made no predictions about how communication would directly influence performance, for this dependent variable, the evenness of a team's communication predicted larger increases in board evaluations ($\beta = .17$, $p < .01$). Finally, consistent with Hypothesis 8, independent of past evaluations of the team and the team's objective performance, a team's current level of coordination predicted boards' evaluations: teams that reported themselves as more coordinated improved their evaluations more than less coordinated teams ($\beta = .20$, $p < .01$). We suspect that both even levels of communication and coordination influenced the board evaluations over and above the objective measures of performance, because a team's communication and its coordination was directly visible to its board during their multi-hour reviews.

Mediation or indirect effects. The coefficients in Tables 2 and 3 and summarized in Figure 2 represent a path analysis (Wright, 1921) of the hypothesized causal relationships among variables in this study. In each stage of the model, variables hypothesized to be causally prior have been held constant. We follow Cohen and Cohen's suggestion and use unstandardized beta weights in the path analysis, because these are more stable over replications than standardized

beta weights (Cohen & Cohen, 1983). We do not use a structural equation model, such as

LISREL, because the relatively small number of teams in the study precludes simultaneously

assessing both the measurement and the causal models.

Insert Figure 2 About Here

Taken together, the path analysis shows that group process variables—communication

and shared beliefs about expertise—influenced coordination, which in turn influenced team

performance. A follow-up analysis to those presented in Table 3 tested whether coordination

mediated any direct relationship between group process variables and performance (Baron &

Kenny, 1986). This test examines whether the direct relationship between an independent and

dependent variable is significantly reduced when the presumptive mediator is entered into the

equation. As seen in Table 1, none of the communication or shared belief measures had a

significant direct correlation with any of the three financial performance measures. Therefore,

coordination could not mediate these relationships. However, as seen in Table 1, both evenness

of communication and shared cognitions about the distribution of expertise in a team were

significantly correlated with the board's evaluation of team.   However, comparison of the Model

4 in Table 3 with a similar model excluding coordination shows no evidence of mediation. Thus,

the group process variables primarily had indirect effects on a team's performance through their

influence on coordination. Only evenness of communication had a direct effect on board

evaluations.

Discussion

The results of this research help increase our understanding of the strategies teams use to achieve coordination, how some of these strategies interact with one another, and the effects of coordination on teams' performance.

Coordination Strategies

Our research suggests that both work process and group history influence coordination. To summarize the results, coordination was influenced by evenness of communication, shared cognitions about the distribution of expertise within the team, and time working together. Coordination was also influenced by the interactions between shared cognitions and frequency of communication, and between shared cognitions and team history. Contrary to our predictions, however, there was neither a main effect of communication frequency on coordination, nor an interaction of communication frequency with history working together.

The failure to find a main effect of frequency of communication on coordination is in contrast to previous studies demonstrating the value of communication for team performance (e.g., Cummings, 2001; Kiesler, Wholey & Carley, 1994; Pelz & Andrews, 1966; Thompson, 1967; Van de Ven, 1976). Although more communication is typically associated with better coordination and performance, this relationship is not inevitable. Part of the problem is methodological. In cross sectional research, it is impossible to distinguish cases when excess communication harms performance from cases where teams increase their communication to compensate for poor coordination and performance (Smith, 1994). A more substantive problem is that communication takes time and effort, which group members could use to perform their individual tasks (Perlow, 1999). Therefore we conducted supplementary analyses to determine whether communication frequency had a curvilinear relationship with coordination. There was

no increase in R-squared when the squared value of communication frequency added to Model 2

in Table 2 and the coefficient for the curvilinear component of communication was not

statistically significant. Thus there was no evidence from this experiment that lower performing

teams were communicating "too much".

In contrast, we did find a main effect of evenness of communication on coordination. On

average team members communicated very evenly (with a mean of .93 on a index with a

theoretical maximum of 1.0). There was, however, variation around this mean. The significant

effect of even communication implies that greater evenness of communication, not withstanding

high average evenness of communication, improve performance. This result did not occur simply

because teams with the least even communication were especially uncoordinated. Results were

substantively the same after excluding the ten-percent of the teams with the least even

communication. These results strongly suggest that in the small managerial teams typical of this

simulation, involving everyone equally in communication improves coordination and, ultimately,

performance.

As predicted, shared cognition among team members about the distribution of expertise

was associated with increases in coordination. These shared cognitions likely facilitated task

assignment, information distribution, advice-seeking, and the like. Although the focus in this

research and the literature as a whole is on knowledge of the distribution of expertise within a

group. However, it is also possible that agreement about distribution of expertise is associated

with other shared beliefs as well, including a common view of goals, strategies, and work tasks.

This is likely because agreement about expertise was acquired in the context of performing and

discussing particular tasks, as teams developed and executed a strategy. In general these

members' beliefs about the distribution of expertise were accurate (i.e., the correlation between

groups members' evaluation of a target's knowledge and the target's self-assessment was high).

Whether shared cognitions would have the same effects if they were inaccurate is an open

question.[1]

Our finding that work history led to greater coordination is consistent with other research

showing that teams that worked together longer improve performance, at least to some limit

(Katz, 1982). It is likely that experience of working together improves coordination through

multiple routes. Part of the improvement occurs because individuals perform better when they

are more familiar with many features of their work environment, including tools, the physical

environment, and the people they work with (Goodman & Leyden, 1991). Surprisingly,

however, teams' knowledge about the expertise of other members did not increase over time.

Neither shared cognitions (average correlations among team members) nor accuracy (average

correlations between team members judgments and a target's self-assessment) increased over

administrations of the questionnaire (r=-05 and .12 respectively). These findings are reminiscent

of Levesque, Wilson and Wholey's findings (2001) that shared cognitions about many aspects

of a team's environment declined as they worked together and increased their division of labor.

Part of the improvement in team's coordination with experience occurs because groups

become more efficient in communication as they work together (Kanki, Folk, & Irwin, 1991;

Kanki & Foushee, 1989; Krauss & Fussell, 1991). In addition, we believe that part of the

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[1] We focused on agreement in beliefs rather than accuracy for three reasons. First, these two attributes of shared beliefs are inherently related, in the sense that when individuals have beliefs about a common object that are perfectly accurate they are necessarily in perfect agreement with each other. This connection makes it difficult to tease apart the separate contributions of agreement and accuracy. Second, there are fundamental ambiguities in defining the accuracy of person perception judgments (Cronbach, 1955). For example, it is possible to use an individual's self-assessment as the criterion against which others' assessments are evaluated. In the case of person perception judgments, however, there is little reason to believe that self-assessments are closer to the truth than others' assessments. Finally, in analyses not reported in this paper, we included both agreement between self and others, which can be thought of as an accuracy measure, and the agreement among others, our consensus measure, to predict coordination and performance outcomes. Including the accuracy measure did not improve the predictive power of any of our models, and so it was eliminated for reasons of parsimony and simplicity of presentation.

improvement occurs because groups develop standard operating procedures as they work

together longer (Gersick & Hackman, 1990). One limitation of this research is that we did not

directly measure the development of standard operating procedures, and therefore, cannot

definitively point to their role in improving coordination over time.

Our findings also highlight some of the ways in which coordination strategies can

interact. Stout, Cannon-Bowers, Salas, & Milanovich {, 1999 #1123}theorize that shared

cognitions should allow groups to coordinate with less explicit communication. Our study is

consistent with this prediction. The interaction between shared cognitions and communication

frequency suggests that shared beliefs and communication are alternate ways of achieving

coordination. Teams were relatively uncoordinated when they had neither shared cognitions nor

adequate communication, but being above average on either communication or shared cognitions

improved coordination. However, being above average on both did not further increase

coordination. It is important to understand more fully the developmental process by which

shared cognitions can substitute for other means of coordination. Because we collected data at

only three time periods in the present study, however, we do not have sufficient data to

determine in detail how these tradeoffs evolved.

The negative interaction between shared cognitions about expertise and time is consistent

with Moreland, Argote, and their colleagues' suggestion that shared cognitions about expertise

have their impact on group performance primarily by facilitating in task assignment (Liang,

1995; Moreland et al., 1996). Early in their history, when many tasks were new, teams need to

understand each other's skills and abilities to match team members to these tasks. For example,

in the present simulation, team members needed to assess who was most knowledgeable about

finance or production before assigning members to executive roles, and they needed to know

who was most computer-savvy and could program spreadsheets to assign someone the task of

uploading data. It is likely that later in their history, these assignments would have been

routinized as part of the team's standard operating procedures, and they no longer needed to

return to the basics for the initial decisions.

Coordination as outcome

As expected, teams that were better coordinated had better outcomes, with Hypothesis 8

being confirmed for the outcomes of profits, stock price, and board evaluations. The effect of

coordination on profits remained, even after controlling for sales, which itself was a major

determinant of a team's profit. This finding suggests that teams that were more rather than less

coordinated were able to wring greater profits from a comparable level of sales. Sales directly

reflect a team's decisions about product quality and pricing. In the simulation, consumers bought

more product if it met their preferences and was inexpensive. However, within this general

economic model, teams had latitude to influence profits. They could charge more for their

product in regions where consumers were relatively insensitive to price or where they

particularly appreciated some product feature, like environmental friendliness. They could react

quickly to price changes by competitors, to retain their own competitive position. They could

control costs, by avoiding stock outs, by selling their products in regions close to their factories

to reduce transportation costs, by maintaining efficient plant capacity, or by advertising only in

regions where consumers were sensitive to this type of marketing. Increasing revenues or

reducing costs through these methods required decision-making and performance involving

multiple team members. It appears that better coordinated teams were able to integrate

information across functional areas to make and execute these business decisions.

A team's coordination had an impact on its board of directors' evaluations over and above the team's financial performance, as measured by sales, profits and stock prices. Why was this the case? One reason is that the board members had direct access to rich information about the team above and beyond financial data. In particular, board members could directly evaluate the quality of the management team, the coherence of their strategy, their future plans to deal with competitors and how well they supported each other during meetings. That is, by reading planning documents and observing meetings, the boards of directors had evidence directly relevant to a team's coordination and rewarded teams through higher evaluations if they appeared more coordinated.

Limitations and Future Directions

Inferring causation. Our theoretical model and the summary of results in Figure 2 presents the relationships among variables as unidirectional. Methodologically, we have used time series data to infer the direction of causation. This research design allows stronger causal inferences than is possible from cross-section designs. In general, self-reported measures of group process were collected before measures of group performance, although at time three, these variables were measured contemporaneously. Our analyses included lagged dependent variables, which further strengthen the causal claims we are making. By including lagged dependent variables in the models, the analyses model the way an independent variable at one time period influences *changes* in the dependent variable from the preceding time period (Cohen & Cohen, 1983). The influence of the dependent variable at the prior period is partialled from both the dependent variable and from the independent variables in the current period.

Despite the panel design, both theoretically and empirically, the relationships among the key variables are likely to be bi-directional. While our methods demonstrate one of the causal

paths, they do not preclude others. As an example, consider the links between communication, shared cognitions, and coordination. Our results suggest that evenness of communication and shared beliefs both increase coordination, and that communication frequency and shared beliefs trade off in causing coordination. However, alternative causal paths are also plausible. For example, as research by Smith and his colleagues suggests, groups that are poorly coordinated at one period may subsequently increase their communication to get back on track (Smith, 1994). Similarly, when a team discovers that work assigned to one member is not being done in a timely way (a symptom of poor coordination), this discovery may change their assessment of the distribution of expertise in the group and may also increase communication levels as they try to resolve the problem. Both experimental research and observational research with a finer temporal granularity could help resolve some of these ambiguities about causal direction.

The nature of shared cognitions. The current research looked at only one type of shared cognitions–consensus about the distribution of expertise within the team. The focus of our own research and much of the organizational literature on transactive memory has been on slowly changing aspects of a team's internal environment—team members' expertise and skills. We expect that these shared cognitions represent many beliefs about relatively slowly changing aspects of a team's internal environment. However, it is unclear how results obtained from examining shared cognitions about expertise would generalize to shared cognitions about more rapidly changing features of the internal team environment, such as others' time availability (Perlow, 1999) or about shared beliefs about the external environment, such as the behavior of competitors.

Despite the focus in the small groups literature on transactive memory and other beliefs about the internal environment (e.g., Liang, Moreland & Argote, 1995; Hollingshead, 200),

future research should also look at shared cognitions about the external environment. Situational

awareness (Endsley, 1995) or knowledge about the external environment may be even more

important in predicting a team's performance. There is substantial evidence that for teams

embedded in organizations, as opposed to laboratory groups, mechanisms for focusing on the

external environment are crucial to success, especially in a changing environment. In particular,

research in managerial decision-making teams (D'Aveni & MacMillan, 1990), software

engineering teams (Curtis, 1988) and new product development teams (Ancona & Caldwell,

1992) all suggest that failure results when teams ignore such changes as the preferences of their

customers, the behavior of their competitors, or the technology base on which they are

performing their work.

Conclusion

Our research has important consequences of team coordination for performance and

interesting tradeoffs among the strategies teams use to achieve coordination. Shared cognitions

seem to be alternatives to compensate for deficits in communication and a history of working

together in achieving coordination. Additional research is needed to understand the causal route

by which shared cognitions are formed and through which they influence group process and

outcomes more generally. Qualitative studies of the nature of teams' communication could be

especially valuable. In addition, there is a need for the development of detailed process models.

We also believe that more empirical research is needed to identify the effects of different types

of shared cognitions.

Acknowledgements

TABLES

Table 1. Means, standard deviations, and standard errors of the mean for variables used in regression equations.

Variable (range in parentheses)	Time 1		Time 2		Time 3		Correlations (data collapsed across wave)						
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	1	2	3	4	5	6	7
1 Frequency of Communication (1-5)	3.14	.52	2.32	.51	2.43	.58							
2 Evenness of Communication (.00-1.00)	.93	.05	.93	.04	.93	.05	-.51						
3 Shared Cognition (-1.00-1.00)	.44	.15	.46	.19	.42	.24	.17	.05					
4 Coordination (1-5)	3.70	.36	3.75	.64	3.93	.48	-.03	.26	.38				
5 Sales ($15,039-$82,930)	35,349	8,045	37,961	9,346	37,488	12,893	-.15	.16	-.02	.01			
6 Profits (-$5,247 - $12,504)	2,295	2,526	1,828	3,151	1,178	3,224	-.07	.21	.12	.41	.71		
7 Stock Price per Share ($33.66- $192.61)	70.75	18.98	75.97	20.80	100.38	36.89	.16	.19	.16	.40	.62	.76	
8 Board Evaluation (1-6)	4.66	.88	4.93	1.06	5.37	1.14	.04	.28	.28	.59	.42	.62	.65

Note: N=50 for all analyses.
For the correlations, |r| >=.27, p <.05; |r|>=.36, p<.01

Table 2: Predicting coordination

Variable	Model 1 Main effects			Model 2 Main effects + interactions		
	Beta	SE	p-value	Beta	SE	p-value
Intercept	-.76	.43		-1.08	.48 *	
Lagged Coordination	.32	.10 **		.41	.10 ***	
Frequency of Communication	.04	.14		-.56	.56	
Evenness of Communication	.17	.12		.19	.11 +	
Shared Cognitions about Expertise	.22	.09 **		1.21	.44 **	
Time (Team History)	.36	.10 *		.49	.18 **	
Communication Frequency X Shared Cognitions				-.21	.11 *	
Time X Communication Frequency				.27	.22	
Time X Shared Cognitions				-.42	.17 **	
Rsq	.38			.44		
Change in Rsq				.06		
df	44			41		
Wald Chi Square	33.99			47.40		
Difference in Chi Square				13.41 **		

Note: 1-tailed *p*-values

[+] *p* <= .05, [*] *p* <= .025 , [**] *p* <= .01 , [***] *p* <= .001

Table 3: Predicting team performance

Variable	Model 1 Sales			Model 2 Profits			Model 3 Stock price			Model 4 Board evaluation		
	Beta	SE	p	Beta	SE	p	Beta	SE	p	Beta	SE	p
Intercept	.25	.61		.57	.38		-1.00	.45		-.23	.39	
Lagged dependent variable	.46	.13	***	.03	.08		.66	.12	***	.44	.09	***
Frequency of Communication	-.53	.68		.26	.43		.40	.18		.05	.41	
Evenness of Communication	-.13	.13		.01	.09		.05	.09		.17	.08	**
Shared Cognitions	.13	.52		.14	.33		-.21	.36		-.35	.31	
Time (Team History)	-.08	.24		-.31	.15	*	.61	.18	***	.20	.16	
Coordination	-.05	.11		.21	.08	**	.20	.08	**	.20	.07	**
Time X Communication Frequency	.11	.27		-.13	.17		-.11	.19		.02	.16	
Time X Shared Cognitions	-.09	.20		.09	.12		.01	.14		.13	.12	
Communicaton Freq. X Shared Cognitions	-.13	.13		.03	.08		-.02	.09		-.06	.08	
Sales				.67	.17	***	-.03	.10		-.04	.08	
Profits							.47	.11	***	.32	.10	***
Stock price										.14	.08	†
Rsq	.21			.61			.63			.71		
df	41			39			38			37		

Note: † $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Figure 1. Interactions of shared cognitions and history and communication frequency on coordination.

Note. For illustration, interaction plots show level of coordination when (A) frequency of communication was a standard deviation above the mean (high communication) or below (low communication) or (B) when coordination was measured at the second questionnaire or the third questionnaire shared crossed with shared cognition when it was a standard deviation above the mean (high agreement) and below the mean (low agreement).

(A)
Shared cognition x
Communication

(B)
Shared cognition x
History
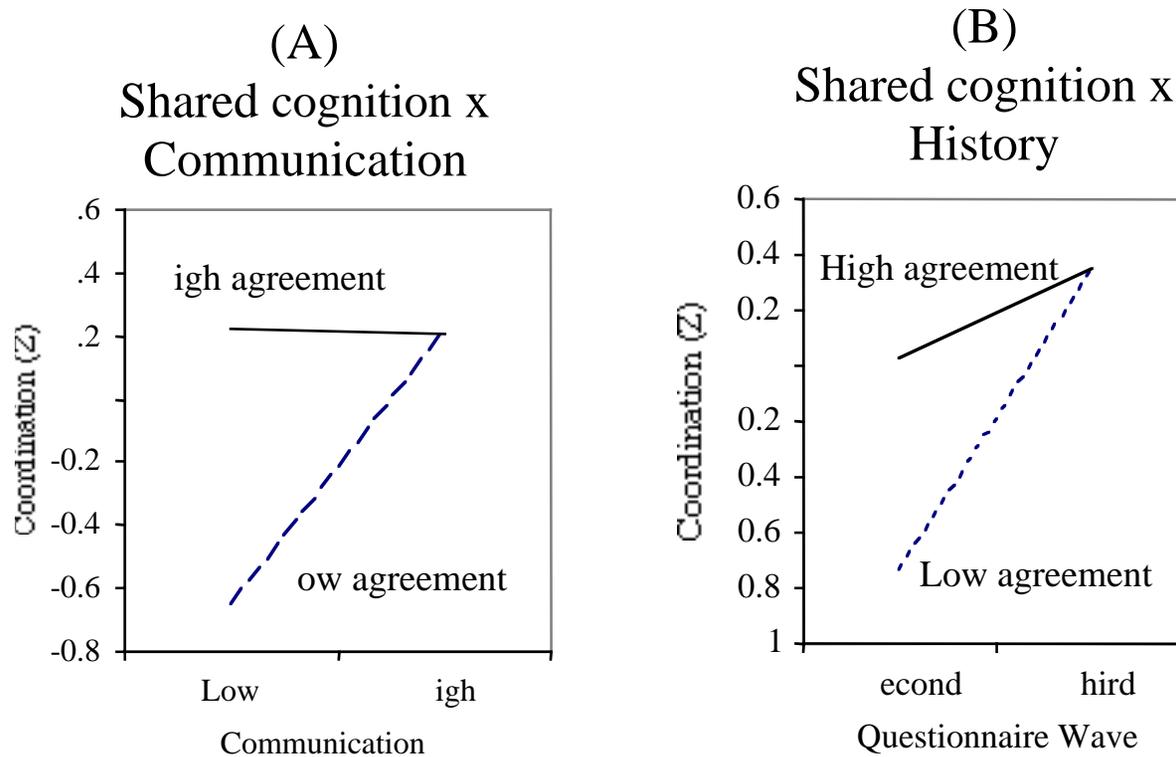
Figure 2: Path model, summarizing the relationships among time, communication, shared cognitions, coordination, and performance outcomes.

Note: Numbers represent unstandardized beta weights. Only relationships where p < .05, 1-tailed, have been retained. Models control for the lagged dependent variable, but this link has not been shown for simplicity.
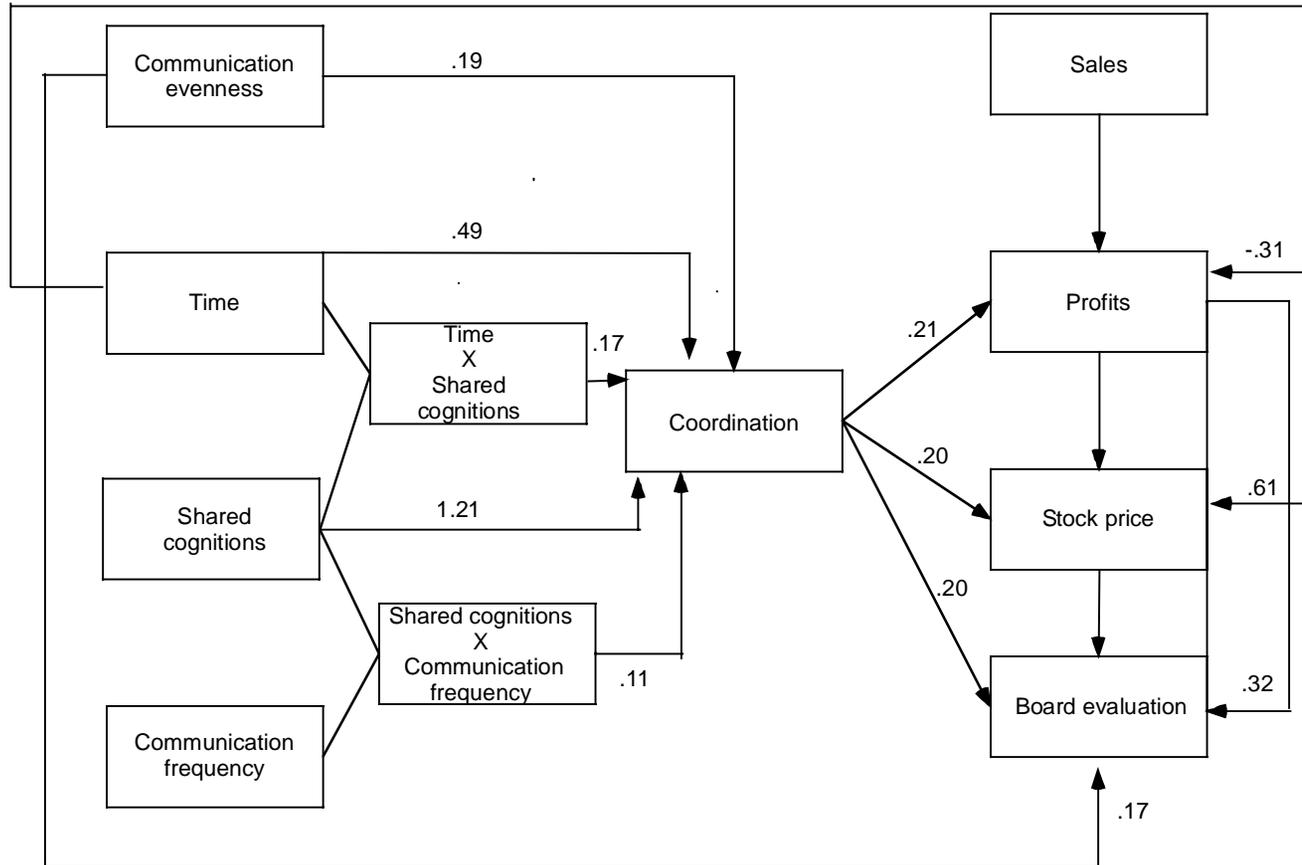
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