FINAL REPORT

Grant Title:
EXPLORING THE CONTENT OF SHARED MENTAL MODELS IN PROJECT TEAMS

Office of Naval Research Award Number:
N000140210535

Principle Investigator:
SARA McCOMB
Associate Professor
Isenberg School of Management
University of Massachusetts Amherst

Grant Period:
15 APRIL 2002 through 30 SEPTEMBER 2005

UMassAmherst
ISENBERG
SCHOOL OF MANAGEMENT

121 Presidents Drive, Amherst, MA 01003
Telephone: 413-545-5580 Fax: 413-545-3858
www.som.umass.edu

MEMORANDUM

Date: 26 January 2006

To: see Distribution

From: Jo-Ann Bourguignon, UMass/Amherst ISOM

Re: ONR #N00014-02-1-0535 Final Report

Attached you will find a copy of Dr. Sara A McComb's Final Report, titled "Exploring the Content of Shared Mental Models in Project Teams," which was delivered to Mr. Michael Letsky at ONR's Ballston Office, in November, 2005.

Please accept my apologies for this delay of your copies. I am a newcomer to my post, and did not become aware of this task until Ms. Woodbury contacted us.

Your consideration will be appreciated.

Sincerely,

Jo-Ann Bourguignon

Jo-Ann Bourguignon
Financial Analyst and Grants Administrator
Dean's Office, School of Management
413-577-6598

Distribution:

Ms Valerie Woodbury, ONR Regional Office, 495 Sumner Street, Boston, MA
Mr. Roger Swenson, ONR Regional Office,495 Sumner Street, Boston, MA
Defense Technical Information Center, 8725 J.J.Kingman Road, Suite 0944, Ft. Belvoir, VA 1/30
Naval Research Laboratory, Attn: code 5227, 4555 Overlook Ave., SW, Washington, DC 1/30

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1.0 EXECUTIVE SUMMARY

The goal of this project was to advance our understanding of the mental model convergence process. Five technical objectives were established to achieve this goal. Two phases of experimentation were undertaken to address the objectives. The first was a quasi-experiment where teams of students undertaking semester-long projects completed questionnaires at four time periods during the semester. The second were laboratory behavioral simulations where teams of three students completed two simulation sessions on progressively difficult tasks. The objectives and the corresponding findings are summarized.

First, a model of mental model convergence was developed by integrating existing theory from literatures such as shared mental models, project teams, group development, information processing, information sharing, and transactive memory. This model depicts a three-phase approach to mental model convergence. Specifically, team members (1) orient themselves to the team and its task, (2) differentiate their own personal mental models from the mental models of their team mates, and (3) integrate these differing perspectives.

The second objective was to explore the way in which individually-held mental models converge among team members to become shared. The students in the quasi-experiment provided responses to sentence stems regarding a set of teamwork mental models (e.g., "The goals of our project are . . ."). These responses were analyzed to ascertain the commonality among team members. By comparing the results across time periods, increased convergence over time was uncovered. The transcripts from the laboratory sessions are being coded to identify patterns associated with the mental model convergence process.

Three methods were examined for measuring mental model convergence to address the third objective. The first two were described in the previous paragraph. The third was examined using data collected at the end of the simulation. Team members completed questionnaires comprised of existing scales designed to measure team perceptions about constructs such as goal clarity, cooperation, and team skills. The interrater agreement among member responses was used to score convergence in team members' mental models.

The fourth and fifth objectives were to confirm that multiple mental models function simultaneously and to determine how shared mental models regarding teamwork impact team performance. The quasi-experiment results indicate that team members who have a common understanding at the beginning of the project of their team's goals and how they are going to interact and at the end of the project understand who is doing what task perform better. Using the behavioral simulation data, team performance was regressed on the teamwork mental model convergence scores. The results confirm that multiple mental models function simultaneously because the mental models tested had unique relationships with performance. The results also reveal relationships between the mental models and performance. From the first session, the goal acceptance, cooperation and coordination mental models were related to time performance and the goal clarity and cooperation mental models were related to member satisfaction. From the second session, goal clarity (negative) and cooperation mental models were related to time performance, the team staffing quality mental model was related to quality performance, and the cooperation mental model aided satisfaction.

2.0 PROJECT SUMMARY

No consensus among researchers studying shared cognition exists regarding the identification of what should be shared, the measurement of shared mental models (SMM), and the effects of SMM on team outcomes (Cannon-Bowers & Salas, 2001). This research project was undertaken to address these issues and extend our theoretical understanding of shared cognition in at least three ways. First, minimal research has been conducted in the area of SMM that integrates extant research from related fields (Mohammed & Dumville, 2001). This research project drew together research on SMM, project teams, group development, information processing, information sharing, and transactive memory. Further, evidence is included from areas similar to SMM, such as group mind (e.g., Weick & Roberts, 1993), interpretive schema (e.g., Bartunek, 1984; Dougherty, 1992), intersubjectivity (e.g., Eden et al., 1981), shared cognition (e.g., Cannon-Bowers & Salas, 2001), shared meaning (e.g., Smircich, 1983), sociocognition (e.g., Gruenfeld & Hollingshead, 1993), and team mental models (e.g., Klimoski & Mohammed, 1994). Second, in this research, mental model convergence (MMC) is modeled from an information processing perspective. While other studies have proposed that information processing can occur at the group level (e.g., Corner et al., 1994; Gibson, 2001; Gruenfeld & Hollingshead, 1993; Hinsz et al., 1997), none have specifically applied information processing to teamwork functions as was done in this project. Third, this research extends our current understanding of SMM content by investigating the simultaneous existence of multiple mental models. Previous work has discussed possible SMM content requirements (e.g., Cannon-Bowers et al., 1993) and research has tested for the simultaneous existence of teamwork and taskwork mental models (e.g., Mathieu et al., 2000; Smith-Jentsch et al., 2005). To my knowledge, however, multiple *teamwork* mental models have never been captured in one study.

2.1. GOALS

The long term goal of this research is to advance the theoretical understanding of shared cognition in project teams by (1) integrating existing theory in related fields to establish a model of mental model convergence; and (2) validating the model through experimentation.

2.2. TECHNICAL OBJECTIVES

This project has five objectives: (1) to devise a model of mental model convergence; (2) to explore the way in which individually-held mental models converge among team members to become shared; (3) to examine different means of measuring mental model convergence; (4) to distinguish among the multiple mental models working simultaneously within a team; and (5) to determine how shared mental models regarding teamwork impact team performance.

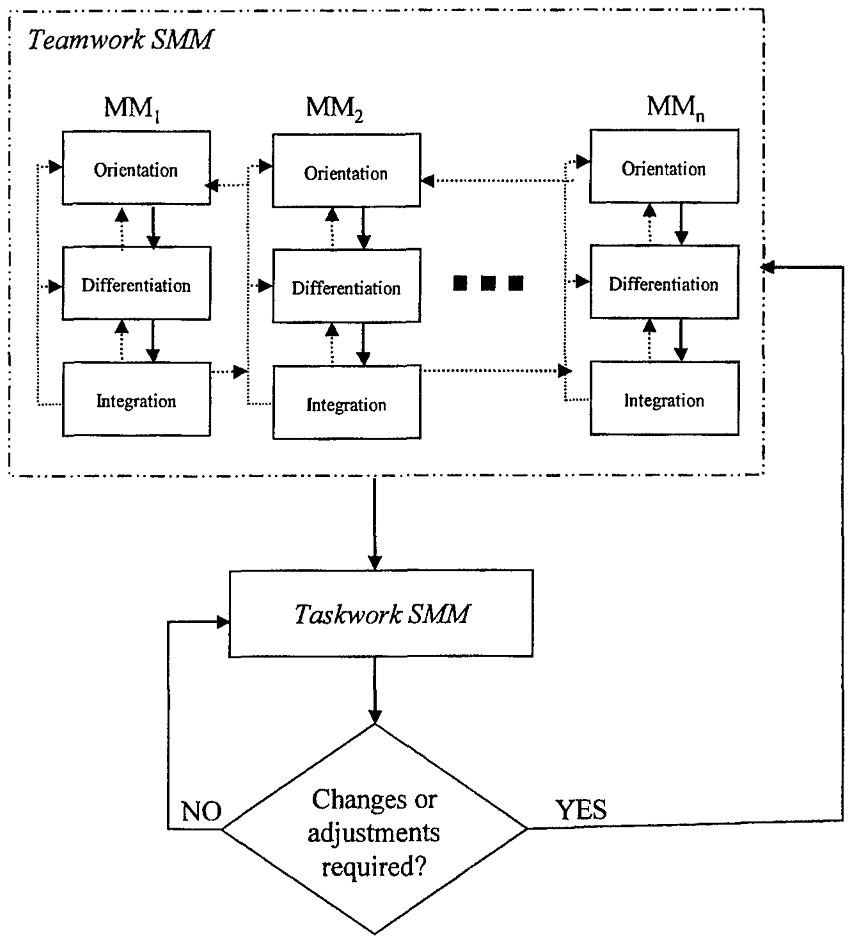
2.3. APPROACH

Two phases of experimentation were undertaken: (1) a longitudinal quasi-experiment to test for the convergence of individually-held mental models over time; (2) a set of controlled behavioral simulations to examine the effects of communication medium (FF/CM), session (time 1/time 2), and condition (unrestricted/time pressure/environmental uncertainty) on mental model convergence and team performance.

3.0 CONCEPTUALIZATION

The conceptualization of mental model convergence (MMC) (shown in Figure 1) underlying the research conducted for this proposal achieves the first technical objective: to devise a model of MMC. The model is focused on developing teamwork SMM because successful teams put significant effort into developing protocols for working together as a team, such as an agreed upon approach for conducting the requisite work (Katzenbach & Smith 1999). Ensuring that team members explicitly focus on teamwork at the onset of team activity, as suggested in Figure 1, is critical for at least two reasons. First, many organizations provide the most support for team development early in the team's life cycle (Druskat & Pescosolido 2002). Second, team members will develop protocols (implicitly or explicitly) for collective work (i.e., the teamwork phase of the team's life cycle) (Smircich 1983); moreover, they will develop them very quickly and sustain them for extended periods of time (Gersick 1988). Even when MMC occurs implicitly as individual team members actively consider teamwork issues relevant to their own personal agendas, the phases proposed will still be relevant. The results, however, will be inconsistent across team members. Further, the accuracy and comprehensiveness of the resultant SMM may be questionable. Under these circumstances, team members need to actively think about teamwork at the beginning of their life cycle. Thus, this model advocates that teams begin their life cycle by focusing on teamwork.

Figure 1. Model of Mental Model Convergence



During this focus period, team members develop shared mental models (SMM) by proceeding through the three phases of MMC: orientation, differentiation, and integration. These three phases stem from group development and information processing research. Whether the phases of group development are called forming, storming, and norming (Tuckman 1965); team finding, designing, and transforming (Uhl-Bien & Graen 1992); or some other variation found in the literature; the generalized process is basically the same (Tuckman & Jensen 1977). Members: (1) orient themselves to their unique domain; (2) create their own view of the situation, which may or may not be similar to their fellow team members' views; and (3) allow their individual perspective to evolve into a team view. Likewise, information processing occurs when individuals differentiate among available alternatives and subsequently reconcile, or integrate, similarities and differences among the alternatives to determine a course of action (Driver & Streufert 1969; Schroder et al. 1967).

This model exploits the synergies between group development and information processing and represents a bottom-up, or emergent, process (Kozlowski & Klein 2000). The process begins at the onset of team activity when each individual team member has a unique, independent view of the team, its assignment, and its context. The team members then begin to orient themselves to the team situation. Orientation is retained from the research on group development to represent the phase where the team members collect information about their unique domain that will be used to create SMM. Differentiation and integration stem from information processing (Driver & Streufert 1969; Schroder et al. 1967). Differentiation occurs as team members interpret their situation in the second phase of group development. From an information processing perspective, interpretation occurs as team members sort through information they have collected. This sorting process allows them to differentiate among their fellow team members' knowledge and beliefs. It also represents the phase of MMC where team members shift from individual-level mental models to team-level mental models. As a result, the mental models held by individual team members depict the differences among team members' knowledge and beliefs about the team and its task.

In the integration phase of MMC, the individual team members' mental models remain at the team level, but the differences sorted out during differentiation are transformed into a converged representation of the collective views of the team members. Thus, integration can be viewed as a transformational process (Dansereau et al., 1999). Specifically, this process takes place as the team members integrate their perspectives of the team by identifying and strengthening the interrelationships among themselves in order to achieve unity of effort. I do not intend to imply that all team members will hold an identical set of mental models at the conclusion of the integration phase. Rather, the degree of integration (i.e., the strength of the interrelationships that are developed among team members) must be carefully considered.

As shown in Figure 1, multiple mental models can be developed simultaneously, although the progression may occur at different speeds for each one. The speed may be dependent, in part, upon the amount of previously held knowledge team members possess that is applicable to the current situation. For example, if a majority of team members have worked together on previous projects, logic suggests that the time required for attaining MMC will be much shorter than the time required for a set of individuals with no previous experience working together. Additionally, the information processed for one mental model may influence the development cycle of others. As such, while the development phases are depicted as occurring linearly, new information attained regarding one mental model may have ramifications for other mental models. The team may need to regress to an earlier phase and revise the affected mental model(s), accordingly. The dotted arrows in Figure 1 allow for this iterative process to occur. Upon creation of teamwork SMM, team members then shift their focus to their assigned taskwork until a time when one or more teamwork mental models need revision. The decision point in Figure 1 represents the provision for revising teamwork mental models. Taskwork may also require a unique set of SMM, but was not the focus of the present study.

4.0 EXPERIMENTATION

4.1. QUASI-EXPERIMENT

4.1.1. Technical Objectives

The quasi-experiment addressed the following technical objectives (from section 2.2):

(2) to explore the way in which individually-held mental models converge among team members to become shared

(3) to examine different means of measuring mental model convergence

(4) to distinguish among the multiple mental models working simultaneously within a team

(5) to determine how shared mental models regarding teamwork impact team performance

4.1.2. Data Collection

One-hundred two undergraduate business students from the University of Massachusetts Isenberg School of Management participated in the quasi-experiment. These students were enrolled in one of two classes that required the completion of a team semester-long project. The students were allowed to self-select their teams in both classes. Twenty-five teams with three to five members each comprise the sample. Team members earned extra credit for participating in the study if they completed all questionnaires throughout the semester. If all team members from the team completed all questionnaires, then the team was entered in a random drawing where they had an opportunity to win $50 per member. The odds of winning the prize money were 1:5.

At four points during the semester, the team members completed a questionnaire. Time 1 was immediately after the semester project was introduced and Time 2 was one week later. Time 3 and Time 4 questionnaires were administered at mid-semester and at the end of the semester, respectively. Questionnaires were used to collect data, because in circumstances where mental models can be manipulated explicitly, i.e., subjects are aware that they must manipulate their mental models in order to complete their assigned tasks, they can be appropriately described via verbalization methods such as questionnaires (Rouse and Morris, 1986).

To assess knowledge similarity of the team member mental model content, questionnaire items were written based on the sentence completion test developed in the field of integrative complexity (Schroder et al., 1967). Respondents were asked to complete sentence stems related to the mental models of interest. Sentence stems were written to identify individual perceptions regarding the project goals ("The goals of our project are . . ."), team processes ("Our team has discussed coordinating workflow among team members in the following manner . . ."), team communication mediums ("Our team has discussed using the following modes of communication to exchange information . . ."), and team organization structure ("Our project team is organized (i.e., who is the leader, etc.) in the following manner . . ."). These sentence stems required respondents to focus on directly observable behaviors rather than generalizations drawn from espoused theory, following Argyris and Schön's (1974) methodology, to overcome the inherent difficulties in tapping theories-in-use.

The responses were content analyzed. The commonality of responses was determined and a score was assigned representing the degree of sharing found in the team members' mental models for each sentence stem. Scores were assigned based on an Agreement Index developed for this project that is analogous to the 7-point Integration Index devised by Schroder et al. (1967). Independently, two raters assessed each team member's response for a given team to determine a score. Their interrater reliability was 73%. When the raters did not agree, they discussed their respective scores and came to an agreement on the appropriate score for the team's mental model under consideration.

4.1.3. Findings

The findings are shown in Figures 2 and 3. In Figure 2, the rater's scores for the entire sample's mental models are plotted. The significant shifts in level of agreement are detailed. In Figure 3, the sample was split into two groups based on their team performance score (assessed as the team's grade on their semester-long project). Thus, the graphs depict the convergence patterns of high performing and low performing teams for comparison. These results address each technical objective outlined in section 4.1.1 as described in the following paragraphs.

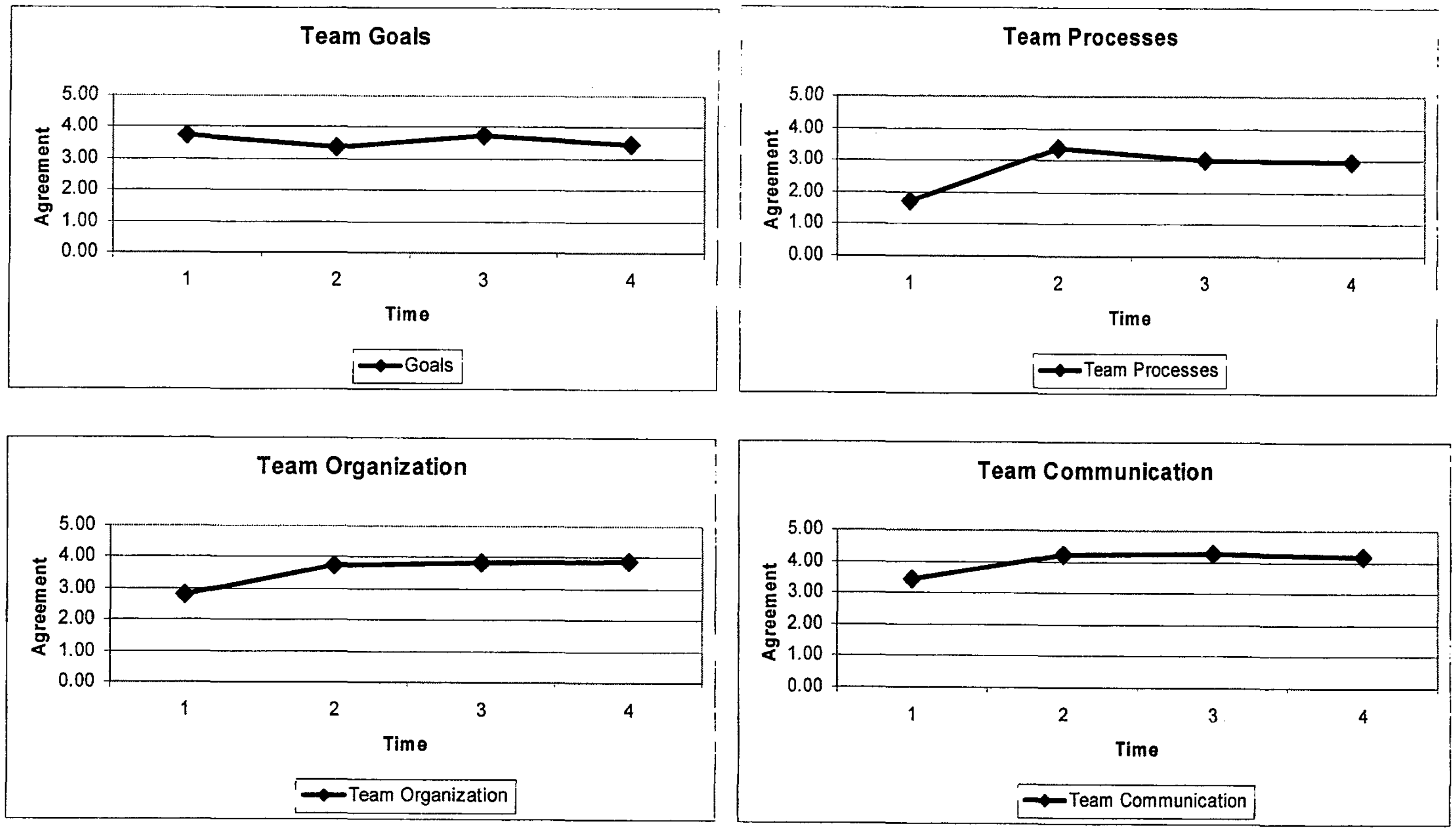
The first two objectives were to explore the way in which individually-held mental models converge among team members to become shared and to examine different means of measuring MMC. The sentence completion approach proved to be a useful method for assessing mental model content. The results in Figure 2 can be used to explore convergence over time. For team processes, team organization, and team communication, the shift in mental model content converges significantly from the initial questionnaire to the second that was completed one week later. The shift was not significant for the team goals mental model. One plausible reason for this lack of significance may be that the project goals in both classes are explained thoroughly just prior to when the team members complete the first questionnaire and the initial understanding of the team's purpose is well established and commonly understood.

The next objective was to distinguish among the multiple mental models working simultaneously within a team. As can be seen in Figure 2 and 3, the patterns of convergence and the mental models' relationships with team performance are different across mental models. These results provide evidence that multiple mental models function simultaneously and in different ways.

The last objective was to determine how shared mental models regarding teamwork impact team performance. The results in Figure 3 show the varying results for high and low performing teams for each mental model studied. Significant differences between high and low performing teams were found as follows, where high performing teams had more convergent mental model content: goal mental model Time 1, team processes mental model Time 1 and Time 2, team organization mental model Time 3 and Time 4. These results suggest that teams who understand their goals and how they are going to interact at the onset of the team's life cycle and how responsibilities are divided at the end of their life cycle will perform better.

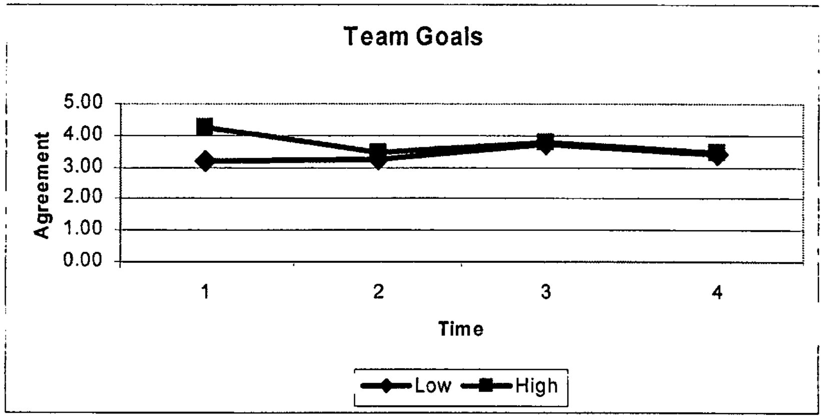
One additional finding of interest relates to shifts in the mental model content over time. As new information became available to the team, the mental model content shifted and the level of convergence remained high. For example, as the semester progresses, team members' goal mental models shifted from containing information about the overarching goal to more detailed information about the task oriented goals required to complete the project. Similarly, the team organization structure mental model went from a high level description of the structure to a detailed description of who is doing what tasks needed to complete the project.

Figure 2: Mental Model Convergence Over Time

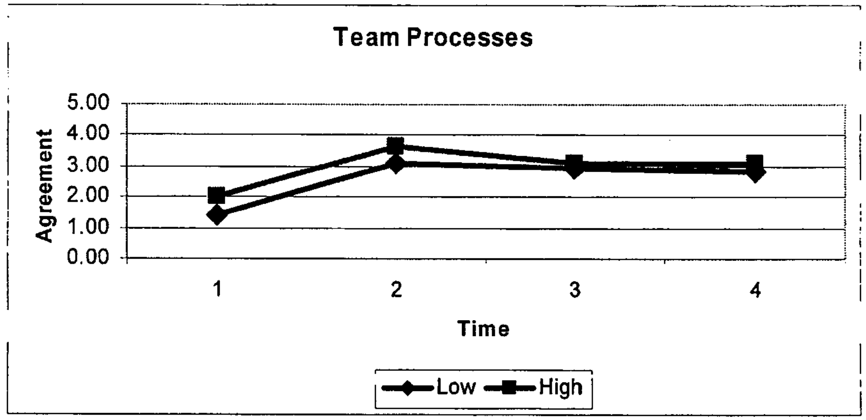


The shift from T1 to T2 in agreement is significant for Team Processes, Team Organization, and Team Communication at the $p<0.05$.

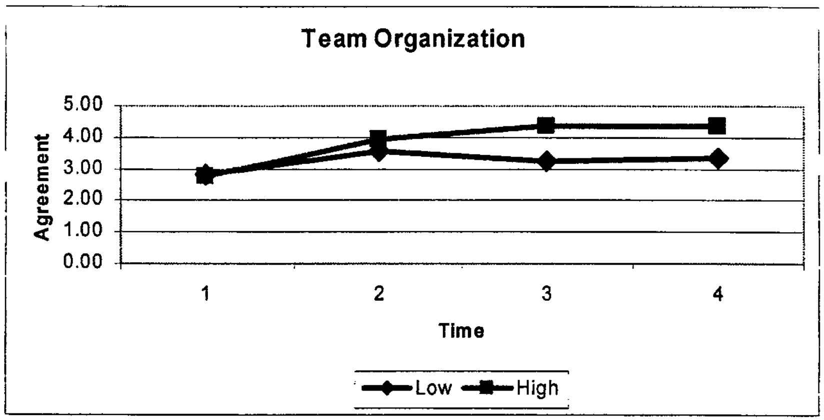
Figure 3: Mental Model Convergence-Performance Relationship



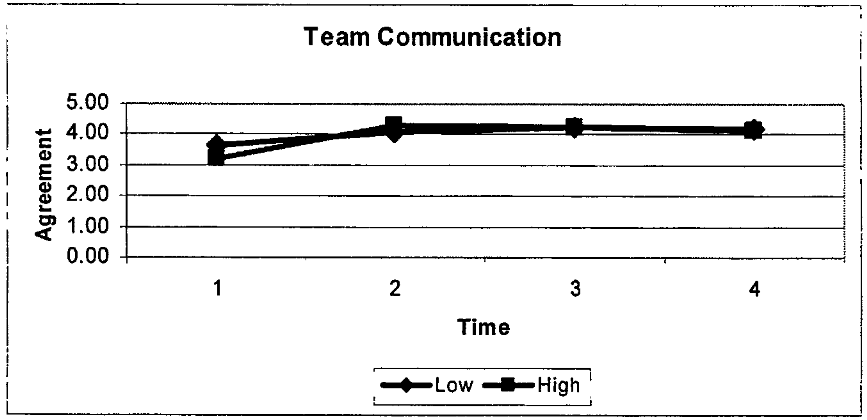
Difference between High and Low performing teams is significant at T1 ($p=0.06$).



Difference between High and Low performing teams is significant at T=1 ($p=0.10$) and T=2 ($p=0.08$).



Difference between High and Low performing teams is significant at T=3 ($p=0.06$) and T=4 ($p=0.08$).



No significant different between High and Low performing teams over time.

4.2. LABORATORY BEHAVIORAL SIMULATIONS

4.2.1. Technical Objectives

The laboratory behavioral simulations addressed the following technical objectives (from section 2.2):

(2) to explore the way in which individually-held mental models converge among team members to become shared
(3) to examine different means of measuring mental model convergence
(4) to distinguish among the multiple mental models working simultaneously within a team
(5) to determine how shared mental models regarding teamwork impact team performance

4.2.2. Data Collection

Two-hundred sixteen undergraduate business students from the University of Massachusetts Isenberg School of Management were randomly formed into teams of three. The students received extra credit for their participation. Additionally, the teams with the highest performance received a cash bonus of $50 per team member (odds of winning were approximately 1:5).

The participants performed a personnel scheduling task adapted from Bachrach et al. (2001), Earley (1994), and Steele-Johnson et al. (2000). The participants were asked to assign 10 employees, each with different hourly wages to a work schedule for a hypothetical organization. Workforce requirements (i.e., number of employees per shift) were given to the team. To ensure collaboration, each team member represented a different organizational function with conflicting rules for schedule completion, in the sense that maximizing one function's rules led to breaking the others' rules. The functional roles and associated rules were: (1) human resources representative, each employee can work no more than 10 hours per day and 50 hours per week; (2) union representative, each employee must work four hours per day if called into work and 30 hours per week; (3) operations manager, the schedule requirements must be met exactly. If any of the rules were broken in the final schedule, a penalty was assessed. The task was pretested using a comparable sample to ensure that the students found the exercise interesting and that the level of difficulty was appropriate to the population and time allotted for each session.

We used a 2 (communication medium) x 2 (session) x 3 (condition) design. Three-person teams were randomly assigned to a computer-mediated (CM) or face-to-face (FF) ***communication medium*** to complete the simulated task. The FF team members were seated around a table in a private room. Each participant had a worksheet and instructions. Only one solution per team was accepted. The sessions were video-recorded; each participant gave consent to the video-recording procedure. A digital timer placed on the table recorded the time elapsed since the session began. The CM sessions were conducted in a laboratory consisting of 10 personal computers linked in a local area network. Thus, three teams could be simultaneously completing the behavioral simulation. Participants from one team were seated so no members from the same team were next to each other. Using this arrangement, the team members could see each other (since they were located in the same room), but were far enough apart to be unable to read each other's notes. Furthermore, participants were not allowed to talk with each other during the simulation. The teams in the CM condition communicated through a synchronous computer conferencing system specifically developed for the purposes of the simulation. The system consisted of a screen with the task requirements (this view was identical to the paper copy given to all participants in both media conditions), a text messaging area, and a timer depicting the elapsed time since the beginning of the session. A unique simulation environment was created for each team that allowed them to work synchronously on the schedule. All team members had equal access to the screen and could assign/delete workers, view any assignments or deletions made by team mates, and exchange messages with team mates. The communication was not anonymous; the messages were identified by the sender's name and appeared in the order in which they were sent. The team members could scroll through the communication history when/if they wanted to review past messages.

Each team gained experience working together as a team by completing two ***sessions***. The second session was scheduled at the convenience of all team members, between three and seven days after the first. The functional roles the team members represented, and their associated rules, remained the same for the first and second sessions, but the schedule requirements changed. In the first session, employee requirements per *day* were given (see Figure 4). For the second task, employee requirements per *shift* were given (see Figure 5), which made the second task more complex than the first.

The ***conditions*** were unrestricted, time pressure, and environmental uncertainty. The teams assigned to the unrestricted condition were given unlimited time to complete the task and were unbothered throughout the session. Under time pressure, teams were given 45 and 30 minutes to complete the task during the first and second sessions, respectively. Environmental uncertainty was introduced by promoting (first session) or demoting (second session) one of the employees available to be scheduled 20 minutes into the session. The sample size by condition is shown in Table 1.

Table 1. Behavioral simulation sample size by communication medium and condition

	FF	CM
Unrestricted	36	36
Time Pressure	30	31
Environmental Uncertainty	33	33

After study participants volunteered for the simulation, they were randomly assigned to teams. The teams were informed about the exact time when their team was scheduled. Upon arrival, the team members were introduced and seated. The teams were informed that the general goal of the simulation was to investigate how teams work together and reminded that the best performing teams would receive a prize of $50 for each team member. The teams were told that the task was estimated to take about 45 minutes to complete, but the quality of their work schedule determined the team's performance. The teams were not pressed to finish within 45 minutes and were left to work until all three members were satisfied with the solution (except in the time pressure condition). In the CM condition, a brief training session on the use of the computer software was conducted immediately after the instructions were given.

Figure 4. Session 1 workforce schedule worksheet

WORKFORCE SCHEDULE WORKSHEET SCENARIO 1 Team ______

Hour	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
8 – 10 am							
10 – 12 am							
12 – 2 pm							
2 – 4 pm							
4 – 6 pm							
6 – 8 pm							
Employees required per shift	**3**	**3**	**5**	**4**	**6**	**7**	**4**

Figure 5. Session 2 workforce schedule worksheet

WORKFORCE SCHEDULE WORKSHEET SCENARIO 2 Team ______

Hour	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
8 – 10 am	2	2	3	2	4	4	4
10 – 12 am	2	2	3	2	4	4	4
12 – 2 pm	3	3	4	3	4	5	4
2 – 4 pm	3	3	4	3	4	5	4
4 – 6 pm	3	3	5	4	6	7	5
6 – 8 pm	3	3	5	4	6	7	5

The teams read written instructions about the task before they started working together. After the task was completed and the final solution submitted to the experimenter, each participant individually completed a questionnaire regarding the team and its processes. Existing scales were used when available and were created for this study when no appropriate scale could be identified. The measures included collective efficacy (Riggs et al., 1994), goal acceptance (Latham & Steele, 1983), team membership (based on Ganster & Dwyer, 1995), work allocation (devised for this study), decision making (Coopman, 2001), team member skills (devised for this study), interdependence (Johnson et al., 1983), goal clarity (Weber & Weber, 2001), satisfaction (Van Dyne & LePine, 1998), cooperation (Campion et al., 1993), conflict (Jehn & Mannix, 2001), coordination (Denison et al., 1996), and cohesion (modified from Seashore, 1954).

Two dependent measures were used to assess team performance following the guidance of Straus and McGrath (1994), who identified quantity, quality and speed as the primary indicators of team task performance. In this experiment the teams were asked to develop one workforce schedule, in approximately 45 minutes. Thus, the quantity was not a relevant performance indicator in this study. The teams developed as many "practice" schedules as they wished, but were required to agree upon one final schedule per team for submission at the end of the simulation session. The teams' schedules were assessed for ***quality***. Quality was calculated as the cost associated with the particular assignment developed, including penalties for any broken rules. Specifically, using each employee's cost per hour and the corresponding number of hours assigned to work, the cost per employee was calculated. The cost for all employees was added. Next, the schedules were checked to see if the rules given to the teams were enforced. Each time a rule was broken, a penalty of 1.8 times the respective employee wage was added. Finally, speed to solution was recorded as the ***time*** from the moment the team members started working until the final solution was submitted.

Our measurement approach created performance measures where better performance was the smaller value. To aid interpretation of results and follow the more conventional approach of "more is better," we transformed both measures. Quality performance reported is calculated as the optimal assignment score divided by a team's score. Thus, the closer a team's score is to the optimal score, the closer their quality performance is to 1.0 (i.e., higher values represent better quality performance). Time performance is calculated as the slowest team's time plus one minus a team's recorded time. Thus, the slowest team (i.e., the team with the worst time performance) has a score of 1 and the fastest team will have the highest score (i.e., the most minutes finished before the slowest team).

4.2.3. Findings

The results from the laboratory behavioral simulations address the technical objectives outlined in section 4.2.1 as described in the following paragraphs.

The first and second objectives were to explore the way in which individually-held mental models converge among team members to become shared and to examine different means of measuring MMC. Two measurement approaches have been undertaken to address these objectives. First, the use of interrater agreement to assess the degree of convergence was tested. The commonality across team member's mental model content provides a means of measuring

MMC. Commonality may range along a continuum from no commonality in mental model content to identical content, with most team members having some degree of overlap between the two extremes. Interrater agreement is a commonly used statistic to assess overlap of this type. In particular, we apply Lindell and colleagues' (1999) $r^{*}_{wg(J)}$ as it provides an index of interrater agreement for multi-item scales such as the ones we used to collect data regarding the mental models of interest. To follow the paradigm that mental models are held at the individual level, we separated this team-level statistic into the individual contributions from each team member to the team's interrater agreement score. This separation allowed us to assess (1) the convergence of the individually held mental models over time and (2) their impact on team performance. To examine this approach, we analyzed the unrestricted data set. The results in Table 2 demonstrate the applicability of this technique for the set of teamwork mental models tested. The numbers in the body of the table represent how convergent each individual's mental models are with her/his team mate's mental models. In each case, the degree of convergence increases from the first session to the second. Thus, this approach demonstrates that mental models converge over time in answer to the first objective and is, therefore, a viable measure of mental model convergence in answer to the second objective.

Table 2. Results of paired t-test

	Time 1	Time 2	*t*-value
Goal acceptance mental model	0.75 (0.24)	0.80 (0.25)	-2.48**
Goal clarity mental model	0.69 (0.30)	0.75 (0.28)	-2.28*
Membership mental model	0.53 (0.38)	0.67 (0.33)	-4.17***
Cooperation mental model	0.75 (0.37)	0.83 (0.24)	-4.35***

M (*SD*) reported.
$^{+}p < .10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

The second measurement approach used to watch convergence unfold over time and measure the degree of convergence is process tracing, a qualitative analysis of transcript data. A coding scheme was devised by the principle investigator and a doctoral student who had worked extensively on this project. Two graduate students unfamiliar with the study hypotheses are currently coding the transcripts. Based on the coding scheme, they are looking to code three dimensions. First, they are identifying topic changes and completed conversations. Second, they are categorizing statements as they relate to one of six different mental model contents: (1) approach-how the team plans to attack the task; (2) goal-the objective of the assigned task; (3) member-participant skills that may or may not be related to the task; (4) rules-roles assigned to each participant (i.e., union representative, human resource manager, production manager), rules associated with each role, penalties associated with breaking rules, and schedule requirements; (5) task-when the team discusses actual work being done to complete the task; and (6) work allocation-how the team members plan to distribute the tasks among themselves. Third, they are coding the type of exchange that is taking place: (1) action-someone stating that they are doing something or directing someone else to do something; (2) agree-statement of agreement or confirmation; (3) apply-statement applying a rule or an approach the team members have agreed upon; (4) clarify-questions or questioning statements about team activity; (5) information-statement of fact that passes information to the rest of the team; (6) suggest-statement suggesting a course of action; and (7) summary-statement integrating more than one person's input. By using the process tracing methodology, we will be able to identify the degree of detail shared among team members that lead to effective team performance in answer to the first objective and patterns associated with mental model convergence in answer to the second objective. Tables 3 and 4 provide coded transcript excerpts from two CM teams (Teams 28 and 30) as examples of these two phenomena. Team 30 is a higher performing team (i.e., their quality score was higher than Team 28's score). In Table 3, Team 28 shares details of the rules that govern their behavior, whereas Team 30 simply identifies that they each have different rules. Team 28 spends considerable time during their session revisiting the rules in attempts to clarify (well beyond the discussion included in the excerpt). Team 30 doesn't speak about the rules in any detail for the remainder of their session. Table 4 provides a sample showing how Team 30's mental models converged regarding their approach to the task. While, conclusions cannot be drawn based on these samples, the power of process tracing to uncover the way in which mental models converge is demonstrated.

The third and fourth objectives were to distinguish among the multiple mental models working simultaneously within a team and to determine how shared mental models regarding teamwork impact team performance over time. In Table 5 the results of performance regressed on a set of control variables and the teamwork mental model convergence scores are presented. As can be seen from these results, the four teamwork mental models examined have differing relationships with the three performance measures tested, thereby confirming that multiple mental models are functioning simultaneously on teams.

The results in Table 5 also allow us to examine the relationship between teamwork mental models and team performance (the fourth objective). The speed with which the team is able to complete its task during the initial stage of team interaction (i.e., session 1) is augmented by a common understanding of the importance of its goal and a corresponding commitment to work towards it (the goal acceptance mental model) and a shared feeling that team members could collectively work together to accomplish the task (the cooperation mental model). In the second session, an agreement about the cooperative nature of team interaction was still important, but, with respect to the team's goal, too much agreement about the degree of clarity regarding the assignment (the goal clarity mental model) degraded performance. This result is not surprising given that for this set of data, the time to complete the task was not restricted in any way. Thus, teams who shared the common goal of getting the best solution in order to win the prize money spent more time completing the task. No teamwork mental models impacted the quality of the team's solution during the first session. In the second session, a commonly held belief that the team was staffed with members able to complete the task (the membership mental model) resulted in a strongly positive relationship with team performance. Finally, we examined the relationships between teamwork mental models and team member satisfaction. In the initial phases of team interaction, a common understanding with her/his team mates about the clarity regarding the assignment and agreement regarding the cooperative work environment led to higher individual-level satisfaction with the team. The cooperation mental model continued to be an important indicator of satisfaction during the second session.

Several other interesting findings have been uncovered through data analysis. These results are highlighted in the journal article, conference paper, and dissertation summaries included in section 7.0 of this report.

Table 3: Differing levels of detail in the rules mental model

Team 28 Time 1

change	rules	information	a: and make sure each works the 30 hours a week and atleast 4 a shift
		information	a: it's at the bottom of the blue sheet
		information	a: the requirments
finish	rules	summary	b: Okay, our instructions are different
change	rules	information	c: it says employees canwork 10/day and 50 a week before the go overtime
		information	b: mine doesn't say anything about thirty hours
		agree	b: okay
		clarify	a: really
		clarify	c: whats on your nick?
		information	b: how much we get penalized
		clarify	c: no time lmt or anything ?
		information	a: yeah 1.8 right
		information	b: it's complicated to explain
		agree	b: yup
		agree	c: yeah thats teh overtime
		information	a: it's not over time it's the union contract requirements
		clarify	b: so our guidelines are less than 10 hours a day per person and less than 50 /week per person??
		information	c: all mine says is that employees can only work 10/day or 50/weke before the
			penalties
		information	a: no at lease 30 hours per day
			a: no per week
		clarify	b: and did I hear that we have 30
		agree	b: okay nice
		agree	b: thanks
finish	rules	summary	c: so atleast 30 not more than 50 per week
finish	rules	summary	a: and if they are schedualed to work they have to work at lease 4 hours a day
		agree	b: beautiful, lets do it.
		agree	a: yeah
		agree	c: ok cool

Team 30 Time 1

chage	rules	clarify	a: can emplaoyees whork more then one shift in the day
		clarify	b: yes
		agree	a: aight
		information	b: just no more than 10 hrs per day
		information	a: my papaer did not say that
		clarify	b: oh look at the bottom paragraph
		information	a: i am the production manager
		information	b: oh i am the human resource manager
		summary	a: mustt be differenrt
		information	c: no less than4 hrsandno more than 30hrs
		clarify	b: todd what are u?
		clarify	c: confused
		summary	a: we all have different parts and have to work as a team
		clarify	c: I have houly wages... do you?
		clarify	a: yeah
		summary	b: ok so todd is no less than 4 per day and mine is n more than 10 per day
		information	b: i have workforce wages
		clarify	b: i think its the same
		clarify	a: thats the same thing miss SOM
finish		agree	b: ok

Table 4: Approach mental model convergence

Team 30 Time 1

change	approach	suggest	c: I say we fill up the days more employees are needed like day 5 and 6
		suggest	b: ok so howabout ABC work 10 hrs day 6
		suggest	b: and only 4 hrs on day 7
change	task	clarify	c: how many hrs is that total?
		clarify	b: 30 if leave day 3, 5, 6 and 2 shifts on day 7
			b: for ABC
		agree	c: ok
		agree	c: that will work
		suggest	b: so remove them from shift 12 to 4 on day 7 nick
		suggest	a: we need to clear it all i think
		agree	b: ok wait one sec
		agree	b: ok
change	approach	suggest	a: lets go through and max out each emoployee one at a time
change	task	action	b: ok so clear all
		clarify	a: is that ok with todd
		clarify	c: ok
		agree	b: go
change	rules	clarify	a: wasn't it said that an employee can max out at 50 hrs ???
		information	b: for me but not for todd
		clarify	c: not with me..its only 30 with me
		information	b: todd is 30 hrs per week
		agree	a: ok
change	approach	suggest	b: so we will max out ABC
		unrelated	c: I have 1 minute left on my clock
change	task	information	a: a is maxed out
		action	b: ok so put B and C with him
		agree	a: ok
		agree	c: good

Table 5. Results of regression analyses

	Time Performance		Quality Performance		Team Member Satisfaction	
	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2
Control variables						
Time performance Time 1	n.a.	0.21^{**}	n.a.	n.a.	n.a.	n.a.
Quality performance Time 1	n.a.	n.a.	n.a.	0.40^{***}	n.a.	n.a.
Member Satisfaction Time 1	n.a.	n.a.	n.a.	n.a.	n.a.	0.05
Communication medium	0.27^{***}	0.28^{***}	0.09	0.14^{**}	0.12	0.19^{**}
Team member ability	-0.01	0.02	-0.02	-0.03	-0.04	-0.02
Main effect						
Goal acceptance mental model	0.26^{***}	-0.06	-0.05	0.07	0.11	0.07
Goal clarity mental model	-0.10	-0.15^{*}	0.06	-0.03	0.15^{*}	-0.06
Membership mental model	0.07	0.06	0.10	0.33^{***}	0.11	-0.03
Cooperation mental model	0.33^{**}	0.21^{**}	0.07	-0.07	0.20^{**}	0.34^{***}
F-value	16.7^{***}	8.6^{***}	1.5	13.9^{***}	9.4^{***}	6.4^{***}
R^2	0.33	0.23	0.04	0.32	0.21	0.18
R^2-adjusted	0.31	0.20	0.01	0.30	0.19	0.15

Standardized estimates reported.
Experimental condition: 0 = CM; 1 = FF.
$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

5.0 DELIVERABLES

In addition to the journal articles and conference papers discussed in section 7.0, two products resulted from this project. The first is the means of measuring mental model convergence through interrater agreement. The r_{WG} and individual contributions to r_{WG} could be used in real-time to assess team mental model convergence and identify any individual(s) who need to revise their individually held mental models to increase the degree of convergence.

The second tool is the Decision tree for Information SHaring (DISH) tool. The study results have been mapped to a decision tree to help collaborators focus on (1) the information that needs to be shared and (2) the processes we found to be most effective under different collaborative conditions. The DISH tools for FF and CM teams are presented in Figures 6 and 7, respectively. The first decision relates to the conditions under which the team is working (i.e., unrestricted, time pressure, environmental uncertainty). The second decision relates to the amount of time the team has been working together (i.e., inexperienced or experienced). Finally, the type of performance the team wants to optimize (i.e., time or quality performance) must be specified.

Figure 6: DISH results for face-to-face teams

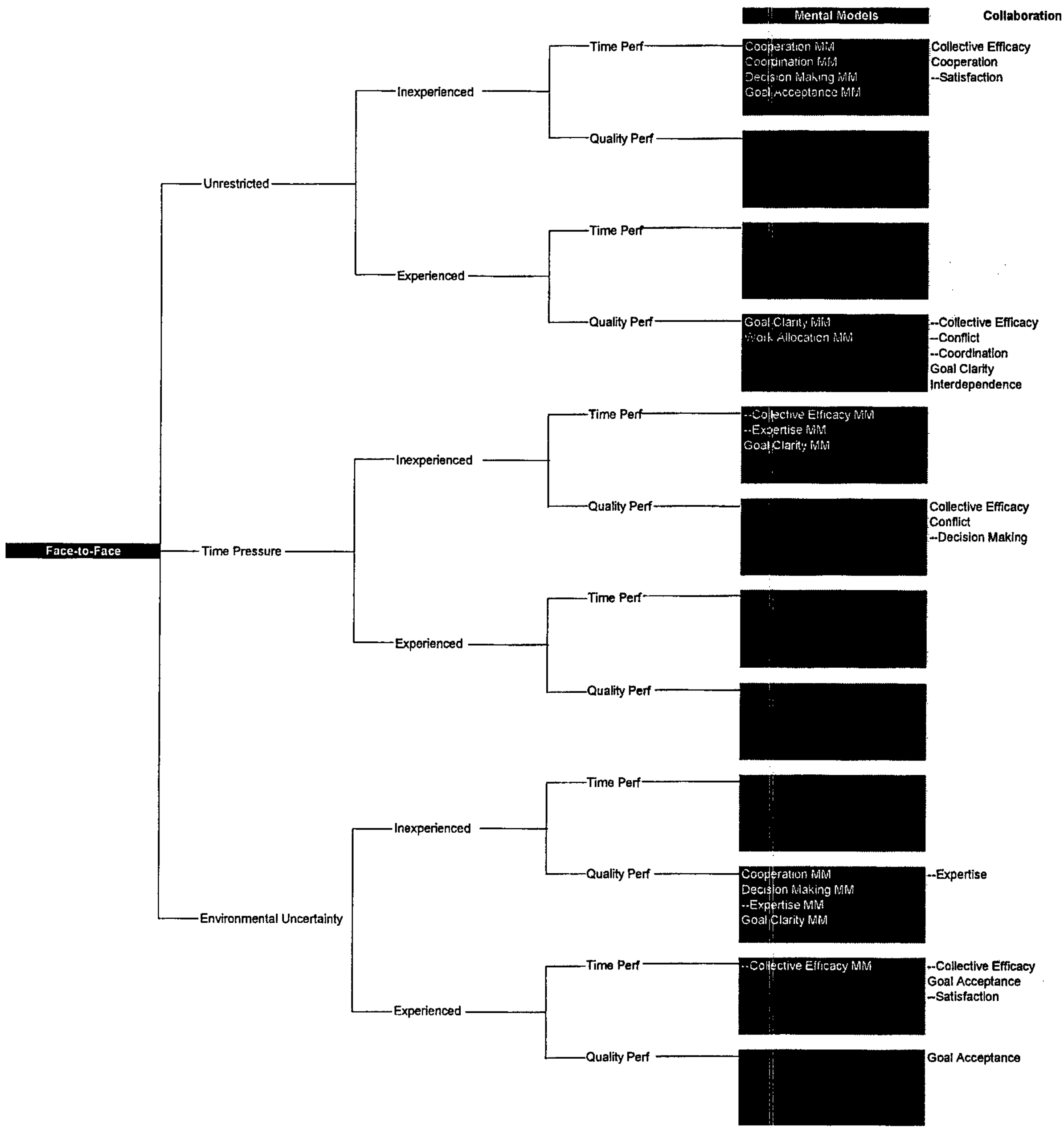
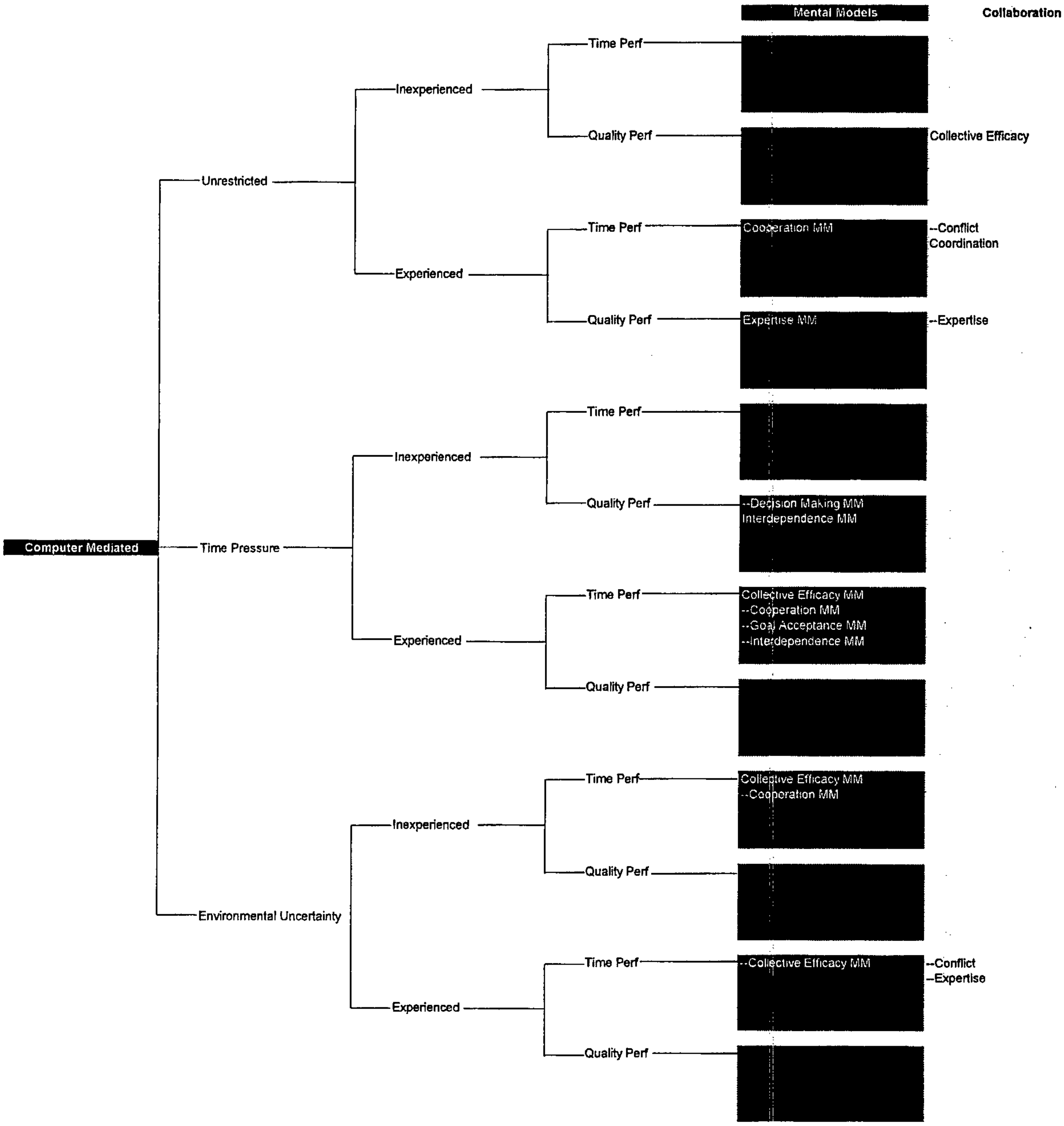


Figure 7: DISH results for computer-mediated teams



6.0 IMPACT

The results of this research impact practitioners and academicians. Practitioners can use the results to guide teams as they work to achieve the appropriate levels of cognitive unification. Managers in organizations using cross-functional project teams may find a number of useful strategies in this research, because an understanding of mental model content and the mental model convergence process should improve the effectiveness of project teams. First, knowledge of the specific mental model contents and the need to actively think about these issues may be communicated to newly formed cross-functional project teams to help them focus their attention on teamwork issues. By discussing the issues that should be actively addressed, managers and team leaders can help to expedite and manipulate the way in which shared mental models develop. Explicitly developing shared mental models should create a solid foundation upon which taskwork can be accomplished more expeditiously. Further, team trainers may devise training programs focused on improving teamwork through the development and maintenance of shared mental models based on this work. Specifically, the results of this research can be used to develop learning aids that will help teams create shared mental models at the onset of their life cycle and diagnostic tools to pinpoint areas for intervention when existing teams are not performing effectively. The creation and validation of these tools is an opportunity for practitioners and academicians to collaborate.

Researchers interested in learning more about how teams can function more effectively may also find value in this work. In general, exploring the cognitive aspects of teamwork, through MMC, may provide insight into how team members can make the necessary shift in their perspectives from the individual to the team. Further, increasing our understanding of the cognitive processes associated with effective teamwork facilitates developing theoretical explanations for the respective success and failure of seemingly similar teams. Finally, this research advances the team cognition literature by integrating various extant literatures and studying empirically the model of MMC.

This research project relates specifically to project teams. They are not, however, the only team type that can benefit from this research. The type of team will dictate the appropriate content of the mental models. The content requirements will, therefore, be unique for each type of team under investigation. The development process, however, will be consistent across team type. Regardless of team type, team members must be able to orient themselves to the team and task, differentiate among themselves and integrate their various perspectives to create and sustain fully functioning SMM.

7.0 PUBLICATIONS

To date, two conference papers have been presented, one conference paper has been accepted for presentation, one journal article has been conditionally accepted, one dissertation has been completed, three journal articles are in preparation (submission of all three is expected by year end), five additional journal articles and one additional conference paper are planned. The publications resulting from this research effort are summarized on the following pages.

7.1. LISTING OF JOURNAL ARTICLE SUMMARIES

7.2. LISTING OF CONFERENCE PAPER SUMMARIES

7.3. LISTING OF DISSERTATION SUMMARY

Manuscript Title:
Mental model convergence: A conceptual framework and preliminary evidence

Author:
McComb, S.A.

Publication Status:
Manuscript conditionally accepted for publication in *Research on Multi-Level Issues*.

Research Question:
What is the mental model convergence process?

Summary:
This manuscript presents the conceptual development of the process by which the content of individually held mental models converges over time. An overview of this process is presented in section 3.0 of this report. Additionally, the results of the quasi-experiment (discussed in section 4.1.3) are presented as preliminary evidence of the convergence process. Moreover, these results highlight the influence of converged mental models on team-level performance.

Manuscript Title:
Capturing the convergence of multiple mental models and their impact on team performance

Authors:
McComb, S.A. and Vozdolska, R.P.

Publication Status:
Manuscript in preparation for submission.

Hypotheses:
[H1] Interrater agreement will depict mental model convergence.
[H2] Multiple mental models will exist simultaneously.
[H3] Shared mental models about the team and teamwork processes will positively influence team performance.

The results of this manuscript were presented in section 4.2.3.

Manuscript Title:
Different time-tables: Understanding processes in computer-mediated and face-to-face teams

Authors:
Vozdolska, R.P. and McComb, S.A.

Publication Status:
Manuscript in preparation for submission.

Hypotheses:

[H1] The differences among processes in CM and FF teams will decrease after the second performance episode.

[H2] The process effects on performance in CM and FF teams will be more similar after the second performance episode than after the first.

Results:
The unrestricted experiments conducted provided data for this study. The two performance episodes referenced in the hypotheses are session 1 and session 2 of the behavioral simulation. The experimental results are shown in Tables 6 and 7.

The results in Table 6 indicate that when the teams completed their performance episodes, they did not differ significantly in their quality performance achieved, so the processes they used can be compared directly. The results from the t-tests support our first hypothesis. In the first time period all four processes are significantly different. In the second performance episode two of the four processes are essentially the same, showing that the processes used by CM and FF teams started to converge.

Table 6: T-test comparisons between FF and CM teams

Dependent Variable	Face-to-face		Computer-Mediated		t-Value
	Mean	St.Dev	Mean	St,Dev	
Quality Performance (T1)	0.958	0.04	0.94	0.08	-1.06
Quality Performance (T2)	0.983	0.02	0.97	0.05	-1.84
Collective Efficacy (T1)	4.28	0.62	3.77	0.64	-3.44***
Conflict (T1)	1.86	0.51	2.15	0.55	2.31*
Decision Making (T1)	4.39	0.54	4.04	0.65	-2.51**
Coordination (T1)	3.92	0.61	3.57	0.70	-2.21*
Collective Efficacy (T2)	4.50	0.42	4.21	0.59	-2.48*
Conflict (T2)	1.77	0.47	1.96	0.71	1.34
Decision Making (T2)	4.40	0.41	4.15	0.62	-2.05*
Coordination (T2)	4.26	0.49	4.07	0.58	-1.50

*p <0.05, ** p< 0.01, *** p<0.001

The results in Table 7 support our second hypothesis. During the first performance episode the effects on performance are very different. For FF teams none of the processes studied has an effect on performance, while for the CM teams collective efficacy and coordination are significant predictors. During the second performance episode both regressions are significant, the only difference is that decision making is marginally significant for CM teams and non-significant for the FF teams.

Table 7: Results of Regression Analysis for Team Processes Time 1 and Time 2 (N=72)

Variable	Face-to-Face Teams Quality Performance		Computer-Mediated Teams Quality Performance	
	Time 1	Time 2	Time 1	Time 2
Time Performance (T1)	0		0	
Major	0.008		-0.02	
Years Spent in College	-0.003		-0.02	
Max Grade per Team	0.008		-0.02	
Collective Efficacy (T1)	-0.011		0.11**	
Conflict (T1)	-0.007		-0.02	
Decision Making (T1)	-0.007		-0.01	
Coordination (T1)	0.005		-0.06*	
Adj. R^2	0		0.24*	
Quality Performance (T1)		0.12		0.21*
Time Performance (T2)		0		-0.001
Major		0.006		-0.02
Years Spent in College		-0.002		-0.02
Max Grade per Team		0.01**		-0.01
Collective Efficacy (T2)		-0.009		0.02
Conflict (T2)		-0.02**		-0.03*
Decision Making (T2)		-0.006		-0.05*
Coordination (T2)		-0.009		0.04
Adj. R^2		0.46**		0.29*

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Conclusions:

The results from these analyses show that CM and FF team processes should eventually converge. Given that the CM teams had enough time to get comfortable with their leaner medium, they are able to establish the same processes as the FF teams. This result will allow researchers and practitioners to use the vast extant literature on team performance (comprised primarily of research conducted on FF teams) as a baseline for working with CM teams rather than devising a new research stream for what some consider to be a unique team type.

Manuscript Title:
Incorporating human behavior: A framework for modeling and simulation

Authors:
Vozdolska, R.P. and McComb, S.A.

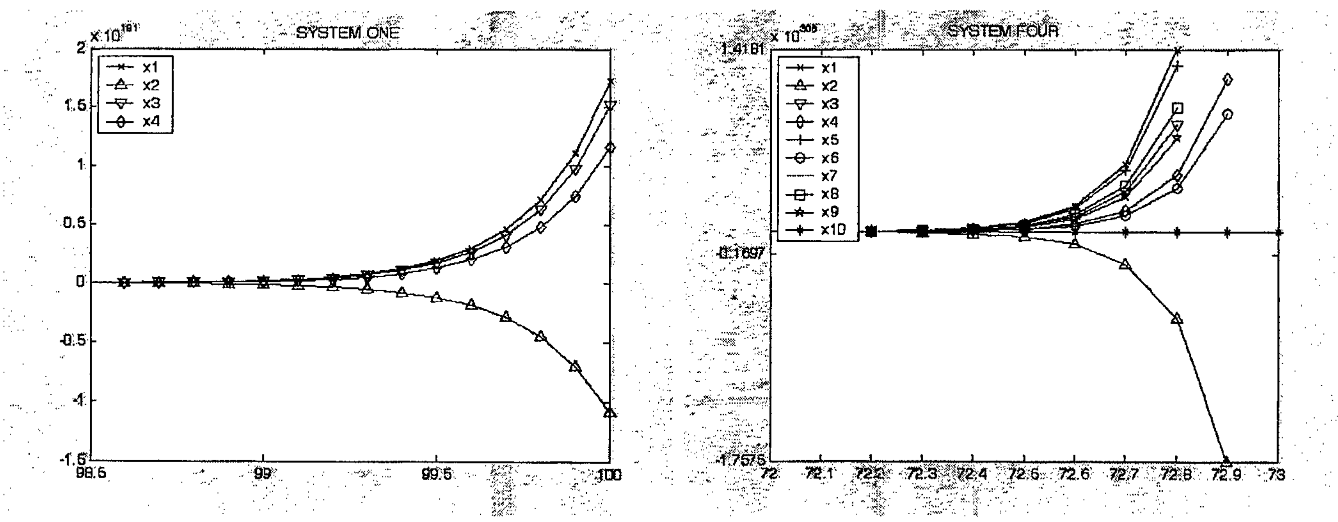
Publication Status:
Manuscript in preparation for submission.

Research Question:
What is an effective approach for constructing quantifiable models of interdependent social system behavior?

Results:
An eight step framework for constructing quantifiable social behavior models is theoretically developed. The steps are presented in Figure 9 of this report when the conference paper about this framework is presented. Each step is based on existing literature. The framework is illustrated with a model of team communication presented parallel to the discussion of each step. The team communication model demonstrates the applicability of the framework proposed to social science research.

Models developed using this framework can be simulated (for our research, we used Matlab to simulate the model). In Figure 8, we present a subset of the simulations performed to demonstrate the result's usefulness. These results highlight how we can compare the behavior of systems with varying numbers of internal states. allow us to draw conclusions about the modeled system's behavior from the overall form of the relationships, the relative order in which the state variables appear compared to each other, and the absolute value for each variable at a specific time.

Figure 8: System performance samples



Conclusions:
We advocate two main requirements for model development. First, the model must be constructed precisely. Second, the model must be based on existing evidence. Indeed, the model must be strictly grounded in empirical research and, ultimately, tested against some known outcomes; otherwise the results obtained may not be predictive of true system behavior.

The framework we presented helps bridge the gap between qualitative and quantitative paradigms in two distinct ways. First, researchers can augment a model that traditionally would not have a human component, such as a project management model, with a second, complementary model of social behavior, such as our model of team communication. Alternatively, human behavior can be incorporated into system models directly, such as adding the functional expertise of the team to the aforementioned project management model. When constructs are to be incorporated, using the framework can aid the developer in ensuring that the behavior variables are operationalized appropriately.

Planned Journal Articles

[1] ***Examining how mental model convergence unfolds over time.*** Transcripts of the behavioral simulation sessions will be analyzed using process tracing to look for (a) patterns in the mental model convergence process and (b) the level of detail among each individual team member's converged mental models (i.e., are individual mental models completely overlapping or do individuals share only high level details). This analysis will be used to better understand the relationship between team performance and both the convergence process and the level of detail included in converged mental models.

[2] ***Exploring the effects of time pressure and environmental uncertainty on mental model convergence.*** The aforementioned study of mental model convergence measured as interrater agreement will be replicated using the data from the time pressure and environmental uncertainty conditions.

[3] ***Understanding processes in computer-mediated and face-to-face teams dealing with time pressure and environmental uncertainty.*** The aforementioned study comparing the processes used by CM and FF teams will be replicated using data from the time pressure and environmental uncertainty conditions.

[4] ***Computer-mediated and face-to-face team behavior comparison.*** The two models developed in Patrashkova's dissertation will be presented and the conclusions about team behavior made. The comparison between CM and FF teams shows that CM teams experience more difficulties in establishing patterns in their behavior. More team processes fluctuate than in FF teams. Face-to-face teams are more satisfied with the team and are able to establish stable team behavior more quickly.

[5] ***Exploring team behavior.*** The models from Patrashkova's dissertation will be explored in terms of sensitivity to initial conditions, stability, equifinality and controllability of the systems.

[6] ***Determining the effects of team member personality on team conflict and performance.*** Each team member completed a personality questionnaire. This data will be used to study mediating effects of team conflict on the relationship between member personality and team performance.

Conference Paper Title:
Enhancing safety in the event of catastrophic failure: The case for continual use systems

Authors:
McComb, S.A. and Deshmukh, A.V.

Conference:
First International Conference on Safety and Security Engineering, Rome, Italy, 13-15 June 2005.

Publication:
Manuscript will be published by Wessex Institute of Technology in a forthcoming volume.

Research Question:
What is the most effective system design for response systems?

Results:
The experiments conducted with environmental uncertainty provided data for this study. The experimental results are shown in Table 8. Each team's experimental session was reviewed to determine if they developed a routine for solving the task and if they were able to recover after the interruption. We compared the performance of (1) those with and without routines, (2) those who recovered with those who did not recover, and (3) those that had a routine *and* were able to recover with those that did not exhibit both behaviors. As can be seen in the table, teams with routines (p=0.12) and teams able to recover (p=0.07) perform more effectively than those in the opposite condition. Teams meeting both conditions, however, demonstrated the most significant difference between conditions (p=0.05). Thus, our results indicate that both an established routine and the ability to invoke it after an environmental disturbance are critical for a team's ability to perform at the highest levels.

Table 8: Study results

	Routine		Recovery		Routine and Recovery	
	Yes	No	Yes	No	Yes	No
N	53	13	43	23	41	25
Mean	3126	3229	3103	3226	3098	3225
SD	200	267	148	293	145	285
p-value	0.12		0.07		0.05	

Note: Low scores indicate better performance.

Conclusions:
The results of this study were used to build a case for the design and implementation of continual use, robust systems that can be used during normal operations and function effectively during disruptions as an alternative means of preparing for extreme event failures. In the manuscript, we present an example of an information infrastructure that allows the realization of such continual use processes and highlight opportunities for further research.

Conference Paper Title:
A framework for social system modeling and simulation

Authors:
Patrashkova, R.P. and McComb, S.A.

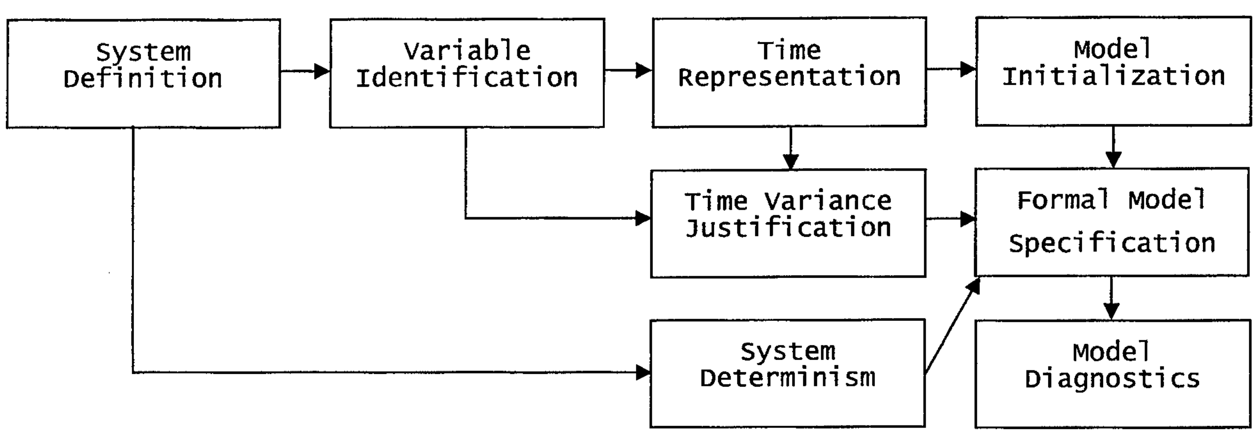
Conference:
Academy of Management, Honolulu, Hawaii, 5-10 August 2005.

Publication:
Abstract published in the Academy of Management Proceedings.

Research Question:
How can a social system be represented as a rigorous mathematical formalization?

Results:
A framework, comprising the steps presented in Figure 9 is developed. The theoretical background for each step is thoroughly presented. Next, its application to social science models is discussed and last, each step is illustrated by building a model of team communication.

Figure 9: Framework for devising a rigorous mathematical formalization



Conclusions:
Our framework builds upon systems theory and social science research. A systems-based social science model will represent the total system performance, even when a change in only one or a few of its parts is contemplated, and thus may help us better understand how social system behavior unfolds over time.

The purpose of our framework is to help future researchers avoid the epistemological complications that often accompany the use of social science research in mathematical models and simulations. Such a framework can help researchers without extensive mathematical training to develop and test quantitative models, as well as replicate, empirically verify and extend the output of models already developed.

Conference Paper Title:
Accomplishing globally distributed work: A case for helping virtual teams with their taskwork processes

Authors:
McComb, S.A. and Vozdolska, R.P.

Conference:
First International Conference on Management of Globally Distributed Work, Bangalore, India, 28-30 December 2005.

Research Question:
Will the processes found to contribute to the performance of FF teams be the same for CM teams?

Results:
The second session of the unrestricted experiment provided data for this study. The multiple regression results are shown in Table 9.

Table 9: Study results

Taskwork Processes	β
Intercept	123.50***
Time Performance T1	0.03
Team Skills	8.89***
Communication	-36.13***
Conflict	-12.74***
Decision Making	-11.38**
Work Allocation	11.63+
F	14.74***
R^2	0.75

+p=0.06, *p <0.05, **p< 0.01, ***p<0.001

Communication, conflict, decision-making, and work allocation all play a significant role in explaining team performance. More communication, greater intrateam conflict, and including everyone in decision-making all resulted in longer times to complete the scheduling task. Time performance could be enhanced by equitably allocating the necessary work.

Conclusions:
Through this research we aimed to identify the taskwork processes that support and degrade virtual team performance. Our results indicate that taskwork processes do impact team performance. Thus, teams should be given training about and facilitators should assist teams to achieve effective communication, conflict avoidance and resolution, decision-making, and work allocation skills. For example, effective communication via electronic media is not easy for all individuals. Trainers and facilitators must focus on helping team members scribe concise, informative messages that focus on quality, not quantity of communication.

Planned Conference Paper

[1] ***Examining how mental model convergence unfolds over time.*** Transcripts of the CM teams in the control condition will be analyzed using process tracing to look for (a) patterns in the mental model development process and (b) the level of detail among each individual team member's converged mental models (i.e., are individual mental models completely overlapping or do individuals share only high-level details). This analysis will be used to better understand the relationship between team performance and both the development process and the level of detail included in converged mental models.

Dissertation Title:
Modeling teams: A general systems theory approach

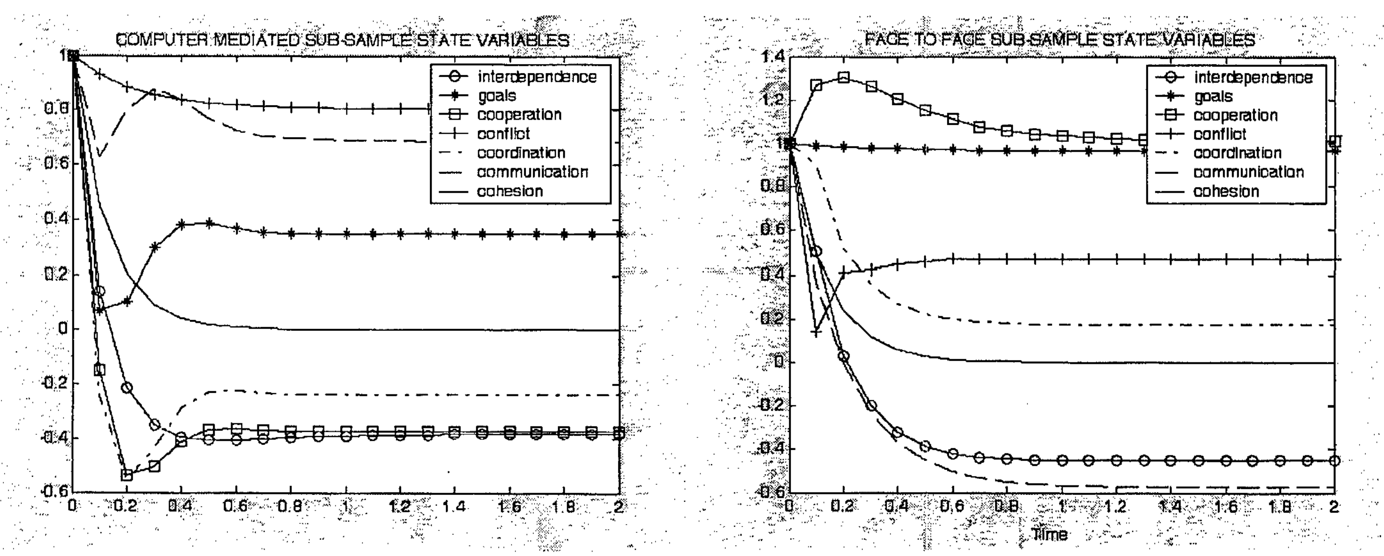
Author:
Patrashkova-Vozdolska, R.P.

Research Objectives:
(1) to design a framework that will facilitate the development of dynamic social systems models;
(2) to show that GST is applicable to team modeling and (3) to introduce the understanding of dynamic social system behavior that can be achieved though GST.

Results:
The purpose of this doctoral dissertation is to show that models exhibiting complex team behavior can be developed successfully and when analyzed provide information about behavior that cannot be obtained with conventional statistics. To achieve this goal, the following activites were undertaken: (1) developed a framework for model development based on General Systems Theory, (2) constructed a team model, derived from the team behavior literature, (3) designed and conducted a behavioral simulation to collect data for the model estimation, (4) estimated the model parameters based on the data, (5) simulated the behavior of the modeled system using Matlab, and (6) analyzed the simulation model to evaluate the behavior of the system.

To provide data for the model the 72 teams from the unrestricted experiment were used. Multiple regression analyses showed that all hypothesized relationships are significant, except Team Quality Performance was the dependent variable. Based on the statistical results, simulation models were constructed and simulations performed. The simulations demonstrate the dynamics of the systems studied. Further, the simulated systems were analyzed to assess stability, equilibrium, equifinality and controllability. These analyses showed that the systems studied are stable, non–equifinal, not completely controllable and do not achieve equilibrium. The data were split and separate models for CM and FF constructed. To demonstrate the usefulness of the simulated output, these models are presented in Figure 10 and allow us to visually compare the dynamics of the systems.

Figure 10: System performance samples for CM and FF teams



Conclusions:

The aim of the dissertation research was to develop a complex dynamic model of team behavior. This aim was achieved and the model was developed, verified with an empirical behavior simulation and analyzed to provide expanded team behavior understanding. The simulation output allowed us to see the dynamics of the modeled system, compare different systems, as well as evaluate causality, based on the timing of events in the simulation. Further, the system can be diagnosed and inferences about structure and behavior can be derived when the GST specific analyses (e.g. stability, equifinality) are applied. Last, the simulation output helps determine when a change may occur in team behavior and thus can help with planning longitudinal research. In conclusion, simulations allow us to see and estimate system behavior dynamics in a way that complements the results achieved with conventional statistics.

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