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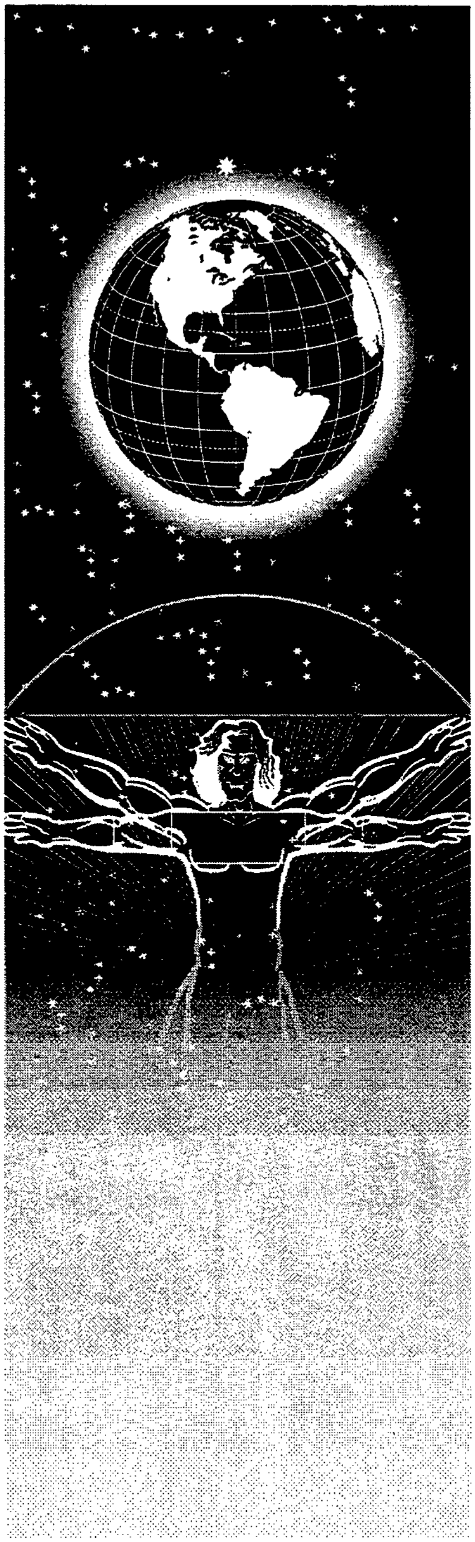

UNITED STATES AIR FORCE RESEARCH LABORATORY

TESTING THE EFFECTS OF TEAM PROCESSES ON TEAM MEMBER SCHEMA SIMILARITY AND TEAM PERFORMANCE: EXAMINATION OF THE TEAM MEMBER SCHEMA SIMILARITY MODEL

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FOR THE COMMANDER

HENDRICK W. RUCK, PhD
Chief, Crew System Interface Division
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This report examines the relationships among team membership influences, team interaction processes, and team member schema similarity, and their potential impact on team performance. Team membership influences were assessed as the similarity of team members on six individual difference variables: trust, self-monitoring, private self-consciousness, public self-consciousness, perspective-taking, and team experience. Team interaction processes that occurred as the two-member teams completed a team problem-solving task were coded. Team membership influences and team interaction processes were examined as antecedents to team member teamwork schema similarity, which was conceptualized as team member teamwork schema agreement and accuracy. Team member teamwork schema agreement and accuracy, as well as team interaction processes, were then tested as antecedents to team performance. The results supported team interaction processes as predictors of team performance. Moderate support was found for the team membership influences-team interaction processes link and for the team member schema similarity-team performance link. However, no support was found for the role of either team membership influences or team interaction processes as antecedents to team member teamwork schema similarity. The results are discussed in terms of Air Force applications. Suggestions for future research are offered.

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PREFACE

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INTRODUCTION

Teams, crews, multi-operator units, and collaborative systems abound in the Air Force. Dr. Michael McNeese has developed a research program to study the socio-cognitive variables operating within these multi-person units. Because Air Force teams operate in environments that are characterized by ill-defined and emergent situations, McNeese's research program has incorporated theories of situational awareness, crew schemata, shared cognition, social construction of knowledge, and interpersonal interaction to understand the development of meanings necessary for effective functioning in these environments (e.g., Brown, Whitaker, Selvaraj, & McNeese, 1995; McNeese, Zaff, Citera, Brown, & Whitaker, 1995; McNeese, 1993; Nosek & McNeese, 1997; Wellens & McNeese, 1987; Young & McNeese, 1995). This type of research will produce knowledge that will be applicable to the development of joint collaborative systems technology within the Air Force. The research study reported in this document is part of this research program.

The research reported below focused on cognitive processes within teams. Specifically, the research examined team member schema similarity, its predictors, and its relationship to team performance. This research is relevant to co-located or distributed teams. It also has implications for applied Air Force problems such as UCAV (Unmanned Combat Air Vehicle) operation, transport command centers, information warfare, battlefield management, C^3I, and joint collaborative systems such as data walls, avatars (Wells & Hoffman, 1996), intelligent agents, and knowledge rooms.

For example, UAV operation requires that pilots coordinate with field controllers, tower personnel, and manned air vehicles in complex, dynamic, ill-defined situations. During the chaos of combat, the UCAV crew must be able to construct meaning quickly in these ambiguous situations. UAV crew members must be able to understand each other and have shared situational awareness. This ability to understand one another and to establish shared situational awareness is developed, in part, through team member schema similarity.

Below, the conceptual model used to guide the current research is described, relevant past research is reviewed, and a modified version of the model is presented. Then the present study is described.

Team Member Schema Similarity Model

The Team Member Schema Similarity Model (Rentsch & Hall, 1994) is shown in Figure 1. The critical variable in the model is team member schema similarity (TMSS). Team member schema similarity (TMSS) refers to the degree to which team members have similar team-related schemas. A schema is a complex knowledge structure that organizes new information and facilitates understanding (Poole, Gray, & Gioia, 1990). Schemas are developed from past experience and individuals enter a team with a schema for understanding the team process (Bettenhausen & Murnighan, 1991).

Although team members may develop many team-related schemas (e.g., schemas of team members, schemas of the task), the focus of the present study is on teamwork schemas (Cannon-Bowers & Salas, 1990). Teamwork refers to the processes by which team members interact, communicate, and complete the team's work (Salas, Montero, Glickman, & Morgan, 1988). Teamwork schemas contain knowledge and information relevant to communicating about, evaluating, and compensating for teammates' performance (Cannon-Bowers & Salas, 1990). Teamwork schemas will guide team members' assumptions, expectations, and behavior regarding teamwork.

Rentsch and Hall (1994) suggested that TMSS refers to schema accuracy as well as schema agreement. According to Eisenberg, Monge, and Farace (1984), the concept of coorientation, which they attributed to Newcomb (1961), involves perceptual agreement and perceptual accuracy as primary variables. Perceptual agreement among individuals exists when individuals have similar perceptions. Perceptual accuracy exists when individuals are able to describe another individual's perceptions accurately. These coorientation concepts are often discussed with respect to attitudes (e.g., Eisenberg et al., 1984; Poole & McPhee, 1983), but have been extended to the study of team member schema similarity (Rentsch & Hall, 1994).

A critical or optimal level of TMSS, in terms of both schema accuracy and schema agreement, is hypothesized to enhance team effectiveness. Empirical research has revealed some support for this hypothesis (Rentsch, Pape, & Brickman, 1997; Rentsch, 1993).

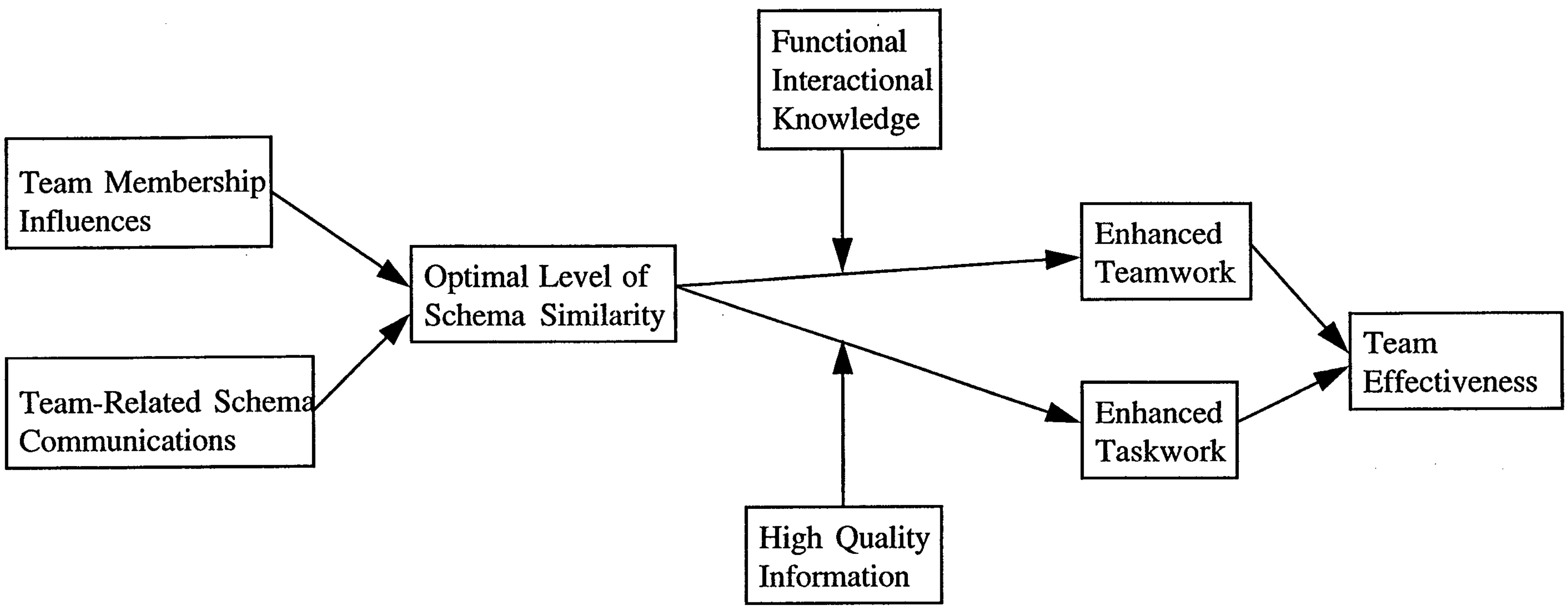

Figure 1. Rentsch and Hall (1994) Team Member Schema Similarity Model

TMSS and team effectiveness

Team effectiveness is a critical factor in many Air Force problems such as UAV operation, information warfare, C^3I, and joint collaborative systems. Several researchers have suggested that schema similarity, or shared understandings, among team members will enhance team effectiveness (e.g., Bettenhausen, 1991; Cannon-Bowers, Salas, & Converse, 1993; Cannon-Bowers & Salas, 1990; Klimoski & Mohammed, 1994; Mitchell, 1986).

As presented in Figure 1, it is hypothesized that optimal levels of team member schema similarity will predict team effectiveness. Team members who have schema similarity have similar knowledge about teamwork and they organize this information similarly. Teamwork schema similarity is hypothesized to enhance team effectiveness because similar teamwork schemas among team members will allow them to interact efficiently and effectively. Team members with high TMSS will be able to anticipate, facilitate, and compensate for one another's behavior.

In addition, similar teamwork schemas may reduce process losses typically associated with teams (Steiner, 1972). Communication among team members is also likely to be enhanced as team members' teamwork schemas become increasingly similar. Team members may be aware of the information required by one another and fully understand the information that is being communicated to each other. Moreover, team members are likely to anticipate and understand each other's actions when TMSS is high.

Organizational researchers have obtained indirect evidence for a relationship between TMSS and team performance. Much of this research has explored concepts related to TMSS, but has not investigated TMSS directly. Mitchell (1986) demonstrated that teams in which members were trained to disclose their internal frames of reference performed better than teams that did not receive this type of training. Exchanging internal frames of reference most likely served to increase the level of schema accuracy among team members. Walsh, Henderson, and Deighton (1988) found that team members negotiated belief structures regarding task strategy and that schema consensus among team members predicted team performance. Rentsch (1993) found that teamwork schema similarity predicted three aspects of team effectiveness described by Hackman (1987): client satisfaction, member growth, and team viability. The latter two studies focused on schema agreement.

Researchers in the military realm have studied team cognitions as team mental models. They have examined the relationship between team cognitions and team performance (e.g., Cannon-Bowers et al., 1993). Much of this research also provides indirect evidence that team mental models predict team performance (Cannon-Bowers et al., 1993).

Most of the research provides evidence relevant to TMSS conceptualized as schema agreement. The accuracy component of TMSS has not been explored extensively to the authors' knowledge. Thus, one purpose of the present study was to test the roles of team member schema accuracy and agreement in the prediction of team effectiveness. Rentsch, Pape, and Brickman (1997) examined TMSS conceptualized as schema agreement and schema accuracy. Their results revealed that agreement and accuracy predicted team effectiveness significantly and that schema accuracy may be a more significant predictor of team effectiveness than schema agreement.

Antecedents of TMSS

As shown in Figure 1, two antecedents of team-related schema similarity are team membership influences, such as person-environment fit, and schema content communication, such as that which occurs during socialization processes. These antecedents are expected to regulate the degree of schema similarity among team members to an optimal level. It is assumed that an optimal level of schema similarity exists for any given team and that when schema content is of high quality, the optimal level of schema similarity will enhance team effectiveness maximally.

In the present study, we focused on a subset of team membership influences and a subset of schema related communications as predictors of TMSS. The team membership influences we examined were individual differences. The schema related communications in our study were team interaction process variables. Below, we elaborate these portions of the model.

Team membership influences as individual differences

One type of team membership influence included in the model is person-environment (P-E) fit. Supplementary P-E fit occurs when individuals' characteristics are similar to those of other individuals who are already in the environment (Muchinsky & Monahan, 1987). Supplementary fit may occur through the Attraction-Selection-Attrition (ASA) process (Schneider, 1987). Schneider (1987) hypothesized that individuals are attracted to organizations containing people who are similar to themselves (Attraction), organizations select individuals who are similar to others already in the organization (Selection), and individuals who gain entry into the organization, but who are significantly different from those already in the organization, are predicted to leave the organization (Attrition).

One outcome of the ASA process is similarity among organizational members. Schneider, Goldstein, and Smith (1995) have proposed that organizations may benefit from homogeneity, because homogeneity will enhance coordination, cooperation, and communication. The implication is that when individuals are similar they will approach problems similarly.

In other words, individuals who are similar in terms of individual difference characteristics are likely to have similar schemas. Extending this logic to teams implies that similarity among team members' individual difference characteristics may enhance TMSS. Thus, an optimal level of TMSS may be due, in part, to similarities among team members' individual difference characteristics (Rentsch & Hall, 1994).

Although similarity among team member individual difference characteristics may be related to TMSS, it may also be the case that the level of the individual difference characteristics existing within the team may also be related to TMSS. To the authors' knowledge there is very little research on the role of team membership influences, such as team members' individual difference characteristics, and TMSS. However, there is indirect evidence to suggest that these variables may be related to TMSS (Pape, 1997).

For example, Pape (1997) hypothesized that high levels of teamwork schema accuracy and agreement would exist when perceivers were high on trust and perspective-taking, and when targets were high on private self-consciousness. She hypothesized that targets high on self-monitoring would have low levels of accuracy and agreement. Extending this logic to the team level of analysis, team members who are high and similar in terms of several individual difference variables, such as perspective-taking, trust, and private self-consciousness, and who are low and similar on self-monitoring are likely to experience high TMSS. These variables were investigated in the present study.

<u>Schema related communications as team interaction processes</u>

Schema related communication processes include communication that occurs during training, team member socialization, and team member interactions. In the present study, schema communication processes as a result of team member interactions were examined as predictors of TMSS.

Within the organizational literature, researchers tend to agree that interaction among organizational members leads to similar interpretations of organizational events (e.g., Schein, 1985; Schneider & Reichers, 1983). Through interaction, individuals construct a social reality (Berger & Luckmann, 1966). Organizational research has indicated that social interactions are important to the development of shared meanings and to shared understanding of organizational events. For example, Rentsch (1990) found that those individuals who interacted with one another interpreted organizational events similarly to one another, but they may have interpreted them differently than those with whom they did not interact.

Within the team context, there is evidence that interaction is also a primary cause of schema similarity among team members (Bettenhausen & Murnighan, 1991; Gersick, 1989; Walsh, Henderson, & Deighton, 1988). Many researchers agree that groups require social construction of knowledge and metacognitive processes to solve problems successfully (e.g., Young & McNeese, 1995). However, the research has not addressed the nature of the interactions leading to socially constructed meaning. No definitive theory for studying these interaction processes has been developed. Therefore, another purpose of the present study was to determine team interaction process variables that predict TMSS and team performance.

Team interaction processes have been examined in the group communication and crew coordination literatures. Our summary of this literature is presented next.

Team Interaction Processes

Pavitt and Curtis (1994) reviewed the group communication literature and reported that small group discussions have been approached from a functional perspective and from an interactional perspective. The primary proponents of the functional perspective are Benne and Sheat, Bale, and Hirokawa (Pavitt & Curtis, 1994). These theorists have developed coding schemes to record and analyze communication functions. Benne and Sheat developed a theory of functional roles, which they assessed by coding communications in such categories as initiating, opinion seeking, and coordinating. Bale's interaction process analysis scheme is perhaps the most popular scheme. Interactions are coded as functions such as "shows solidarity," "gives suggestions," and "asks for information." Hirokawa codes essential functions in such categories as "establishing operating procedures." Pavitt and Curtis described the human systems model (HSM) and the interact systems model (ISM) as two examples of the interactional perspective.

Within the military research literature, team interaction processes have been examined in the study of crew coordination (Achille & Schulze, 1996; Sperry, 1995), team communication (Leedom & Simon, 1995; Oser, Prince, Morgan, & Simpson, 1991; Sperry, 1995), and emergent leadership (Kimble & McNeese, 1987). These studies tend to employ a variety of coding schemes. Dyer (1984) stated that "... as many different content analysis schemes exist as there are research studies" (p. 296).

Example coding schemes include Oser, McCallum, Salas, and Morgan's (1989) effort to code team member behaviors that were related to team coordination. They coded behaviors into such categories as "Helped another member who was having difficulty with a task," and "Praised another member for doing well." Kimble and McNeese (1987) assessed emergent leadership, in part, by coding commands, suggestions, questions, statements, agreeing responses, and disagreeing responses. Oser et al. (1991) coded communication content using nine categories: commands, observations, suggestions, statements of intent, inquiries, acknowledgments, replies, non task-related, and uncodable communications. Simon, Morey, Locke, and Blair (1995) attempted to identify basic crew coordination qualities. In addition, Hakel, Weil, and Hakel (1988) cited several methods for coding communication, including Greenbaum's (1974) functional classification (e.g., informative, integrative, regulative, innovative) and Nieva, Fleishman, and Reick's (1978) classification of team behaviors (e.g., orientation, organization, adaptation, motivation).

Team interaction processes related to team performance

As Tower and Elliott (1996) note, although team member communication and coordination are hypothesized to be related to team performance, very little empirical research has been conducted to test the nature of these linkages. However, according to Tannenbaum, Beard, and Salas (1992), existing research evidence tends to support communication processes, coordination processes, and decision making processes as predictors of team performance.

For example, Hakel et al. (1988) reported that intrateam communication patterns differentiated high from low performing teams. Kimble and McNeese (1987) cited research that found flight crew communication was related negatively to number of errors. In addition, in their own study, using a complex task and three-person teams, Kimble and McNeese (1987) analyzed data from audiotapes by coding frequency of commands, suggestions, questions, statements, agreeing responses, and disagreeing responses for each team member. Among other findings, they found that teams that talked in longer utterances performed better than teams that spoke in shorter utterances.

Endsley (1997) specified communication/interaction measures that have been related to effectiveness, including: time spent talking, contingency planning, democratic decision making, sharing an understanding of the problem, defining team member roles and functions, team members engaging actively in the task, team members compensating for one another, ensuring that team members understand the team's goals and plans, considering alternatives, identifying information gaps and incongruent information, encouraging different opinions, checking to be sure team members share a common perspective, obtaining information from other team members, delegating, prioritizing, contingency planning, and questioning team assumptions and expectations.

Endsley (1997) also reported team processes that are related to low team effectiveness such as: presenting few novel or conflicting ideas, rejecting relevant information, misinterpreting information, lack of information sharing, losing track of goals, and relying on expectations.

<u>Team interaction processes related to TMSS</u>

Team interaction processes and TMSS are likely to have a reciprocal relationship. Team member communication is important because it is critical to developing similar understandings, and similar understandings, in turn, imbue communication with meaning (Fischer, 1996). Again, the available research evidence is indirect.

Dyer (1984) reported research by Obermayer and colleagues revealing that experienced aircrews communicated more frequently during nonroutine missions than during routine missions compared to less experienced crews. This suggests that experienced aircrews might have had TMSS for routine situations and therefore did not require high levels of communication for these situations.

Endsley and Jones (1997) reported research in which it was found that crews with higher performance communicated less than crews with lower performance. This finding is consistent with that reported by Dyer. Perhaps when team members have similar teamwork schemas, communication is reduced.

Endsley and Jones (1997) focused on information warfare and situational awareness at the individual and team level. They defined situational awareness as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley, 1988, p. 97). According to Endsley and Jones (1997), mental models are critical for situational awareness. Endsley and Jones differentiated team situational awareness and shared situational awareness. Team situational awareness refers to the "degree to which every team member possesses the situational awareness required for his/her job responsibilities" (Endsley, 1995, p. 39). Shared situational awareness refers to the "degree to which team members possess the same situational or shared situational awareness requirements" (p. 53). Shared mental models and communication are thought to be means by which team and shared situational awareness are achieved (Endsley & Jones, 1997).

Research has revealed that "intrateam familiarity" was related to high team coordination. That is, crews that had flown together in the recent past tended to be better coordinated (Leedom & Simon, 1995). These results may suggest that when team members are highly familiar with one another, and therefore, presumably, have interacted frequently, that they may develop TMSS.

Although there are many approaches for studying team interaction processes, none specifically address the sense-making, or socially constructed aspect, of interaction. Interaction might enhance performance and it seems to be related to TMSS. Yet there exists a need to further study interactions and communication within teams (Duffy, 1993). As stated earlier, one purpose of the present study was to explore the interaction variables that may predict TMSS.

Team Interaction Process Variables

Content, function, and structure of communication occurring during interactions have received some research attention. In the study of TMSS, we believe that interactions should be assessed in terms of the schema-related communication that occurs. Therefore, we attempted to assess variables that tapped the depth of schema information that team members revealed to one another and the degree to which the communication process was complete. These variables are described in this section.

We developed the Team Interaction Coding Scheme (TICS) to record the nature of the interactions occurring among team members. In particular, we focused on the degree to which team members tended to share interpretive information with one another. We assessed: depth of meaning of informing oriented communication, depth of meaning of learning oriented communication, quality of exchange, consensus evaluation communication, openness and acceptance of communication, and egocentricity versus mutuality of interaction. In addition, TICS was used to code group cohesion, task motivation, and team metacognition.

Depth of meaning

Meloth and Deering (1994) described cooperative learning methods. They conducted a study in which two cooperative learning conditions were compared: reward and strategic. The reward condition was designed to promote interdependence among group members. In contrast, the strategic condition was designed to explicate the link between strategy and learning. The strategic condition is interesting because it focused on enhancing metacognitive processes to increase the use of strategy in learning.

Meloth and Deering used a coding scheme that included the form in which the information was conveyed. They noted that complex communication forms revealed more information than surface-level forms. For example, more information was conveyed when a team member explained his or her logic than when he or she made a nonspecific request. Meloth and Deering hypothesized that learning would increase as students used more complex communication. Their results revealed that students in the strategic condition did engage in more complex communication than students in the reward condition and that students in the strategic condition experienced more learning than those in the reward condition. However, social behavior was not affected by the strategic condition, nor was the perception of collaboration.

The TMSS of the students in learning groups was not assessed in this study. However, it seems likely that the complex communication, which required the students to reveal a portion of their schemas, would result in schema similarity within the cooperative learning groups.

We hypothesized that the more schema information that team members reveal, the more likely it is that they will develop TMSS. Depth of meaning refers to the degree to which the communicator reveals his or her schema. Depth of meaning is relevant to informing oriented communication and to learning oriented communication.

Depth of meaning in informing oriented communication

Depth of meaning in informing oriented communication refers to the degree to which the communicator reveals his or her underlying understandings when he or she provides information to another. An individual may provide information to reveal various depths of meaning. Providing information at the deepest level of meaning will reveal one's assumptions, interpretations, or reasonings regarding a line of logic. The deepest level of meaning will make tacit knowledge explicit.

Informing a team member by suggesting a strategy, or telling how information relates explicitly to other information in a path of logic, explaining how information is related to the problem at hand, and giving directions provides less depth of meaning than the type of informing oriented communication described above. The depth of meaning in informing oriented communication decreases as the communicator provides information related to a path of logic and/or describes what information is relevant to the current problem. The communication becomes surface level as the communicator tells about or provides information not related to the current path of logic and/or provides information seemingly without connection to a path of logic. Finally, a communicator who discloses very little information is not operating at any level of depth of meaning. In this case, the communicator is not providing any information regarding his or her schema.

Depth of meaning in learning oriented communication

Depth of meaning in learning oriented communication is similar to that of informing oriented communication, except that it refers to the level of meaning that one seeks from a team member. Learning oriented communication refers to seeking information from another. An individual may seek to obtain information to reveal various depths of meaning. Seeking to make tacit knowledge explicit is the deepest level of meaning in learning oriented communication. At the highest level of depth of meaning in learning oriented communication, the questioner is asking about a current line of logic, asking about interpretations or reasonings, asking why the other is pursuing a line of logic, and/or seeking information about the other's assumptions.

As the communicator seeks less abstract information from another, the depth of meaning in learning oriented communication decreases. Thus, the next level would be asking for suggestions, strategy, or how information relates explicitly to other information in the current path of logic, seeking direction and/or asking about beliefs. The communication becomes surface level to the extent that the questioner is requesting information unrelated to current path of logic, and/or asking for information seemingly without connection to a path of logic. Clearly, the lowest level is characterized by asking very few questions, which indicates that the individual is seeking no information from other team members.

Quality of exchange

Tower and Elliott (1996) coded communication among team members by assessing the number of queries, transmits, receptions, slights (query sent, but not received), unresponses (query sent, received, but no response), and forgets (query sent, received, responded to, response was not received). They used these variables to develop a measure of communication efficiency, which correlated significantly with team performance. However, these variables also seem to capture the quality of the interaction.

High quality of interaction occurs when information is actually sent and received, and receipt of the information is acknowledged (i.e., the sender knows that the receiver has actually received the intended message). We elaborated on these categories to assess the quality of the exchange directly.

Quality of exchange addresses the degree to which team members have communicated effectively. High quality of exchange requires that the message sender checks that the receiver has in fact received the message (i.e., understood the message), that the receiver acknowledges the message and checks that he or she has in fact received the message (i.e., checks that he or she understands the message in the same way as the sender understands it), the receiver responds and tests that the original sender receives the message (i.e., understands it), and the original sender checks that he or she has received the message.

Quality of exchange increases as the communicators increase their efforts to confirm understanding by acknowledging communications, by restating communicated messages, and by seeking and/or providing clarification. Low quality of exchange is characterized by unilateral communication such as when questions are asked without expectation of an answer, or when information is stated rhetorically, or when the questioner or informer appears to be thinking aloud. In general, the lowest level of exchange quality occurs when communicators tend to ignore each other.

Consensus evaluation communication

Consensus evaluation communication refers to providing and seeking contradictory and/or confirmatory information regarding how similarly communicators are thinking about teamwork or the task. Consensus evaluation communication indicates that the communicator is evaluating the degree of agreement between him/herself and other team members. Three primary forms of contradictory or confirmatory communication are: providing confirmation (e.g., statements or other indications of agreement), seeking confirmation (e.g., questioning or other tests of agreement), and contradictions (e.g., statements of disagreement or correction).

Egocentricity versus mutuality

Driskell and Salas (1992) described collective behavior as critical to group functioning. They stated "...interdependence or collective behavior of group members -- what Allport (1962) called *reciprocal give-and-take behavior* -- is the critical essence that constitutes a functioning group..." (p. 278). They defined collective behavior as "...the tendency to attend to task inputs from others in an interdependent manner..." (p. 278). They further elaborate on the concept as "...the tendency to coordinate, evaluate, and utilize task inputs from other group members in an interdependent manner in performing a group task" (p. 278). This process has been conceptualized using such terms as coordinated behavior, mutual responsiveness, and mutual influence (Driskell & Salas, 1992).

Driskell and Salas (1992) obtained empirical results revealing that egocentric team members did not utilize information from their partners and they viewed their teammates' input as being of little value. Driskell and Salas assessed collectivity as a tendency or trait. However, egocentric behaviors may be the key variable.

We studied egocentricity versus mutuality of interaction as a team level variable that refers to the degree to which team members work together interdependently. High levels of mutuality are characterized by an even distribution of member contributions to task performance. The team moves from mutual to egocentric interactions as the team members work increasingly independently. Mutuality of interaction is likely to be related to TMSS. The more interdependently the team members work, the more likely they are to share schema related information or to negotiate a similar schema.

Openness and acceptance

Open and accepting communication refers to the willingness of team members to consider other team members' input. A high degree of openness and acceptance is characterized by immediate discussion of another's input. The more persuasion required before input is considered or discussed, the lower the level of openness and acceptance.

Group cohesion

Group cohesion is a team level variable that refers to the degree of interpersonal attraction and liking that exists among team members (Moreland, Argote, & Krishnan, 1996). Fulk (1993) discussed the importance of attraction within a group. According to Fulk, high attraction to a group will be conducive to internalizing or complying with the group. Attraction to others causes people to desire to agree with those others. Fulk found that individuals who were attracted to their work groups had technology attitudes similar to those of their work group members. When individuals were not attracted to their work groups, there was no significant relationship between their technology attitudes and the attitudes of their work group members.

Fulk's research suggests that high group cohesion may be related to high TMSS. Behavioral indicators of high cohesion include team members sitting together closely, speaking warmly to one another (Moreland et al., 1996), acting friendly, communicating easily, engaging in high levels of eye contact, and saying "we" instead of "I."

Task motivation

Task motivation refers to the degree to which team members are involved in the task psychologically. High levels of task motivation are characterized by making positive comments about the task, engaging in the task actively, initiating task activities, compensating for one another, and focusing on the task. Low levels of task motivation are characterized by making negative comments about the task, disengaging from the task, and distracting the team from its task focus.

High task motivation is hypothesized to predict team performance. It may also be related to TMSS, because highly motivated teams may be characterized by high levels of interaction among team members as they attempt to complete the task successfully.

Metacognition

Metacognition refers to process observations of self, others, and/or the team and includes elaborating ideas; planning remedial actions; detecting omissions; and detecting, acknowledging, monitoring, and identifying errors (McNeese, 1993).

The Present Study

One purpose of the present study was to test a portion of the TMSS model. Individual differences were examined as team membership variables. Team interaction processes were examined as schema related communication variables. Team member schema similarity was assessed as teamwork schema accuracy and teamwork schema agreement. The variables explored in the present study are shown in Figure 2. The relationships between team member individual differences and team process variables were also explored.

METHOD

Participants

The participants were 90 undergraduate students at a midwestern university who comprised 45 two member same-sex teams. There were 20 male teams and 25 female teams. The participants were required to meet a number of criteria. First, participants were required to have basic mathematics and reading skills. Second, participants were restricted to those with no previous training as an aircraft pilot. Third, participants needed to have normal or corrected 20/20 vision. Fourth, they were to be between the ages of 18 and 30. Finally, each member of the team was not to be acquainted with his or her partner prior to participation in the study. The restrictions were assessed either through participants' self-evaluation or by background information items.

The mean age of the participants was 19.62 years, with 91.1% of the sample between 18 and 22 years old. Seventy percent of the sample was composed of freshmen undergraduate students. Approximately 72% of the participants were Caucasian.

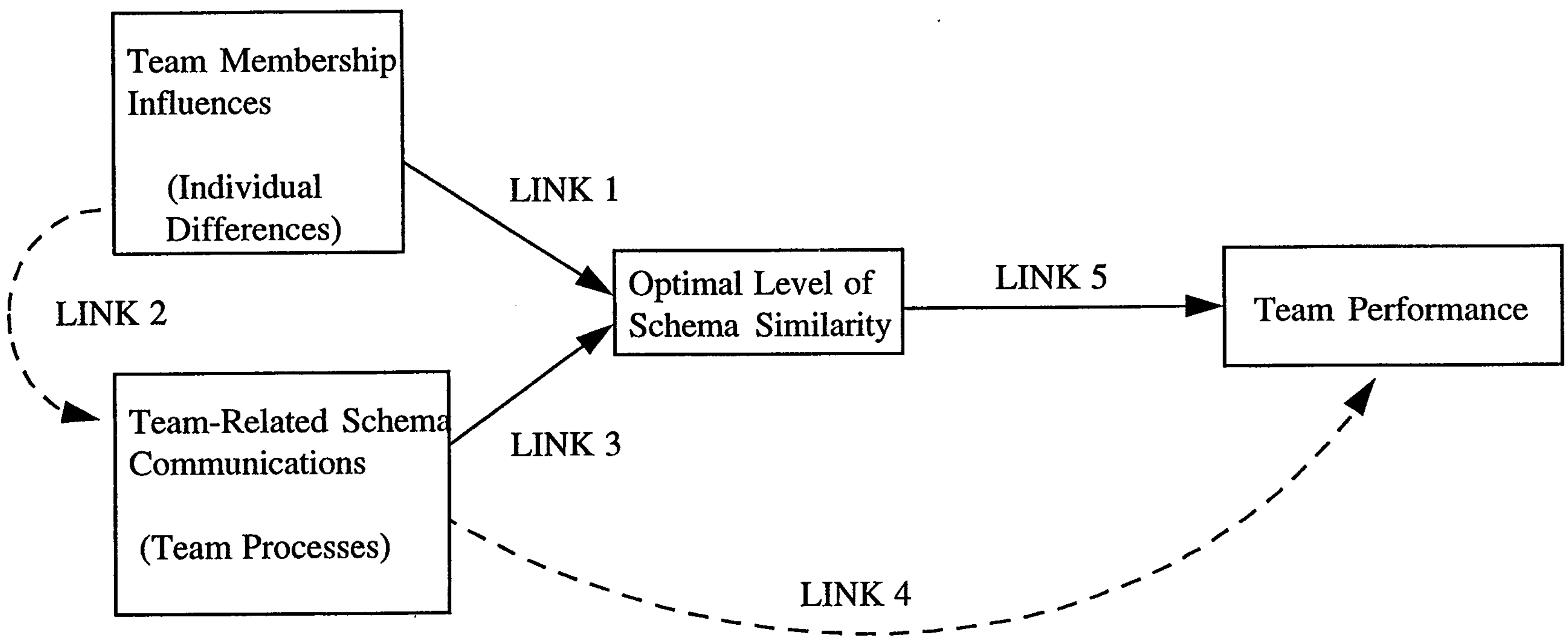

Figure 2. Portions of the Team Member Schema Similarity Model tested in the present study

Task

The task used for the present study was *The Adventures of Jasper Woodbury: Rescue at Boone's Meadow*. The Jasper task is a complex, ill-defined task requiring problem solvers to identify the problem and the subproblems needed to solve the task, to distinguish between relevant and ill-relevant information, to coordinate relevant information, and to evaluate alternative possible solutions. Middle-school level mathematics are required to solve the problem (McNeese, 1993; Vye, Goldman, Voss, Hmelo, & Williams, undated).

The Jasper task presents a story problem on laser video disc in which an injured eagle must be rescued from a remote location. Alternative routes, modes of transportation, and individuals are available for rescuing the eagle. Two problems are to be solved: (1) What is the quickest way to move the eagle? (2) How long will that take? An ultralight plane is included in the Jasper task as one possible mode of transportation, producing the restriction that participants should not have been exposed to pilot training.

When solving the problem, team members could refer back to the laser video disc by using a Macintosh computer system. They were instructed to record their answer in writing along with any information used to arrive at their answer. The team members were instructed to produce one team answer. The teams were videotaped as they attempted to solve the problem. They were stopped after 60 minutes if a solution had not been reached. Only two teams were stopped. All other teams reached a solution in 12 to 56 minutes. The average time to solution for the sample was 32.51 minutes.

Personality Characteristics Measures

Trust

The Interpersonal Trust Scale (Rotter, 1967) was used as the measure of trust. This scale contained 25 items designed to measure a generalized expectancy of interpersonal trust. The items were rated on a five-point Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree). Sample items included "Most people can be counted on to do what they say they will do" and "In dealing with strangers one is better off to be cautious until they have provided evidence that they are trustworthy." Rotter found that the split-half reliability, corrected by the Spearman-Brown formula, for this scale was .76, with .77 for males and .75 for females (Rotter). For the present study, the split-half reliability, corrected by the Spearman-Brown formula, was .63 for the complete sample. In addition, the corrected split-half reliabilities were .62 and .66 for females and males, respectively in the present study. Rotter also found that the test-retest reliability was .56 with a time interval of seven months (Rotter), and .68 for a three month interval (Rotter). The internal consistency estimate for the present study was .63, with estimates of .64 for females and of .63 for males. Rotter also provided evidence of the scale's construct and discriminant validity. He found that the Interpersonal Trust Scale was not related to gullibility or to the Marlowe-Crown Social Desirability Scale. In addition, the Interpersonal Trust Scale was related positively to a sociometric rating of trust, and both measures were related significantly to trustworthiness. Rotter also found that the Interpersonal Trust Scale did not correlate significantly with measures of scholastic aptitude in college student populations.

Private and public self-consciousness

The Self-Consciousness Scale (SCS; Fenigstein et al., 1975) contained subscales for both private and public self-consciousness. The third subscale of the SCS, social anxiety, was not used in the present study. Responses were made on a five-point Likert scale with a range from 0 (extremely uncharacteristic/not at all like me) to 4 (extremely characteristic/very much like me). Sample items for the ten item private self-consciousness subscale were "I reflect about myself a lot" and "I'm generally attentive to my inner feelings." Sample items for the seven item public self-consciousness subscale were "I'm concerned about what other people think of me" and "I usually worry about making a good impression."

Examinations of the reliability and validity of the SCS have been conducted. Test-retest reliabilities were computed, with a two week interval, for the private self-consciousness, public self-consciousness, and social anxiety subscales along with the total SCS (Fenigstein et al., 1975). The reliability coefficients were .79, .84, .73, and .80 for private self-consciousness, public self-consciousness, social anxiety, and the whole scale, respectively. The internal consistency estimates for the present sample were .54 for private self-consciousness and .76 for public self-consciousness. Rentsch and Heffner (1992) found similar internal consistency estimates of .62 for private self-consciousness and .79 for public self-consciousness.

Carver and Scheier (1981) gave an overview of the validity evidence of the SCS. They reiterated evidence of construct, convergent, and discriminant validities. They cite an article by Carver and Glass (1976) that reported discriminant validity evidence for the SCS.

Self-monitoring

Snyder and Gangestad (1986) developed an 18-item measure of self-monitoring. Sample items included "I find it hard to imitate the behavior of other people" and "In different situations and with different people, I often act like very different persons." Participants responded true or false to each item. The 18-item Self-Monitoring Scale had a coefficient alpha of .70, which is higher than the original 25-item measure developed by Snyder (1974). For the present sample, the internal consistency estimate on the 18-item scale was .69. The validity of the 25-item measure has been demonstrated (e.g., Briggs, Cheek, & Buss, 1980; Snyder, 1974). Researchers (e.g., Kring, Smith, & Neale, 1994) have begun to use the 18-item Self-Monitoring Scale.

Perspective-taking

The Interpersonal Reactivity Index (Davis, 1980) contained a perspective-taking subscale. This scale consisted of seven items. A sample item from this scale was "I sometimes try to understand my friends better by imagining how things look from their perspective." Responses were made on a five-point Likert scale from 0 (does not describe me very well) to 4 (describes me very well). The test-retest reliability was .61 for males and .62 for females, with a time interval that ranged from 60 to 75 days (Davis). Internal consistency reliability (alpha coefficient) estimates for the perspective-taking subscale ranged from .71 for males and .75 for females (Davis, 1980). The sample internal consistency reliability estimate found in the present study was slightly higher at .77, with estimates of .72 for females and .80 for males.

Team experience

The team experience measure consisted of seven items from Rentsch, Heffner, and Duffy (1994) and three additional items developed for a study conducted by Rentsch, Pape, and Brickman (1997). The items were rated on a seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). A sample item was "I know how to make teams more effective." The internal consistency reliability estimate from the present study for all ten items was .89. A subset of the items identified through factor analysis by Rentsch et al. (1997) was used in further analyses. The reliability estimate in the present study for these seven items was .90.

Teamwork Schema Similarity Measure

Teamwork schema similarity was assessed using a measure developed by Pape (1997). Open ended interview questions were asked of eight same-sex teams after completion of the Jasper task. Each team produced a list of words describing teamwork as it may occur on any team. These descriptors represented their cognitive teamwork categories. Then each team provided behavioral examples of each teamwork category. Behaviors that were similar to one another were grouped together by the developer of the measure. Six of the teamwork categories were mentioned by three or more teams during the interview. The behaviors provided as exemplars for these high frequency categories were examined, and those exemplifying two or more of these categories were retained for the development of the scale items. These behaviors were selected because they were potentially open to more than one interpretation with respect to meanings of teamwork. The behaviors were then written into 15 items.

The Teamwork Schema Questionnaire consisted of 15 items rated on a seven-point Likert scale from 1 (extremely unimportant) to 7 (extremely important). A sample item was "Team members critique each others' ideas." First, each individual completed the measure for him or herself. That is, the individual indicated how he or she viewed teamwork. For this portion of the measure, the participants received the following instructions:

> Think about what teamwork means to you. Think about teamwork as it may occur on any team. Thinking about teamwork in this way, please read each of the following statements. Think about how important these behaviors or events would be in telling you about the nature or meaning of teamwork. Ask yourself "Does this event tell me anything about the meaning of teamwork?" When considering the importance, keep in mind your view or meaning of teamwork.

Then the participants completed the items as they believed their partner would respond. The instructions for this portion of the measure were:

> Now please complete the same questionnaire, but this time, respond how you think your partner would respond to the questionnaire. Please rate how important you think your partner would say each of the following items is to his or her meaning of teamwork. When considering the importance, keep in mind your partner's view of teamwork.

The degree of agreement and accuracy among the two team members was determined by computing the absolute difference score by item (Cronbach & Gleser, 1953).[1] The absolute difference formula is $|D| = \Sigma |Xi - Yi|$, where Xi is the response on item i for one member and Yi is the response on item i for the second member. The absolute differences were then summed across all 15 items. A greater degree of agreement or accuracy was indicated by a lower difference score. Thus, each participant had one agreement difference score, indicating the degree of agreement between his/her own responses and those of his/her partner, and one accuracy difference score, indicating the degree of accuracy that individual had in assessing how his/her partner would respond compared to the partner's actual responses. Therefore, the team members had the same agreement difference scores, but each had their own accuracy difference score.

Demographic Variables

Participants were asked to provide background information that was used to describe and characterize the sample. Participants were asked to provide information about their age, sex, race, class, pilot experience, mathematics skills, and acquaintance level with partner. The participants were also asked about the presence of a leader on the team, their team experience, satisfaction with the team's performance and with the teamwork, and the amount of anxiety they experienced during the task.

Coding Measures

Team performance

Eight aspects of team performance were coded: problem space identification, errors, corrections, math errors, corrections of math errors, speed, solution accuracy, and solution quality. Similar types of performance measures for the employed task have precedence in the research literature (e.g., McNeese, 1993; Vye, Goldman, Voss, Hmelo, & Williams, undated).

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[1] All results were also computed using the square root of the mean squared difference scores. The pattern of results was similar to those using the absolute difference scores. Therefore, the results using the absolute difference scores are reported here.

Problem space identification referred to how much of the problem space (issues and numerical information presented in the Jasper video) was identified by one or both team members. Errors were coded as the number of times, throughout working on the problem, that the team created an error, such as violating the constraints of the task, using the wrong information, misusing information, or using information not provided to them in the Jasper video. Raters also recorded the number of these errors that were corrected. Math errors simply referred to the number of errors in calculation, and corrections of math errors were also recorded. Speed was coded as the time that it took the team to reach a solution. Accuracy was rated in terms of how close the team came to finding the best solution (i.e., the fastest possible time to rescue the eagle) out of 27 possible solutions. Also, the solution quality was rated on a four-point Likert scale from 1 (poor) to 4 (excellent).

Two raters independently coded each of these performance domains by reviewing each team's written work and the videotape of the team. The average interrater agreement for 45 teams was 93%. The raters resolved any discrepancies in ratings through consensus.

Team interaction processes

Team processes were coded using the Team Interaction Coding Scheme (TICS), a coding scheme developed for this study. TICS assessed nine categories of team interaction processes: depth of meaning in informing oriented communication, depth of meaning in learning oriented communication, quality of exchange, consensus evaluation communication, egocentricity versus mutuality, openness and acceptance of communication, group cohesion, task motivation, and team metacognition.

Depth of meaning in informing oriented and in learning oriented communication referred to the level at which team members provided information to or requested information from one another, respectively. The deepest level of information included communicating assumptions, beliefs, and explanations of logic. Low levels of information included communicating facts about the task or information unrelated to the task discussion. Ratings ranged from 1 (very little information disclosed/very few questions asked) to 5 (explaining/asking about the current line of logic; explaining/asking about interpretations or reasonings; explaining/asking why [the other member was] pursuing a line of logic; providing/seeking information about assumptions). Depth of meaning in learning oriented communication and depth of meaning in informing oriented communication were coded for each member and for the team as a whole. Raters coded both the highest level of informing oriented and learning oriented communication that occurred within the team and the most characteristic level.

Quality of exchange was rated for the team as a whole. High quality occurred when team members communicated information clearly to one another and checked to ensure that the information was received and understood. Thus, ratings ranged from 1 (Communication was unilateral. Questions were asked rhetorically or as if the questioner was thinking aloud; information was stated rhetorically or as if the informer was thinking aloud.) to 5 (The communication process was complete, because the original message was understood and responded to, and the response was understood.).

Consensus evaluation occurred when team members sought or provided indications that they were or were not in agreement. Frequency ratings were made on both positive consensus evaluation and negative consensus evaluation for each team member and for the team as a whole. Positive consensus evaluation included indications of agreement (e.g., "Right." "I agree." "Do you agree?"). Negative consensus evaluation included indications of disagreement (e.g., "No." "That's wrong." "I don't agree."). Both positive and negative consensus evaluation were rated on a scale from 1 (occurred almost never) to 5 (occurred very frequently).

Egocentricity versus mutuality referred to the degree to which team members worked together to complete the task. High ratings indicated that members displayed behaviors indicative of mutuality, such as both members working together to come to a solution. Teams were given low ratings when members displayed egocentric behaviors, such as working independently of one another. The ratings ranged from 1 (one member dominated or took nearly full responsibility for functions, task components, and time segments and the other member followed along passively and did not contribute, or contributed only when prompted -OR- each member worked independently) to 5 (each team member coordinated, evaluated, and utilized task inputs from the other member in an interdependent manner; there was a fairly even distribution of contribution across functions, across task components, and across time). This variable was rated for the team as a whole.

Openness and acceptance occurred when a team member was willing to listen to and to discuss another's ideas. The rating scale for this variable ranged from 1 (tended to ignore the other's input) to 5 (considered and discussed the other's input immediately). In addition, a rating of 9 (not enough information to make a judgment) was given in the appropriate cases. Ratings were given to each team member on this variable.

Group cohesion referred to the level of attraction or liking between team members. Indicators of high cohesion included making eye contact, sitting close to one another, speaking warmly, joking with one another, and so forth. This variable was rated on a scale from 1 (almost no indicators of high cohesion, mostly indicators of low cohesion) to 5 (almost no indicators of low cohesion, mostly indicators of high cohesion). Group cohesion was rated for the team as a whole.

Task motivation was rated for each team member. Task motivation was rated highly to the degree that team members showed a high task focus and displayed energy for and interest in the task. Thus, ratings were given on a scale of 1 (almost no indicators of high task motivation, mostly indicators of low task motivation) to 5 (mostly indicators of high task motivation, almost no indicators of low task motivation).

Metacognition was rated, in terms of frequency, for each member and for the team as a whole. Metacognition occurred when team members made observations regarding their process, thinking, or logic (e.g., monitoring errors). Ratings ranged from 1 (almost no indicators of metacognition) to 5 (mostly indicators of metacognition).

The total time during which the team worked was divided into quarters. Each process variable was rated on a five-point Likert-type scale for each quarter (with the exception of openness, which could be rated as 9). Thus, 112 ratings were made for each team (28 ratings per quarter for each of four quarters). Two raters coded each variable. It should be noted that these two raters were different from the two raters who coded performance. One rater prepared a transcript of the videotape and then reviewed the videotape using the transcript and TICS to rate the members and the team on the team interaction processes. The other rater also used the transcripts when reviewing the videotape to make the TICS ratings. The average interrater agreement across all of the ratings was computed using Scott's (1955) *pi*, which takes into account the proportion of agreement that would be expected by chance. Using Scott's index, an average interrater agreement of 75% was computed for 44 teams. One team was not rated for process due to the poor sound quality of the videotape. All coding discrepancies were resolved through a consensus process, during which the raters discussed the reasons behind their ratings and referred back to the transcripts and videotapes when necessary.

Procedure

After completing a consent form, each individual of the same sex team completed the personality characteristics measures. Next, the team viewed the Jasper laser video disc (approximately 17 minutes in length) without interruption. Teams were instructed to refrain from taking any notes during this initial presentation. The team then worked together to complete the Jasper task. The teams had access to the laser disc video and could go back and forth within the laser disc video to gather information they deemed necessary for task completion. The teams were instructed to record in writing their work and a single final team solution. This instruction was given to increase the interdependence of the team members as they worked on the task. If the team did not complete the task within an hour of beginning to work on the task, they were stopped by the experimenter. This time limit is consistent with previous research using this task (e.g., McNeese, 1993) and corresponds to the greatest length of time any of the pilot study teams needed to complete the task. Only two teams were stopped. The team members were not told of the time limit in order to avoid the potential effects that this knowledge could have on their performance.

After the team completed the task, they were given the opportunity to take a short break. Following the break, each team member was asked to complete the teamwork schema measure for himself or herself. Then, each team member completed the teamwork schema measure as he or she believed his or her team member would respond. Finally, the background information sheet was completed. After both members completed these measures, the solution to the task was presented, and the team members were given the opportunity to ask any additional questions.

RESULTS

Factor Analysis of Process Variables

Team-rated variables

The team-rated process variables were factor analyzed. Negative consensus, metacognition, and the most characteristic level of team-rated learning oriented communication were dropped due to lack of variance. The remaining team-rated process variables were submitted to a principal components factor analysis using varimax rotation. Two factors emerged (see Table 1), accounting for 63.8% of the variance. Each factor had an eigenvalue greater than 1. The first factor, which accounted for 37.8% of the variance, was comprised of the highest level of informing oriented communication, the most characteristic level of informing oriented communication, the highest level of learning oriented communication, and positive consensus evaluation communication. This factor was labeled "depth of exchange" (referred to as Exchange) because the variables loading on this factor involved exchanging information. The second factor, which accounted for an additional 26.0% of the variance, was comprised of quality of exchange, egocentricity versus mutuality, and cohesion. This factor was labeled "team member interdependence" (referred to as Interdependence) because each of these variables involved interdependence among team members.

Scale scores for the team-rated variables were created by summing across the ratings of the variables that comprised each factor. In other words, exchange scores were created by summing team-rated positive consensus, the highest level of learning-oriented communication, and the highest and most characteristic levels of informing-oriented communication. Interdependence scores were created by summing team-rated quality of exchange, egocentricity versus mutuality, and cohesion.

<u>Individual-rated variables</u>

The individual-rated process variables were also factor analyzed using principal components analysis with varimax rotation. Negative consensus and metacognition were dropped due to lack of variance. Three factors emerged from this analysis. The third factor was comprised solely of the openness variable, and therefore openness was dropped and the remaining individual-rated process variables were submitted to a second factor analysis. Two factors emerged from this analysis (see Table 1), accounting for 63.4% of the variance. Each factor had an eigenvalue greater than 1. The first factor, which accounted for 42.4% of the variance, was comprised of the highest level of learning oriented communication, the most characteristic level of learning oriented communication, and positive consensus evaluation communication. This factor was labeled "depth of learning" (referred to as Learning) because each of the variables on this factor involved seeking information. The second factor, which accounted for an additional 21.0% of the variance, was comprised of the highest level of informing oriented communication, the

Table 1

Factor Analyses of Process Variables

	Factor Loadings	
Team-Rated Variables	Depth of Exchange	Team Member Interdependence
Highest Level of Informing	.89	-.05
Positive Consensus	.89	.18
Most Characteristic Level of Informing	.74	.05
Highest Level of Learning	.50	.14
Quality of Exchange	.07	.91
Egocentricity versus Mutuality	-.12	.74
Cohesion	.19	.70
Percent Variance Explained	37.8%	26.0%
Eigenvalue	2.65	1.82

	Factor Loadings	
Individual-Rated Variables	Depth of Learning	Depth of Informing
Positive Consensus	.81	.16
Highest Level of Learning	.76	.24
Most Characteristic Level of Learning	.75	-.01
Most Characteristic Level of Informing	.01	.92
Highest Level of Informing	.38	.76
Task Motivation	.07	.59
Percent Variance Explained	42.4%	21.0%
Eigenvalue	2.55	1.26

most characteristic level of informing oriented communication, and task motivation. This factor was labeled "depth of informing" (referred to as Informing) because providing information was related to each of the variables on this factor.

A team level score was obtained for each factor by aggregating (summing) ratings for each member. Scale scores were then created by summing the aggregated scores of each variable comprising the factors. In other words, learning scores were created by summing the aggregated scores for positive consensus with the highest and the most characteristic level of learning oriented communication. Informing scores were created by summing the aggregated scores for task motivation with the highest and the most characteristic level of informing oriented communication.

Thus, four team level process variables were used in subsequent analyses, two from the team-rated variables, exchange and interdependence, and two from the aggregated individual-rated variables, learning and informing. As can be seen by examining the results of the factor analyses, the individual-rated factors learning and informing comprised, with the exception of task motivation, the team-rated factor exchange. Table 2 shows that these variables were correlated significantly. Exchange correlated with informing and with learning (r = .71, .92, respectively, $p < .05$).

In the following sections, the findings related to each link in the model (see Figure 2) will be reported. Each link was examined using correlational analyses.

Tests of Team Member Teamwork Schema Similarity Model

Teamwork schema accuracy and schema agreement were each computed using absolute difference scores. High levels of schema accuracy and schema agreement were therefore indicated by low scores. Similarities on the individual difference variables were computed as standard deviations. Therefore, low scores also indicated high similarity.

No significant correlations were found between the team member schema similarity and individual difference variables (Link 1). The results of the correlational analyses can be seen in Table 2. An additional set of exploratory regression analyses were conducted. For each individual difference variable, the similarity of the individual difference and the mean level of the individual difference were entered simultaneously as predictors of schema agreement or schema accuracy. All resulting multiple Rs were nonsignificant.

Table 2

Correlations of Individual Differences, Team Member Teamwork Schema Similarity, and Team Processes

	1[a]	2	3	4	5	6	7	8	9	10	11
1. Interdependence	--										
2. Exchange	.22	--									
3. Informing	.39**	.70**	--								
4. Learning	.34*	.92**	.60**	--							
5. Similarity of Trust	-.19	-.08	-.08	-.14	--						
6. Similarity of Public Self-Consciousness	-.20	-.07	-.02	-.13	.01	--					
7. Similarity of Private Self-Consciousness	-.15	.16	.15	.05	.17	.12	--				
8. Similarity of Self-Monitoring	-.01	.15	-.06	.14	-.04	-.03	-.13	--			
9. Similarity of Perspective-Taking	.01	-.20	-.11	-.10	.02	.00	.20	-.35*	--		
10. Similarity of Team Experience	-.17	-.11	-.39**	-.09	-.07	-.06	.19	.02	.23	--	
11. Teamwork Schema Accuracy	-.06	-.05	-.04	-.04	.27	.28	-.20	-.17	.12	-.04	--
12. Teamwork Schema Agreement	.07	.07	.03	.12	.23	.07	-.11	-.06	.20	.06	.75**

[a] n = 44 for all correlations in columns 1 through 4; n = 45 for all other correlations.

* $p < .05$; ** $p < .01$.

Link 2 involved the relation between individual differences and team process. Similarity of team experience predicted informing ($r = -.39$, $p < .05$). Thus, high levels of similarity on team experience related to high levels of informing. No significant correlations were found between the remaining process and individual difference variables. The results of the correlational analyses are shown in Table 2.

Link 3 involved the relation between team process and team member teamwork schema similarity. No significant correlations were found between these variables (see Table 2).

The relation between team process and team performance is represented as Link 4. Exchange predicted speed ($r = .75$), number of errors ($r = .31$), number of corrections ($r = .33$), problem space identification ($r = .44$), and the consideration of multiple routes ($r = .32$; all $p < .05$). Additionally, informing predicted speed ($r = .39$), and problem space identification ($r = .37$; all $p < .05$). Learning predicted speed ($r = .74$), errors ($r = .32$), problem space identification ($r = .43$), math errors ($r = .33$), and the consideration of multiple routes ($r = .31$; all $p < .05$). No significant correlations were found between the remaining process and performance variables. The results of the correlational analyses are presented in Table 3.

Exploratory regression analyses were performed to control for speed in the process-performance relations. Each performance variable was regressed on speed in Step 1 of a hierarchical regression analysis. In Step 2 a single process variable was entered. After controlling for speed in this manner, the only relation remaining significant was that between depth of learning and errors. In addition, after controlling for speed ($R = .27$, $p < .05$), depth of learning accounted for a significant amount of additional variance in solution quality ($\Delta R^2 = .10$, $p < .05$).

Link 5 involved the relation between team member teamwork schema similarity and team performance. One significant correlation was found (see Table 4). Schema accuracy related to problem space identification ($r = -.33$, $p < .05$). Thus, the identification of a large portion of the problem space was related to high levels of schema accuracy.

Table 3

Correlations of Team Processes with Team Performance

	1[a]	2	3	4	5	6	7	8	9	10	11	12
1. Interdependence	--											
2. Exchange	.22	--										
3. Informing	.39**	.70**	--									
4. Learning	.34*	.92**	.60**	--								
5. Solution Quality	-.16	.11	.22	-.01	--							
6. Speed [b]	-.08	.75**	.39**	.74**	.28	--						
7. Solution Accuracy [c]	-.06	-.05	-.01	.02	.02	.22	--					
8. Errors	.09	.31*	.13	.32*	-.43**	.18	-.01	--				
9. Corrections	-.02	.33*	.22	.30	-.07	.34*	.01	.44**	--			
10. Problem Space Identification	-.15	.44**	.37*	.43**	.59**	.64**	.02	-.04	.20	--		
11. Math Errors	.15	.27	.23	.33*	-.11	.39**	.18	.39**	.24	.12	--	
12. Corrections of Math Errors	.16	.27	.25	.27	.04	.34*	.19	.15	.23	.14	.65*	--
13. Consideration of Multiple Routes	.12	.32*	.30	.31*	.30*	.44**	.07	.17	.32*	.44*	.17	.15

[a] $\underline{n} = 44$ for all correlations in columns 1 through 4; $\underline{n} = 45$ for all other correlations.

[b] Speed was coded as time to solution (i.e., higher values indicate slower speed).

[c] $\underline{n} = 29$ for all correlations involving Solution Accuracy.

* $\underline{p} < .05$; ** $\underline{p} < .01$.

Table 4

Correlations of Team Member Teamwork Schema Similarity with Team Performance

	1	2	3	4	5	6	7	8	9	10	11
1. Schema Agreement	--										
2. Schema Accuracy	.75**	--									
3. Solution Quality	-.22	-.29	--								
4. Speed [a]	-.03	-.19	.28	--							
5. Solution Accuracy [b]	-.19	-.07	.02	.22	--						
6. Errors	-.07	.00	-.43**	.18	-.01	--					
7. Corrections	.13	-.08	-.07	.34*	.01	.44**	--				
8. Problem Space Identification	-.12	-.33*	.59**	.64**	.02	-.04	.20	--			
9. Math Errors	-.03	-.09	-.11	.39**	.18	.39**	.24	.12	--		
10. Corrections of Math Errors	.17	.02	.04	.34*	.19	.15	.23	.14	.65**	--	
11. Consideration of Multiple Routes	-.07	-.26	.30*	.44**	.07	.17	.32*	.44**	.17	.15	--

[a] Speed was coded as time to solution (i.e., higher values indicate slower speed).

[b] $n = 29$ for all correlations involving Solution Accuracy; $n = 45$ for all other correlations.

* $p < .05$; ** $p < .01$.

DISCUSSION

Summary of Results

In summary, significant correlations supported Links 2, 4, and 5 of the model. Link 2, which involved the relation between individual differences and team process, received some support because similarity of team experience was related to high levels of depth of informing. Link 4 involved the relation between team process and team performance. It was found that depth of exchange was related to solution time, number of errors, number of corrections, degree of problem space identification, and consideration of multiple routes. Additionally, a high level of depth of informing was related to slow speed times and to a high degree of problem space identification. Also, high levels of depth of learning were related to slow speed, a high number of errors, a high degree of problem space identification, a high number of math errors, and consideration of multiple routes. The results involving the relation between team member teamwork schema similarity and team performance (Link 5) showed that high teamwork schema accuracy predicted a high degree of problem space identification. Links 1 and 3 were not supported. The link between team process and team performance (Link 4) received the most support. Below, the implications of the results are discussed.

Implications

Individual differences

The overall nonsignificant effects of the individual difference variables were surprising and disappointing. The expectation that the individual difference variables would predict TMSS and team interaction processes was based on a very limited amount of indirect research evidence. The individual difference variables examined in the present study were selected because personality and social psychological research suggested that people possessing these characteristics were sensitive to social cues (Pape, 1997). Therefore, we expected these characteristics to be related to sharing and deciphering schema related communication. The only significant relationship obtained was from an exploratory analysis. Team member similarity on a single item measure of team experience, "How much team experience do you have?", was correlated significantly ($r = -.41$, $p < .05$) with depth of informing. Item ratings for team experience were made on a 1 (This is my first team experience) to 4 (I have worked on many teams) scale.

We conducted post hoc analyses testing the direct relationships between the individual difference variables and team performance. No significant results were revealed. Based on the results from our study we suggest that team interaction processes are better predictors of team performance than are individual difference variables. However, if researchers pursue the study of individual difference characteristics and team performance, we suggest strongly that they include the Armstrong Laboratory Aviation Personality Survey (ALAPS; Retzlaff, King, McGlohn, Callister, 1996) as a measure of individual differences. The variables on the ALAPS are designed to assess individual differences related to collaborative work and therefore may be related more strongly to TMSS and to team interaction processes than the individual difference variables assessed in the present study.

Team performance

In past research, team effectiveness has often been assessed by the teams rating their own performance (Tannenbaum, Beard, & Salas, 1992). However, in the present study, performance was rated by observers and by objective assessments (e.g., speed). Teamwork schema accuracy was significantly related to solution quality and to problem space identification. These results in conjunction with those found in past research studies, in which teams rated their own performance (e.g., Rentsch et al., 1997), suggest that schema accuracy requires more study.

In addition, included on the background survey was a single item on which team members rated their evaluation of the team's effectiveness. This item correlated significantly with TMSS accuracy and agreement ($r = -.36, -.38$, respectively, $p < .05$).

Team interaction processes

A major contribution of the present study is the Team Interaction Coding Scheme (TICS). Communication content, function, and structure have received some research attention in the past (e.g., Hakel, Weil, & Hakel, 1988; Oser, Prince, Morgan, & Simpson, 1991; Pavitt & Curtis, 1994; Simon, Morey, Locke, & Blair, 1995; Sperry, 1995; Tower & Elliott, 1996), but as noted earlier many coding schemes focus on communication type (e.g., questions, commands). TICS was designed to tap the sense-making, or socially constructed aspects, of interaction content. Specifically, TICS assessed the degree to which team members tended to share interpretive information with one another and the degree to which team members acted interdependently.

Although the hypothesized link between team interaction processes and TMSS was not supported, team processes were related significantly to team performance. Our results suggested that depth of exchange and depth of learning were the best predictors of team performance. However, these processes were also related to a high number of errors. This result is inconsistent with Kimble and McNeese's (1987) report that flight crew communication was related negatively to number of errors. It should be noted that number of errors and number of corrections were correlated significantly ($r = .44$, $p < .05$). After controlling for corrections, depth of exchange did not predict errors significantly, whereas depth of learning remained a significant predictor of errors.

Other significant results for depth of exchange and depth of learning were consistent with past research results. Past research has indicated that teams that communicated in longer utterances performed better than teams that spoke in shorter utterances (Kimble & McNeese, 1987). Our results may shed some light on this finding, because team processes were related to speed. That is, the teams that took more time to complete the task also shared deeper meanings than teams that took less time to complete the task. Although we did not measure length of utterance directly, it is likely that when team members shared depth of meaning they spoke in longer utterances than when team members shared surface level information. In addition, teams that took more time also performed better than teams that took less time. As the exploratory analyses revealed, depth of learning may be a critical predictor of team performance.

Interestingly, team member interdependence, which included information regarding quality of exchange, egocentricity and mutuality, and cohesion, did not predict team performance. It is possible that team members did not interact long enough for significant variance to develop on this variable. High ratings on the component variables are likely to have been related to the length of time that team members had to interact with one another. For example, past research on cohesion has shown it to be related to the length of time that group members had interacted (Mabry & Barnes, 1980).

Exploratory analyses indicated that team member interdependence was significantly ($p < .05$) related to attitudinal variables, such as satisfaction with the team's performance ($r = .32$), satisfaction with the teamwork that occurred ($r = .37$), and willingness to work with the same person in the future ($r = .46$). Team member interdependence also correlated significantly with a rating of team effectiveness and with the tendency to view the dyad as a team ($r = .32$, $.39$, respectively, $p < .05$).

Baker and Salas (1992) suggested that teamwork may evolve; therefore, researchers need to develop teamwork measures that are generalizable to teams in many settings and to different team tasks. Our efforts to develop team interaction process measures are in line with this objective and with the need for more empirical research examining team member communications and team performance (Tower & Elliott, 1996). Although we have attempted to address the nature of interactions and communication within teams, there continues to be a need for more research in this area (Duffy, 1993). Below, we describe additional ideas for future research.

Limitations and Future Research

The study proved fruitful in providing some support for portions of the Rentsch and Hall (1994) model. However, future research might address several methodological issues in the present study concerning the nature of the task, the measures, and the teams.

The task

The Jasper task presents a complex, ill-defined problem that requires the participant(s) to discover the quickest method for rescuing a wounded eagle from a remote location. The nature of the task is such that a single individual working alone may solve the problem successfully. Indeed, the task has been employed in studies examining individual performance (e.g., McNeese, 1993). The task may also be completed by two or more participants working together as a team. However, because the task may be completed by one individual, it is possible that one team member could complete the task with little or no input from other team members.

The nature of the Jasper task is such that it does not necessarily require intense interaction between team members. After reviewing the videotaped teams in the present study, it was evident that some teams, albeit few, did operate at a low level of interdependence. Future researchers might consider using tasks that require intense interaction and interdependence among team members. Interaction among team members provides the opportunity to observe schema-indicative behaviors.

In addition to considering an intensively interactive task, future researchers might consider testing the TMSS model within the context of an ecologically valid synthetic task environment. For example, the VIPER/VECTOR tasks (McNeese, personal communication), developed in Armstrong Laboratory, or the TRAP task (Wilson, McNeese, Brown, & Wellens, 1987), modified to realistically portray the UCAV or the command-post environment, would provide ecologically valid task environments.

<u>The measures</u>

As described above, team member teamwork schema similarity was conceptualized as consisting of both schema agreement and schema accuracy. Schema agreement and schema accuracy were measured by difference scores in the present study. This method has been used in previous studies of team member schema similarity (e.g., Rentsch et al., 1997) and in studies of cognitive congruence (Engle & Lord, 1997). However, team member schema similarity involves similarity of schema structure and similarity of schema content. Absolute difference scores might not provide as much information regarding schema structure as other measurement methods (e.g., multidimensional scaling and pathfinder). Future researchers should consider and compare various team member teamwork schema similarity measurement methods.

The measures selected to assess individual differences were standard measures used in previous research. However, several measures had relatively modest reliability estimates (e.g., trust, private self-consciousness). It is worth noting that the only individual difference variable to produce a significant result was team experience, which was the measure with the highest internal consistency reliability estimate.

<u>The teams</u>

The nature of the teams that participated in the present study have several implications for the results. Team members who participated in this study were undergraduate students, who worked together for one session. Although the results from the present study may apply to work teams that meet for a single short session, the results may not generalize to work teams that meet for multiple sessions over longer time periods for the following reasons.

First, team members who realize that they will be working together in the future may be motivated to invest the effort to develop TMSS, whereas team members working together for one short session may not be motivated to do so. Second, perhaps when team members are afforded more time to demonstrate behavior related to individual differences the relationship between individual differences and TMSS might become significant. Third, it is possible that TMSS takes a long time to develop (i.e., more than 60 minutes). The teams in the present study interacted for an average of only 32.5

minutes. Results shown in Table 3 indicated that speed was significantly related to the depth of exchange, depth of learning, and depth of informing. Clearly it takes more time to convey deep meaning than it takes to convey surface level information. However, team process variables were not related to team member schema similarity. Perhaps the teams did not have enough time to engage in enough deep communication to develop TMSS. The communication must occur and then the team schemas must be formulated or negotiated to develop team schema agreement. Team schema accuracy may take additional time to develop, because team members must integrate the deep communications into a schema of their team member's teamwork schema.

Based on these concerns, we suggest that future researchers consider longitudinal studies of team interaction processes and TMSS. Alternatively, the study of existing work teams should be considered.

Future Applications

Application of the theoretical constructs and the measures that we have developed within an ecologically valid synthetic task environment can contribute to building the foundation for future research on Joint Cognitive Systems. As we acquire knowledge of team member schema similarity and its relation to shared responsibility and team performance, we can pursue research relating these variables to collaborative systems technologies such as datawalls or knowledge rooms. In addition, understanding how team members interact will facilitate the design and development of human-machine communication (Wellens & McNeese, 1987).

We know that the *New World Vistas Air and Space Power for the 21st Century* publication indicates that collaborative computing is a high priority. Collaborative computing may take the form of advanced "groupware," which may be used to facilitate group interaction and decision making among co-located or distributed group members, and human-machine interaction. Clearly, understanding the effects of the joint cognitive system designs on TMSS will enhance the utility of these technologies. MUDs, or Multiple User Dimensions, are described as "....in effect social virtual realities....to manage the details of the social interaction..." (NWV, p. 100). The New World Vistas report goes so far as to suggest that a "virtual Pentagon" (p. 101) may become a reality. These innovations require extensive knowledge of socio-cognitive processes and their relationships to technology.

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