

The Impact of Cross-Training on Team Effectiveness

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The authors examined the role of cross-training in developing shared team-interaction mental models, coordination, and performance in a 2-experiment study using computer simulation methodology (for Experiment 1, $N = 45$ teams; for Experiment 2, $N = 49$ teams). Similar findings emerged across the 2 experiments. First, cross-training enhanced the development of shared team-interaction models. Second, coordination mediated the relationship between shared mental models and team performance. However, there was some inconsistency in the findings concerning the depth of cross-training necessary for improving shared mental models. Results are discussed in terms of the impact of different levels of cross-training on team effectiveness.

Despite widespread use in organizations, teams have not always lived up to expectations. There are many reasons for teams not performing to their potential, such as poor member composition (Barrick, Stewart, Neubert, & Mount, 1998; LePine, Hollenbeck, Ilgen, & Hedlund, 1997) and ineffective pay systems (Lawler, 2000). However, team members often have simply not been prepared to operate as a unit (Mohrman, Cohen, & Mohrman, 1995). Sundstrom (1999) argued that organizations can foster effective teams by providing them with the necessary managerial support, and well-designed training is a primary support system. The development of appropriate training remains a challenging priority for team-centered organizations, in part because empirical research on team training strategies has been slow to accumulate. In this article, we describe two experiments designed to address how one particular team training strategy, cross-training, influences team effectiveness.

Conceptual models of team effectiveness have generally taken an input–process–outcome perspective, in which team training is viewed as an organizational input affecting team processes (e.g., coordination) and various team outcomes (e.g., Gist, Locke, & Taylor, 1987; Gladstein, 1984; Guzzo & Shea, 1992; R. Hackman, 1983; Tannenbaum, Beard, & Salas, 1992). Following Kraiger, Ford, and Salas's (1993) suggestion that training programs should

be reoriented to focus more on teaching underlying knowledge rather than a finite set of skills, more attention has been placed on the examination of knowledge structures (i.e., mental models) as an indication of training effectiveness and as a precursor to team processes and outcomes (Marks, Zaccaro, & Mathieu, 2000; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000).

The experiments that we conducted in this study examined the effects of cross-training on shared knowledge structures as an indicator of cross-training effectiveness. We expected these shared knowledge structures to improve coordination processes and more distal team performance. From a conceptual standpoint, we sought to determine how teams benefit from various levels of cross-training through two experimental studies. Although both experiments tested similar hypotheses, they used different samples, experimental settings, tasks, measures, and manipulation operationalizations.

In both experiments, we focused on action teams, a specific type of team that is characterized by highly interdependent work arrangements (Kozlowski, Gully, McHugh, Salas, & Cannon-Bowers, 1996). An *action team* is essentially any team in which expertise, information and tasks are distributed across specialized individuals, where team effectiveness depends on rapid, complex, and coordinated task behavior, and the ability to dynamically adapt to the shifting demands of the situation (Kozlowski et al., 1996). As opposed to other types of teams, such as service and production teams, action teams contain more specialized skill sets, rely more heavily on coordination, perform in less familiar and more challenging environments, and may be more temporary (Sundstrom, 1999). To operate successfully in challenging environments, action team members have specialized task-related skill sets as well as honed teamwork abilities to coordinate their activities with teammates (Sundstrom, 1999). Because action teams are highly interdependent, overall performance is unattainable without task contributions from each member and successful interaction among the team members (Blickensderfer, Cannon-Bowers, & Salas, 1998). We believe cross-training is a particularly effective training strategy for action teams because their distributed role structure and

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highly interdependent action would place a premium on understanding other members' roles and collective contributions to team goals.

Cross-Training

Conceptual Research on Cross-Training

Cross-training was defined by Volpe, Cannon-Bowers, Salas, and Spector (1996) as "an instructional strategy in which each team member is trained in the duties of his or her teammates" (p. 87). The goal of cross-training is to enhance knowledge of interpersonal activities by introducing team members to the roles and responsibilities of their teammates. Cross-training has been touted as contributing to team communication, coordination, and controlled team regulation by encouraging members to understand the activities of those around them (Blickensderfer et al., 1998). By providing members with knowledge about what information has to be shared and what activities must be performed interdependently, individuals are better able to anticipate the needs of other members (Cannon-Bowers, Salas, Blickensderfer, & Bowers, 1998; Volpe et al., 1996) and to provide assistance to members in need of help (Dickinson & McIntyre, 1997). In addition, Blickensderfer et al. argued that the knowledge gained from training teaches members how to compensate for teammates' limitations.

Blickensderfer et al. (1998) detailed three types of cross-training that differ on the depth and method in which members' roles are taught to teammates. The three types are not completely distinct in that they build on each other. The least in-depth form of cross-training, *positional clarification*, involves verbally presenting team members with information about their teammates' jobs through lecture or discussion methods. For a product development team, this positional clarification cross-training might involve a meeting in which each team member's general roles in and contributions to the product development cycle are discussed. The second form of cross-training, *positional modeling*, entails both verbal discussion and observation of team members' roles. This form of cross-training encourages individuals to learn by observing interrole functions. Methods for providing positional modeling could be by direct behavioral observation or recording (e.g., videotape). In this case, individuals could shadow their teammates in action or watch recordings of expert teams modeling interrole behavior. For instance, product development engineers could spend a day with industrial designers and marketers or watch a videotape that shows engineers at work performing different activities. Finally, *positional rotation* provides a hands-on approach to learning interpositional information by giving members experience carrying out teammates' duties through active participation in each member's role. Individuals are provided with training and first-hand experience in their team members' roles. This type of training parallels the concept of job rotation in the sense that individuals spend time learning to perform others' jobs, although it is also likely to include both discussion of members' roles and modeling.

The goal remains the same in all three types of cross-training: to teach teammates about the roles and responsibilities of other teammates in hopes of improving coordination and ultimately team performance. However, the type of cross-training is thought to create either a more or a less detailed understanding of interrole behavior. At one extreme, positional rotation focuses on providing

members with expanded, adaptable knowledge and skill bases that build redundancy into a team's expertise load. At the other extreme, positional clarification intends to raise awareness of the range and timing of activities performed by the team, especially those involving multiple members.

Empirical Research on Cross-Training

Empirical research on cross-training as a strategy for increasing team members' base of interrole knowledge is in its infancy. Two published studies have examined the impact of cross-training on team performance. First, Volpe et al. (1996) examined the impact of cross-training on teamwork behaviors and performance of two-person teams using an aircraft simulation platform. They operationalized cross-training as positional rotation and compared the performance of teams receiving this manipulation with the performance of teams in a no-cross-training control condition. Findings indicated that (a) positional rotation influenced team processes such that team members with cross-training volunteered more information before it was requested and (b) positional rotation improved some aspects of team performance. A follow-up study by Cannon-Bowers et al. (1998) used three-person teams performing a radar simulation task with greater interdependence demands and again compared the positional rotation form of cross-training with a control condition. Findings were consistent with those of Volpe et al.: Cross-trained team members volunteered more information and performed better.

Together, these findings suggest that cross-training is an important strategy for preparing interdependent teams to work more effectively. However, both studies operationalized cross-training as positional rotation, and thus far no studies have investigated positional clarification or modeling. Yet, there are compelling reasons to examine the two less in-depth forms of cross-training. Of the three types of cross-training referred to above, positional rotation is the most in-depth because it requires actual work experience in the role of other teammates and often requires a significant training commitment. Although positional rotation is useful in some settings that benefit from interchangeable knowledge and skills among members, the time demands (training each member in the roles of all others), practicality (e.g., training waitresses to operate as chefs, training emergency room nurses to operate as surgeons), and potential negative transfer of interrole training may render positional rotation unrealistic for many work settings.

Thus, we conducted empirical tests of the two less in-depth forms of cross-training: positional modeling and positional clarification. First, we conducted a study to examine the efficacy of two previously unexplored forms of cross-training. We followed up with a second experiment comparing the two less in-depth forms of cross-training with positional rotation. As depicted in Figure 1, both studies examined effects of cross-training on three types of criteria: shared mental models, coordination and backup behaviors, and overall team performance.

Shared Mental Models

Several researchers have argued that effective teamwork depends on the emergence of shared knowledge representations or mental models (e.g., Cannon-Bowers, Salas, & Converse, 1993).

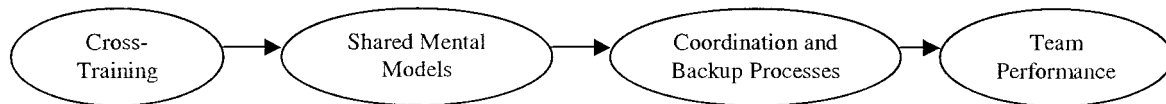


Figure 1. Proposed effects of cross-training on team effectiveness.

Mental models have been defined as “mechanisms whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states” (Rouse & Morris, 1986, p. 351). They organize information about systems, the environments in which they operate, and the response patterns required of systems with respect to environmental dynamics (Veldhuyzen & Stassen, 1977). Such mental models developed by individual team members represent knowledge and understanding about the team’s purpose and characteristics, connections and linkages among collective actions, and various roles and behavior patterns required of individual members to successfully complete collective action.

Team members may have different mental models of such topics as the team task, equipment, members, and team members’ interaction (Cannon-Bowers et al., 1993; Klimoski & Mohammed, 1994). In this article, we refer to mental models as the content and organization of interrole knowledge held by team members within a performance setting. Team-interaction models contain procedural knowledge about how team members should work together on a task within a given task domain, including information about who should do what at particular points in time. These models capture the sequence of interdependent activities that need to be carried out for teams to complete their mission.

Researchers have stated that the basic objective of team training is to foster similar mental models of the team’s task structure, team structure, and process by which the two interact (Baker, Salas, Cannon-Bowers, & Spector, 1992; Volpe et al., 1996). *Mental model similarity* refers to the extent to which mental models are shared among team members. Shared mental representations of knowledge pertaining to teamwork and taskwork enable teammates to work under the same assumptions and have similar expectations regarding the roles and responsibilities of their teammates. They also may foster more efficient strategy development by reducing excessive deliberation (Baker et al., 1992; Cannon-Bowers et al., 1993). Recent empirical evidence suggests that mental model similarity improves coordination processes, which in turn enhance team performance (Marks et al., 2000; Mathieu et al., 2000).

Effective cross-training should provide a way to increase the similarity of teammates’ team-interaction mental models because training focuses specifically on providing members with information about others’ roles and how team members combine their responsibilities to accomplish collective tasks. Positional clarification training is geared not so much at developing additional skills but rather at raising members’ awareness of others’ roles. More intensive forms of cross-training (e.g., positional modeling, positional rotation) come closer to training additional skills and, in doing so, should further raise one’s general knowledge of teammates’ duties. Individuals who do not receive any training on team members’ roles and responsibilities would not be expected to have a comprehensive understanding of how others contribute to col-

lective success, and thus would not share significant team-interaction knowledge.

We expected that cross-training would increase the development of shared team-interaction mental models. Experiment 1 compared teams receiving the modeling and clarification training with those receiving no cross-training. We anticipated that role modeling would increase these shared models more so than a less intense type of cross-training, role clarification. In addition, we thought that both forms of cross-training would increase the development of shared team-interaction models beyond the level of those teams receiving no cross-training.

Hypothesis 1_{Experiment 1}: Teams receiving positional-modeling cross-training will develop more shared team-interaction models than those in the positional clarification cross-training condition, who will yield more shared team-interaction models than those in the control condition.

Experiment 2 contrasted teams receiving the modeling and clarification training with those receiving positional rotation. In this study, we expected that teams receiving positional rotation would have the most similar models, followed by those receiving positional modeling. We expected that teams receiving positional clarification would have the least similar models as compared with the two other conditions.

Hypothesis 1_{Experiment 2}: Teams receiving positional rotation cross-training will develop more similar team-interaction models than those in the positional-modeling cross-training condition, who will have more similar team-interaction models than those in the positional clarification cross-training condition.

Coordination and Backup Processes

Input-process-outcome models view teamwork processes as mediating mechanisms linking variables such as team training with criteria such as team performance. Effective teamwork processes have been defined as members’ interdependent acts that convert inputs to outcomes through cognitive, verbal, and behavioral activities directed toward organizing taskwork to achieve collective goals (Marks, Mathieu, & Zaccaro, 2001). We, as have others, distinguish team processes from *taskwork*, defined as “a team’s interactions with tasks, tools, machines, and systems” (Bowers, Braun, & Morgan, 1997, p. 90). Taskwork represents *what* it is that teams are doing, whereas teamwork describes *how* they are doing it with each other.

Two important teamwork processes are coordination and backup behavior. *Coordination* has been defined as the process of orchestrating the sequence and timing of interdependent actions (Marks et al., 2001). It refers to the management of synchronous and/or simultaneous activities and involves information exchange and mutual adjustment of action (Brannick, Roach, & Salas, 1993) to align the pace and sequencing of team members’ contributions

with goal accomplishment. This feature of teamwork is closely intertwined with taskwork required of the team. The more interdependent the tasks, the more teams rely on coordination as a central process for effective functioning (Tesluk, Mathieu, Zaccaro, & Marks, 1997). Teams experiencing communication breakdowns and those that get out of sync are likely to be experiencing problems with their coordination process. This is what Steiner (1972) referred to as "process loss" due to coordination.

Backup is defined as assisting team members in performing their tasks. Assistance may occur (a) by providing a teammate with verbal feedback or coaching, (b) by behaviorally assisting a teammate in carrying out actions, or (c) by assuming and completing a task for a teammate (Marks et al., 2001). Backup includes the provision of feedback and task-related support as well as the seeking of help from teammates when necessary. Teammates need to be informed of others' role assignments so as to identify what type of assistance is required at a particular time and to effectively back up one another. Backup is critical to team effectiveness, especially in challenging and highly interdependent, time-critical situations in which undetected mistakes by members jeopardize team success.

We expected that shared interrole team-interaction models generated by cross-training would increase the quality of team coordination and backup processes. Sharing team-interaction information has been shown to enhance members' ability to predict how their teammates will coordinate activities (Mathieu et al., 2000). Having similar ideas regarding interrole responsibilities enables members to visualize how each person can contribute to the team objective and where potential weaknesses lie. This knowledge should empower teams to make better decisions regarding how to coordinate actions and synchronize timing of interdependent actions. It should also enhance the quality of backup behavior by enabling teammates to better predict what their teammates are going to do and what type of help they may need. In addition, we expected to reconfirm that effective team coordination processes improve team performance. Thus, we predicted the following for both Experiment 1 and Experiment 2:

Hypothesis 2: Team coordination and backup processes will mediate the relationship between shared team-interaction models and team performance.

Experiment 1

Method

Participants and Design

A total of 135 undergraduates in 45 three-person teams from a southeastern university participated in the study. Twenty-six percent of the students were men, and 74% were women. Their mean age was 19.90 years ($SD = 2.33$ years). We used a between-subjects single-factor design to manipulate cross-training, which consisted of three levels: positional modeling, positional clarification, and a no-cross-training control group. Cross-training was manipulated through the use of training videotapes that provided teams with different levels of interpositional knowledge. Participants were randomly assigned to training condition and to roles within teams.

Experimental Setting

The task used in this study was a PC-based Apache helicopter flight simulator called Longbow2 (1997). Longbow2 was originally designed as

a two-player simulation, but for this study the task was modified to create a three-person team. Three team members worked together as pilot, gunner, and radar specialist to operate the Apache helicopter and were charged with conducting attack missions in challenging battlefields. Roles were divided as follows: (a) The pilot was in charge of flying the aircraft; (b) the gunner operated the weapon systems, which included selecting, loading, and shooting various ammunition; and (c) the radar specialist was responsible for monitoring and interpreting radar systems containing critical enemy information. Team members were given 15 min to take out various enemy ground targets on the battlefield (e.g., surface-to-air missiles, anti-aircraft artillery, enemy tanks). Team members communicated with each other during the simulation through an aircraft cockpit system consisting of interconnected microphone-equipped headphones. There was no redundancy in role functions (e.g., only the pilot could fly the helicopter; only the gunner could select, load, and shoot ammunition; and only the radar specialist had access to enemy radar and waypoint information).

The task was highly interdependent: To perform it effectively, team members had to work together closely. There was no way to effectively complete the task without the integrated contributions of all three members (Tesluk et al., 1997). A good plan of attack aided team performance, although it was impossible to plan for the precise nature and timing of the challenges that the teams faced. The complex and dynamic nature of the task was primarily due to three elements: (a) roving enemy helicopters attempting to shoot down Apaches, (b) the unfamiliar and variable terrain (e.g., valleys, mountains, plains), and (c) unanticipated enemy surface-to-air missiles. Successful performance depended on the ability of team members to coordinate their activities, primarily through the exchange of mission-critical information, so as to kill enemy targets and avoid being killed by enemy forces. Teams received real-time verbal feedback as to whether they had killed a particular target, and they had access to a computer screen indicator of weapon supply levels.

Cross-Training Manipulation

The intent of this manipulation was to compare the effects of two of Blickensderfer et al.'s (1998) cross-training levels and a no-cross-training control condition. All participants received a training program in which they learned how to perform responsibilities associated with their position (e.g., pilots learned to fly and maneuver the plane, gunners learned to select and shoot weapons, and radar specialists learned to interpret radar screens). After task training, teams received one of two cross-training manipulations or the control, all of which consisted of watching a videotape. Team members in the positional clarification condition watched a videotape presenting the responsibilities of the other two team members. Teams that received positional modeling watched a videotape containing (a) the positional clarification training and (b) video clips that modeled each team member performing his or her responsibilities. This condition went beyond what was trained in the positional clarification condition in that participants were able to first hear about and then observe an expert modeling the performance functions of each position. Members of teams in the control condition received no information on the specific roles of teammates. They watched a videotape that contained some general (and study-irrelevant) information about Apache helicopters as well as some additional intrarole task-related information to ensure all conditions were equivalent on the presentation of more general task-related knowledge. All three training conditions (positional clarification, positional modeling, and control) lasted 15 min.

Measures

Manipulation check. Cross-training effects were evaluated by participant responses to a 15-item multiple-choice scale that measured interpositional knowledge (Blickensderfer et al., 1998). Questions asked participants about their knowledge of team members' equipment and task-related

responsibilities. Sample items included "When the helicopter is destroying an enemy, what must the pilot do?" and "Who is responsible for identifying targets?" Participants were given 1 point for each correct item. Items were then summed to form a total score ranging from 0 to 15.

Shared team-interaction models. Team-interaction models were assessed using teammates' individual ratings of the relations among critical task concepts. Subject matter experts conducted a comprehensive team task analysis for each of the team positions and then identified 10 task-related concepts across the three roles that were critical to team interaction for mission success. These included *escape enemy attacks, follow waypoints, identify enemy, position helicopter for targeting, adjust speed, fire weapon, announce enemy approach, adjust altitude, adjust speed, and select target*. Each of the 10 concepts was anywhere from very closely related to not at all closely related to each of the other concepts. For example, identifying the enemy (performed by the radar specialist) and selecting the appropriate weapon for that enemy (performed by the gunner) were quite related. Adjusting altitude was highly related to escaping enemy attacks, though it was far less related to selecting waypoints.

Participants were provided with a matrix that listed concepts across the top and down the side. They were asked to make judgments about the relatedness of each pair of concepts by using a Likert-type scale that ranged from 1 (*not related*) to 9 (*very related*). Following the procedure referred to by Kraiger and Wenzel (1997), these data were fed into the Pathfinder (Schvaneveldt, 1990) computer program, which produced a similarity index (the "C" index) reflecting the overlap among each pair of member similarity matrices on a scale from 0 (*no overlap*) to 1 (*complete overlap*). These three C values (one for each pair of teammates) were then averaged to form the similarity score.

Team coordination processes. Coordination processes were tapped by using expert ratings of two different types of coordination variables, coordination and backup behavior. Coordination refers to interdependent team activities in which team members worked together to execute an action. An example of good coordination is when the radar specialist provided the pilot with navigational information (waypoint directions, enemy locations), enabling the pilot to successfully fly the helicopter in the appropriate direction. Backup behavior refers to the extent to which teammates assisted each other in performing their responsibilities when the responsible teammate was not executing the appropriate taskwork. An example of good backup behavior is when the pilot prompted the gunner to change to the appropriate weapon selection for a nearing target. In this study, backup was also considered indicative of team coordination among members' roles.

All team communication occurring during the performance episodes was audiotaped and rated by two highly trained graduate student subject matter experts. Communication among team members regarding mission-related topics such as discussions of strategies and provision of feedback was not allowed, other than during actual practice sessions and performance periods. Subject matter experts rated separately the overall frequency (i.e., how much it occurred) and quality (i.e., how well it was executed) of team coordination as well as the overall quantity and quality of team backup behavior by using Likert-type scales ranging from 1 (*very poor*) to 7 (*very good*). Interrater reliability correlations were .82 for both coordination and backup processes. The correlation between the coordination frequency and quality dimensions was .90; thus, a decision was made to average the two indices into one index of overall team coordination.

Team performance. Teams were given two goals to achieve during each of the two 15-min performance missions: (a) kill their targets along the mission route and (b) stay alive for the duration of the mission. There were a total of 15 targets along the mission route. The duration of the mission was 15 min, unless either (a) helicopters were shot down before the end of the mission (occurred in 89% of missions) or (b) helicopters took out all of the targets and completed the mission before 15 min elapsed (occurred in 4% of missions). When the latter situation occurred, we credited the team with 15 min of "alive time." Thus, a team's total

performance score was computed as the sum of the number of targets acquired during the course of each mission and the team's minutes of "alive time," averaged over the two parallel missions. Team performance scores could range from 0 (*no targets killed, helicopter killed by enemies immediately*) to 30 (*killed 15 targets, stayed alive for the duration of the 15-minute mission*).

Procedure

Participants were informed at the outset that they would be participating in a 4-hr team performance study. They were also told that they would first be trained on how to operate the simulation, complete some questionnaires related to the simulation, and then conduct two timed performance missions. All participants received 1.5 hr of role-specific task skills training. This training consisted of an interactive videotape requiring participants to periodically stop and conduct exercises developed to aid the learning process (e.g., conduct role-specific maneuvers, complete questionnaires). Three role-specific 15-item position competency tests were administered to participants on an individual basis immediately following training. A sample question from the pilot's test included "To bring the helicopter to a hover, steady the collective at: a) 100%, b) 52%, c) 40% or d) 0%." After participants completed training, they were given the 15-item competency test. Experimenters immediately graded the tests. For each incorrect item, the experimenter spent additional time with participants to ensure that role-based tasks were mastered. In addition, during the initial team practice session, experimenters used coaching and checklists to ensure that all team members reached a basic level of competency on the simulation before advancing further in the experiment. Next, teams received the cross-training manipulation followed by three 15-min practice sessions. Team members were able to communicate freely with each other during practice sessions, but they were not allowed to talk about the experiment during breaks. Though waypoints and terrain were laid out differently (e.g., mountain ranges located at different waypoints), practice missions gave the teams opportunities to practice the same skills needed in the performance task. Team members then individually responded to manipulation check items and completed concept maps, followed by two parallel, counterbalanced 15-min performance episodes.

Results

Manipulation Checks

A one-way analysis of variance assessed mean differences on the interpositional knowledge scale total score across the two cross-training conditions ($M_{\text{Modeling}} = 12.98$, $SD = 2.11$; $M_{\text{Clarification}} = 11.42$, $SD = 1.66$) and the control condition ($M_{\text{Control}} = 10.24$, $SD = 1.92$). Results indicated there was a significant difference across the three conditions, $F(2, 140) = 24.08$, $p < .01$. Tukey post hoc tests revealed significant differences between each of the three conditions.

Means, standard deviations, and scale intercorrelations are reported in Table 1. Correlations indicated that flight simulation experience, PC experience, team gender composition, average team age, mean Scholastic Assessment Test performance, college grade point average, spatial orientation, and team member friendship were not significantly correlated with key study variables.

Hypothesis 1

A one-way analysis of variance indicated cross-training significantly influenced development of shared mental models, $F(2, 44) = 9.84$, $p < .01$. Means were in the expected direction ($M_{\text{Modeling}} = 0.33$, $SD = 0.06$; $M_{\text{Clarification}} = 0.33$, $SD = 0.07$;

Table 1
Means, Standard Deviations, and Correlations Among Variables for Experiments 1 and 2

Variable	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7	8	9	10	11	12	13
Experiment 1															
1. Mental model similarity	0.30	0.08	—												
2. Coordination processes	4.28	1.07	.24	—											
3. Backup behavior quantity	3.01	1.10	.30*	.59**	—										
4. Backup behavior quality	3.81	1.37	.29*	.71**	.69**	—									
5. Team performance	9.02	3.40	.34*	.54**	.50**	.45**	—								
6. Flight simulation experience ^a	0.35	0.52	-.08	-.18	-.20	-.23	-.09	—							
7. PC experience ^b	5.26	1.07	.11	.08	.05	.02	-.08	-.01	—						
8. Team gender composition ^c	3.23	0.81	.22	-.07	.00	-.08	-.04	-.09	.12	—					
9. Average team age ^d	22.19	2.99	-.05	-.20	-.22	-.08	.00	-.07	-.17	-.18	—				
10. Mean SAT performance ^e	1,151.22	90.25	-.06	-.03	.21	.01	.26	-.02	-.05	-.15	.02	—			
11. College grade point average ^f	3.04	0.31	.02	.09	.25	.22	.17	-.07	-.05	.26	-.02	.30*	—		
12. Mean spatial orientation ^g	3.79	0.93	-.08	.28	.09	.05	.18	.31*	-.01	.02	-.13	.13	.20	—	
13. Friendship with teammates ^h	1.78	1.04	.07	-.10	-.02	.06	-.21	-.04	.03	.15	-.19	.02	.08	-.25	—
Experiment 2															
1. Mental model similarity	68.42	19.35	—												
2. Coordination processes	63.11	14.26	.34*	—											
3. Team performance	5.53	3.87	.30*	.46**	—										
4. Team gender composition ^c	2.08	0.70	-.13	.05	-.12	—									
5. Average team age ^d	19.04	0.96	.01	-.09	-.17	.07	—								
6. Flight simulation experience ^a	1.95	0.62	-.06	.07	.04	.06	.07	—							

Note. Analyses were conducted at the team level: $N = 45$ for Experiment 1, and $N = 49$ for Experiment 2.

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

^a Response to the question "In the past year, on average, how many hours per week have you spent playing flight simulation games?" Participants responded on a scale ranging from 0 (*none at all*) to 8 (*7 hours or more*). Responses were averaged across team members. ^b Response to the question "How often do you use personal computers?" Participants responded on a scale ranging from 1 (*never*) to 7 (*every day*). Responses were averaged across team members. ^c Gender composition of team: 1 = team composed of 3 men; 2 = 1 woman, 2 men; 3 = 2 women, 1 man; and 4 = all women. ^d Average of team members' ages (in years). ^e Average team member total Scholastic Assessment Test (SAT) score. ^f Average team member grade point average. ^g Average spatial orientation, as indicated by the Air Combat Effectiveness Simulation spatial ability test. ^h Average team member response to the following question: "Approximately how well do you know the people working with you today?" Responses ranged from 1 (*not at all*) to 7 (*close friends*).

$M_{\text{Control}} = 0.24$, $SD = 0.06$); however, a Tukey post hoc analysis showed that significant differences existed only between the two cross-training conditions and the control condition. Thus, teams receiving positional clarification and positional-modeling cross-training developed mental models with a higher percentage of shared team-interaction knowledge than did teams receiving the control condition, but there were no significant differences in shared mental models between the two cross-training conditions.

Hypothesis 2

We examined team coordination processes as mediators of the relationship between shared mental models and team performance by using a procedure described by Baron and Kenny (1986). To test coordination as a mediator, we first examined whether shared mental models accounted for significant variance in team processes (coordination, backup quality, and backup quantity) and team performance and whether team coordination processes were related to performance. If these paths were significant, we would examine the impact of shared mental models on performance after controlling for team coordination processes.

We examined expert ratings of team backup and coordination processes as the subjective index of team coordination and tested the role of these processes as a mediator of the relationship

between shared mental models and team performance using the same procedures as those outlined in the Experiment 1 Results section. Three indices of process (coordination, backup quantity, and backup quality) were used to tap team coordination. Results from bivariate regression analyses indicated that shared mental models accounted for significant variability in team backup behaviors (for backup quantity, $r = .30$, $p < .05$; for backup quality, $r = .29$, $p < .05$) and performance ($r = .34$, $p < .05$). These findings indicated shared mental models are associated with improved backup behaviors and performance. Results from an additional multiple regression analysis revealed coordination processes explained significant variability in team performance, $R^2 = .42$; $F(3, 44) = 9.97$, $p < .01$; $\beta_{\text{Backup quantity}} = .30$, ns ; $\beta_{\text{Backup quality}} = -.02$, ns ; $\beta_{\text{Coordination}} = .38$, $p < .01$. These findings suggest that as team coordination processes improved, team performance increased as well.

To test for mediation, we entered shared mental model percentage into the regression equation after controlling for team coordination processes. Shared mental models did not produce a significant increment in variance in performance after we controlled for coordination processes, $\Delta R^2 = .03$; $\Delta F(1, 40) = 1.54$, ns . These results indicated the relationship between shared mental models and team performance was completely mediated by team coordination and backup processes.

Experiment 2

Method

Participants and Design

A total of 147 undergraduates in 49 three-person teams from a mid-Atlantic university participated in the study. Sixty-three percent of the students were men, and 37% were women. Their mean age was 19.40 years ($SD = 1.66$ years). We used a between-subjects single-factor design to manipulate cross-training, which consisted of three levels: positional rotation, positional modeling, and positional clarification. Cross-training was manipulated with videotapes that provided teams with different levels of interpositional knowledge and through practice sessions in which members rotated roles within the team. Participants were randomly assigned to training condition and to roles within teams.

Experimental Setting

This study took place in a laboratory setting equipped with a low-fidelity tank battle simulation called Team Wargame Interaction Simulation Training (TWIST; Cheshire, 1993; Marks et al., 2000). Each participant was trained to operate a tank as part of a three-tank platoon. Members communicated with each other during the simulation through a modified aircraft cockpit system that consisted of interconnected microphone-equipped headphones. Participants were required to work as a team from separate but networked tanks to capture enemy pillboxes located in enemy territory. Teams were asked to take over enemy pillboxes, pick them up, and relocate them in friendly territory, where they were rebuilt as allied weapons. Enemy tanks provided an unpredictable threat on the battlefield by searching out and shooting at tank platoon members. The battlefield contained several different types of terrain (e.g., roads, grasslands, and swampland) and obstacles (e.g., water, thick forests, and barriers) that added complexity to tank movement. Enemy pillboxes and enemy tanks attacked platoon members who ventured within range of them. When platoon members were shot and killed, they were reconstituted within 10 s and placed randomly on the battlefield. Thus, although members were not permanently out of the game when killed by enemies, it cost them time to resurface and join the battle.

To effectively perform this task under the given time restrictions (40 min), the three team members had to work together closely. Although some advanced planning facilitated well-orchestrated teamwork, it was impossible to fully anticipate and thus prepare for all team operations because the nature of the environment was challenging, with deadly enemies constantly circling the battlefield in search of members of the tank platoon and its acquired resources. The performance environment was also challenging because there was no single effective strategy for mission accomplishment. Roles were distributed among team members such that no tank could complete all the functions required to capture, move, and then rebuild allied pillboxes. For example, not all team members had the ability to shoot, and only one team member could build defense systems—both of these functions were required for mission success. This task placed a premium on synchronization among tanks because teams could be successful only by coordinating either sequentially (Tank A builds a barrier, Tank B shoots a pillbox, and then Tank C picks it up and rebuilds it on friendly territory) or intensively (Tanks A and B shoot simultaneously at a pillbox while Tank C works as an enemy decoy; Tesluk et al., 1997).

Teams made decisions about what capabilities to use, when to use them, and how different actions would affect mission accomplishment. Successful performance on this task depended on team members' abilities to develop strategies for operating in a complex and dynamic environment, coordinate actions, and carry out various mission-related functions. TWIST provided continuous feedback to each team member during the performance period. Permanent indicators on each of the computer screens

allowed all team members to monitor current resource levels as well as indicators of mission success.

Cross-Training Manipulation

The intent of this manipulation was to expose teams to one of three different cross-training levels proposed by Blickensderfer et al. (1998). All participants received a training program in which they learned how to operate their tank, including the specific responsibilities (e.g., building barriers and bridges, shooting, carrying pillboxes) associated with their position. Following this intrarole task training, teams were given one of three cross-training manipulations, all of which consisted of watching a 14-min videotape and then conducting a subsequent 20-min practice session. Teams in the positional clarification condition watched a videotape that presented information about how different members' roles contributed to collective goal accomplishment. This training simply presented the functions of each team member so as to make all members aware of the responsibilities of each position. Teams receiving positional modeling watched a training videotape containing (a) the positional clarification training video and (b) video clips of each team member performing his or her responsibilities. This condition went beyond what was trained in the interpositional awareness condition in that participants first heard about and then observed an expert modeling the performance functions of each position. Teams in the positional rotation condition received (a) the positional awareness training video, (b) the positional-modeling training video, and (c) hands-on practice time in each of the other two team positions.

Measures

Manipulation check. Cross-training effects were evaluated by participant responses to the following statements: "I understand the responsibilities of my teammates" and "I would feel comfortable switching roles with [my teammate]." Responses were made on a 5-point Likert scale that ranged from 1 (*strongly disagree*) to 5 (*strongly agree*).

Shared team-interaction models. Concept mapping is a measurement strategy used to capture the overlap in teammates' mental models (Marks et al., 2000; Minionis, 1994). Novak (1990) argued that knowledge domains can be measured by linking concepts in a hierarchical structure, which is what the concept-mapping technique aims to accomplish. In the present experiment, participants were asked to choose from 50 concepts important to team interaction and place 12 of them in a prespecified hierarchical structure illustrating the sequence of task-related activities required to accomplish their mission. Examples of concepts included the following: *travel in V formation*, *build barriers*, *shoot pillbox*, and *ambush from forest*. Overlap in team members' concept maps was assessed by the percentage of shared concepts placed identically on the concept maps. Higher scores on the mental model measure (ranged from 0% to 100%) indicated that a greater percentage of concepts were shared by all three members of a team.

Coordination. The measure of team coordination used for this study was a computer-logged objective index of tank distance from the other two tanks on the battlefield. Although team members had access to a paper map of the entire battlefield, they were able to view only approximately one sixth of the map on their computer screens at any given time. Thus, tanks in close proximity could see each other and work together to accomplish the task. Tanks that were farther apart were not able to visually locate each other and were not easily able to work together. Coordination scores indicated the average distance between each pair of tanks (e.g., mean of distance scores between Hawk and Falcon, Hawk and Eagle, and Eagle and Falcon tanks). Coordination indices were objectively computed every minute over the course of a 40-min performance mission and then averaged. Scores were reversed before statistical analysis so that higher scores would represent less dispersion and thus better coordination.

Team performance. Team performance was operationalized as the number of pillboxes captured and rebuilt on the battlefield. Teams were

told to capture and rebuild as many of the 15 pillboxes as they could in the allotted 40 min. Performance scores ranged from 0 to 15.

Procedure

As in Experiment 1, participants were informed that they would be taking part in a 4-hr team performance study. They were also told that they would first be trained on how to operate the simulation, complete some questionnaires related to the simulation, and then conduct a timed performance mission. All participants received 2 hr of individual skills training on tank driving, weapon systems, and team strategies for movement across the battlefield and capturing enemies. This training consisted of a series of videotaped segments interspersed with individual and team practice sessions. Experimenters used coaching and task checklists to ensure that teams reached a basic level of competency on the simulation before advancing further in the experiment. All teams reached a fairly high level of task proficiency before receiving the manipulations. Extensive pilot testing conducted during and after the development of the TWIST training program indicated that teams performed a test mission after training, on average, approximately 70% as well as expert teams did.

Next, teams received the cross-training manipulation followed by a 35-min practice session. Teams in the positional rotation condition spent 14 min of this practice period in other members' roles (7 min per role). The duration of practice sessions was determined from extensive pilot research. Until this point, team members were allowed to communicate with each other only during practice missions. Though the battlefield was laid out differently (e.g., pillboxes located in different locations), practice missions gave the teams the opportunity to practice the same skills needed in the performance task. Team members then individually responded to manipulation check items, completed concept maps, and took part in a 40-min performance period.

Results

Manipulation Checks

A one-way analysis of variance and a Tukey post hoc analysis indicated that participants receiving positional modeling and rotation perceived a greater understanding of their teammates' responsibilities, $F(2, 144) = 44.11, p < .01$ ($M_{\text{Rotation}} = 3.56, SD = 0.99$; $M_{\text{Modeling}} = 3.49, SD = 1.00$), than did those receiving positional clarification ($M_{\text{Clarification}} = 1.94, SD = 0.86$). Teams receiving positional rotation perceived a greater comfort in switching roles with teammates, $F(2, 144) = 65.78, p < .01$ ($M_{\text{Rotation}} = 4.05, SD = 1.14$), than did those receiving positional modeling and clarification ($M_{\text{Modeling}} = 2.58, SD = 0.98$; $M_{\text{Clarification}} = 1.65, SD = 0.86$).

Means, standard deviations, and scale intercorrelations are reported in Table 1. Correlations indicated that computer gaming experience, team gender composition, and average team age were not significantly correlated with key study variables.

Hypothesis 1

A one-way analysis of variance indicated that cross-training significantly influenced the development of shared mental models, $F(2, 46) = 6.92, p < .01$. Means were in the expected direction ($M_{\text{Rotation}} = 74.75, SD = 15.19$; $M_{\text{Modeling}} = 73.75, SD = 14.99$; $M_{\text{Clarification}} = 56.75, SD = 22.36$); however, a Tukey post hoc analysis showed significant differences existed only between the positional clarification condition and the other two conditions. Thus, teams receiving positional-modeling and rotation cross-

training developed mental models with a higher percentage of shared team-interaction knowledge than did teams receiving positional clarification, but there were no significant differences in shared mental models between the positional-modeling and rotation conditions.

Hypothesis 2

Results from bivariate regression analyses indicated that shared mental models significantly predicted coordination, $R^2 = .12$; $\beta = .34$; $t(45) = 2.45, p < .05$, and performance, $R^2 = .09$; $\beta = .30$; $t(45) = 2.10, p < .05$. These findings suggest that the presence of shared mental models improved both team coordination and performance. Results from an additional bivariate regression analysis revealed that coordination accounted for significant variability in team performance, $R^2 = .21$; $\beta = .46$; $t(45) = 3.34, p < .01$, suggesting coordination improved team performance. These significant effects meet Baron and Kenny's (1986) necessary preconditions for a mediation test.

To test coordination as a mediator, we entered mental model similarity into the regression equation, after controlling for coordination, and it did not predict a significant increment in variance in performance, $\Delta R^2 = .02$; $\Delta F(1, 44) = 1.31, ns$. Supporting Hypothesis 2, these results indicated the relationship between shared mental models and team performance was completely mediated by coordination.

Discussion

These experiments sought to examine cross-training as an antecedent of shared team-interaction models and to explore how shared team-interaction knowledge models facilitate team coordination processes and team performance. Findings from both studies indicated cross-training facilitated the development of team-interaction mental models. In addition, both experiments found that team coordination processes fully mediated the relationship between shared team-interaction models and team performance.

Though both experiments found cross-training positively influenced the development of shared team-interaction knowledge, their specific results differed somewhat, adding ambiguity to the question of how much cross-training is sufficient. Experiment 1 compared the two less in-depth forms of cross-training (e.g., positional clarification and modeling) with a no-training control and found teams receiving either type of cross-training developed more shared models than those in the control condition. Experiment 2, designed to test the differential effects of three types of cross-training, found the two more in-depth types of cross-training (positional modeling and rotation) created more shared team-interaction models than did the least in-depth (positional clarification) training condition. This finding suggests that although more intense forms of cross-training created more shared team-interaction knowledge among team members, it was not necessary to provide them with positional rotation to achieve this effect. In other words, teams that received modeling of interrole behaviors developed models that were just as shared as those developed by members with direct hands-on experience in all roles.

Although findings from both experiments support the premise that cross-training affects the similarity of members' interrole team-interaction knowledge, they do not provide a straightforward

message with regard to the question “How much cross-training is needed?” When its results (development of similar mental models) as well as the time and effort investment are taken into consideration, Experiment 1 supports positional clarification as the best cross-training strategy for developing shared team-interaction knowledge, whereas Experiment 2 supports interpositional modeling. However, we must note that the pattern of means was somewhat surprising (i.e., the means for the clarification and modeling conditions were very similar in Experiment 1 yet quite dissimilar in Experiment 2). Furthermore, the clarification condition in Experiment 2 appeared to generate the same level of mental model similarity as the control condition in Experiment 1.

Though there were many similarities across the two simulation environments (e.g., both were dynamic and somewhat unpredictable environments requiring highly interdependent actions for maximum effectiveness), one critical difference may explain the incompatible findings. In the tank simulation, members operated individual tanks, often performed activities individually, and were not always colocated in the same area of the battlefield. In the helicopter simulation, members worked together “inside” a single helicopter in which they were always colocated and working together on the same team task. Thus, team members’ proximity may have operated as a moderator.

This difference in the two experimental task environments might shed some light on when certain types of cross-training interventions are more appropriate. A more intense form of cross-training (i.e., modeling) may be necessary to create shared team-interaction knowledge in task environments in which coordinating the sequence and timing of interdependent actions is critical, yet team members are not colocated and accessibility to information cues about what others are doing is more limited as compared with team members working side-by-side. Modeling goes beyond pure lecture or description to provide a graphical representation of what other members are doing and how they are doing it. This may be a better source of crystallizing members’ understanding of interrole knowledge for those who do not work closely with their team members yet are expected to synchronize interdependent activities.

For example, increasing the interrole awareness of furniture sales, warehouse, and delivery staff—personnel who heavily rely on each other to meet consumers’ needs but who do not often work together physically or temporally—may both enhance coordination and reduce friction. Simply informing sales and delivery staff of warehouse bottlenecking problems may not be enough. Shadowing warehouse personnel for a day would probably be a more effective way to point out the warehouse employees’ responsibilities and challenges, making it easier for them to communicate with each other and to work through coordination problems.

However, in situations in which team members work together in real time on the same task, simply providing members with an explanation of team members’ responsibilities (combined with time spent working together as a team) may be sufficient to create shared understandings of each other’s roles. For instance, road crew members who work together all day are in a position to observe individual team members’ contributions.

We should point out an initial concern regarding an alternative explanation for these findings: Team members with a better understanding of the task might score more similarly on the mental model assessment than those with a less clear understanding, thereby raising team similarity scores solely as a function of

mental model accuracy. To investigate this alternative interpretation for the meaning of mental model similarity, we had six subject matter experts complete the mental model measure used in Experiment 1. Using Pathfinder, we computed similarity indices for each pair of experts and found extremely low scores. Experts then subjectively rated the “accuracy” of each expert’s model by using the graphical output produced by the Pathfinder software. All models rated high in accuracy, providing evidence that there were multiple correct ways to conceptualize the task at hand. Thus, team similarity scores were not simply a function of average team accuracy.

We also found team processes fully mediated the relationship between mental model similarity and team performance across both experimental settings. Consistent with findings by Mathieu et al. (2000) and Marks et al. (2001), more similar perceptions of team-interaction information led to better coordination and backup responses, which in turn improved the team’s ability to accomplish its overall goal. It appears as though shared understandings of interrole behaviors reduce coordination losses (thereby resulting in tighter team coordination), facilitating goal attainment.

Findings such as these raise questions about how much and what knowledge should be shared for effective teamwork. In these experiments, no team members shared identical team-interaction models. In Experiment 2, teams that were one standard deviation above the mean on mental model similarity had approximately 83% overlap in procedural knowledge, and teams that were one standard deviation below the mean shared about 48% of their models. In these experiments, more shared knowledge with regard to team interaction resulted in better coordination. However, more shared knowledge with regard to other types of information, such as team compositional factors, the task, and equipment (Cannon-Bowers et al., 1993), may not be as critical for improving team coordination processes. In many team environments, such as a surgical team, members contribute unique expertise. Coordination processes are not likely to be further enhanced to the extent that all members have identical understandings of how to conduct open-heart surgery; however, a shared conception of how this team of doctors and nurses will work together during the surgical procedure would likely facilitate team coordination and effectiveness.

This point brings up a larger issue concerning the importance of flexible expertise within a given team context. On the basis of the premise that most organizations have limited time and resources to devote to training team members, to what extent should they be cross-training individuals to develop interchangeable expertise among members versus developing depth in a given position? In other words, how much (if any) cross-training would be beneficial in a given team context? Although this study focused only on contrived action teams, we believe that most work teams (e.g., project, service, management, production) would benefit from providing members with at least enough understanding of their teammates’ roles to discuss trade-offs of various strategies and behaviors related to team performance (Mohrman et al., 1995). For teams that place a premium on coordination, interteam feedback, and backup behavior, fairly extensive cross-training (at least positional modeling) probably makes sense. In addition, we suggest that the need for interchangeable expertise may be a function of the severity of the consequences of team failure, the logistics involved in finding an external replacement, and the resource investment in cross-training.

Overall, the present study extends prior research on cross-training in two primary ways. First, we provided a more detailed examination of cross-training as a strategy for team training by investigating different levels that varied in depth and method of presentation. Previous research (Cannon-Bowers et al., 1998; Volpe et al., 1996) has found that teams receiving positional rotation were more effective than those with no cross-training, but further examination of the impact of less in-depth forms (i.e., clarification and modeling) had not been explored. This question has particular importance for organizations considering not only training content but also its costs (e.g., money, time).

Second, this study is the first to link cross-training with shared mental models as a training outcome. Our findings lend support to the idea that shared team-interaction models are an important mechanism through which cross-training affects team processes and performance. A shared understanding of team-interaction information is likely to enable members to coordinate better and faster, to identify where problems occur, and to help those who need assistance. The focus of this study was on action teams, yet we believe cross-training could be useful for the range of teams, to varying degrees. Whereas action teams may benefit from more in-depth cross-training because of their need to work highly interdependently and dynamically, other types of teams might also gain from a better understanding of members' roles and functions. In addition to action teams, Sundstrom (1999) suggested that work teams could be categorized into five other types: project, production, service, management, and parallel. Service teams, for example, might be able to function more effectively with a greater understanding of how each team member contributes to customer or patient care. Project and production teams might also benefit from a better conceptualization of how roles are allocated and who is expected to contribute what.

Both experiments were conducted in experimental laboratories using low-fidelity simulators. We believe the complex environments offered by the TWIST war game and Longbow2 simulations allowed us to design challenging, interdependent environments appropriate for the controlled study of action teams. Although laboratory experiments have made significant contributions to the study of team training (Driskell & Salas, 1992; Mathieu et al., 2000; Weaver, Bowers, Salas, & Cannon-Bowers, 1995), the external validity of the research findings raises concerns, and we suggest future examinations of the impact of cross-training in applied settings.

This research used ad hoc teams assembled for 4 or 5 hr, for the sole purpose of these experiments; thus, these findings may not be representative of teams that have a long history together (J. K. Hackman & Morris, 1975). However, team training research should, at least in part, target newly formed teams with members who do not have established relationships because this is representative of many organizational teams that are candidates for job training.

In conclusion, this study provides evidence of the influence of cross-training on shared mental model development and gives further support to claims that shared mental models influence team coordination processes and performance. Our results highlight the importance of cross-training in a laboratory setting and start to identify what types of cross-training would be most beneficial for action teams as well as when positional rotation may not be beneficial. Continued research in the domain of team training will

provide organizations with a useful empirical base to guide team development efforts. Without clear guidance on team-focused instructional strategies, organizational training dollars will continue to be spent on development of individual strategies for effective performance. Preliminary experimental research on cross-training has found promising results warranting further investigation.

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