Team Training and Transfer in Differing Contexts

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Teams are used extensively in the workplace, and schools have been including teams in classroom learning. However, most theory-based learning research has focused on individuals. This research examined team-level knowledge acquisition and performance in two complex military tasks: An Unmanned Air Vehicle simulation and a peacekeeping simulation. Training occurred in co-located or distributed contexts, and testing occurred in the same or opposite context. Distributed performance was greater than for co-located teams. At initial transfer, all teams showed performance decrements but performance subsequently improved. Results for communication conditions (push-to-talk, no push-to-talk) revealed context effects at test, where using push-to-talk produced a greater decrement in performance. Improvements in both training and learning theory are suggested by identifying several variables that affect team performance.

Key Terms: learning, training, transfer, team cognition, context

In most real world situations, students learn in one context (school) and then are expected to apply their knowledge to a different context (job). Although transfer of learning has been studied extensively (for reviews see Lee, 1998; Singley & Anderson, 1989), most research has focused upon individual learning and transfer. However, most students are expected to learn in groups or teams, and often are expected to perform in teams in the workplace at a later time. Group learning has been studied at a social level, but team training and cognition has only recently become a focus for researchers (Cooke, Salas, Cannon-Bowers & Stout, 2000). Distributed learning has been available for some time with media such as videotape and correspondence courses, but increased use of the internet and the use of other new technologies have made distributed training of individuals and teams more readily available. Distributed team training can be a cost effective means of instruction; however, scholars have reported mixed results regarding team performance in distributed learning conditions (e.g., Hahn; 1990). By combining distributed learning and team training ideas and studying team learning and transfer in co-located or distributed contexts, a greater understanding can evolve regarding learning within collaborative situations and the role that context plays in that learning.

Theory of Transfer Related to Context Change

The predominant transfer theory derives from Anderson's learning theory (Anderson, 1982, 1983). His theory predicts that transfer will occur when overlapping productions between two situations exist (Anderson, 1982, 1983, 1993). A production rule takes the form of IF (condition) THEN (action). For example, one might say, "If it is raining, then take an umbrella." One can imagine that this particular production would be true whether one is in Seattle or in Tokyo. However, note that this might be different if a production were specifically tied to a certain context. For example, after an individual learns how to drive an automatic car, the same productions should fire whenever an individual is driving any automatic car. If, however, a person learns how to drive an automatic car but is then required to drive a manual (stick shift) car, then the productions do not overlap exactly and some transfer will not occur. Thus, when the context (driving a car) is held constant but the task is changed slightly (automatic to manual), a decrement in performance usually results (Singley & Anderson, 1989).

One can imagine that if the context is vastly different then the condition portion of the productions would not overlap and performance should be greatly disrupted. Indeed, in studies of memory or state dependent learning, one can find up to 47% better recall of items when recall is in the same context as learning (Baddeley & Godden, 1980). Similar results have been found for contexts as obvious as drug induced states (Davies & Thompson, 1988; Eich, 1980, 1989) or as subtle as mood effects (Bower, 1983; Ellis,

Thomas, McFarland, & Lanem, 1985; Ellis, Thomas, & Rodriguez, 1984; Teasdale, 1983). However, these results have not always been replicated (Davies & Thompson, 1988; Fernandez & Glenberg, 1985; McDaniel, Anderson, Einstein & O'Halloran, 1989; Saufley, Otaka, & Bavaresco, 1985; Smith, 1994) and contradictory results have been found (Bjork & Richardson-Klavehn, 1987; Smith, 1988). Thus, although a constant context may be better in general; salient cues might overcome contextual effects.

Context might not be solely defined by a change in physical location or an internal change based on chemical ingestion, however. Defining the most relevant aspects of context might be the more important focus for a researcher or instructor (Wickens, 1987). Wickens referred to two types of relevant aspects of context: context alpha and context beta. Context alpha is the surrounding context or environment of a central task, and context might be irrelevant because the demand characteristics of the central task remain constant. Context beta seems to have an effect on a task, because context is needed to clarify the meaning of actions in the face of ambiguity (Wickens, 1987). Baddeley (1982; 1997) proposed a similar context-task model. Context can be independent of the central task, or can be interactive where context "changes the way in which a stimulus is perceived" (Baddeley, 1997, p. 207). Independent (non-interactive) context in this sense has an arbitrary relationship with the central task, while interactive context bears on one's processing of the central task. In the first type, there should be little or no context effects on task performance, but in the second type, if relevant aspects of context are encoded during learning, there should be disruption of task performance at test due to context effects.

Research in human factors psychology lends credence to these context-task approaches. Strayer and Drews (2004) explored a number of audio contexts in relation to a central task, driving, in order to discover types of audio contexts which might disrupt the central task. The researchers found that listening to radio or books on tape did not affect driving performance. In Baddeley's model, those context types might be considered independent. However, Strayer and Drews found that talking on a hands-free cellular telephone significantly disrupts driving performance, and so context becomes interactive in that case. Thus, identifying contexts which become interactive with task should help researchers predict diminished performance in those contexts.

Distributed Training

Under ideal training situations, multiple individuals can be trained together to form effective teams. However, constraints of physical location and time often play a role in limiting team training. One promising solution to these problems is distributed learning. Distributed learning in one form or another has always been of interest to educators, which is usually called *distance learning* (e.g., Boling & Robinson; 1999; Phelps, Wells, Ashworth, & Hahn, 1991). With the increased use of the internet, interest in providing distributed training has increased (Kerka, 1996). The internet provides advantages including the transfer of video and audio in real time, as well as access to repositories of public information that might be difficult to visit in person (Butler, 2000). Bell and Kozlowski (2002), and Cohen and Gibson (2003), suggest that an important defining characteristic of distributed teams is that they are divided by space or are dispersed geographically. Co-located teams work in physical proximity. Some researchers have noted a benefit for distributed learning over traditional face-to-face instruction (Chute, Balthazar, & Poston, 1989). They reason that students must take more personal responsibility and be more active in their learning and this added responsibility results in a benefit for distributed learning.

Studies performed in military settings tend to show no difference in achievement between distributed learners and co-located learners. In three studies that compared distributed and co-located learners using Army participants, Hahn (1990) found no differences between distributed and co-located trainees using Air Combat Command (ACC). Phelps et al. (1991) also found no differences using a Computer-Mediated Communication (CMC) system, and Keene and Cary (1992) showed a benefit for distributed learners over co-located learners using interactive video teleconferencing training. A fourth study by Bramble and Martin (1995) found that community colleges could provide adequate training for the military when using the U.S. Army's two-way audio/video Teletraining Network. Thus, distributed learning is thought to be cost effective, and can be an efficient way to provide training.

On the other hand, distributed learning may have a different meaning in the context of collaborative training. Few studies have examined collaborative distributed learning and even fewer studies have examined team distributed training (Frost & Fukami, 1997; Kerka, 1996). Computer internet/web contexts have generally been designed for the individual (Calvani, Sorzio, & Varisco, 1997); however, groupware and CMC has allowed for the possibility of the delivery of team distributed learning. Results from studies comparing CMC to co-located learning have found mixed results. For example, studies have suggested that CMC can be a hindrance to the creation

of meaning (Mantovani, 1996) and can lead to lengthy decision making (Hedlund, Ilgen, & Hollenbeck, 1998) in comparison to co-located learning. These studies are limited because they tend to focus on organizational and social factors rather than team cognition and performance.

Purpose and Hypotheses

Teams train on a complex task and then are tested in this research. The test represents a different complex task with some overlapping productions. At test, teams remain in the same context, or the context changes from distributed to co-located or vice versa (refer to *Figure 1* for a depiction of context conditions). A slight decrement in performance would be expected for teams staying in the same physical context but performing at test on a slightly different task. However, a larger performance decrement is expected for teams transferring to differing physical contexts. These expected results are tempered by the contradictory research findings discussed above, because a physical context change may not be the context of importance or relevance to the team. If the important context is not the physical context but some other context (for example, a computer simulation), and physical context does not change, then only the decrement for task change at test should occur.

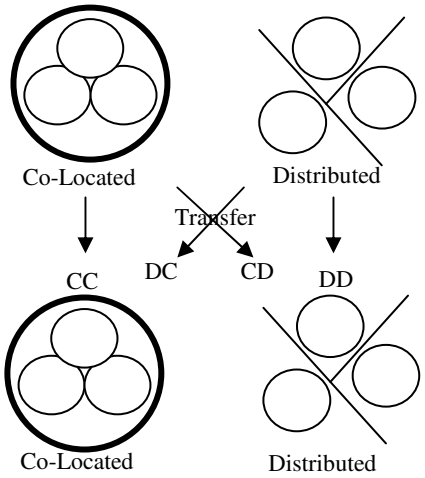

Figure 1. Experimental conditions, experiments 1 and 2
CC = Co-Located Training, Co-Located Test.
CD = Co-Located Training, Distributed Test.
DC = Distributed Training, Co-Located Test.
DD = Distributed Training, Distributed Test.

Individual learning and transfer theory is tested in the following experiments in realistic team training environments to determine whether the same results for individual learning and transfer would hold for team learning and transfer. The two experiments described in this research are conducted using two different complex military simulations: an Unmanned Air Vehicle (UAV) simulation, and a peacekeeping simulation. Each simulation mimics real life parameters, but allows for experimental control. These simulations were chosen for this research because they provided for three persons to work together as a team, where each person held a distinct role with differentiated tasks and duties (Salas, Dickinson, Converse & Tannenbaum, 1992). Further, each simulation was a complex task, where team learning would occur with some difficulty over several missions. Also, the two simulations afforded transfer capabilities to a different but similarly-difficult simulation task.

EXPERIMENT 1: UNMANNED AIR VEHICLE (UAV) SIMULATION

METHOD

Participants were 27 teams of three students each, all with no previous military experience, attending New Mexico State University. Participants signed up to participate on days and times that were convenient for them. Twelve teams were composed of males and females, and there were five teams with all-female and ten teams with all-male participants. All participants were between the ages of 18 and 30. Participants received $6 per hour.

Design

Participants were assigned to one of four conditions: (a) train co-located and test co-located, (b) train distributed and test distributed, (c) train co-located and test distributed, and (d) train distributed and test co-located (refer to *Figure 1*). All participants were trained in co-located (face-to-face) or distributed contexts for five missions. At test, there were three missions, and teams remained in the same or changed to a different physical context.

Materials

This experiment used the CERTT (Cognitive Engineering Research on Team Tasks) Lab, a Department of Defense (DOD) funded laboratory for studying team cognition (Cooke & Shope, 1998, 2004). The hardware consists of three participant consoles and an experimenter control workstation that can be arranged to simulate distributed or co-located team contexts.

Software.

The synthetic task environment (STE; see Martin, Lyon & Schreiber, 1998 for a description) was an abstraction of Predator UAV operations (Cooke, Rivera, Shope & Caukwell, 1999; Cooke, Shope, & Rivera, 2000). The UAV-STE was abstracted from

results of cognitive task analyses (Gugerty, DeBoom, Walker, & Burns, 1999) of the Predator operational context, with the goal of providing an experimenter-friendly test-bed for the study of team cognition.

The goal of the simulation is for the team to fly the UAV to waypoint targets and orient the vehicle so that targets can be photographed. Task scenarios used for training and test included a number of waypoints selected from a database of waypoints created for the UAV simulation. Waypoints were specific locations shown on a map. Team members were to work together to obtain photographs of targets on the ground at each waypoint. For a specific explanation of the simulation, refer to Cooke, Kiekel, and Helm (2001) and Cooke et al. (2000).

The three team members held different randomly-assigned roles, and missions could only be accomplished through interaction and information sharing among the members. The roles were Air Vehicle Operator (AVO), Payload Operator (PLO), and DEMPC (Data Exploitation, Mission Planning and Communication Operator). AVO controlled airspeed, heading, altitude, and monitored UAV systems. PLO adjusted camera settings, took photos, and monitored camera equipment. DEMPC determined flight paths under varying constraints. Each team member was trained on unique material and had access to two displays of information, and monitored a unique screen to avoid system alarm states.

Communication. Participants communicated over aviation-quality headsets and an intercom system which allowed for recording of communication, duration, and speaker and listener identities. Participants pushed a button and held it down when they communicated with other team members or the experimenter (push-to-talk).

Training materials. Because each team member was trained on unique material and had access to two unique displays of information, training material was different for each team member. The training program included a tutorial and 30 min of individual hands-on skill training. Team success depended upon individual learning by team members before the team could achieve optimal performance (Denning & Smith, 1997; Randall, 1999) and therefore, assessment of individual learning was performed, as well as team assessment. A set of multiple choice questions were used for this assessment (e.g., whether the individual had learned what roles were present, how well one had learned declarative knowledge associated with one's role).

Procedure

Each person trained individually on a computer for his/her specific role. Training was not considered complete until each individual had achieved a level of proficiency in their portion of the training sessions as measured by the assessment. When participants reached criterion, the team performed five training missions with feedback provided. Experimenters checked off skills as individuals mastered them (e.g., AVO needed to change altitude and airspeed; PLO needed to take a good photo of a target). Performance scores at team and individual levels were provided at the conclusion of missions.

Team performance was measured using a composite score that was based on mission variables, including number of targets successfully photographed, amount of film used, time spent in alarm states, amount of fuel used, and number of critical waypoints visited. Penalty points for each of these variables were weighted and subtracted from a maximum score of 1,000 points (Cooke, Kiekel, & Helm, 2001, p. 302).

For the co-located condition, three consoles were placed in a horseshoe shape in the laboratory. Team members sat at their consoles and could physically interact with each other. For the distributed condition, participants worked in separate areas and could not see each other. Team members were led into areas at different times and took breaks in separate rooms.

The study was conducted over two days with one day separation. Teams completed eight missions that lasted 40 min each, with three practice missions on the first day, two practice missions the second day, and three test missions (without feedback).

Results

A dedicated computer automatically recorded measures of individual and team performance. The numbers of teams in each condition were: CC: 8 teams, CD: 5 teams, DC: 5 teams, and DD: 9 teams. Power was calculated at .80, and a large effect at $\alpha = .01$ was expected (Cohen, 1992). Performance data are shown in *Figure 2*.

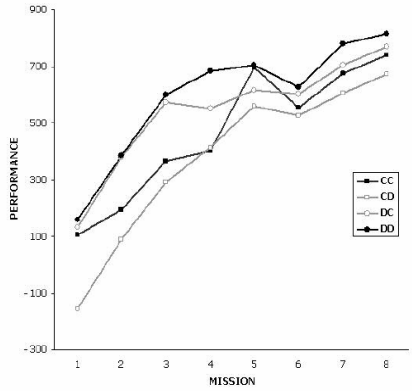

Figure 2. Experiment 1: Team performance results

Training. There were 13 teams in the co-located condition and 14 teams in the distributed condition. A repeated measures ANOVA was performed with co-located versus distributed (training context) as the independent variable and performance on training missions as the dependent variable. Distributed teams performed significantly better on the training missions than co-located teams, $F(1, 25) = 7.0$, $p < .01$, $d = 2.74$. Performance improved over missions, $F(4, 100) = 45.9$, $p < .01$, but there was no interaction between missions and training context. The means of co-located and distributed teams are shown in Table 1.

Table 1: Performance of Co-located versus Distributed Teams

	Missions				
	Mission 1	Mission 2	Mission 3	Mission 4	Mission 5
Co-located	5.3	153.2	337.9	406.2	643.7
sd	(57.2)	(47.2)	(55.3)	(87.1)	(50.8)
Distributed	141.7	380.6	581.4	597.4	646.9
sd	(42.2)	(58.9)	(51)	(67.5)	(67.9)

Test. A repeated measures ANOVA was performed using performance on the first mission at test (Mission 6) as the dependent variable. The three independent variables were (1) performance on training missions (Missions 1 through 5), (2) training context (co-located, distributed), and (3) test context (same, different context). As predicted, all teams suffered a decrement in performance at initial test, $F(1, 127) = 14.9$, $p < .01$, $d = 1.61$; mean mission 5 = 645.4, $SD = 42$; mean Mission 6 = 577.6, $SD = 42.3$. Results showed a decrement in performance due to the test, consistent with Singley and Anderson's (1989) results for interference between tasks. Though performance declined at the initial test mission, all teams improved from test mission 6 to test mission 8. A repeated measures ANOVA showed $F(2, 46) = 11.7$, $p < .01$ (mission 6 mean = 577.6; mission 7 mean = 690.8, $SD = 40.8$; mission 8 mean = 753.0, $SD = 33.5$). These results are also consistent with data reported in Singley and Anderson (1989).

EXPERIMENT 2: PEACEKEEPING SIMULATION

In Experiment 1, distributed condition teams performed better than co-located teams in training. Also, in all conditions, teams suffered a performance decrement (with no one condition suffering a greater decrement) in performance in the initial test mission after transfer. These results should be viewed with some caution because co-located conditions did not fully allow participants to look at each other or communicate easily with each other physically, since the arrangement of consoles was in a horseshoe configuration, and participants pushed buttons and held them down to communicate, even in co-located conditions.

In addition, the computer simulation was difficult, and demanded a large portion of the participants' attention. The complex task may have created a context and actually allowed the distributed condition, with its greater isolation from the physical distraction of other teammates, to interfere with the complex task itself. As Smith and Vela (2001) indicate in a meta-analysis of context effects, greater task processing lessens encoding of physical context, thereby lessening transfer interference. Thus, context is not just represented by geographic location but also includes the computer simulation context. If task demand is high in the simulation, then differences in physical context may not make as much of a difference, and may be independent of the central task (Baddeley, 1997).

In Experiment 2, a different complex simulation was used and physical differences were increased in co-located and distributed conditions. The co-located condition used smaller computer workstations with participants facing each other, and the distributed condition used three computer workstations in three separate rooms.

In Experiment 2, the effect of communication context on learning and transfer is also explored (push-to-talk; no push-to-talk). The type of audio equipment used for team verbal communication represents another form of context in this research. Teams in Experiments 1 and 2 use push-to-talk communications as a way of coordinating and monitoring team efforts, but a comparison set of teams in Experiment 2 have open communication lines, without pushing buttons to communicate. Push-to-talk has been a traditional communication method used in the military, and recently has emerged in cellular radio communications (e.g., Woodruff & Aoki; 2003). However, Kun, Paek, and Medenica (2007) found that push-to-talk communications, coupled with inaccurate automotive speech recognition systems in cellular phone communications, hinder driving in a high-fidelity simulation. Therefore, we believe that teams performing a complex task together should benefit by having open communication channels in Experiment 2, since the act of pushing-to-talk might hinder communication and task performance, becoming interactive with the central peacekeeping task (Baddeley, 1997).

Method

Participants

Sixty teams of three students each, all with no military experience, participated at New Mexico State University. Participants signed up to participate on days and times that were convenient for them. A majority of the teams were composed of males and females (46), but there were seven teams with all-female and seven teams with all-male participants. Participants ranged in age from 18-30. Participants received $6 per hour as compensation.

Design

The same design as in Experiment 1 was used. For 20 of the teams, team members were required to push-to-talk (PTT); whereas, for 40 of the teams, team members did not use push-to-talk technology (NPTT). Thus, communication (PTT; NPTT) was manipulated in Experiment 2 as a communication context.

Materials

Simulation software. Aptima's Dynamic Distributed Decision-making (DDD) software was developed for the Army and is used by soldiers (see Aptima Corporation, 2005; also see Hollenbeck & Ilgen, 2000; Ilgen & Hollenbeck, 1999, 2000; Kleinman, Young, & Higgins, 1996). The software allows for the team to interact through standard PCs and the internet. The internet connection allows members to immediately see other team members' actions on their screens. Participants communicated with each other over headsets. In this experiment, two communication conditions were designed in order to replicate results from Experiment 1 using PTT, and to test a second communication condition which allowed for open communication without pushing buttons (NPTT). The participants in the PTT condition were required to push a button and keep it depressed in order to talk. Communication could only occur when the button was depressed. NPTT participants spoke into their headsets without the need to push buttons to communicate. Communication was digitally recorded.

In the task, teams used role-specific resources to respond to problems that would arise within peacekeeping operations in Bosnia. For example, if there was a problem in the refugee camp, dismounted troop resources could be sent to respond to the problem. As in Experiment 1, training and transfer missions differed in two respects. Participants received feedback in training missions and different problems arose during the mission.

Each team member acted in a specific role. The G2 (army intelligence officer/general staff) could send in a variety of intelligence resources to gather information. G3 (army operations officer/ general staff) could send in a third party to intervene in problem situations, and could gather information from infantry and police activity. S3 (army operations officer/unit staff) controlled patrol resources that gathered information or carried out security operations. S3's resources included troops that could directly interact with local populations.

In addition to these team roles, the software allowed for five different total events that could occur in each of four geographic event areas (Crowd, Elections, Refugees, Memorial). For training, participants received three of the events for each location in each mission, and for test after transfer, participants received two novel events in each mission. A participant could click on the Crowd, Elections, Refugees, or Memorial locations to extract more information about a problem in order to better determine what resources to send in, or to ask some other team member to send in. After an event had occurred and resources were sent to an area, feedback appeared in the form of a report during the simulation. Each team member could continuously monitor his/her own performance score and overall team score in each mission. Events were timed and if no resource or few resources were sent in, escalation in a later event at the same location could occur.

Computer-based training materials. A self-paced computer-based tutor was developed that provided information on the simulation and about Bosnia. Tutoring on the software simulation included a description of the individuals' specific role and responsibilities, as well as what other participants' roles were, what icons on the map meant, and where and how to find information as the simulation progressed (scores, icons for events, etc.). The basic material on Bosnia included a history, maps of the conflict and the current state of affairs. Periodically during training, the computer presented knowledge-based assessment questions and participants needed to correctly answer these questions before being allowed to continue with the material.

Procedure

The same procedure as Experiment 1 was used in Experiment 2; however, teams performed six training missions and two test missions.

Results and Discussion

Description of Data

Individual and team performance scores were automatically calculated. One PTT team was eliminated from the training analysis due to missing performance data for one mission. Power was calculated at .80 for this experiment, and a medium effect at $\alpha = .05$ was expected (Cohen, 1992).

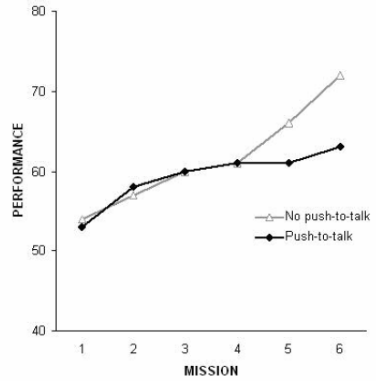

Figure 3. **Experiment 2: Push-to-talk versus no-push-to-talk team performance results**

Push-to-talk versus no push-to-talk. Mean PTT and NPTT team performance for the six training missions is shown in *Figure 3*. A repeated measures ANOVA was performed with PTT versus NPTT as the between subjects variable, and performance in training missions 1-6 as the within subjects variable. Teams in the NPTT condition out-performed PTT teams, $F(1, 57) = 3.9$, $p < .05$, $d = 0.35$. Since results for training were different for the two communications context conditions, the two groups are treated separately in the team performance analyses.

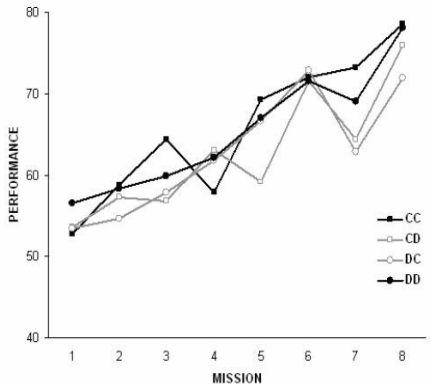

Figure 4. **Experiment 2: No push-to-talk team performance results**

PTT Analyses

PTT training data. Overall performance data for PTT are shown in *Figure 4*. Eleven co-located and 8 distributed teams participated. Means for training missions are shown in Table 2. A repeated measures ANOVA was conducted using Missions 1-6 as the within subjects variable and co-located versus distributed as the between subjects variable. All teams improved from the first to the last mission, $F(5, 285) = 24.10$, $p < .01$. All teams received the same initial declarative training; however, distributed teams performed better than co-located teams on training missions, $F(1, 17) = 6.1$, $p < .05$, $d = 0.99$.

Table 2
Push-to-talk Training with Co-located versus Distributed Teams

	Missions					
	Mission 1	Mission 2	Mission 3	Mission 4	Mission 5	Mission 6
Co-ocated	54	55	56	58	60	51
sd	(2.7)	(1.8)	(1.5)	(2.3)	(1.3)	(2.4)
Dist-ributed	52	61	65	64	63	67
sd	(3.3)	(1.5)	(2.2)	(1.2)	(3.3)	(1.6)

Note. The standard errors are shown in parentheses.

PTT test data. Five teams participated in the CD condition; 6 were in CC; 4 were in DC; and 5 teams participated in the DD condition. A repeated measures ANOVA was conducted with training missions as the repeated measure, Mission 7 performance score was the dependent variable, and training context (co-located versus distributed) and test context (same context versus different context) were the independent variables. Teams in co-located training increased performance at test when compared to teams with distributed training, $F(1, 118) = 5.8$, $p < .01$. However, an interaction between training and test contexts was significant, $F(1, 118) = 55.4$, $p < .01$. Rather than decreasing in performance, as in Experiment 1, all team context conditions increased, except for the DC condition. Results contradict findings from Experiment 1 and findings by Singley and Anderson (1989).

A repeated measures ANOVA was conducted with Missions 7 and 8 as the within subjects variable, and co-located versus distributed and same versus different context as between subjects variables. Teams improved from Missions 7 to 8, $F(1, 16) = 5.9$, $p < .05$, $d = .47$ (mean Mission 7 = 65.8, $SE = 2.4$; mean Mission 8 = 70.5, $SE = 2.1$). No significant increases were found in conditions except DC, where mean Mission 7 = 57.8, $SE = 3.0$; mean Mission 8 = 73.4, $SE = 2.6$. CD and DD teams increased performance from Missions 6 to 7, and CC teams did not improve from 7 to 8. Distributed teams who changed context showed diminished performance.

NPTT Analyses

NPTT training. Twenty distributed and co-located NPTT teams participated. Means are displayed in Table 3. A repeated measures ANOVA was performed using Missions 1-6 as the within subjects variable and co-located versus distributed as the between subjects variable. All teams improved from the first mission to the last training mission, $F(5, 190) = 29$, $p < .01$. No difference was found between conditions in training, $F(1, 38) = 0.2$, $p = .67$, $d = .05$.

Table 3
No Push-to-talk Training with Co-located versus Distributed Teams

	Missions					
	Mission 1	Mission 2	Mission 3	Mission 4	Mission 5	Mission 6
Co-located	53	58	61	60	64	72
sd	(1.8)	(1.3)	(1.6)	(1.4)	(1.8)	(2.2)
Distributed	55	56	59	62	67	72
sd	(2.3)	(1.4)	(1.3)	(1.4)	(1.5)	(2.4)

Note. The standard errors are shown in parentheses.

NPTT test. An analysis of covariance (ANCOVA) was performed with training missions as the repeated variable, first test mission (Mission 7) performance as the dependent variable, and co-located versus distributed and same context versus different context as the independent variables. Although *Figure 5* shows that all teams suffered a decrement in performance from training to test, the main effects of co-located versus distributed training and different versus the same context overwhelm the results, $F(1, 239) = 10.4$, $p < .01$ and $F(1, 239) = 67.0$, $p < .01$ respectively. Teams that trained in the distributed context showed a significantly greater performance decrement, and teams that changed contexts experienced a greater decrement than teams that remained in the same context.

A repeated measures ANOVA was performed with Missions 7 and 8 as the within subjects variable and co-located training versus distributed training and different versus same context as the between subjects variables. Similar to Experiment 1, all teams improved from Missions 7 to 8, $F(1, 36) = 22.9$, $p < .01$. A main effect for different contexts was found, where teams who transferred to the different context showed a larger performance increase from Missions 7 to 8, $F(1, 36) = 5.7$, $p < .05$ (mean difference for different contexts = 10.3, $SE = 2.9$; mean difference for same contexts = 7.2, $SE = 2.1$). Taken with the test results above, when NPTT communication was employed, context change effected a greater change in performance than other factors.

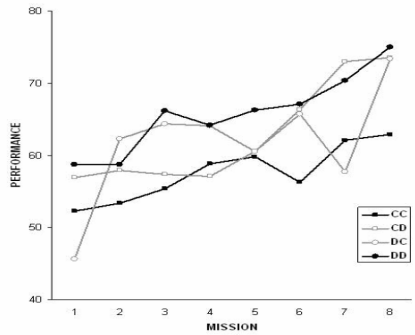

Figure 5. **Experiment 2: Push-to-talk team performance results**

General Discussion

This research examined the effects on teams when they train in the same location (co-located) or in separate locations (distributed) and when the transfer to test occurs in the same context or in different contexts. Previously, research with individuals has shown extensive context effects when participants change contexts but some contradictory results have also been found (e.g., McDaniel et al.; 1989). Two experiments were conducted in this research using two different simulations but each held essentially the same design.

Overall Team Performance

We were primarily interested in whether changes in physical context affect team performance in the same way that they tend to affect individual performance. In Experiment 1, distributed teams performed better than co-located teams in training but at test, no change of context effects were found, where change of context would result in poorer performance. All teams performed lower on the first test mission after transfer than on the last training mission and all teams increased performance for the final missions.

In Experiment 2, a difference was found in communication context between PTT and NPTT teams. In training, distributed PTT teams performed better than co-located teams; but at test, co-located teams performed greater than distributed teams. All teams increased performance for the final test mission. On the other hand, the NPTT condition evidenced no differences between distributed and co-located teams during training. In addition, at transfer, teams who changed context (co-located to distributed or distributed to co-located) performed less well than those teams who stayed in the same context. Although all teams again improved between the final two test missions, teams that changed context increased

performance at a significantly greater rate (i.e., they bounced back).

Generally, one would expect differences in results across experiments because some variables changed between the UAV and peacekeeping experiment. Critical changes were: a) hardware change from large consoles to standard computer desks and low profile headphones, b) UAV simulation to peacekeeping simulation, and c) PTT and NPTT communications conditions. Nonetheless, there were interesting consistencies in the results across the two experiments.

Training results for Experiment 1, which included PTT communications, were similar to those for the PTT condition in Experiment 2. Distributed teams performed better on training trials than co-located teams. One explanation is that the task was difficult to learn and therefore distributed teams performed better because they did not have the distraction of interacting in the physical presence of others and could focus primarily on the materials at hand. However, in Experiment 2, with an NPTT communications protocol, no differences in conditions were found. Therefore, even if task difficulty played a role in distributed versus co-located training, some other factor may be more important and general across experiments.

Another explanation is that pushing buttons to communicate with other team members adds to cognitive load and affects performance. Co-located teams may have found it awkward to use PTT when sitting face-to-face with other people. Further, most undergraduates do not have training in PTT communications, unless they have used cellular telephones with that technology. PTT may have become an interactive context with the simulation (Baddeley, 1997), because NPTT teams did not show the differences in physical context conditions.

For transfer, results differed between experiments and between comparable PTT conditions in Experiments 1 and 2. Results in Experiment 1 suggest that task interference at test played the largest role in determining test performance. However, this is not the same for the Experiment 2 PTT conditions. The test situation was at the same level of difficulty as the training missions, so the transfer missions may have become additional learning trials and increased performance should be expected. The only condition which did not increase performance was the DC condition. Performance for this condition was likely diminished in part by the PTT technology for the same reason that co-located teams' performance diminished during training. For the NPTT condition, assuming the same level of difficulty at test as the PTT, the same increase of performance is expected but was only obtained for the CC teams. The other conditions decreased in performance with the largest decrease for those teams changing context. Thus, for NPTT, transfer (physical context change) played the most important role in the decrement of performance with test playing a lesser role.

In summary, interference (decrement in performance) was found in Experiment 2 in the distributed to co-located PTT teams but not for other conditions. This supports the idea that physical context change (context effects) can be found in certain situations. However, when a task is difficult to learn, such as when PTT is added to an already demanding simulation task, then attention must be focused in order to accomplish the task, and a dual task, such as pressing a button while talking, may be difficult and may become interactive with the central task. The dual task may become even more difficult when it is considered unnatural (such as when one is sitting across from someone else). Thus, task difficulty and interactive context may affect whether context effects are evidenced. These results are consistent with the literature on context and memory. Smith and Vela (2001) indicate that physical context effects are fairly reliable but may be affected by other variables, including task difficulty. This would be consistent with results found for PTT in both Experiments 1 and 2. This explanation reflects the complexity of transfer and defining the critical context for transfer to occur. Whatever is most salient to the participant or to the team (or causing the most difficulty in the learning context) thus defines the critical context.

Theory of Learning and Transfer

During learning, people form productions based upon the skills and tasks to which they are exposed (Anderson 1982, 1983). These productions become stronger over time and performance improves along a learning curve (Pirolli & Anderson, 1985) similar to that found in this study. In the PTT conditions for both experiments, distributed teams performed better than co-located teams. These results could be due to interference with the desire to speak to someone directly when in a face-to-face situation. Speaking directly without pushing a button is a more automatic response and in order to perform well in the PTT conditions, participants must inhibit this automatic response (refer to Hull, 1952).

Anderson's theory of transfer posits that overlapping productions result in transfer (Singley & Anderson, 1989). The theory predicts a slight decline in performance at test but subsequent improvement. Focusing solely on conditions where physical context did not change, results from Experiment 1 are consistent with this prediction, but the results from Experiment 2 are not uniformly supportive of this

prediction. Because experiments included change of context conditions, some other mechanism to handle the change in physical context must be included.

One can imagine that the physical environment could be encoded into the condition side of the production rule and prevent or deter transfer from occurring. For NPTT, there was a strong context effect indicating interference. However, in Experiment 1, changes in context conditions diminished less and for PTT, teams that changed context performed better at test.

If a situation is not exactly the same, transfer can still occur. As Lee (1998) has argued, transfer may be a more active process than is suggested by overlapping productions. It may be a matter of noticing critical similarities and ignoring superficial aspects (which is, however, difficult for novices to do). Other aspects of a situation may also be important and the relevance of various parameters may be what matters most. In this study, without PTT and controlling for test difficulty, physical context became important. However with PTT, physical context became less important for some and more important for others. That is, for Experiment 2 PTT, the distributed to co-located condition performed lower at test. This result was probably due to PTT in a more rigorous environment – an interaction between hardware and environment. Thus, treating the condition side of a production rule as a series of variables with different relevance ratings may more accurately reflect transfer in complex situations.

Implications

In these experiments, team performance at test was similar to findings in past research which investigated individual performance at test. Team transfer can be hindered under a range of potential circumstances but there is really no uniform rule that can be applied. Although scholars should examine all possible factors that could play a role in performance to determine which ones are most critical to team learning, a good place to start would be to examine the task itself. For example, if the task creates an especially compelling context, other factors, such as physical context, may play a smaller role. In addition, the task may include hardware necessary to execute the task; in this case, PTT. In previous transfer and interference research, Singley and Anderson (1989) found that a decrement in performance occurs at the point of interference but that individual performance recovers, where individuals perform better after initial transfer. Results obtained across both experiments support this finding for teams. If a team trains in distributed areas and then are brought together to perform a task, an initial decrement in performance may be found but recovery will occur. For example, military personnel could be trained at specific training sites across the country and be brought together for a peacekeeping activity in another country. However, we do not really know how much of a performance decrement will be incurred or how quickly recovery will occur. If the performance decrement is high, it may significantly impair the ability to recover to an original performance level. In this study, the decrement was not so severe and performance surpassed its original level; however, further research should be performed to examine the parameters involved in determining the extent of performance decrement that greater context changes could effect.

Future Directions

Results of the studies reported here suggest important future directions in teams research. Although we found that PTT may be a critical context factor, task difficulty provides a context for a team which may predict test performance. PTT was used in Experiment 1 primarily to simulate hardware used in the military. Further testing with PTT would not necessarily provide information about basic processes, unless extensive practice with PTT is provided before actual missions are performed.

Another direction that is much more challenging is the issue of the provision of more adequate feedback and examining more configurations for both team communications and physical environment. Because communication occurred in our studies via headsets, all verbal communications were captured. Recent developments in automatic analysis of text could be applied to automatic analysis of team communication when performing a task, if communication could be automatically transcribed (Foltz & Martin, 2004). Note that this is dependent upon the current form of verbal communication. Several other configurations of communication and physical context are possible.

Some physical contexts are not as pure as those we tested in Experiment 2. Instead, four team members may be in a van with two next to each other, one in the front seat with equipment and the other driving. Distributed team members may be able to see the other members, but the team is geographically separate. Thus, the number of possible communications and physical contexts could be varied and should uncover other issues in team training and transfer.

Conclusion

The goal of these studies was to examine distributed versus co-located training and transfer to similar or different environments. Distributed training was not always detrimental. In addition, change of context is not always detrimental but can be when other factors do not play a large role in either training or ability to perform the task. For example, hardware factors, such as communication equipment, can play a

large role in transfer. Results of these studies are consistent with previous literature on individuals. Examining teams as they perform missions in different contexts can successfully inform and extend current theories of training and transfer.

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