CHANGES IN TEAM COMPOSITION AFTER A BREAK: BUILDING ADAPATIVE COMMAND-AND-CONTROL TEAMS

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An experiment exploring the effects of team composition on the acquisition and retention of team performance and cognitive skill is reported. Team performance was measured in the context of photographing ground targets in an unmanned aerial vehicle synthetic task environment. Team process was taken as a measure of team cognition. Experimental results include the findings that team mixing and longer retention intervals have a short lived deleterious effect on team performance immediately after the interval, while team mixing has a positive effect on team process after the interval. These findings suggest that changes in team composition and retention interval can lead to improvements in team cognition if a brief decrement in team performance post-interval can be afforded. These results are interpreted as perturbation of established coordination patterns due to team mixing leading to more flexible and adaptive teams. Implications for process-oriented research are also considered.

INTRODUCTION

Command-and-control (C^2) tasks in military and civilian (i.e., emergency response) domains are challenging from a team perspective due to factors that include a lack of familiarity among team members and extended intervals with little or no team training. These factors are likely to play a pivotal role in team performance and the team cognition thought to underlie that performance.

Team cognition has been commonly conceptualized as knowledge-oriented with the focus on task and team knowledge that is shared among team members. Shared in this context often means commonly held, but may also mean distributed or complementary (Bolstad & Endsley, 2003; Cooke, Salas, Cannon-Bowers, & Stout).

Alternatively, a process-oriented perspective is that team cognition is more than the sum of the knowledge of individual team members. Instead, it emerges from the interplay of the individual knowledge of each team member and team process behaviors (Cooke & Gorman, 2006). Our focus is on interaction and team process more than team knowledge, and constructs like team coordination and adaptation take a front seat to shared knowledge. Coordination is the *timely and adaptive sharing of information among team members*.

These two perspectives have different implications for how team cognition is measured and modeled with the knowledge-oriented perspective relying on knowledge elicitation and cognitive modeling and the process-oriented perspective relying on process and time series measurement and dynamical systems modeling.

In this paper we present a study that examines the impact of a retention interval during which teams received no training and team member familiarity for which team composition was the same or mixed after the interval on team performance and cognition. The context for this study was a three-person simulation of C^2 of a Predator drone (CERTT Lab's UAV-STE; Cooke & Shope, 2005). In order to examine effects from both perspectives of team cognition we took a variety of knowledge-oriented and process-oriented measures. In this paper we limit our discussion to team performance and process measures.

Acquisition and retention of cognitive skill in individuals has a long history of research leading back to Ebbinghaus (1885/1913). However acquisition and retention of cognitive skill by teams has received little attention (but see Rhodenizer, Bowers, & Bergondy, 1998). As a result, there are many practical questions that have not yet been answered such as 1) How long can team coordination processes persist without retraining? 2) How much retraining if any, is needed? 3) What processes are lost or diminished? And 4) How can we train for maximum retention of team process? Finding answers to these questions also has theoretical implications. For instance, there are few instructional design guidelines for designing instruction for teams, and almost nothing about team learning and retention guidelines. Finally, how does the *ad hoc* nature of C^2 teams that may be composed "on the fly" after long periods of inactivity affect team performance and cognition? In this paper we specifically address this last question. In terms of team performance we hypothesize that teams will suffer performance deficits with longer retention intervals (Bryant & Angel, 2000; Schendel & Hagman, 1991) and in the face of new team members (e.g., Katz, 1982).

METHOD

Participants

Forty-three three-person teams of volunteers (unfamiliar with other team members) from the Arizona State University Polytechnic Campus community participated in one 6.5 hour session and one 3.5 hour session which was scheduled either 3-6 (short interval) or 10-13 (long interval) weeks after the first session. Individuals were compensated for their participation by payment of $10.00 per person hour with each of the three team-members on the highest performing team for the first session receiving a $100.00 bonus.

Task

CERTT's UAV-STE task involves three team members who must interact in order to photograph ground targets during 40-minute missions (Cooke & Shope, 2005). Each team member plays a specialized role: AVO (pilot), PLO (photographer), and DEMPC (navigator). In addition, each team member monitors warnings and alarms specific to his or her role. Thus the task requires a high degree of coordination, mostly through communication over headsets.

Design and Measures

Retention Interval (Short vs. Long) and Team Composition (Same vs. Mixed) were manipulated as between-subjects factors. Dependent measures were team performance, team process, team coordination, team situation awareness, teamwork knowledge, and taskwork knowledge; however this paper focuses only on team performance and process

Team performance was measured for each of eight missions and was a composite outcome score based on components such as number and rate of successful photographs, time spent in alarm or warning states, consumables used (i.e., fuel and film), and mission time. Penalty points based on the rate of executing these components were weighted *a priori* in accord with importance to the task and subtracted from a maximum score of 1000.

After each target was completed, the experimenters were prompted to rate the quality of team process around that target on a one (poor) to five (excellent) Likert scale. The experimenters were trained to rate the teams with regard to the quality of communication, the timeliness of interaction, and whether or not the right information got to the right team member. After agreeing on a score, one experimenter entered a rating. Team process is thus a judgment based on the quality of coordination at each target.

Procedure

Participants were randomly assigned to teams and to role (AVO, PLO, DEMPC). Teams were randomly assigned to one of four conditions: Long interval-mixed, long interval-same, short interval-mixed, short interval same.

In Session 1 teams were all treated identically. Each individual received training on his or her role to a criterion level of understanding. Teams then completed five 40-minute UAV reconnaissance missions. For each target during a mission, experimenters rated the team process of the team in the vicinity of the target waypoint. Teams received performance feedback after each mission. After completing the fifth mission, teams were compensated for their Session 1 participation and scheduled for Session 2.

In Session 2, the teams returned after either the short or long retention interval. In addition, the teams in each of the short and long conditions returned with either the team members they had in Session 1 ("same") or different team members ("mixed").

At the beginning of Session 2 teams received individualized refresher training on their individual tasks and role responsibilities and were tested to ensure that individual skills were at the same level. Team members were not allowed to interact before their first Session 2 mission. Teams then completed three 40-minute UAV reconnaissance missions. Team performance and process were measured as before. Teams were then debriefed and paid for Session 2.

RESULTS

Mean team performance for each experimental condition over missions is given in Figure 1.

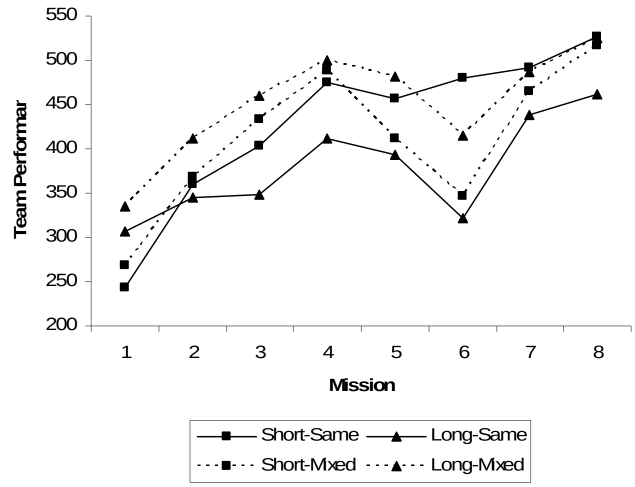

Figure 1. Mean team performance by mission. Retention interval occurred after Mission 5.

Difference scores reflecting post-retention interval change in team performance and process were generated by subtracting each Session 2 (i.e., Missions 6, 7, and 8) score from the team's baseline score. Mission 4 served as the most stable baseline because Mission 5 contained some situation awareness tests that affected the team's score in a negative way. Mixed teams, together for the first time in Session 2, had no Session 1 team data. Therefore, the average score at Mission 4 for each of the three originating teams served as a baseline for each mixed team.

Mean team performance difference scores over condition for Session 2 missions are presented in Figure 2. A mixed factor Mission X Composition X Retention Interval ANOVA (with Mission serving as a repeated measure and Composition and Retention Interval as between-subjects factors; and setting the alpha cutoff fpr significance to .10) revealed a significant interaction among these three factors (F (2,34) = 3.52, $p < .05$). Using zero as the null hypothesis of no decrement, *t*-tests on the team performance difference scores at Mission 6 revealed that only the Short-Same condition exhibited no decrement (t (9) = .24, $p > .80$), while the Long-Same (t (8) = -2.17, $p < .06$), Short-Mixed (t (9) = -3.32, $p < .01$), and Long-Mixed (t (9) = -3.76, $p < .01$) conditions each exhibited decrements. For the Mission 7 difference scores, no significant differences from the null value of 0 were found. For the Mission 8 scores, the two Short interval conditions exhibited significantly larger difference scores than the null value of zero (Short-Same: t (9) = 2.85, p < .02; Short-Mixed: t (9) = 3.04, p < .02).

Team process ratings were averaged over targets in order to generate mission-level scores. A mixed factor Mission X Composition X Retention Interval ANOVA (with Mission serving as a repeated measure and Composition and Retention Interval as between-subjects factors) on the team process difference scores revealed a significant interaction between Mission and Composition (F (2,34) = 3.27, p = .05). Mean team process difference scores over the Same vs. Mixed conditions for Session 2 missions are given in Figure 3. Using zero as the null value, t-tests revealed that Mixed teams improved over Missions 7 and 8 (t (19) = 3.54, p < .01 and t (19) = 4.87, p < .001, respectively). All other t-tests failed to reject the null hypothesis of zero difference score.

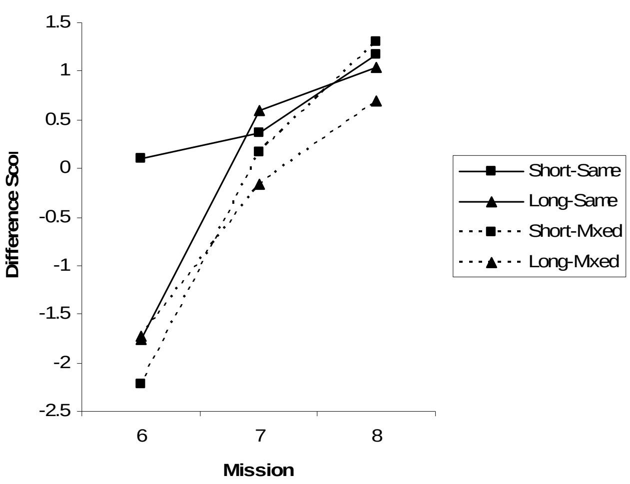

Figure 2. Mean team performance difference scores (baseline = Mission 4 score).

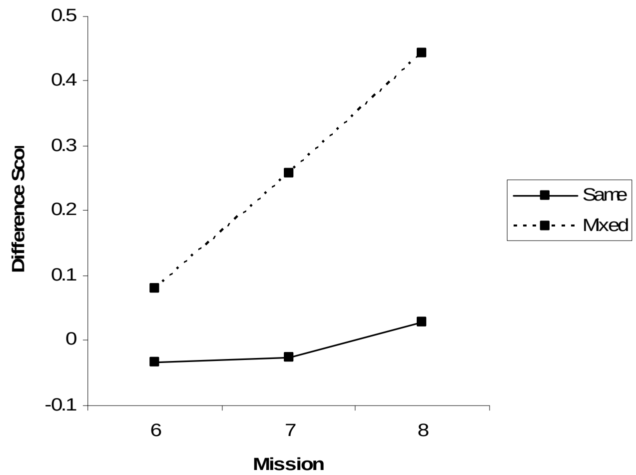

Figure 3. Mean team process difference scores (baseline = Mission 4 score).

DISCUSSION

Based on the results reported here, the effect of retention interval length and team member familiarity differs based on the team criterion examined. For the team performance measure, both interval length and team mixing appeared to have a deleterious effect, at least for the first post-interval UAV mission, after which teams appeared to recover rather quickly. In addition, the Short-Same teams appeared to attain the highest post-retention performance levels relative to their pre-interval scores.

On the other hand, team mixing appeared to have a positive effect on team coordination as measured by quality of team process. Specifically, mixed teams exhibited increased observer ratings of team process post-interval, while familiar (same) teams tended to linger at about the same level with minimal improvement. These findings do not appear to be spurious, as other (unreported here) process-oriented measures of team situation awareness and coordination based on communication patterns suggest the same pattern of findings.

Based on the findings reported here and as predicted, long retention intervals and team membership changes have negative (but short lived) effects on team performance. Surprising however, is the finding that changes in team composition lead to improvements in team process. We speculate that those changes perturb the rigid coordination that has been established in familiar teams, leading to a flexible, more adaptive team. For example, we have found differences in team situation awareness that suggest that unfamiliar teams display more accurate process behaviors when coordinating a response to an unpredictable change in the situation.

Team composition differences identified using the process measure supports the importance of a process-oriented perspective on team cognition and the general perspective that team cognition is heavily tied to team interaction. The notion of a process-oriented, relation-focused perspective suggests the need for both time series measurement and dynamical systems modeling through which processes may be more directly studied.

Practical implications of these findings are as follows: If the goal is rapid reuptake of team performance after a break, keeping intervals short and teams familiar may be most desirable. On the other hand, if flexibility is primarily required, changing team composition may be more desirable, if one can afford a brief “hiccup” in post-retention performance, such as the brief decrement in Mission 6 performance reported here.

ACKNOWLEDGEMENTS

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