COGNITIVE ABILITY CORRELATES OF PERFORMANCE ON A TEAM TASK

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This study examined the relationship between two cognitive ability measures, Grade Point Average (GPA) and verbal working memory capacity, and performance on a team task. Forty 3-person teams of students voluntarily participated in two experiments that required three team members to maneuver a simulated Uninhabited Air Vehicle (UAV) to take reconnaissance photos. Each of the team members assumed a different role with unique responsibilities. Low workload missions required that participants take 9 photos of various targets, whereas high workload missions required 20 photos and involved additional route constraints. The high workload manipulation produced significant reductions in team performance and in the performance of each of the three roles. Working memory capacity was more highly correlated with role performance and GPA was more highly correlated with team performance. Although both cognitive ability measures were significantly correlated with performance on the task, a different pattern of correlations was obtained in each experiment.

INTRODUCTION

Many of the studies that have examined the relationship between individual cognitive ability and team performance have used a single test score to measure cognitive ability. For example, Heslin (1964) found in most of the studies that he reviewed that there was a positive correlation between general cognitive ability, as assessed by college grades or test scores, and team performance. More recent studies, (LePine, Hollenbeck, Ilgen, and Hedlund, 1997; Hollenbeck, Moon, Ellis, West, Ilgen, Sheppard, Porter, and Wagner, 2002) have also found that higher cognitive ability is associated with better team performance, although many of the correlations are small.

However, none of these studies attempted to relate different cognitive abilities to task performance. Different roles in a team task, such as the UAV (Uninhabited Air Vehicle) ground control task that is used in the CERTT (Cognitive Engineering Research on Team Tasks) lab, may require different cognitive abilities. Thus, knowing which abilities are important for a given role may allow one to more precisely understand the nature of the task and more effectively assemble and train teams to optimize performance. The purpose of the research presented here is to examine the relationships between two measures of cognitive ability (i.e., grade point average and performance on a verbal working memory task) and team performance. Further, we examined these relationships in the context of performance on a high workload version of the task on which teams were trained. It was anticipated that the importance of cognitive abilities should be most apparent when workload is great. Also, this task context is similar to the situation that team members sometimes confront, in which the training environment does not perfectly map onto the operational environment

Grade point average (GPA), although not an ideal measure of cognitive ability, was used because it was readily available. Grade point average is a fairly gross measure of ability that may be influenced by reporting biases that reduce its validity. In contrast, standardized measures of cognitive ability, such as the verbal working memory task, are not based on self-reports and may allow us to better understand the cognitive mechanisms that affect performance.

EXPERIMENT 1

Method

Participants. Twenty 3-person teams of New Mexico State University students voluntarily participated in the experiment. Individuals were compensated for their participation by payment of $6.00 per person hour to their organization. The three team-members on the team with the highest performance score were each awarded a $50.00 bonus. Most of the participants were male (65%) and participants ranged in age from 18 to 40.

Measures. The data presented in this paper are from a subset of measures of team and individual performance and cognition taken in this experiment. Here we focus on measures pertaining to individual cognitive ability and their relation to performance.

The team task that was used in this study required three team members to work together to maneuver a simulated UAV (Uninhabited Air Vehicle) to take reconnaissance photos. The team was composed of an AVO (Air Vehicle Operator), DEMPC (Data Exploitation, Mission Planning, and Communication Operator), and PLO (Payload Operator). The AVO controlled airspeed, heading, and altitude and monitored UAV systems, the DEMPC oversaw the mission and determined the flight path under various constraints, and the PLO adjusted camera settings, took photos, and monitored the camera equipment.

Team performance was measured using a composite score based on the result of mission variables including time each individual spent in an alarm state, amount of fuel used, amount of film used, number of missed targets, number of critical waypoints missed, time spent in a warning state, and route sequence violations. Penalty points for each of these components were weighted *a priori* in accord with importance to the task and subtracted from a maximum score of 1000.

Each individual role within a team (AVO, DEMPC, and PLO) also had a composite score based on various mission variables including time spent in alarm or warning state as well as variables that were unique to that role. Penalty points for each of the components were weighted *a priori* in accord with importance to the task and subtracted from a maximum score of 1000. Score components were weighted to reflect the importance of tasks for a given role. For example, the PLO's score was heavily influenced by performance on the photo variables that were unique to that role.

A measure of verbal working memory capacity, which was administered individually, was taken from the Air Force CAM 4 computerized test battery (Kyllonen et al., 1990; Kyllonen, 1995). This measure consisted of 32 items, each of which presented participants with four to seven words, the last three of which the participants had to remember in order. The stimuli were one-syllable adjectives such as <u>big</u>, <u>cold</u>, and <u>fast</u>. The color of the stimuli was varied so that participants had to transform the words. When the stimulus was white, the participant remembered the word that had been presented, but when the word was yellow, participants had to remember the antonym of the word (e.g., the opposite of <u>big</u> is <u>small</u>). The last three stimuli for an item were either consistent, either all white or all yellow, or were inconsistent, which means that white and yellow stimuli were mixed. Stimuli were presented at the rate of one word every 2.5 seconds and participants had 18 seconds to respond to each list of words. The working memory task presumably tapped working memory capacity because the participants were required to retain and manipulate the stimuli.

Procedure. Two six-hour sessions, which were 48 hours apart, were run on two separate days. The participants were randomly assigned to teams and to roles (AVO, PLO, or DEMPC). Half of the teams participated in a co-located mission environment and half in a distributed mission environment. However, this factor had no influence on the team or role scores and will not be discussed further.

The participants first performed the working memory task and then learned about the UAV task by means of a computerized tutorial. During the rest of the session, the participants engaged in three forty-minute low workload missions in which their performance goal was 9 photos of various targets. The second session consisted of four forty-minute missions with the first mission being a low workload mission and the remaining three missions consisting of high workload missions (20 target photos and more route constraints). Other measures of performance and cognition were taken during the missions and in sessions separate from the mission. At the end of the experiment participants completed a set of questions that included a report of their grade point average.

Results

We first examined the correlations between verbal working memory capacity and GPA (See Table 1). The working memory score and GPA for teams are based on the average of individual members' values. An alpha of .10 was used due to low power with such a small sample (N=20). None of the correlations between the individual difference variables were significant in Experiment 1.

Table 1. Correlations Between Individual Difference Variables in Experiments 1 and 2.

	GPA		
Verbal Working Memory Score	AVO	DEMPC	PLO
Experiment 1	.15	.24	.09
Experiment 2	.17	.14	*.42*
Team Verbal Working Memory Score	Team GPA		
Experiment 1	.06		
Experiment 2	**.54**		

p < .10
p < .05

Figure 1 displays the effect of the workload manipulation on role and team performance. The high workload manipulation reduced the performance scores of the teams and of all the roles (AVO, DEMPC, and PLO). The reduction in scores between missions 4 and 5 was significant for teams (F (1, 19) = 1820.88, $p < .01$), AVOs (F (1, 19) = 5.86, $p < .05$), DEMPCs (F (1, 18) = 97.08, $p < .01$) and PLOs (F (1, 19) = 103.12, $p < .01$).

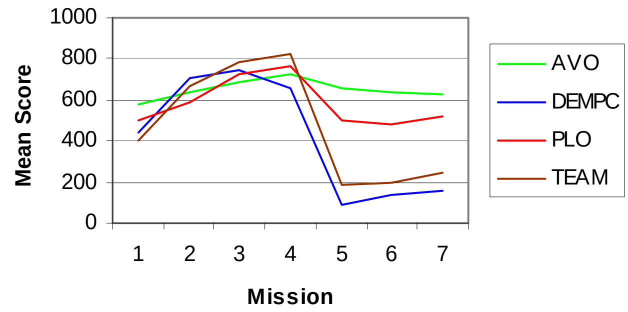

Figure 1. Mission Performance by Team and Role Experiment 1.

We next examined whether cognitive ability variables could be used to predict performance in the high workload mission. Table 2 displays the correlations between the individual difference variables and both role and team performance in Mission 5.

Table 2. Correlations Between Individual Difference Variables and UAV Task Performance in Mission 5 of Experiments 1 and 2.

Individual Performance on UAV task	GPA			Verbal Working Memory Score		
	Avo	Dempc	Plo	Avo	Dempc	Plo
Experiment 1	.19	**.46**	-.07	.02	*.45*	.16
Experiment 2	.29	-.02	.38	**.54**	.28	.25
Team Performance on UAV task	Team GPA			Team Working Memory Score		
Experiment 1	.15			.09		
Experiment 2	**.63**			**.48**		

p < .10
p < .05

The only significant correlations in Experiment 1 were between DEMPC performance and both predictor variables. DEMPCs with higher GPAs and those with better working memory scores obtained higher scores in Mission 5. Semipartial correlations were examined to determine whether one variable was more highly correlated with DEMPC performance when the effect of the other variable was controlled. The values were very similar: .36 for GPA and .35 for verbal working memory capacity.

EXPERIMENT 2

Method

Participants. Twenty 3-person teams of New Mexico State University students voluntarily participated in the experiment. Individuals were compensated for their participation by payment of $6.00 per person hour to the participant. The three team-members on the team with the highest performance score were each awarded a $50.00 bonus. All of the participants were male and participants ranged in age from 18 to 40.

Measures. The measures were identical to those in the first experiment.

Procedure. The participants engaged in one seven-hour session. This experiment differed from Experiment 1 in that participants took part in only one high workload mission, compared to three in Experiment 1.

Results

Table 1 shows the correlations between the individual difference variables. The working memory score and GPA for teams are based on the average of individual members' values. An alpha of .10 was used due to low power with such a small sample (N=20). Significant positive correlations were obtained between GPA and verbal working memory capacity for PLOs and teams.

As in the first experiment, we examined the effects of a high workload mission on the performance of skilled teams. The high workload manipulation reduced the performance scores of the teams and of all the roles (See Figure 2). The reduction in scores between missions 4 and 5 was significant for teams (F (1, 19) = 311.64, p < .01), AVOs (F (1, 19) = 19.55, p < .01), DEMPCs (F (1, 19) = 268.07, p < .01) and PLOs (F (1, 19) = 77.09, p < .01).

We next examined correlations between the cognitive ability variables and performance during Mission 5 of the UAV task (See Table 2). The only significant correlation involving role scores was for the AVOs. Higher working memory scores were associated with better performance on Mission 5 of the UAV task. For teams, average GPA and the average working memory score were both correlated with team performance in Mission 5. Teams with higher GPAs or higher working memory scores performed better in the high workload mission.

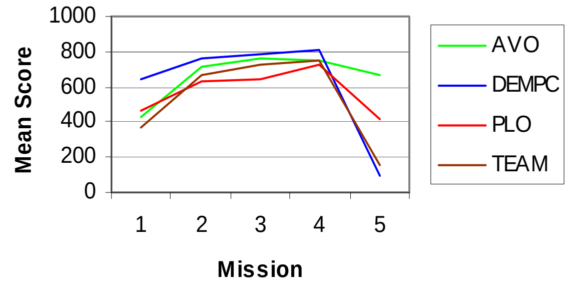

Figure 2. Mission Performance by Team and Role Experiment 2.

Semipartial correlations were examined to determine whether one variable was more highly correlated with team performance in Mission 5 when the effect of the other variable was controlled. The correlation for GPA was much higher than for verbal working memory capacity: .44 for GPA and .17 for verbal working memory capacity.

DISCUSSION

It appears that the working memory task was more highly correlated than GPA with individual performance on the UAV task. In the first experiment, both GPA and verbal working memory capacity were correlated with DEMPC performance. However, in Experiment 2, working memory capacity was correlated with AVO performance, but GPA was not significantly correlated with role performance. In contrast, GPA was more useful than the working memory score when predicting team performance. Team GPA was more highly correlated than team working memory capacity with team performance in Experiment 2.

We investigated whether differences between Experiments 1 and 2 may have been due to the placement of the high workload mission. In Experiment 1, Mission 5 came before the middle of the session, whereas in Experiment 2 it came at the end when participants may have been more fatigued. However, there were no significant differences in mission performance between Experiments 1 and 2 for AVOs, t (38) = -.37, DEMPCs, t (37) = -.12, PLOs t (37) = 1.28, or teams, t (36) = .76. Other differences between the experiments that may explain our findings include the recipient of compensation (organization versus participant) and gender composition.

Although we cannot explain why the results differed, both experiments suggest that cognitive ability variables may be used to predict performance on a team task when the workload is increased. Furthermore, almost all of the correlations were in the expected direction (i.e., positive) and many in Experiment 2 were sizeable (around .3 or .4), though not significant.

Although GPA may be useful when predicting team performance, other measures, such as verbal working memory capacity, may be helpful in understanding the mechanisms that are responsible for individual performance on a team task. With additional measures of working memory capacity from other domains, such as spatial reasoning, and other measures of ability, such as perceptual speed, we may be able to account for more of the variance in task performance, and begin to understand the mechanisms that are responsible for the performance of various members of the team.

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