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Original Research

Team Coordination Style Is an Adaptive, Emergent Property of Interactions Between Critical Care Air Transport Team Personnel

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A B S T R A C T

Objective: Critical Care Air Transport (CCAT) teams care for critically ill or injured patients during long-duration flights. Despite the differences between the CCAT domain and a more traditional clinical setting, CCAT clinicians are not explicitly trained how to coordinate care in the aircraft environment. We characterized the team coordination patterns adopted by CCAT teams and explored any links between team coordination style and performance.

Methods: This retrospective study used transcripts from 91 CCAT teams as they completed simulated patient care scenarios during an advanced training course. Qualitative and quantitative measures were used to characterize team behavior.

Results: Vocalized content varied by team role, with physicians acting as leaders. The type of content verbalized by each team role depended on the team coordination style. The team coordination style and the content of vocalized messages were not affected by prior team member deployment or the characteristics of particular scenarios, and the team coordination style did not predict measures related to patient status.

Conclusion: Individual team member coordination behaviors vary depending on the coordination style used by the team as a whole. Coordination style appears to arise from the interactions among individual team members rather than in response to situational factors external to the team.

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Critical care patients require teams of trained, skilled clinicians working as a cohesive unit toward a common goal.[1] Teams must work together particularly well in the US Air Force's Critical Care Air Transport Team (CCAT) environment where the care team is isolated aboard an aircraft and must function independently.[1] CCAT aircrew care for critically ill or injured patients during long-duration flights from lower-tier treatment facilities to definitive care centers, often in Germany or the United States. CCAT teams are typically composed of a critical care−trained physician, a critical care/emergency department nurse, and a respiratory therapist (RT).[2] Coordination among these clinicians is critical for delivering high-quality medical care in this unique environment, but the patterns of information flow among CCAT members and factors affecting such patterns in the CCAT domain have not been characterized. Toward this end, we examined coordination among CCAT members during simulated care scenarios to both characterize distinct coordination patterns between teams and identify whether such patterns predict team performance. By exploring these issues, we gained a better understanding of CCAT team behavior and ways to improve training and, ultimately, patient care. Our study incorporates elements of communication (eg, conveying patient status) and coordination (eg, planning interventions). For simplicity, we use "coordination" as a blanket term in the document to reflect information sharing and actions in support of the overall goal of delivering patient care.

High-quality coordination is a major component of team functioning.[3] Cooke's[4] theory of interactive team cognition posits that teams think via the interactions between team members. Team coordination predicts team-level performance better than individual team members' aggregate knowledge or skill.[5] Team coordination is particularly important in the medical domain because communication errors are a leading cause of preventable medical harm.[6] Strong nurse-physician teamwork is associated with improved surgical patient outcomes,[7] whereas poor communication can increase the risk of surgical complications and death.[8]

Medical errors are attributable to the interaction of various components of a system rather than the actions of any one individual.[9] In the medical domain, the system can include personnel, standardized procedures, equipment, and the physical design of the work space.[10] Systems may be as large as a patient care network or as small as an operating suite.[9] In the same spirit, we have defined the aircraft setting as a system for the purposes of this study. It is important to characterize team coordination in the CCAT domain to understand domain-specific influences on team performance and, ultimately, patient outcomes. Each CCAT member contributes unique knowledge and skills, requiring effective coordination to achieve quality patient care.[11]

Team cognition is tied to context, including other team members and the work setting.[5] The available tools and resources and the sociocultural systems in which people operate all influence how they accomplish tasks.[12-14] The CCAT domain is very different from a typical care setting, adding challenges to coordination. For example, long flights (often more than 6 hours) across multiple time zones can contribute to fatigue among caregivers.[15] Patients frequently have injuries with which clinicians have little opportunity for practice in their nondeployed duties (eg, blast injuries), and aspects of flight such as reduced ambient pressure can affect patient physiology.[15] CCAT personnel may be responsible for up to 6 patients at once[2] and must manage the associated ventilators, monitors, and infusion pumps.[6,11,16] These changes from the traditional care environment may increase the workload or force clinicians to deviate from their habitual behaviors tailored to their typical work setting. In effect, clinicians may have to work harder as a team to maintain cohesive patient care.

In addition to a high workload and a unique patient population, the physical environment in which CCAT clinicians work is vastly different from the standard intensive care unit environment. The hospital intensive care unit environment is typically well lit, has tolerable noise levels, and has ample space. In contrast, the flight environment is much more limited. Lighting may be dim for operational reasons, making it challenging to locate supplies or identify anatomic landmarks. The aircraft also produces high ambient noise, making verbal interactions between clinicians and patients harder to hear and necessitating a greater effort to speak loudly. Space is limited, so equipment and medications must be secured directly on and around the patient's litter, and there is little room to maneuver around the patient to provide care. In addition, the only resources available to CCAT teams are those packed on the aircraft before takeoff.

Tight physical spaces that restrict movement, caregiver fatigue, high workload, poor lighting, and elevated levels of ambient noise may all affect coordination both within the care team and between clinicians and patients.[6] Davis et al[15] found that task saturation was specifically associated with impairments on teamwork and communication measures in simulated CCAT patient care scenarios. This increase in workload compared with a standard clinical setting, in combination with the challenges induced by the physical environment of the aircraft, may impair coordination and therefore degrade the quality of care if teams are unable to adapt.

Despite the importance of coordination to health care delivery and the particular challenges of working in the CCAT environment, current CCAT training lacks explicit instruction on how to coordinate effectively. CCAT personnel deploy as individuals rather than as stable teams; accordingly, current training emphasizes individual knowledge and skills such as the physiological factors of flight and their potential impacts on patients and clinicians.[11] The importance of coordination is stressed, and classes review closed-loop communication, but other team-level processes are mainly addressed informally via nonstandardized debriefing sessions or implicit practice during team-based training scenarios. Likewise, training evaluations assess individual team members instead of the team as a whole.

Each team member must have the necessary skills to fulfill the unique responsibilities of their role for the team to function. However, emphasizing individual skill neglects an important aspect of overall care delivery. Evidence suggests that communication volume and content vary depending on one's role within a team.[17] A better understanding of how each member contributes to the overall team will help tailor training to improve coordination between various team roles and promote the inclusion of emergent team-level processes that could likely benefit from explicit feedback and attention during training.

Despite the challenges of the flight environment and the lack of explicit training in team coordination, CCAT personnel are a highly successful and vital contributor to the US military's combat casualty care system. Thus, we believe CCAT personnel likely learn to adapt as they gain experience in the aircraft environment. Generally, teams composed of members with domain-relevant experience tend to perform better than teams without such experience.[18]

In addition to domain-related experience, interpersonal familiarity may also help team performance.[19,20] However, team membership is unstable in the CCAT domain. Because CCAT personnel deploy individually, CCAT teams are ad hoc groups that can change across deployments and from mission to mission. However, shifting teams' makeup is not necessarily undesirable. Teams that learn to adjust to the behaviors of new members demonstrate adaptive and flexible coordination patterns.[21,22]

We anticipate that CCAT clinicians develop coordination practices as they gain experience, both within the aircraft environment generally and also working across various teams. As teams form and disperse, emergent coordination patterns likely develop within each team based on these individual practices.

This study used audio and video from CCAT training simulations to 1) characterize the various patterns of communication used by CCAT teams; 2) identify differences in communication patterns as a function of prior deployment experience of team members; and 3) link patterns of communication to team performance, which was assessed based on patient parameters. We expected that different CCAT teams would adopt unique coordination patterns to adapt to the flight environment, but these varied coordination patterns would not be equally effective. We further hypothesized that prior CCAT experience would affect how team members coordinate by helping individuals anticipate other team members' needs.

Methods

This study was funded by the United States Air Force 711th Human Performance Wing and was deemed exempt by the Naval Medical Research Unit Dayton Institutional Review Board (project #18-05457).

We relied on archival videos of training exercises from the CCAT Advanced Course at the Center for Sustainment of Trauma and Readiness Skills (CSTARS), University of Cincinnati Medical Center, Cincinnati, OH. We analyzed a sample of 91 teams that completed 1 of 4 different simulated patient care scenarios during courses completed in 2016 and 2017. The sample included all teams during this time period for which we had a complete set of simulator data (ie, a transcript of communications and matching simulator data files for each manikin). Individual trainees' names in the course records, transcripts, or simulator file names were deleted or replaced with an identification number to generate a deidentified data set for analysis. Demographic information was not available for 7 individuals (2 doctors, 3 nurses, and 2 RTs); individual participants could not be identified for 21 teams.

The CCAT Advanced Course is a 2-week course that serves as the final stage of training to certify new CCAT clinicians as ready to deploy and as periodic refresher training for current CCAT aircrew. The first week of the course is primarily lecture based to convey the unique aspects of providing critical care in the flight environment (eg, the effects of reduced barometric pressure on patients with head trauma). The second week of the course consists of simulated patient care scenarios, including "validation scenarios" that trainees must pass to be considered eligible for deployment.

Simulations were conducted in a room set up to mimic the dimensions, light levels, and noise of a C-130 transport aircraft. Each simulation required the team to care for 2 patients (Chuck and Dave) represented by 2 high-fidelity patient simulation manikins controlled by CSTARS staff from a separate control room. Team members communicated with one another via headsets comparable to those used in the aircraft. Audio and video data were recorded as part of a single data stream. In addition, Chuck and Dave each had separate files that recorded their vital signs, interventions completed by the trainees, and any inputs from the operator at the control station. Each validation scenario required the teams to demonstrate different capabilities, such as managing patients with cardiac issues, airway issues, amputations, or head trauma.[a] Each scenario began the same way for each team and followed a basic outline to ensure the targeted skills were assessed. However, the exact details of the scenario varied across teams because the simulated patients responded to the specific actions and interventions of each team. Each scenario lasted approximately 30 to 45 minutes from the start of patient care to the end of the scenario. Team members were shuffled across scenarios so that team composition changed every time. Thirty-one teams in the sample completed validation scenario 1, 18 teams completed validation scenario 2, 29 teams completed validation scenario 3, and 13 teams completed validation scenario 4.

Analysis

Several independent measures were derived from transcripts of the teams' interactions during their simulated scenarios. Transcribed utterances were separated by speaker with time stamps corresponding to the beginning of each utterance. Transcripts were spot-checked for accuracy; speakers were identified as the doctor, nurse, or RT by members of the research team with CCAT expertise. Data processing was performed using Excel (Microsoft, Redmond, WA) and Matlab (MathWorks, Natick, MA). Statistical analyses were performed in SPSS (IBM Corp, Armonk, NY). We used measures of communication content, team member deployment experience, and the distribution of communication across team members to predict team performance. Each measure is described in the following sections.

[a] We have omitted detailed descriptions of the scenarios at the request of CSTARS personnel to prevent future trainees from potentially having advance knowledge of the scenarios. Those interested in learning more about the scenarios are invited to contact the lead author directly.

Measures of Communication Content

We generated a qualitative coding scheme to quantify and compare verbal communication content between team members. We developed an initial coding scheme based on a priori expectations of behaviors that may differentiate teams as well as a literature review of team communication measures, with particular emphasis on communication in the military and/or medical domain.[23-26] We also examined a sample of several transcripts that could not otherwise be used (ie, those with missing simulator files) to identify any additional behaviors that may be of interest. We refined our preliminary coding scheme using an iterative process of applying it to our developmental transcripts and modifying as needed to reduce overlap and ambiguity among coding categories and eliminate rare or superfluous categories. Our final coding scheme included 17 variables (Table 1 and Supplemental Table 1). The coding categories of "uncodable," "medical crew director," "patient interaction," and "miscellaneous" were excluded from our main analyses and are not discussed further.

Each transcript was coded by a single member of the research team who tallied the total number of instances of each coding category in each utterance. Utterances were transcribed as complete conversational turns by the speaker; a single utterance could be a very brief statement or several sentences long. Therefore, we coded individual pieces of information within each utterance, which was defined as something that could stand alone as its own sentence. For example, the utterance "Chuck's temperature is 102 and his heart rate is 87" would count as 2 pieces of information because the message can be divided into 2 sentences: "Chuck's temperature is 102" and "Chuck's heart rate is 87." A single coding category was assigned to each individual piece of information in the utterance; the preceding example would be scored as 2 instances of providing an update (either prompted or unprompted as appropriate). If the rater was uncertain about how to code a particular utterance, the uncertainty was resolved by discussion with other team members.

Raw frequencies (ie, counts) of the number of individual instances of each coding category were normalized as a percentage of the total coded behaviors at both the team and individual level. Normalizing the data allowed us to compare the relative use of each category across teams without concern for interteam or individual differences in the total volume of speech. These normalized frequencies served as the variables used in the analyses described in the Results section.

Experience

We operationalized experience as a binary predictor variable at the team level. We considered a team "experienced" if at least 1 team member had previously deployed as a CCAT crewmember. Fifty-one teams had no experienced members, and 13 teams had at least 1 experienced member. The remaining teams had incomplete data, preventing a conclusive determination.

Distribution of Communication

We calculated a rough metric of how evenly speech was distributed across the team members, which is referred to here as an "egalitarianism score." We determined the percentage of a team's total speech generated by each team member (based on word count) and then averaged the difference in those percentages across each possible pair of speakers. For example, if the doctor contributed 50% of the speech, the nurse contributed 30%, and the RT contributed 20%, the difference between the doctor and nurse would be 20%, between the doctor and RT would be 30%, and between the nurse and RT would be 10% for an average difference (egalitarianism score) of 20. Higher averages implied that a single team member tended to contribute the largest volume of speech, with a maximum possible value of 66.67 (1 person generated 100% of utterances) and a minimum possible value of 0 (all team members spoke equally).

Table 1
Communication Coding Scheme

Category	Coded Behavior	Definition
Communication patterns	Speaker target	The intended target of the utterance. This category could be scored as doctor, nurse, RT, entire team, or unsure.
Sharing information (status)	Request update	Requests for information, such as asking for a patient's vital signs or the status of a task.
	Provide update	Utterances that conveyed information about the patient's status or progress on a task. This category was scored as "prompted" if the information was provided in response to a request and as "unprompted" if the information was provided proactively.
Sharing information (message intent)	Request clarification	Requests to clarify the intent of a statement, repeat something, or confirm a dose or procedure.
	Provide clarification	Providing additional details about intent or repeating a statement. This category was scored as "prompted" if the speaker was responding to a request for clarification or as "unprompted" otherwise (typically correcting a misstatement; eg, "Chuck's heart rate is 73. I mean Dave's heart rate, sorry.")
Sharing information (clarity of communication)	Closing the loop	Statements confirming that another person's statement or request was agreed to or understood.
	Getting attention	Trying to get someone's attention or direct a message to someone specific.
	Communication quality	Statements related to making sure messages were received and understood, typically by the speaker of the message. This category also applied to troubleshooting issues such as a bad headset.
Action-oriented behavior	Stating a goal	Statements that conveyed a desirable end state, whether for the patient or the team.
	Activity coordination	Statements related to determining what should be done, who should perform the action, and how tasks should be accomplished.
Other	Cross talk	Periods in which multiple team members attempted to talk over one another, resulting in incomprehensible communications. These were explicitly noted in the transcripts.
	Uncodable/ambiguous	Statements that were unclear or were cut off before the meaning of the sentence became apparent. We did not analyze this category.
	MCD	This category was used to note when team members communicated with the MCD, a member of the aircrew associated with the aircraft who can offer assistance such as communicating with the pilot or acting as an additional set of hands for simple tasks. Course instructors played the role of the MCD, and we did not analyze these communications.
	Patient interaction	This category was used to note when team members spoke to the patient, played by 1 of the simulator operators speaking through the manikin from the control room. We did not analyze these communications.
	Miscellaneous	Any utterance that did not fit into a predetermined coding category was counted as "miscellaneous." We did not analyze this category.

MCD = medical crew director; RT = respiratory therapist.

For the rest of the article, we refer to teams with high values on our egalitarianism scores as having a "centralized" communication style and teams with lower values as having an "egalitarian" communication style. Egalitarianism scores were normally distributed (mean $\pm$ standard deviation = 23.09 $\pm$ 8.06, minimum = 5.93, maximum = 41.97).

Team Performance

The CCAT Advanced Course is meant to validate individual caregivers as ready to deploy; performance is evaluated at the individual level rather than the team level. Therefore, we developed a team-level performance measure to evaluate the effects of coordination patterns on team performance.

We derived an objective measure for each simulation scenario based on time. For each scenario,[b] members of the research team with CCAT experience identified the most relevant physiological parameters and defined thresholds based on clinical guidelines (eg, target blood oxygen saturation) or identified useful clinical end points such as the return of spontaneous circulation in the case of a cardiac arrest. We then used the simulation data from Chuck and Dave to calculate the time spent outside of target parameters and/or the time between the onset of a critical event and its end point. We summed the total time for each criterion across Chuck and Date within each scenario to calculate a team's total time. The total time reflected the time spent outside of desired physiological states or the time to resolve critical events; longer times indicated worse team performance.

Because each scenario had different criteria, we converted each team's time to a z score relative to the other teams within each scenario; z scores reflect the number of standard deviations a value is above or below the mean, placing all teams on a common scale and allowing us to compare each team's relative performance across scenarios. These z scores served as our outcome measure for all subsequent analyses predicting team performance and were reverse scaled so that larger z scores indicated good performance relative to other teams. The z scores ranged from -2.45 to 2.08.

Results

Many of our measures and analyses relied on the behavioral categories identified in the transcripts using the qualitative coding scheme. Therefore, our first analysis evaluated whether our coding scheme was applied consistently by each of the 3 raters who coded the transcripts. We established the reliability of our coding scheme using a weighted Cohen's kappa. Kappa was calculated for each coding category individually based on a set of 6 transcripts coded independently by 3 separate raters. Because kappa cannot accommodate more than 2 raters at a time, we used the lead investigator (who developed the initial coding scheme) as a "gold standard" against which each of the other 2 raters were compared.

Cohen originally described a kappa value of 0.4 as the threshold for "moderate" agreement, but others advocate for a more stringent standard of 0.6.[27] We adopted a threshold of 0.5 to provide flexibility to account for the semiexploratory nature of the study and the fact that the most challenging utterances were coded via consensus. Kappa had to be greater than 0.5 for both pairs of raters (ie, the lead investigator with rater 1 and with rater 2) for the category to be considered reliable. Unreliable categories were removed from further analysis. Table 2 lists the kappa values for each category and pair of

[b] Due to operational considerations from the CSTARS training staff, we once again omit specific details of which parameters were considered most relevant in each scenario. Please contact the lead author for more details if desired.

Table 2
Kappa Values for Each Category and Pair of Raters

Category	PI/Rater 1	PI/Rater 2
Speaker target[a]	0.74	0.69
Request update[a]	0.73	0.69
Provide update (prompted)[a]	0.60	0.55
Provide update (unprompted)[a]	0.75	0.71
Request clarification[a]	0.68	0.50
Provide clarification (prompted)	0.65	0.47
Provide clarification (unprompted)	0.44	0.33
Closing the loop[a]	0.77	0.74
Getting attention[a]	0.74	0.73
Communication quality	0.44	0.26
Stating a goal[a]	0.58	0.67
Activity coordination[a]	0.81	0.69
Cross talk[a]	0.90	0.88

PI = Principal Investigator.
[a] Categories that were judged to be reliable; unreliable categories were excluded from further analyses.

raters. Ten categories were deemed reliable and retained for further analysis. Note that several of these categories even exceeded the more stringent 0.6 cutoff suggested by McHugh.[26]

We also verified that our outcome measure was normally distributed and met the assumptions of parametric statistical tests. Descriptive statistics indicated that the distribution was normal enough to proceed (skewness = −0.51, standard error = 0.25; kurtosis = −0.27, standard error = 0.50). Because we normalized the outcome measure using z scores (eliminating any differences between scenarios), we completed the remaining analyses with the data pooled across scenarios into a single sample, ignoring any cross-scenario differences unless otherwise noted.

Effects of Team Role and Team Style on Communication Content

The next phase of our analysis focused on describing differences in communication content across team members. We evaluated differences in the types of communication used by the doctors, nurses, and RTs and examined how having a centralized or egalitarian communication style affected those behaviors.

We first characterized differences in the content of communication from the doctors, nurses, and RTs. We used multivariate analysis of variance (MANOVA)[c] to determine whether the team role (doctor, nurse, or RT) predicted the proportion of each coding category used. MANOVA is a technique designed to test the effects of categorical predictor variables on multiple continuous outcome measures. Using MANOVA allowed us to determine the effect of the team role on all coded behaviors simultaneously. We found significant differences between the team roles in how frequently they used several of our coded categories. Table 3 lists the results of the analysis, including the sum of squares, degrees of freedom, mean squared error, F ratio (the magnitude of the test statistic), p value (the likelihood of achieving our observed F ratio by chance; convention is to use a criterion value < 0.05), and effect size (η_p^2, the proportion of variance in the outcome measure accounted for by the predictor variable under consideration).

Post hoc Tukey tests indicated that doctors requested more updates than the nurses and RTs ($p = 0.01$ and < 0.01, respectively). Nurses and RTs were more likely to provide prompted and unprompted updates than the doctors ($p < 0.01$ for all comparisons). Nurses were more likely than the doctor and RT to request clarification ($p < 0.01$ for both). Doctors were more likely to state a goal than both nurses and RTs ($p < 0.01$ for both), but RTs were also more likely to state a goal than nurses ($p = 0.05$). Finally, doctors were more likely to use activity coordination than nurses and RTs ($p < 0.01$ for both).

We next examined whether a team's communication style affected the types of coded utterance content used by each team member. We took a subsample of 44 teams (the highest and lowest 22 teams on our egalitarianism score, roughly quartiles) and conducted another MANOVA similar to the one described previously but this time with egalitarian status (high vs. low) included as an additional predictor. We again found a main effect of speaker, indicating that different roles on the team used the coding categories differently. However, we also noted an interaction such that doctors, nurses, and RTs used different types of utterances based on whether the team was egalitarian or centralized. Thus, our hypothesis that teams would adopt different patterns of coordination was supported. Table 4 displays the results of the MANOVA.

Although effect sizes are small, our analyses indicated significant interactions between team type and role for prompted updates, requesting clarification, closing the loop, and stating a goal. The proportion of utterances accounted for by prompted updates within each role was lowest among doctors, greater among nurses, and largest among the RTs on centralized teams. Prompted updates were used more equally across the team members on egalitarian teams (Fig. 1). Nurses on centralized teams were more likely to request clarification than their teammates, whereas each team member's use of this category was relatively equal on egalitarian teams (Fig. 2). Doctors on centralized teams were slightly less likely to close the loop compared with doctors on egalitarian teams, but nurses showed the opposite pattern (Fig. 3). Doctors were more likely to state a goal on centralized teams than doctors on egalitarian teams (Fig. 4). Whether a team is egalitarian or centralized seems to be associated with small but noticeable differences in how individual team members communicate.

Exploring Influences on Team Communication Style

The previous analyses indicated that team communication style predicts differences in how individual team members communicated with one another. Therefore, we sought to better explain why teams adopted an egalitarian or centralized coordination style. We explored the effects of experience on team coordination, how individual behavior changed across teams, and whether situational demands affected communication.

We hypothesized that experience would affect how team members coordinated with one another, particularly how well team members anticipated one another's needs. We conducted a Welch's t-test to determine whether experience predicted egalitarian scores because this test is better able to accommodate differences in variance or sample size between groups than a standard t-test comparing sample means. The difference between the 51 teams with no members with deployment experience and the 13 teams with at least 1 member with deployment experience was not significant ($t(25.40) = 0.71$, $p = 0.41$), indicating that experienced teams were no more or less egalitarian than inexperienced teams. Based on our hypothesis that experience would affect team members' ability to anticipate others' needs, we also evaluated whether experience predicted the proportion of provide update (unprompted) at the team level. A Welch's t-test indicated that experience did not predict how much teams used provide update (unprompted) ($t(15.45) = 1.96$, $p = 0.18$). Our hypothesis that prior deployment experience would affect team coordination via improved anticipation of team members' needs was not supported.

We next hypothesized that team behavior emerged from interactions among the individual members. We identified individuals who had participated in multiple teams in our data set and calculated the proportion of total word count contributed by those individuals for each team. We then used matched sample t-tests to compare the highest and lowest contributions within the doctors, nurses, and RTs.

[c] We note that the assumption of independent observations is likely violated due to shared participants across teams. We lack an obvious remedy due to the nature of the CCAT Advanced Course, but we believe each team can be considered unique due to emergent properties of the interactions between team members.

Table 3
Multivariate Analysis of Variance Results Examining the Effect of Team Role on Coded Category Use

Source	Coded Category	SS	*df*	MS	*F*	*p*	η_p^2
Speaker	Request update	280.74	2	140.37	9.55	< 0.01	0.07
	Prompted update	2,437.01	2	1,218.51	45.48	<0 .01	0.25
	Unprompted update	1,810.27	2	905.13	16.70	< 0.01	0.11
	Request clarification	89.50	2	44.75	7.71	< 0.01	0.05
	Close the loop	71.06	2	35.53	1.29	0.28	0.01
	Get attention	2.08	2	1.04	0.13	0.88	< 0.01
	State a goal	34.84	2	17.42	21.81	< 0.01	0.14
	Activity coordination	5,081.29	2	2,540.65	67.92	< 0.01	0.34
Error	Request update	3,966.85	270	14.69			
	Prompted update	7,233.35	270	26.79			
	Unprompted update	14,636.01	270	54.21			
	Request clarification	1,567.11	270	5.80			
	Close the loop	7,440.24	270	27.56			
	Get attention	2,243.32	270	8.31			
	State a goal	215.64	270	0.80			
	Activity coordination	10,099.67	270	37.41			

MS = mean squared error; SS = sum of squares.

Doctors ($t(18) = -8.92$, $p < 0.01$), nurses ($t(17) = 5.68$, $p < 0.01$), and RTs ($t(19) = -5.52$, $p < 0.01$) who participated in multiple teams all demonstrated significant differences between their largest and smallest contributions to the total word count, indicating that they changed their behaviors across teams. These findings indicate that individual behavior changed based on one's teammates, supporting our hypothesis.

Participation across multiple teams was typically confounded with completing a new scenario; it is possible that our findings were attributable to different demands on the doctors, nurses, and RTs across scenarios rather than behavioral changes in response to new teammates. Therefore, we also evaluated whether egalitarianism varied across scenarios. Analysis of variance revealed that the scenario did not affect team egalitarianism ($F(3,87) = 0.38$, $p = 0.77$). We next performed MANOVA using the scenario to predict the use of individual coding categories (Table 5). Overall, the scenario had a minimal statistical impact on how teams used the various coding categories. Therefore, changes in individual and team coordination patterns appear to be driven by changes in team composition rather than by the demand characteristics of particular simulation scenarios.

Table 4
Multivariate Analysis of Variance Results With Egalitarianism as a Second Predictor

Source	Coded Category	SS	*df*	MS	*F*	*p*	η_p^2
Speaker	Request update	96.83	2	48.41	4.34	0.02	0.06
	Prompted update	826.55	2	413.28	18.00	< 0.01	0.22
	Unprompted update	1,331.22	2	665.61	13.18	< 0.01	0.17
	Request clarification	26.11	2	13.06	3.20	0.04	0.05
	Close the loop	57.02	2	28.51	0.98	0.38	0.02
	Get attention	10.44	2	5.22	0.52	0.60	0.01
	State a goal	28.18	2	14.09	15.94	< 0.01	0.20
	Activity coordination	2,533.21	2	1,266.60	33.33	< 0.01	0.35
Egalitarian	Request update	40.08	1	40.08	3.60	0.06	0.03
	Prompted update	7.33	1	7.33	0.32	0.57	< 0.01
	Unprompted update	19.63	1	19.63	0.39	0.53	< 0.01
	Request clarification	0.04	1	0.04	0.01	0.92	< 0.01
	Close the loop	7.33	1	7.33	0.25	0.62	< 0.01
	Get attention	0.07	1	0.07	0.01	0.94	< 0.01
	State a goal	1.10	1	1.10	1.24	0.27	0.01
	Activity coordination	11.42	1	11.42	0.30	0.58	< 0.01
Speaker X Egalitarian	Request update	36.95	2	18.48	1.66	0.20	0.03
	Prompted update	382.20	2	191.10	8.32	< 0.01	0.12
	Unprompted update	165.21	2	82.61	1.64	0.20	0.03
	Request clarification	39.50	2	19.75	4.84	0.01	0.07
	Close the loop	184.57	2	92.29	3.18	0.05	0.05
	Get attention	47.05	2	23.52	2.32	0.10	0.04
	State a goal	9.31	2	4.66	5.27	0.01	0.08
	Activity coordination	164.11	2	82.05	2.16	0.12	0.03
Error	Request update	1,404.75	126	11.15			
	Prompted update	2,893.50	126	22.96			
	Unprompted update	6,363.37	126	50.50			
	Request clarification	514.48	126	4.08			
	Close the loop	3,652.16	126	28.99			
	Get attention	1,276.62	126	10.13			
	State a goal	111.36	126	0.88			
	Activity coordination	4,788.39	126	38.00			

MS = mean squared error; SS = sum of squares.

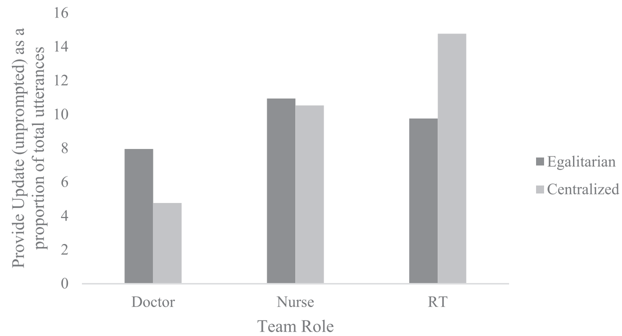

Figure 1. The interaction between team role and egalitarian/centralized team type on provide update (unprompted).

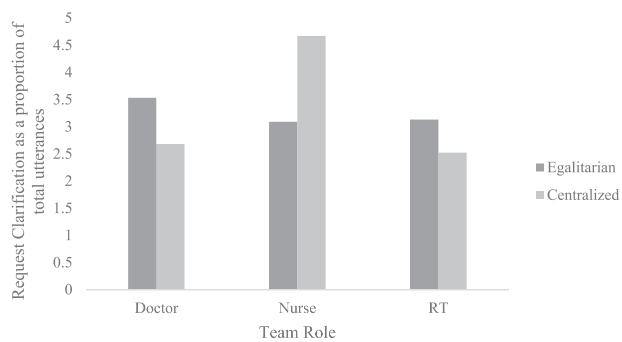

Figure 2. The interaction between team role and egalitarian/centralized team type on request clarification.

Coordination Patterns and Performance

Team coordination style appears to be an emergent property of the interactions among team members. However, various coordination patterns may not be equally effective in the CCAT domain. Therefore, we examined the relationship between communication and our team performance measure. We found a negative relationship between the total volume of communication as measured by word count and team performance (β = −0.26, $t(89)$ = −2.53, p = 0.01). Word count was likewise associated with egalitarianism such that teams who spoke more tended to demonstrate more centralized communication ($r(89)$ = 0.24, p = 0.02). Therefore, we examined whether a team's egalitarianism rating was related to performance. We used regression to predict team performance scores using each team's egalitarian rating. The model failed to predict any variance in performance scores ($R^2 < 0.01$, $F(1,89) = 0.02$, $p = 0.89$). Our hypothesis that different patterns of coordination would not be equally effective was not supported. Whether a team adopts an egalitarian or centralized pattern of coordination does not appear to be related to performance in the CCAT domain.

Discussion

We were partially successful in our effort to identify unique patterns of team coordination in the CCAT domain and link those patterns of coordination to experience and performance. We characterized team coordination behaviors, explored potential influences on the behavior of individuals within a team, and identified differences in coordination patterns across teams based on how egalitarian or centralized they appeared to be. However, our hypotheses were not fully supported because team coordination style did not predict performance, and we did not find any effects of prior deployment experience on coordination. Despite this, we believe our findings have value for the CCAT community. Our findings provide an improved understanding of team dynamics among CCAT aircrew. Furthermore, the fact that we did not find performance differences based on team coordination style implies that none of the observed emergent coordination patterns associated with ad hoc team membership systematically reduces team effectiveness.

CCAT teams are expected to follow a hierarchy based on team role. Consistent with this expectation (and with the function of critical

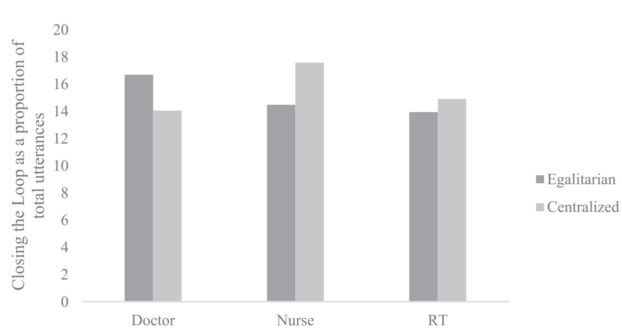

Figure 3. The interaction between team role and egalitarian/centralized team type on closing the loop.

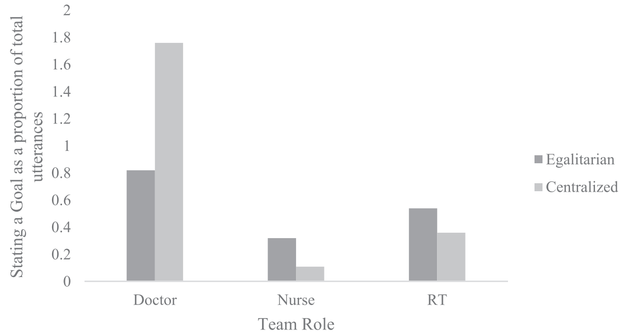

Figure 4. The interaction between team role and egalitarian/centralized team type on stating a goal.

care teams in the civilian world),[28] the teams in our sample demonstrated a clear tendency for doctors to lead the team. We found that on average doctors contributed roughly 52% of the total word count per team, whereas nurses and RTs contributed approximately 28% and 19%, respectively. Doctors also displayed greater numbers of behaviors related to requesting updates, stating goals, and activity coordination. In contrast, nurses and RTs were more likely to provide updates, implying they were answering to the doctor. Differences between the types of communication used by team members with different roles have been observed in other studies as well.[17] However, we also found significant variability in these behaviors; some teams demonstrated a relatively equal distribution of utterances between team members, whereas a single person dominated on other teams.

These differences between teams were associated with changes in the content of utterances between the different team roles. Team coordination style was correlated with the total word count, but the overall lack of a main effect of egalitarianism on the various coding categories indicated that the 2 types of teams did not significantly differ in the overall amount of each type of coded behavior; rather, the interaction between team role and team type indicates that egalitarian and centralized teams allocated those behaviors differently among the team roles. Indeed, nurses and RTs on egalitarian teams appear to have more autonomy and active participation in the task at hand than their counterparts on centralized teams. For example, RTs on egalitarian teams were less likely to provide prompted updates, whereas doctors on egalitarian teams were more likely to use prompted updates (Fig. 1). This shift may indicate that the RT is not being solely "talked at" and is instead a more active participant. These differences between egalitarian and centralized teams were relatively small in absolute terms but are nonetheless noteworthy given the relatively high number of behavioral categories measured and the inherently hierarchical nature of CCAT teams.

Much like other team-level processes such as shared flow[29] or team cognition,[4] whether a team adopts an egalitarian or centralized pattern of coordination appears to be an emergent property of the interactions among team members. Contrary to our hypothesis, the experience of team members did not predict team coordination style. Instead, we found that individuals demonstrated significant changes in their relative contribution to the overall volume of conversation from one team to the next but did not find any substantial link between the scenario and either team egalitarianism or the use of different types of coded utterance content. These findings imply that individuals adapt how much they speak based on their team members rather than the unique demands of any particular scenario. In other words, the social context had a greater impact on individual behavior than the task context.

Teams with a higher overall volume of communication tended to perform worse than teams with lower volumes. However, contrary to our hypothesis, team coordination style failed to explain significant variance in performance. This result is surprising based on the links between team coordination and performance described in the literature,[30] but given the emergent nature of team coordination style, it is possible that clinicians in the CCAT Advanced Course

Table 5
Multivariate Analysis of Variance Results Examining Cross-Scenario Differences in Coding Categories

Source	Coded Category	SS	*df*	MS	*F*	*p*	η_p^2
Scenario	Request update	7.87	3	2.62	0.44	0.73	0.02
	Prompted update	47.00	3	15.67	2.21	0.09	0.07
	Unprompted update	107.91	3	35.97	1.44	0.24	0.05
	Request clarification	9.45	3	3.15	1.28	0.29	0.04
	Close the loop	179.40	3	59.80	5.99	< 0.01	0.17
	Get attention	21.88	3	7.29	2.48	0.07	0.08
	State a goal	3.40	3	1.13	2.32	0.08	0.07
	Activity coordination	165.48	3	55.16	2.28	0.08	0.07
	Cross talk	42.91	3	14.30	1.57	0.20	0.05
Error	Request update	524.53	87	6.03			
	Prompted update	617.92	87	7.10			
	Unprompted update	2180.88	87	25.07			
	Request clarification	214.74	87	2.47			
	Close the loop	868.30	87	9.98			
	Get attention	255.95	87	2.94			
	State a goal	42.52	87	0.49			
	Activity coordination	2109.51	87	24.25			
	Cross talk	791.74	87	9.10			

MS = mean squared error; SS = sum of squares.

adapted their behaviors to their teammates such that the team adopted the coordination style that was collectively most comfortable and effective for that particular group of individuals.

We originally suspected that in the absence of formal coordination training, the current practice of ad hoc team deployment may reduce the performance of individual teams because some would adopt less effective coordination practices than others. Our findings imply that the current practice of ad hoc team deployments may have less impact on team performance than hypothesized, at least in the sense that no observed coordination style seems more or less effective than any other. More research will be needed to draw definitive conclusions and rule out potential alternative explanations such as a biased sample (leading to ceiling effects) or unidentified issues with our team performance measure. This is not to say that ad hoc team assignment leads to optimized performance. Our findings do not preclude the possibility that CCAT teams could be made more effective with the addition of formal coordination training or that teams with stable membership may perform differently than the ad hoc teams studied here.

This study has several limitations related to the unique traits of our data set and our outcome measure. Our data were originally collected for nonresearch purposes, and record keeping was incomplete. We could not always ascertain which video matched a given set of simulation data, reducing the overall sample size. Similarly, it was sometimes impossible to determine which students participated in a given scenario or whether an individual had any prior deployment experience, reducing the data available for specific analyses. The reduced sample size may have generated a sampling error or otherwise made our statistical analyses less reliable than with a larger sample size.

Class composition did not always include an equal number of doctors, nurses, and RTs. As a result, class members of underrepresented specialties sometimes had to repeat scenarios to provide a complete team for the other specialties. Prior exposure by a team member to a nominally unfamiliar scenario may have altered the behavior of some team members because of learning effects. We considered filtering out data from teams in which anyone had prior experience with a scenario. However, we could not ensure we filtered out all examples of duplicate participation in the absence of complete records. Therefore, we elected to keep all teams in the data set and maximize the sample size rather than risk an incomplete (and thus ultimately ineffective) filter.

Despite our decision to maximize the sample size by including all teams, our sample size was still reduced because of incomplete data. We were able to determine deployment status for 64 of 91 teams, 13 of which qualified as "experienced." Therefore, our analysis of experience should be interpreted with caution. Our limited sample of experienced teams also prevented us from exploring role-specific experience effects. Given the differences in behaviors across doctors, nurses, and RTs, we would potentially expect experience to have different impacts on the team depending on which member had deployed.

We also note that our outcome and qualitative measures were developed specifically for this study and have not been validated against any other measure. Similarly, the categories used in our subjective coding scheme or our measures of team coordination may have missed certain elements that are important to coordination and performance in a unique setting such as the CCAT domain. We also acknowledge that we have characterized egalitarianism/centralization as a categorical variable to improve our ability to detect differences between teams. In reality, teams exist on a continuum of very unbalanced contributions among members to nearly equal contributions. Nevertheless, we believe our findings remain relevant for understanding factors that influence team behavior.

Finally, the training setting may have impacted team behavior or performance because of unique qualities of the simulations or scenarios or the influence of trainee expectations. However, the CSTARS training scenarios appear to capture important elements of real-world deployment experiences,[31] so we do not believe the training setting had a notable impact on our conclusions.

Conclusions

CCAT personnel often work with unfamiliar teammates in an extremely challenging environment, requiring them to adapt their behaviors compared with a traditional clinical setting. We have identified unique coordination styles among CCAT teams, with associated differences in the coordination behaviors of each team member. Team coordination style appears to be an emergent feature driven by the interactions of individual team members, implying that individuals can be quite flexible in how they work with others depending on the unique characteristics of a given team. Operationally, we did not find evidence that any adopted team coordination style is consistently detrimental to team performance, but more work needs to be done with a more definitive sample to determine whether factors such as prior deployment experience of team members or formal coordination training may affect team behavior and improve performance.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.amj.2023.01.014.

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