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Facilitating distributed team collaboration

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Abstract

The overall objective of this exploratory study was to investigate how varying collaboration techniques would differentially influence team communication processes and task performance. Participants, as part of two-member teams, coordinated their efforts to perform three collaborative planning tasks using one of three collaboration techniques (face-to-face, voice telephone, instant messenger). Overall, results revealed that collaboration using instant messenger took significantly longer and was perceived as significantly more difficult than collaborating either face-to-face or using voice telephone. No significant differences were found between face-to-face collaboration and using voice telephone. Task performance accuracy did not differ among the three conditions. Analysis of participants' communication exchanges revealed that teams collaborating face-to-face or using voice telephone had almost twice as many communication exchanges as teams collaborating using instant messenger and tended to express more MetaQuery statements (requests to repeat or confirm previous communication) and Acknowledgement statements (one bit statements (e.g., "yes", "no") following another statement). Implications for the design of collaborations tools to optimize distributed team performance are discussed.

Keywords: collaboration techniques, communication processes, distributed teams, team performance

1. Introduction

Distributed teams are rapidly becoming the predominant organizational structure within numerous domains in both the private and public sector (e.g., manufacturing design teams, CSCW, command and control operations). Unlike traditional co-located teams, distributed teams must coordinate their efforts across both time and space, relying primarily upon technology-mediated communication channels to accomplish their goals [1, 2, 3]. Although a variety of technological tools and techniques exist for supporting collaboration among distributed teams, each approach presents unique advantages and disadvantages depending upon the nature of the task, situational constraints, and the team's composition [4, 5].

For example, facial expression, gesture, and variations in pitch and tone of the voice all influence how team members interact and how well the meaning of their communications is interpreted [6]. Yet, the lack of paralinguistic cues inherent in distributed team interactions utilizing text-based collaboration techniques (e.g., electronic mail) may alter the natural exchange of nonverbal feedback that allows each member to assess whether the meaning of their communication was conveyed accurately [7].

Accordingly, the overall goal of our program of research is to better understand the shared tools requirements for supporting effective collaboration among distributed teams. The specific objective of the present study was to determine if the hypothesized negative effects of communication channels characterized by low media richness (e.g., text-based information exchange) can be mitigated by a synchronous information flow, allowing for more expedient transactions between team members.

A secondary objective was to evaluate what level of nonverbal/paralinguistic cues is critical for achieving

effective collaboration performance. Face-to-face interactions would be expected to deliver higher levels of nonverbal/paralinguistic cues, conveying the richness of both audio (e.g., intonation) and visual (e.g., facial expressions, gestures) cues, as compared to audio conferencing (e.g., collaborating via voice telephone), which presents audio cues only.

2. Method

2.1. Participants

Sixteen undergraduate students (13 males and 3 females, mean age 19.63) enrolled as cadets in the Army Reserve Officers Training Corps (ROTC) at a major southeastern United States university participated in this study. Three participants had prior military training (e.g., Junior ROTC) and one participant had prior military active duty experience. A modest financial contribution was given to the Army ROTC Cadet Club as an incentive and remuneration for the cadets' efforts and participation. Participation in the study was strictly voluntary and all participants were treated in accordance with the ethical standards of the American Psychological Association.

2.2. Design

A one-factor between-groups design was utilized in this exploratory study, with collaboration technique (face-to-face, voice telephone, instant messenger) serving as the independent variable. Dependent variables included assessment of both process and outcome performance. Process variables included analysis of the frequency and content of communication exchanges between team members. Outcome performance variables included time on task and task performance accuracy.

2.3. Materials

2.3.1. Collaborative planning tasks

Participants, as part of two-member teams, coordinated their efforts to perform three collaborative planning tasks using one of the three collaboration techniques. Participants were assigned the role of either company commander or platoon leader. These tasks were based on tasks developed and used in prior studies at the United States Military Academy in West Point, NY [8, 9].

The first task (Rank Order Task) consisted of a simple rank order exercise asking participants to organize a list of six soldiers' first names, from highest to lowest rank based on the information provided. Each participant was given three unique statements about the relationship among the soldiers' ranks and one common statement. For example, one of the company commander's statements stated that "Ann is higher in rank than Jill." However, the platoon leader's statement stated that "Ann is lower in rank than Leroy." Thus, participants had to collaborate and share information to determine the correct rank order of the soldiers. Participants had 15 minutes to complete this task.

For the second task (Route Planning Task), participants each received a paper copy of the same terrain map, yet containing different information. The company commander's map provided information on enemy locations. The platoon leader's map provided information on route distances. Participants were instructed to share information and determine which of three possible routes (A, B, or C) was the shortest route that would not encounter enemy units. Participants had 10 minutes to complete this task.

The third and final task (OPORD Task) consisted of two parts. In Part One, participants were each given a set of two maps that contained information about an 'Operations Order' from Higher Headquarters. However, different information was provided on each set of maps. The company commander's maps contained information on platoon location and movement as well as planned course of action. The platoon leader's maps furnished information on the location and strength of enemy forces. Participants were asked to share this information to establish a 'common operating picture,' ensuring that they both had the all same information on their maps. Participants had 20 minutes to complete Part One.

In Part Two, participants completed a post-planning test consisting of 16 questions on the Operations Order they had reviewed (3 questions required multiple responses, for a maximum score of 23). Participants were free to use the information on their own maps, as necessary, but were asked to complete this task independently, without communicating or sharing any information with each other. Participants had 10 minutes to complete the test.

2.3.2. Collaboration tools study survey

A 5-item questionnaire was designed to solicit participants' subjective evaluation of their ease completing the tasks and the collaboration techniques used in the experiment. Specifically, participants were asked to indicate if they found it *easy* to complete each

of the three tasks and collaborate with their team member using the collaboration technique provided. Responses were recorded on a 7-point scale ranging from 1 (*strongly disagree*) to 4 (*somewhat agree*) to 7 (*strongly agree*).

2.4. Apparatus

In the face-to-face condition, participants were seated across from each other at a table in the same room. Participants who communicated either by voice telephone or instant messenger were positioned in separate rooms. For the voice telephone condition, participants communicated with each other using a standard desktop speakerphone. A voice-activated tape recorder was used to record participants' communication exchanges in the face-to-face and voice telephone conditions. The voice recordings were also used to calculate time on task (in seconds).

For the instant messenger condition, participants used Yahoo Instant Messenger on a PC-compatible laptop with standard Internet connectivity. Their communication exchanges were recorded using the built-in logging feature provided by the instant messenger software. These log files were also used to calculate time on task (in seconds).

2.5. Procedure

Upon arrival, participants were grouped into pairs and randomly assigned the role of either company commander or platoon leader. Each pair was then randomly assigned to one of the three experimental conditions. Participants first completed an informed consent form, followed by a biographical data form (e.g., age, gender, prior military experience, etc.). Participants then performed the three tasks using the assigned collaboration technique. Upon completion of the final task, participants were asked to complete the Collaboration Tools Study Survey, and were then debriefed. On average, the total length of the experiment was approximately one hour.

3. Results

3.1. Analysis

Results were analyzed in terms of both process and outcome performance. Process variables included analysis of the frequency and content of communication exchanges between team members. Outcome performance variables included time on task and task performance accuracy. Subjective evaluations of task performance were also examined. The data was analyzed using a one-way between-groups ANOVA, with collaboration technique as the between-groups variable. Post-hoc analyses are reported using Fisher's Least Significant Difference (LSD). An alpha level of .05 was used for all statistical analyses.

3.2. Process performance

The tape recordings for the face-to-face (FF) and voice telephone (VT) conditions were transcribed into text files and verified by two experimenters. Log files were generated for the instant messenger (IM) condition. These transcripts were then analyzed at the team level in terms of communication frequency and communication content, as described next.

3.2.1. Communication frequency

Communication frequency was determined by conducting a simple count of the total number of communication exchanges occurring between participant pairs in each condition. Overall, results revealed no significant differences in total number of communication exchanges on any of the three tasks. Although not significant, it should be noted, however, that for the more challenging OPORD Task, FF teams (M = 127.33, SD = 47.43) and VT teams (M = 143.50, SD = 20.51) exchanged almost twice as many communications as IM teams (M = 73.33, SD = 27.10).

3.2.2. Communication content

A modified version of a common communication coding scheme [10] was created to classify the different types of communication exchanges occurring between participant pairs into 10 categories as follows:

- Query (Q): direct or indirect task-related question
- MetaQuery (MQ): request to repeat or confirm previous communication
- Acknowledgement (ACK): one bit statement following another statement (e.g., "yes", "no")
- Response (R): statement conveying more than one bit of information
- Planning (P): statement involving organization of how task will be completed
- Action (ACT): statement requiring team member to perform a specific action
- Factual (F): objective statement involving verbalized readily observable realities of the environment, representing 'ground truth'

- Judgment (J): sharing of information based on subjective interpretation of the situation
- Non-Task Related (N): personal comments not related to the collaboration activity
- Experimenter-Related (E): comments or questions directed at the experimenter

Two trained experimenters independently coded the transcripts and compared their classifications of the communication exchanges, with consensus reached on any discrepancies. Non-Task and Experimenter-Related statements were not included in the analysis. In general, analysis revealed significant differences only for the MetaQuery and Acknowledgement statements, and only for the Rank Order and OPORD Tasks. These results will be discussed in greater detail next.

For the Rank Order Task, results showed a significant effect of collaboration technique on the number of MetaQuery statements exchanged (F (2, 5) = 7.95, p = .028), and a marginally significant effect for Acknowledgement statements (F (2, 5) = 3.97, p = .093). Post-hoc analysis revealed that FF teams (M = 1.33, SD = 0.58, p = .020) and VT teams (M = 1.50, SD = 0.71, p = .019) expressed significantly more MetaQuery statements than IM teams (M = 0.00, SD = 0.00). VT teams (M = 16.50, SD = 2.12) also expressed significantly more Acknowledgement statements than IM teams (M = 4.67, SD = 1.53) (p = .038).

For the OPORD task, results again showed a significant effect of collaboration technique on the number of MetaQuery statements exchanged (F (2, 5) = 6.98, p = .036), and a marginally significant effect for Acknowledgement statements (F (2, 5) = 4.61, p = .074). Post-hoc analysis revealed that FF teams (M = 5.33, SD = 2.08) expressed significantly more MetaQuery statements than IM teams (M = 0.67, SD = 1.15) (p = .014). VT teams (M = 3.50, SD = 0.71) also expressed more MetaQuery statements than IM teams, but this difference was not significant (p = .10). Finally, FF teams (M = 39.33, SD = 16.50, p = .055) and VT teams (M = 44.00, SD = 1.41, p = .044) also expressed significantly more Acknowledgement statements than IM teams (M = 16.00, SD = 7.55).

3.3. Outcome performance

3.3.1. Time on task

Time on task (in seconds) was analyzed at the team level for each of the three collaborative planning tasks as well as the OPORD Task test. Results revealed a significant effect of collaboration technique on time on task for the Rank Order Task (F (2, 5) = 9.06, p = .022) and the Route Planning Task (F (2, 5) = 8.08, p = .027), and a marginally significant effect for the planning portion of the OPORD Task (F (2, 5) = 5.37, p = .057). No significant differences were found for the testing portion of the OPORD Task (F < 1).

Post-hoc analysis showed that IM teams took significantly longer to complete all three tasks than FF teams or VT teams. Specifically, for the Rank Order Task, time on task for collaboration using instant messenger (M = 906.33, SD = 126.61) was significantly greater than when collaborating face-to-face (M = 357.00, SD = 237.59, p = .013) or using voice telephone (M = 353.00, SD = 110.31, p = .019).

Similarly, for the Route Planning Task, collaboration using instant messenger (M = 497.67, SD = 173.28) took significantly longer than collaborating face-to-face (M = 171.33, SD = 34.59, p = .016) or using voice telephone (M = 163.50, SD = 23.34, p = .022). Finally, IM teams (M = 1187.67, SD = 49.22) also had significantly greater time on task for the planning portion of the OPORD task when compared to FF teams (M = 749.00, SD = 261.26, p = .046) or VT teams (M = 643.50, SD = 258.09, p = .033). No significant differences were found between the FF and VT teams for time on task in completing any of the three planning tasks.

3.3.2. Task performance accuracy

Performance accuracy was analyzed at the team level in terms of: (a) number of soldiers listed in the correct order on the Rank Order Task; (b) selection of the optimal route on the Route Planning Task; and (c) number correct on the testing portion of the OPORD Task. Overall, results revealed no significant effect of collaboration technique on performance for the Rank Order Task (F < 1), Route Planning Task (F < 1), or the testing portion of the OPORD Task (F (2, 5) = 2.89, p = .146). Mean performance for all three conditions was at or close to ceiling.

3.4. Subjective Evaluation

Responses to the Collaborative Tools Study Survey were analyzed for all 16 individual participants (i.e., not at the team level). Responses to the four items soliciting subjective evaluations of ease in task performance were reverse coded to facilitate interpretation and reporting of the results, such that higher numbers indicate that participants perceived greater difficulty in performing the task. Responses to ratings on how interesting participants found the study were not reverse coded (i.e., higher numbers indicate

that the study was perceived as more interesting).

Results revealed a significant effect of collaboration technique on participants' subjective evaluations of how easy they found it to perform the Rank Order Task (F (2, 13) = 4.11, p = .041) and a marginally significant effect for the OPORD Task (F (2, 13) = 3.47, p = .062). A significant effect was also found for perceived ease in collaborating using the assigned collaboration technique (F (2, 13) = 4.06, p = .043). No significant differences were found for perceived ease in performing the Route Planning Task (F (2, 13) = 2.47, p = .123) or rating the study as interesting (F < 1). Overall, participants reported finding the study interesting (M = 5.63, SD = 1.46).

Post-hoc analysis revealed a significant difference between FF teams (M = 2.17, SD = 1.60) and IM teams (M = 4.83, SD = 2.14) on perceived ease in performing the Rank Order Task, with collaboration using instant messenger being perceived as more difficult (p = .016). Although IM teams also rated performing this task more difficult than VT teams (M = 2.75, SD = 0.50), this difference was only marginally significant (p = .076). No significant differences were found between the FF and VT teams on this task.

Post-hoc analysis also showed that IM teams (M = 3.50, SD = 1.87) perceived performing the OPORD Task as significantly more difficult than FF teams (M = 1.67, SD = 0.52) (p = .026). Although IM teams also rated performing this task more difficult than VT teams (M = 2.00, SD = 0.82), this difference was only marginally significant, (p = .089). No significant differences were found between the FF and VT teams on this task.

Finally, post-hoc analysis showed that collaboration using instant messenger (M = 3.08, SD = 1.50) was perceived as significantly more difficult than collaborating face-to-face (M = 1.50, SD = 0.55), (p = .018). A marginally significant difference was found between collaboration using instant messenger and voice telephone (M = 1.75, SD = 0.50) (p = .063). No significant differences were found between the face-to-face and voice telephone collaboration techniques.

4. Discussion and Conclusions

Overall, the results of this exploratory study provide some insight into the differential influence of various collaboration techniques on team communication processes and task performance. Teams collaborating face-to-face or using voice telephone had almost twice as many communication exchanges as teams collaborating using instant messenger and tended to express more requests for confirmation and provide more acknowledgements of communications. However, when compared to teams collaborating face-to-face or using voice telephone, teams collaborating using instant messenger, in general, took longer to complete all three tasks and perceived performing the tasks and using this collaboration technique as more difficult. Thus, these findings suggest that the hypothesized negative effects of collaboration techniques relying on text-based information exchange cannot necessarily be mitigated by a synchronous information flow, such as in using instant messenger. Further, the lack of differences in communication processes between teams collaborating face-to-face or using voice telephone suggests that nonverbal/paralinguistic cues may not be as critical for achieving effective collaboration on basic information sharing tasks, such as used in this study.

In terms of task performance accuracy, no significant differences were found, with teams performing at or near ceiling. This finding may be due to the straightforward nature of the tasks. Specifically, the tasks used in this study were well-structured, with a clearly defined path for task completion and minimal uncertainty. Completion of these tasks primarily involved information sharing, which would be expected to highlight differences in communication processes rather than differences in task performance. Thus, further research is warranted to examine the differential influence of various collaboration techniques on performance of ill-structured tasks, where multiple paths are available for dealing with the task and uncertainty exists in that the outcome associated with each path is unknown (cf. [11]). Such tasks require prioritization and knowing how to maximally and efficiently coordinate resources and efforts with other team members. Also, given the small sample size of this exploratory study, conclusions based on these findings are tentative, pending further research using larger, more complex teams involving multiple positions and varying levels of team interdependencies for task completion.

Nevertheless, this study's preliminary findings do highlight some potential implications for the design of collaboration techniques to support distributed team performance. For example, results showed that teams collaborating using instant messenger took longer to complete tasks than teams collaborating either face-to-face or using voice telephone, yet had only half as many communication exchanges. This finding suggests that task completion may have been hindered due to interacting with the interface associated with this

collaboration technique (i.e., having to physically type information into the system rather than simply voice this information). Collaboration tools that support rapid entry of text information (e.g., audio to text translation software) may help overcome this limitation.

Results also showed that teams collaborating either face-to-face or using voice telephone expressed more requests for confirmation and provided more acknowledgements of communications exchanged. This may be simply an artifact of the more expedient flow of information associated with these collaboration techniques, or perhaps because text-based communication allowed for more complete exchange of information, resulting in less ambiguity as to what was transmitted. Nonetheless, this finding highlights the need to support collaboration using voice communication channels with adequate bandwidth to ensure clear transmission of information.

The long-term goal of our research project is to identify how collaborations tools can best be designed to support the optimal development of the cognitions (e.g., shared situation awareness), behaviors (e.g., team coordination), and attitudes (e.g., collective efficacy) of teams performing in distributed environments [2]. This exploratory study represents our preliminary efforts toward achieving this challenging goal.

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