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A PRELIMINARY STUDY EXPLORING THE PERFORMANCE OF SYSTEMS DEVELOPMENT IN FACE-TO-FACE SETTING IN RELATION TO TELEVISION VIDEO CONFERENCING

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ABSTRACT

This article presents the findings of a preliminary study exploring the performance of systems development in a face-to-face setting in relation to a dispersed setting using television video conference. The study finds that systems development in the dispersed setting using television video conference can produce at the least same performance as in the face-to-face setting. It indicates that better training in virtual work and technologies can produce same performance in lesser amount of time. The study also explored the nature and content of interactions in both the groups, and found that the group using television video conferencing interacted for lesser amount of time on task-related activities.

Keywords: Virtual work, teamwork, video conferencing, face-to-face work, global outsourcing

INTRODUCTION

Virtual work involves geographically dispersed people working interdependently with shared purpose across space, time, and organizational boundaries and using technology to communicate and collaborate. Emerging practices such as distributed information systems (IS) development in onshore and offshore projects use virtual work to avoid travel, and to save time and money. The computer consulting services market, estimated at US$333 billion in 2009 [[12]], could use virtual work to combine the best expertise from various geographic locations at lower costs. The growing offshore IS development market driven by the motive to reduce costs, could take advantage of virtual work to lower costs. In offshored IS development projects, coding and testing are usually done offshore but requirements analysis and some design activities that require face-to-face interactions are often done onshore. Since offshore work is less expensive than onshore work, virtual work can help to increase the amount of offshore work and reduce the outsourcing costs. This article concerns the study of a systems design activity that frequently needs face-to-face interactions and that is not highly suitable for offshoring without effective virtual work.

Virtual work may involve geographically dispersed work group members interacting synchronously (in real-time) or asynchronously (different times). Synchronous work groups may use rich media, less-rich media, or

lean media and collaborative work products. Whereas rich-media includes television video conferencing (TVC), less-rich media includes desktop video conferencing and audio conferencing, and lean media includes chat systems and emails. Only one previous study involved synchronous virtual work using TVC. Studies that synthesized previous study results show that face-to-face (F2F) interactions lead to better group effectiveness and lesser task time than virtual work using less-rich media or lean-media [[5],[21]]. Previous studies used group problem-solving and decision-making exercises in investigating the effectiveness of virtual work and no previous study involved systems development. Few studies investigated the nature and content of interactions between group members in virtual work.

This preliminary study contributes to the body of knowledge in virtual work in the following ways. It is the first study to compare F2F group work and virtual work using rich-media synchronously. It is also the first study to investigate virtual work in the context of systems development. In addition, it is the first study to explore not only the interactions, but also the content of interactions with the objective of identifying the nature of interaction differences in F2F and TVC work groups engaged in systems development.

The next section presents a summary of previous studies and a rationale for this study, and makes thirteen propositions in comparing F2F and TVC work groups in systems development. The third section describes how the study was conducted using a homogenous group of graduate IT students and the fourth section describes the results of the study. The fifth section discusses the outcomes of this preliminary study. The last section concludes this article and indicates future research directions.

F2F AND VIRTUAL WORK

More than one-hundred studies on virtual work [[4],[5],[21]] stress the importance of F2F interactions in group work. From these studies, we gather that F2F interactions are necessary to convey complex information, build consensus, and create shared context required in group work. F2F interactions also provide social context, shared experiences, nonverbal nuances, and contextual cues. In addition, they enable rich communication that fully uses the physical senses and psycho emotional reactions, and have capacity for interruption, repair, feedback, and learning. Furthermore, F2F interactions build shared understanding and definition of the task. F2F interactions create an environment of common understanding, mutual respect, and emotional closeness that support the free expression and discussion of ideas. Virtual groups often do not have task conflicts but relationship conflicts are common, and it may need several meetings to overcome process conflicts. Groups that have low cohesion often run into interpersonal, task, or process conflicts that need F2F interactions, or at the least, rich synchronous communication media to resolve them. Periodic F2F meetings of group members are necessary to successful development and operation of a virtual group. Many studies have compared F2F and virtual work as discussed next.

Previous Studies Comparing F2F and Virtual Work

Bordia synthesized eighteen studies that compared the effectiveness of group work using Computer-Mediated Communication (CMC) and F2F meetings [[5]]. The CMC groups in these studies used computer-mediated communication asynchronously. Bordia concluded that CMC groups took longer time to complete tasks but the quality of performance was not definitively better or worse. Baltes et al. conducted a meta-analysis of thirty-five studies that compared the effectiveness of group decision-making in F2F and CMC groups [[4]]. Their meta-analysis included studies that used both asynchronous and synchronous communication using lean-media but only those that did not have verbal communication. The meta-analysis concluded that CMC decreases task effectiveness and member satisfaction, and increases task time.

Since effective collaborative activities need F2F interactions, synchronous virtual work can use video technology as a substitute for F2F interactions. However, studies involving less-rich media are sparse and studies involving rich-media are rare. The earliest study involving less-rich media compared F2F group work with virtual work using a web conferencing system [[24]]. Please note that the web-conferencing system was used asynchronously in the study. The study concluded that CMC could not outperform F2F teams under comparable circumstances, and F2F teams had better cohesion and satisfaction with the interactions. A study that compared collaborative problem-solving using F2F and desktop video conferencing (DTVC) showed that the quality of solutions reached through DTVC was at least as good as the quality of solutions reached by F2F collaboration but DTVC took longer than F2F collaboration [[23]]. Townsend et al. investigated the use of technology adoption model to DTVC and found that users that viewed DTVC in a positive way are likely to perform better [[22]]. This study did not compare DTVC to F2F group work. Crede and Snizek evaluated group judgment processes and outcomes in DTVC and F2F groups and found no significant differences in the accuracy between the two groups [[8]].

Only a few studies involving rich-media have been reported. A study compared rich-media with high-quality audio conferencing [[9]]. This study concluded that TVC with high-quality images enabled more fluent conversation than with high-quality audio conferencing. It did not make any comparison to F2F group work. Anderson et al. conducted a study to evaluate F2F interactions and video-mediated communication in problem-solving situations [[2]]. They concluded that video-mediated communication with good quality images produced interactions similar to F2F interactions. Although they did not compare the two groups on performance, they indicated that the task outcomes were not different and the video-mediated communication took longer time for interactions. Only one study has compared F2F and TVC, and reported that the quality of task outcome between high-quality video supported remote work and F2F work was the same [[19]].

Using synchronous rich-media with TV is common in distance learning for higher education. Studies in distance learning have compared synchronous rich-media with F2F, and investigated the learning outcomes and teaching behavior [[1],[18]]. Although these studies may not fall strictly under the realm of virtual work, they shed light on the comparative advantages of the two types of interactions between students and teachers. A meta-analysis of studies comparing the effectiveness of distance learning using synchronous video method and traditional classroom format found that students learning through synchronous video had slightly better scores on exams [[1]]. However, the differences were not uniform when the course content was taken into consideration. Better performance scores were associated with certain courses such as languages and lower performance scores were associated with certain other courses such as military-related instruction, and thus, indicating that content of the subject should be a major consideration in choosing between synchronous video and F2F instruction. Table 1 summarizes the findings of previous studies comparing F2F and virtual work.

Table 1: Summary of Results from Previous Studies Comparing F2F and Virtual Work

Study	Media Compared	Type of Study	Conclusion
Bordia (1997) [[5]]	F2F v/s CMC (asynchronous)	Synthesis of 18 studies involving problem-solving or decision-making	CMC groups had longer task times but performance was not better or worse.
Baltes, B. et al. (2002) [[4]]	F2F v/s CMC (both asynchronous and lean-media synchronous)	Meta-analysis of 35 studies involving group decision-making	CMC decreases performance and member satisfaction, and increases task time.
Warkentin, M.E., et al. (1997) [[24]]	F2F v/s Asynchronous web conferencing (less-rich media)	A study involving sharing of information in a crime.	CMC performance was not better, and F2F teams had better cohesion and satisfaction with the interactions.
Vinsonhaler, J.F. et al. (1998) [[23]]	F2F v/s Synchronous Desktop Video Conferencing (less-rich media)	A study involving problem-solving	Same quality of solutions but DTVC took longer time.
Crede, M., Snizek, J.A. (2003) [[8]]	F2F v/s Synchronous Desktop Video Conferencing (less-rich media)	A study involving decision-making	No difference in the accuracies.
Daly-Jones,O., et al. (1998) [[9]]	Audio Conferencing (Synchronous lean-media) v/s TVC (synchronous rich-media)	A study involving negotiations.	TVC had more fluent conversations. TVC was not compared to F2F.
Anderson, A.H. et. al. (1997) [[2]]	F2F v/s TVC (synchronous rich-media)	A study involving problem-solving but no comparison of the two types of work	Found that types of interactions are the same and indicated that task outcomes could be the same with longer task times for TVC.
Olson, J.S., et al. (1997) [[19]]	F2F v/s TVC (synchronous rich-media)	A study involving problem-solving	Quality of task outcome the same.
Allen et. Al. (2004) [[1]]	F2F v/s TVC (synchronous rich-media)	A meta-analysis of 39 studies on distance learning	Students learning through TV had better scores on exam but it depended on the course content

Interaction Patterns in F2F and Virtual Work

Requirements analysis and logical design of databases in systems development need interactions between developers and users, so that developers can understand the requirements of users before developing the system. Interviewing is a primary means of determining user requirements in systems development [[6], [13]], and the interactions between the users and developers are often in the form of an inquiry process involving questions and answers [[14]] with the objective of understanding user requirements. Therefore, its interaction patterns may be different from problem-solving/decision-making situations that involve frequent and intense bilateral interactions, and different from distance-learning situations that involve less frequent and less intense bilateral interactions. We postulate a continuum of interaction patterns and place various types of interactions as shown in Figure 1 not drawn to scale. Because these interaction patterns are different, the results of previous studies – although these studies did not analyze the interaction patterns - involving game playing, mystery solving, problem solving, decision-making, and distance learning may not be extensible to systems development. Therefore, this study makes the first attempt in exploring the effectiveness of TVC group work and F2F group work in systems development in relation to their interaction patterns. A study of interaction patterns would provide clues to improving the effectiveness of group work.

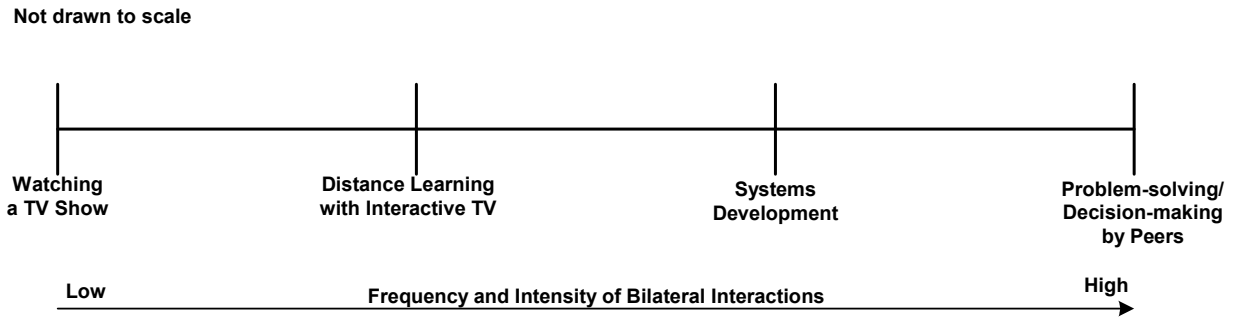

Figure 1: Frequency and Intensity of Interactions in Various Situations

Interaction Process Analysis – developed by Bales [[3]] -- is a method to investigate how frequently members of a group engage in certain types of interactions with the objective of describing the characteristics of various categories of groups and its members [[20]]. For example, a group engaged in a problem-solving exercise could be investigated using Interaction Process Analysis to determine how frequently members agree or disagree and how frequently they seek opinions and suggestions in solving the problem and to determine how various categories of groups, such as F2F and virtual groups, are different or same in these types of interactions. An extension of Interaction Process Analysis called Interaction Content Analysis involves classifying the interactions into categories such as work-related and task-related interactions, and analyzing the effectiveness of a group work in terms of the interaction content [[18]].

The inquiry process during the requirements determination for an information system can be in the form of a developer asking questions related to the system being developed and the user responding with answers to these questions. For example, a developer may ask questions such as "please describe the purpose of the system" to gather new information or ask questions such as "is it true that a software engineer should have skills in at least one programming language to work in the company" to confirm known information. An inquiry can be classified into asking, informing, answering, and confirming [[10]]. In achieving mutual knowledge through interactions, as in systems development, team members need to share information and confirm the correctness and completeness of the received information [[7]]. Therefore, this study uses two classes of task-related interactions: exploratory and confirmatory. Whereas, exploratory interaction involves asking and answering questions related to new concepts and ideas, confirmatory interaction involves asking and answering questions to confirm concepts and ideas known to the team members.

In addition to task-related interactions that involve knowledge transfer, group work in systems development would involve interactions related to transfer of paper work or electronic files as a developer may ask the

user for certain documents related to the system being developed. Group work would also involve work-related interactions and social interactions. Systems development involves interaction of developers with users in understanding user requirements, and individual work in which developers spend time in thinking about their understanding of the user requirements and translating it into requirements definition or design. A developer can be engaged in individual work while thinking about the system, drawing the ER diagram, or normalizing the relational tables, and without interacting with the user. The user may be idle at this time. Similarly, the user may be thinking or taking notes while developer is idle. Furthermore, all the members in a team may be idle. The possible types of interaction between users and developers in system development are summarized in Table 2. This study explores the content of these interactions in F2F and TVC group work in systems development

Table 2: Interaction Types in Systems Development

Interaction Types
Task-specific interaction - Exploratory
Task-specific interaction - Confirmatory
Work-related interaction
Transfer of documents
Social interaction
Developer work – no interaction with user – user idle
User work – no interaction with developer – developer idle
Both developer and user idle

Summary

It can be seen from Table 1 that all studies but one investigated and compared F2F to virtual work using media ranging from asynchronous to less-rich synchronous. In general, the F2F work had shorter task times and better performance compared to virtual work with asynchronous media. Although synchronous virtual work with less-rich media had performance similar to F2F work, it had longer task times. Only one study compared F2F to virtual work using rich synchronous medium and found the quality of tasks to be about the same. In addition, all of these studies focused on tasks involving game playing, mystery solving, problem solving, and decision-making. None of the studies involved systems development. Excepting for one study, none of the studies discussed the nature of interactions. Furthermore, none of the studies investigated the content of interactions in group work. This study makes a beginning in comparing the F2F and TVC group work in systems development, investigating the interaction contents in each group work, and exploring the relationships between the interaction content and performance in each group. First, we make several propositions as discussed below.

Current studies show that F2F work leads to better performance when compared to virtual work using asynchronous media, and similar performance when compared to virtual work using synchronous less-rich media. In comparing the F2F and TVC group work in systems development, the first proposition is:

P1: *In systems development work, the performances of F2F and TVC groups will be the same*.

The performance in systems development is characterized by the development of correct and complete systems. During the analysis stage, performance can be characterized by the determination of correct and complete requirements, and during the design stage, it can be the specification of correct and complete design.
Current studies also show that F2F group work takes less time than virtual work using asynchronous media and less time than virtual work using less-rich media. The second proposition is:

P2: *In systems development work, the F2F group will take less time than the TVC group*.

According to current studies, the productivity (=performance/time) of F2F group work is better than the productivity of virtual work because both groups had similar performances but virtual work had longer task times. In systems development, productivity is important because correctness and completeness of systems development cannot be compromised for development time. Based on the first two propositions, we make the following proposition on productivity:

P3: *The systems development productivity of F2F group will be better than that of the TVC group*.

The total time for systems development work includes idle time and times for work-related interactions, document transfer, task-specific interactions, individual work, and social interactions. Identification of differences in times for various interactions in F2F and virtual work and relating them to performance could lead to productivity improvement methods. Since previous studies show that virtual work needs more coordination, we make a

proposition that TVC group work would need more time for work-related interactions.

P4: *In systems development work, the time spent on work-related interactions by the F2F group will be less than that of the TVC group*.

Anderson et al. [[2]] showed that the types of interactions in F2F and TVC group work are the same, but they did not investigate the amount of time spent on any interaction. We make another proposition that the amount of time for task-specific interactions in the two types of group work would be the same. The amount of time for task-specific exploratory interactions in the two groups would be the same. The amount of time on task-specific confirmatory interactions in the two groups would also be the same. The next three propositions are:

P5: *In systems development work, the time spent on task-specific interactions by the F2F group and the TVC group will be the same*.

P6: *In systems development work, the time spent on task-specific exploratory interactions by the F2F group and the TVC group will be the same*.

P7: *In systems development work, the time spent on task-specific confirmatory interactions by the F2F group and the TVC group will be the same*.

Systems development would involve interactions related to transfer of paper work or electronic files as a developer may ask the user for certain documents related to the system being developed. In a F2F situation, users can handover the documents to developers without much effort but in the TV mediated group work, the user would have to navigate the developer to the electronic folders in computers or fax the documents. Therefore, transfer of documents in the TVC group may take more time. The next proposition is:

P8: *Time spent on users transferring documents to developers in F2F group will be less than the time for such activity in the TVC group*.

Since group members may interact more freely in a F2F situation, social interactions may be more than in the TV mediated group work. Thus, the ninth proposition is:

P9: In systems development work, the time spent on social interactions in the F2F group will be more than in the TVC group.

While the developer is engaged in individual work, the user may be idle and vice-versa. Having interacted with the user and gathered the necessary information to perform analysis or design, a developer may not spend more time on individual work (user idle) in one or the other group. There is no reason to believe that the time spent by the user in individual work (developer idle) would be different in the two types of work. Similarly, the idle time of both users may not be different in the two types of work unless the TVC group work is interrupted by technological glitches. The other propositions are:

P10: *The system developer will spend the same amount of time on individual work in the F2F and TV mediated works*.

P11: *The user will spend the same amount of time on individual work in the F2F and TV mediated systems development works*.

P12: *The idle time for both the user and developer in the two groups will not different*.

If methods, tools, and technologies can be devised to transfer documents between developers and users, the time spent on transfer of documents can be minimized in TVC work. Similarly, if training can be provided to team members in group work, time spent on work-related instructions can also be minimized in TVC work. Excluding these times and the times for social interactions and idleness, team members would be spending time on task-specific interactions and individual work. We define modified-productivity as the ratio between performance and combined time for task-specific interactions and individual work. Based on the propositions P1, P5, and P10, we make the last proposition as follows.

P13: *The modified systems development productivity-ratio for the F2F group will be the same as the modified systems development productivity-ratio for the TVC group*.

We conducted a study to explore the above propositions as discussed in the following sections.

STUDY COMPARING F2F AND TVC VIRTUAL WORK

Participants

The subjects in the study were graduate students specializing in IT management with undergraduate degrees in IT. They were in their second and final year of graduate study in a residential school in India. Students admitted to this school are at least in the top 10% of similar students in the nation. Since the students are in a residential program, the participants had known each other for more than one year both inside and outside of their classrooms. The participants also have had coursework in systems development and database design, both in their undergraduate and graduate studies. Participation in the study was voluntary and the performance of participants in the study had absolutely no bearing on any grade in any coursework. All the participants were Indian nationals fluent in both written and oral English. Prior to the study, a training session was conducted to review the skills of participants in database design, convention, and notation and to bring the skills of all participants to the same level. The participants were informed that they would be designing a database and that would be video recorded.

The study used participants from the same culture, who spoke the same language, and who have been known to each other for about eighteen months, both inside and outside of classrooms. It should be pointed out that the participants took the study so seriously, that they did not have much of social interaction during the videotaping of the study. Grossee points out that building relationships, developing trust and understanding, and showing respect for other cultures and languages are imperative in successful teamwork [[11]]. Thus using a homogeneous group of participants with the same amount of interest, motivation, knowledge, and skills precluded individual differences in participants affecting the study outcome. It enabled us to focus on studying the differences in performance and interactions in F2F and TVC groups.

Materials in the Study

A design case involving a database of personnel inventory in an IT consulting company was identified as the exercise for the participants. The database has six tables and sixteen attributes. The case was selected such that the exercise could be completed in less than one hour. A team involved a developer interviewing a user to understand the system and develop a database for the system. In addition to interviewing, the developer could seek any document related to the system being developed and available with the user. Based on the interview and current system documents, the developer needed to understand the database entities and their relationships. After drawing an entity relationship diagram, the developer had to identify the relational tables in at least 3rd normal form. The developer was also required to identify the primary keys and foreign keys in each table as needed. The study had two sets of teams: one set of teams used F2F interactions to design a database, and the other set used high-quality TVC to design a database for the same system. Each team's database design was evaluated for correctness and completeness of the ERA diagram, database tables, and normalization and a score of 0 to 100 assigned. The score obtained by a team is its performance.

The Study Setup

The first set interacting F2F was video recorded with a single video camera as shown in Figure 2. Six separate teams interacted F2F and designed the database for the same case. In the second set, the developer faced a 27-inch television connected to a high quality video camera facing the user, and the user faced another 27-inch television connected to another high quality video camera facing the developer as shown in Figure 3. The camera was mounted on the television set to simulate a F2F interaction using live high-quality images. The interactions between the user and developer captured through separate cameras were video recorded to single tape such that both the participants could be observed at the same time for coding the interactions. The developer and the user also had inter-connected computers that allowed chatting and sharing of electronic documents. Six teams trained in the use of the above setup developed the database for the same system.

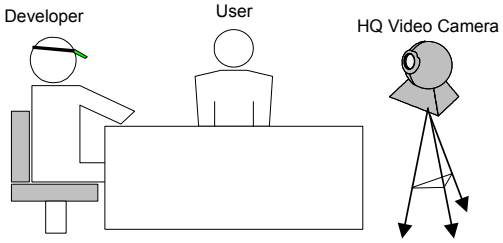

Figure 2: Face-to-face Setup

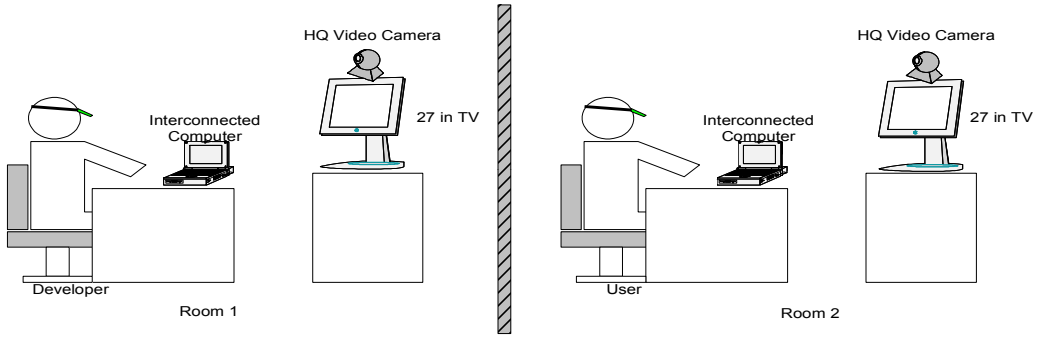

Figure 3: Television Video Conferencing Setup

Coding

The objective of this study is not only to compare the performance and task time in F2F interactions with video-based interactions, but also to explore the content of these interactions. Therefore, each video recording was reviewed to code each interaction into one of the interaction types shown in Table 2. The coding of each video involved identifying the interaction type and the start time of the interaction as shown in Table 3 with an illustration. The start time of the next interaction marks the end of the preceding interaction, and the difference between the start and end times marks the duration. From the coding sheet, we identified the duration of each interaction type for each group in F2F and TVC setups.

Studies on virtual work use various metrics such as performance and task time. To provide clarity, we define the metrics used in this study as shown in Table 4.

Table 3: Interaction Coding Sheet with an illustration

Interaction Start Time	Interaction Class	Interaction Duration	Remarks
0:00:00	Task-specific interaction - Exploratory	0:00:15	Inquiry
0:00:15	Task-specific interaction - Exploratory	0:00:25	Answer
0:00:40	Task-specific interaction - Exploratory	0:00:32	Inquiry
0:01:12	Task-specific interaction - Exploratory	0:00:10	Answer
0:01:22	Task-specific interaction - Confirmatory	0:00:08	Inquiry
0:01:30	Task-specific interaction - Confirmatory	0:00:09	Answer
0:01:39	Transfer of paperwork	0:00:31	Request for a chart
0:02:10	Transfer of paperwork	0:00:21	Help in getting chart
0:02:31			

Table 4: Metrics Used in the Study

Metric	Explanation
Performance	Score obtained in the evaluation of the database designed by the developer.
Overall Productivity	Ratio between the score and the total duration of the project, from start to finish.
Modified Productivity	Ratio between the score and the sum of (time for individual developer work time + time for task-specific interactions)
Interaction Times	Times for various types of interactions described in Table 2.

Analysis Method

In analyzing the data, we used a two-sample t-test to compare the differences in the means of various measures for the TVC and F2F groups. A two-sample t-test should use pooled two-sample test when the two groups have equal variances and use Satterthwaite's approximate two-sample t-test otherwise [[16]]. Therefore, we tested for equality of variances in two groups before selecting the appropriate two-sample t-test. An assumption in the two-sample t-test requires normal distribution of the data from both the groups. However, the two-sample t-test is so robust that the test results are valid as long as the data population is not extremely non-normal.

To double-check the results of two-sample t-tests, we also performed a two-sample Mann-Whitney nonparametric test that does not require normality. In all measures, the Mann-Whitney nonparametric test produced the same conclusions as the two-sample t-tests.

STUDY RESULTS

The data collected from the study found that all groups had very little social interaction between user and developer, very little idle time of developer, and very little idle time simultaneously for both the developer and user. Where it was noticed, it was for an insignificant amount of time. Therefore, these types of interactions and the corresponding propositions P9, P11, and P12 were not explored in the study. Various hypotheses to test the other ten propositions and their results are explained below.

Performance

The first proposition (P1) states that the performance of F2F group in systems development will be the same as that of the TVC group. Please note that the performance in the study is measured by a score between 0 and 100 based on the correctness and completeness of the database designed by a team. The first proposition translates into the following hypothesis:

$H1_0$: *The mean database design scores are not different for groups using F2F interactions and TVC*
Versus
$H1_a$: *The mean database design score of the F2F group is greater than that of the TVC group*.

The F2F group has the sample mean of 92.5 and standard deviation of 2.429 in database design scores. The TVC group's sample mean of 92.17 is close to that of the F2F group. Its standard deviation of 3.06 in database design scores is also close to that of the F2F group. A two-sample t-test for difference in the scores fails to reject $H1_0$ with a p-value of 0.419. Therefore, the differences in the database design performances are insignificant. The finding is similar to the findings in previous studies involving less-rich media.

Project Duration

Project duration is the elapsed time for the project from start to finish. The second proposition (P2) states that F2F group will take less time for systems development than the TVC group. The proposition translates into the following hypothesis:

$H2_0$: *The mean project durations are not different for groups using F2F interactions and TVC*
Versus
$H2_a$: *The mean project duration for the F2F group is smaller than that of the TVC group*.

The F2F group has the sample mean of 34.93 minutes and standard deviation of 3.96 minutes in project duration. The TVC group has a sample mean of 32.0 minutes and a standard deviation of 4.62 minutes in project duration. The TVC group's mean project duration is 8.39% less than that of the F2F group. However, a two-sample t-test for difference in project duration fails to reject $H1_0$ with a p-value of 0.266. It shows that the differences in the mean project durations for the two groups are insignificant. This is in contrast to the findings of previous studies involving both asynchronous and less-rich synchronous media that had longer task times than F2F.

Productivity

The third proposition (P3) states that productivity -- measured as the ratio between the database design score and the project duration -- of F2F group in systems development will be better than the productivity of TVC group. However, the conclusions from the testing of Hypotheses 1 and 2 indicate that the productivity may not be different for the two groups. The third proposition translates into the following hypothesis:

$H3_0$: *The mean productivity ratios are not different for groups using F2F interactions and TVC*
Versus
$H3_a$: *The F2F group's mean productivity ratio is higher than that of the TVC group*.

The F2F group has the sample mean productivity ratio of 2.67 and standard deviation of 0.23. The TVC group has the sample mean productivity ratio of 2.95 and standard deviation of 0.58. Although the TVC group's mean productivity is 10.48% more than that of the F2F group, a two-sample t-test for differences fails to reject $H3_0$ with a p-value of 0.843. Therefore, the mean productivity ratios for the two groups are not different. The above results are in contrast with the findings of previous studies that involved virtual work with less-rich and lean media. This study shows that the productivity of database design with TVC (rich-media) is not different from the productivity of database design in the F2F setting.

Work-related Interactions

The project duration includes times for work-related interactions, document transfer, task-specific interactions, and individual work. Although the project durations in the two settings are not different, various interaction times could be different for TVC and F2F work. Since an identification of differences in times for various types of interactions could lead to productivity improvement methods in group work, we made several other propositions. The fourth proposition (P4) states that F2F group in systems development will spend less time than TVC group on work-related interactions. The fourth hypothesis is:

$H4_0$: *The mean times spent on work-related interactions are not different for F2F and TVC groups*
Versus
$H4_a$: *The F2F group's mean time on work-related interactions is smaller than that of the TVC group*.

The F2F group has the sample mean of 36.83 seconds and standard deviation of 13.89 seconds spent on work-related interactions. The TVC group has the sample mean of 95.2 seconds and standard deviation of 28.4 seconds spent on work-related interactions. Although both the times are small, the TVC group spent about three times the amount of time on work-related instructions. A two-sample t-test for differences rejects $H4_0$ with a p-value of 0.001. It shows that the mean time for the TVC group is greater than that of the F2F group. As participants in the experiment have no experience with TVC, they probably needed more work-related instructions than in F2F work. This finding is consistent with the proposition.

Task-specific Interactions

Task-specific interactions involve asking questions and getting answers in the process of developers inquiring users regarding their system requirements. The fifth proposition (P5) states that time spent on task-specific systems development interactions in F2F group and in the TVC group will be the same. Therefore, the fifth hypothesis is:

$H5_0$: *The mean times spent on task-specific interactions are not different for F2F and TVC groups*
Versus
$H5_a$: *The F2F group's mean time on task-specific interactions will be greater than that of the TVC group*.

The F2F group has the sample mean of 11.09 minutes and standard deviation 1.62 minutes for task-specific interactions. The TVC group has the sample mean of 6.67 minutes and standard deviation of 1.33 minutes for task-specific interactions. The F2F group spent 66.27% more time on task-specific interactions. A two-sample t-test for difference rejects $H5_0$ with a p-value of 0.001. It shows that the mean time spent by the F2F group on task-specific interactions is greater than the mean time spent by the TVC group. Anderson et al. [2] showed that the interaction patterns are not different for F2F and TVC, but this study shows that interaction times in the two groups are different.

The task-specific interaction consists of exploratory and confirmatory interactions. Since the F2F group spends more time on task-specific interactions than the TVC group, it is of interest to explore the differences between the two groups in exploratory and confirmatory interactions. The sixth proposition (P6) states that the time spent on task-specific exploratory interactions in the two groups will be the same. The sixth hypothesis is:

$H6_0$: *The mean times spent on task-specific exploratory interactions are not different for F2F and TVC groups*
Versus
$H6_a$: The *F2F group's mean time on task-specific exploratory interactions will be greater than that of the TVC group*.

The F2F group has the sample mean of 3.03 minutes and standard deviation of 0.67 minutes spent on exploratory interactions. The TVC group has the sample mean of 2.67 minutes and standard deviation of 0.57 minutes spent on exploratory interactions. Although the TVC group has spent 11.88% less time on task-specific exploratory interactions than the F2F group, a two-sample t-

test for differences fails to reject $H6_0$ with a p-value of 0.262. The test shows that the times spent by the two groups on task-specific exploratory interactions are not different. The seventh proposition (P7) states that time spent on task-specific confirmatory interactions in the two groups will be the same. The seventh hypothesis is:

$H7_0$: *The mean times spent on task-specific confirmatory interactions are not different for F2F and TVC groups*
Versus
$H7_a$: *The F2F group's mean time on task-specific confirmatory interactions will be greater than that of the TVC group*.

The F2F group has the sample mean of 8.07 minutes and standard deviation of 0.95 minutes spent on confirmatory interactions. The TVC group has the sample mean of 4.07 minutes and standard deviation of 1.68 minutes spent on confirmatory interactions. The F2F group has spent about twice the amount of time spent by the TVC group. A two-sample t-test for differences rejects $H7_0$ with a p-value of 0.001, and shows that the F2F group spent more time on task-specific confirmatory interactions than the TVC group.

Document Transfer

The eighth proposition (P8) relates to the transfer of documents between users and developers during the systems development process. Per this proposition, the TVC group will spend more time in transferring documents, and it translates into the eighth hypothesis as:

$H8_0$: *The mean time spent on transferring documents is not different for F2F and TVC groups*
Versus
$H8_a$: *The F2F group's mean time on transferring documents is less than that of the TVC group*.

The F2F group has the sample mean of 29.83 seconds and standard deviation of 2.99 seconds spent on transfer of documents. The TVC group has the sample mean of 157.7 seconds and standard deviation of 24.8 seconds spent on transfer of documents. The TVC group spends more time in transferring documents between the team members than the F2F group, and the rejection of the $H8_0$ hypothesis with a p-value < 0.001 confirms it.

Individual Work

The tenth proposition (P10) states that amount of time spent by a developer in both the groups will be the same. The tenth hypothesis is:

$H10_0$: The *mean time spent by the developer is not different for F2F and TVC groups*
Versus
$H10_a$: The *mean time spent by the developer in the F2F group is less than that of the TVC group*.

The F2F group has the sample mean of 22.72 minutes and standard deviation of 2.56 minutes spent on individual systems development work. The TVC group has the sample mean of 21.12 minutes and standard deviation of 5.97 minutes on the same activity. There seems to be little difference between the two groups as a two-sample t-test for difference fails to reject $H10_0$ with a p-value of 0.716.

Modified-productivity Ratio

Modified-productivity is the ratio between performance and the combined time for task-specific interactions and individual work; it excludes time spent on all other activities. Per the thirteenth proposition (P13), this ratio for the two groups will be the same. The last hypothesis is:

$H13_0$: *The mean modified-productivity ratio is not different for the F2F and TVC groups*
Versus
$H13_a$: *The mean modified-productivity ratio for the F2F group is less than that of the TVC group*.

Whereas, the mean modified-productivity ratio for the F2F group is 2.76 with a standard deviation of 0.25, the mean modified-productivity ratio for the TVC group is 3.43 with a standard deviation of 0.80. The TVC group's mean productivity is 24.28% more than the mean productivity of the F2F group, and a two-sample t-test for difference rejects $H13_0$ with a p-value of 0.05. When times for work-related interactions and document transfer are excluded, the TVC group shows same performance in lesser amount of time than F2F group. The testing of various hypotheses and their statistical results are summarized in Table 5.

Table 5: Study Results

Description	Mean Value		Two-sample t-test for significant difference	
	F2F	VC	Significant	Insignificant
1. F2F group has better database design score than TVC group – Max 100	92.50	92.17		t = -0.21 p-value = 0.419
2. F2F group project duration is smaller than TVC group project duration – in minutes	34.93	32.0		t = -1.18 p-value = 0.266
3. F2F group has better productivity ratio than TVC group	2.67	2.95		t = 1.10 p-value = 0.843
4. F2F group spends less time on work-related interactions than TVC group – in minutes	0.61	1.59	t = 4.51 p-value= 0.001	
5. F2F group spends more time on task-specific interactions than TVC group – in minutes	11.69	6.67	t = -5.17 p-value= 0.001	
6. F2F group spends more time on exploratory interactions than TVC group – in minutes	3.03	2.67		t = -1.19 p-value = 0.262
7. F2F group spends more time on confirmatory interactions than TVC group – in minutes	8.07	4.07	t = -5.06 p-value= 0.001	
8. F2F group spends less time on transfer of documents than TVC group – in minutes	0.5	2.63	t = 12.51 p-value= 0.000	
9. F2F group spends less time on individual work than TVC group – in minutes	22.72	21.12		t = -0.61 p-value = 0.716
10. F2F group has lower modified-productivity ratio than TVC group	2.76	3.43	t = 1.96 p-value = 0.05	

Legend: F2F – Face-to-face, TVC – Television Video Conferencing

DISCUSSION

This preliminary study made a beginning in comparing systems development in a face-to-face setting to a virtual setting that uses television video conferencing, and in investigating the content of interactions among group members. It is the first study to compare F2F group work and virtual work using synchronous rich-media in the context of systems development. This is also the first study to explore not only the interactions, but also the content of interactions with the objective of identifying the nature of interaction differences in F2F and TVC work groups engaged in systems development. Although half of the findings were statistically significant with a p-value less than or equal to 0.05 (please see Table 5), the sample size makes it difficult to interpret the findings that are not statistically significant. However, all the results from two-sample t-tests were verified and confirmed by non-parametric tests. Therefore, we follow the discussion with a cautious optimism. More conclusive results can be obtained by repeating the above study with a large number of participants.

The findings of this preliminary study are: 1) the systems development performance, development time, and the systems development productivity in F2F and TVC settings are not different, 2) the contents of interactions between users and developers in the two settings differ, and 3) there is scope for obtaining better systems development productivity in the virtual setting using television video conferencing. The study findings are summarized in Table 6.

Previous studies showed that performance in virtual work with less-rich media is not different from the performance in a F2F setting. Performance with rich media can also be expected to be the same as in a F2F setting as shown in this study. Previous studies also found that F2F work took less time, and therefore, indirectly showed that F2F work has better productivity. This study shows that not only performance but also time and the explicitly measured productivity in the two settings are not different. The high quality video images on 27-inch televisions possibly simulated the face-to-face setting and produced equivalent performance in about the same time. The productivity similarities noted in this study may also be related to the nature of the interactions in systems develop-

ment. Interactions in systems development involve developers' inquiry of users with the objective of gaining knowledge about the system. It involves mostly knowledge transfer from the user to the developer. In contrast, previous studies used problem-solving and decision-making situations that involve intensive bilateral interactions between members in a group. The nature of interactions observed in systems development and their relation to systems development productivity is discussed next.

Table 6: Summary of Findings

Description	Difference between F2F and TVC
Total Duration of the project	No difference
Time for work-related interactions	F2F < TVC
Time for document transfer	F2F < TVC
Time for individual developer work	No difference
Time for task-specific interactions	F2F > TVC
Time for exploratory interactions	No difference
Time for confirmatory interactions	F2F > TVC
Score	No difference
Overall productivity ratio (Score / Total duration)	No difference
Modified productivity ratio (Score / (Time for individual developer work + Time for task-specific interactions))	F2F < TVC

Legend: F2F – Face-to-face, TVC – Television Video Conferencing

Although the study found no significant difference in the mean project durations of the F2F and TVC groups, it found that the mean time for work-related instructions in the TVC group is significantly more than that of the F2F group. This is as expected because people in general have a lot of experience in working face-to-face in comparison to working virtually using television screens. Therefore, the TVC groups needed help and spent more time in getting instructions on working through televisions. This finding points to a need for training in virtual work and virtual work technologies if efficiencies are to be gained.

The study also found that TVC groups needed significantly more time for transferring documents. In handing over documents needed in connection with the development, the F2F groups exchanged it with ease but in the TVC groups, the user had to guide the developer in navigating through the directories in finding the documents. Using a well-designed repository for document sharing and training the team members in using such a repository can reduce the time for document sharing while using TVC.

When TVC groups become efficient in using virtual work technologies and spend just as much time as F2F groups in documents transfer, any difference in project duration of the two groups will be due to times for task-specific interactions and individual work. Please note that not much of social interactions or idle times were observed in either group during this study. We calculated the modified-productivity ratio as the ratio between the database design score and the sum of times taken for task-specific interactions and individual work. A comparison of the modified-productivity ratio for the two groups showed that the TVC group is significantly more productive than the F2F group, which means that TVC group better trained in virtual work and TVC methods and provided with an easy-to-use document sharing system can produce same performance in lesser amount of time than F2F work. This result indicates that efficient design of TVC technologies, training in these technologies, and training in virtual work procedures can lead to productivity improvements and cost savings with TVC work.

Since the study showed that both the groups have no significant differences in database design scores (performance) and the TVC group has significantly better modified-productivity ratio, the TVC group should have been spending less time on individual work and task-specific interactions. The study showed that the amount of time spent on designing the database was not significantly different between the two groups. On the other hand, the study showed that the TVC group spent significantly less time in task-specific interactions than the F2F group. Therefore, the higher modified productivity ratio for the TVC group could be attributed to the lesser amount of time spent by the group on task-specific interactions.

Please recall that exploratory interaction and confirmatory interaction are two classes of task-specific interaction. Since TVC spends less time on task-specific interactions, either one or both classes of task-specific interactions may be less in TVC. The study further found that there is no significant difference between F2F and TVC groups on times spent on exploratory interactions. Thus, both the groups spend about the same amount of time in asking and answering questions related to discovering new information about the system being designed. On the other hand, the TVC groups spent significantly less time on confirmatory interactions than the F2F groups. Thus, the developers in TVC tend to ask fewer questions to confirm what they already know while developers in F2F ask more of such questions. Cramton showed that a dispersed group would have low level of feedback to confirm information due to time lags, and increased effort with slow and restricted feedback channels [[7]]. The TVC has no time lags, provides a feedback channel as open as F2F, and has performance not different from that of F2F. Therefore, we believe that physical proximity of users in F2F may tempt the developers to ask more questions than necessary to confirm what they already know. However, this should not be considered a chatter as both types of groups spent insignificant amount of time on social interactions and confined their interactions to either work related or the task related activities. Moore and Kearsley argue that transactional distance, a measure of understanding between the members, determines the communication effectiveness [[17]]. They also argue that the transactional distance depends not on the geographical distance but on the quality and amount of dialogue between the members. Our study indicates that TVC, while producing the same performance needs less time for task-specific interactions, and therefore, has better quality than F2F. Since virtual groups tend to be more task-oriented than F2F groups [[25]], the TVC groups could have been more focused than the F2F groups. Its task-specific interactions are more productive than in F2F.

CONCLUSION AND FUTURE RESEARCH

Many studies have been conducted on virtual work using less-rich and lean media but only one study has been conducted on rich media. Since offshore outsourcing is a large and expanding global business that uses virtual work, the approach shown in this preliminary study will be useful in more studies to investigate virtual work in systems development environments. In studying virtual work, it is important to understand the content and pattern of interactions to improve virtual work. This study showed a method to record interactions in virtual work to relate the content and pattern of interactions to group performance. More studies are needed to confirm the preliminary findings in this exploratory study and investigate many other questions raised in this study.

Since requirements analysis often uses interviewing methods to elicit information as used in this study, the results are applicable to requirements analysis. Future studies can explore other methods of requirements analysis such as the use of prototypes and newer agile development methodologies in a virtual environment. This study also made a beginning in analyzing the content of interactions, the results of which can lead to better methods in virtual work. The preliminary findings in this study show that systems development using TVC is at the least as good as F2F work. It indicates that productivity in TVC can be higher if users are provided with easy to share data repositories and well trained in virtual work technologies. Decreasing cost of communication technologies, savings in travel and time, and less time for development could make well-designed virtual work more attractive in distributed and offshore systems development.

The developers in TVC and F2F spend about the same time obtaining new information about the application system but developers in F2F spend more time in confirming the known information. A future study can verify this and investigate the why's of this phenomenon. It can also examine and determine interaction protocols suitable for F2F work and virtual work using TVC respectively.

This study involved developers with some knowledge of the application domain. It will be of interest to explore the interaction differences while developers had little knowledge of the application domain. This study also used one developer and one user to develop a database in about forty minutes. Future studies can involve larger groups and larger systems over longer time. Such studies can provide more information on the relative performance, productivity, and cost of TVC and F2F work.

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