Communication and Performance across Time Zones: A Laboratory Experiment

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Research-in-Progress

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Abstract

We often hear that global knowledge work teams are affected by time zone differences, but most research in geographically dispersed collaboration has focused on the effects of distance and has treated time zones as a secondary factor. The experimental study we describe here is part of a larger research program aimed at understanding how technical teams coordinate their work across time zones and which factors influence performance. In this study we investigate how time zone differences affect team performance in a laboratory setting. The study is composed of three phases corresponding to different task type manipulations – simple, complex and equivocal task. In each of the study phases, dyadic teams were randomly assigned into 4 time zone (i.e., work time overlap) conditions: full overlap, 2/3 overlap, 1/3 overlap and no overlap. Teams performed a map drawing task simulating the assembly of software components. We completed data collection for 131 dyad teams. In each phase we collected the following data: team performance (speed and accuracy), exit survey, and chat log capture. In this paper we describe our research design, briefly discuss our preliminary results from analysis of data from Phase 1, and describe our expectations and next steps for the full study. In Phase 1 we found that time separation has a negative effect on accuracy. We also found that a small amount of time separation has a negative effect on production speed but, surprisingly, speed actually increases with further increases in time separation – a “U” shaped curve. Our chat log text analysis also revealed differences in communication patterns across time zone conditions, which helps explain the unanticipated results. To evaluate if the simplicity of our task influenced our results in Phase 1 we manipulated the task in Phase 2 (added complexity) and Phase 3 (more equivocal). Expected results and implications from these subsequent phases are discussed at the end.

Keywords: Temporal boundaries, time separation, coordination across time zones, team coordination, geographically dispersed teams.

Introduction

Working across geographic locations is difficult because team members need to work across boundaries, including distance, time zones, cultural, and organizational (Ahuja et al. 2003; Armstrong et al. 2002; Carmel 1999; Herbsleb et al. 2003). While much of the research literature mentions time zone differences, the specific impact of time separation has been largely neglected. While geographic distance often correlates with time zones (Cummings et al. in press), these two boundaries have very different effects on dispersed collaboration. Distance alone eliminates
several benefits of co-presence, but it can be effectively bridged with technology that allows team members to interact synchronously. However, with time-separated collaboration team members’ work hours not always overlap and there is less time available for synchronous coordination. As the time zone differences widen, the window for synchronous communication narrows and the options for communication methods become more constrained. The result is likely to be a negative impact on project outcome measures, but research has not adequately answered this key question yet: how do team communication, coordination, and performance change with time zone differences? Our study contributes to the research literature by seeking to provide answers to these questions.

In this paper we describe our experimental research design and discuss our preliminary results. This experiment study is unique in its kind in that we simulated short imaginary work days in which dyadic teams worked on a task across four time separation (i.e., work time overlap) conditions. We then measured team performance and captured all team communication. Because the degree of time separation is mathematical in nature – i.e., it can be precisely calculated – it is ideally suited for lab simulation in experiment studies. In the first phase of the study team members performed the simple task of collaborating to draw maps. In this experiment, one team member D (map designer) provided instructions to another member M (map maker) who had to draw the map. We analyzed the data and, consistent with our expectations, we found that the quality of the maps reproduced reduced monotonically with the degree of time separation. However, contrary to our expectations, we found that the speed with which these maps were produced degraded initially with a small time separation, but then increased as time separation increased, reaching the highest speed when teams had no work time overlap. We attributed these results to the simplicity of the task that facilitated batching up instructions from D to M, thus becoming unaffected by time zone differences, but their speed actually improved with little or no overlap because team members were not distracted with synchronous interaction. The result was a rather surprising “U” shape curve. These results are discussed in detail in our first article about this series of studies (Espinosa et al. 2007). In order to better understand the reasons for these findings we analyzed the team communication logs. We also reasoned that speed would degrade monotonically with time zones if the task were more complex or equivocal because the increased need for communication with more complex and equivocal tasks would be hampered by time separation. Consequently, we designed and conducted two more experiment phases to evaluate our results under different task conditions – in Phase 2 we used a more complex task and in Phase 3 we used a more equivocal task.

In the remainder of this paper we describe our research design and preliminary findings. First, we articulate our theoretical foundations and initial hypotheses. We then describe our experimental design and method. We then briefly discuss our preliminary results from Phase 1, followed by a discussion section of Phases 2 and 3 and our next steps in this research.

**Theoretical Foundations and Hypotheses**

There has been more than two decades of research devoted to understanding the differences between co-located and electronic-mediated teams (Sproull et al. 1991) and how media richness affects team performance (Daft et al. 1986). This large body of literature shows that while information technology has improved our ability to collaborate remotely, it has not helped fully compensate for the loss of benefits of synchronous work and co-presence (i.e., the ability to get immediate clarification on an issue; frequent and spontaneous interaction, availability of contextual reference, presence awareness, workspace awareness, etc.). While recent research has begun to address these issues (Carmel 2006; Cummings et al. in press) the effects of specific variations in time zone differences on team performance have not been adequately investigated. Given that distance and time separation are often correlated in global collaboration, and given today’s increased offshore outsourcing practices (Carmel et al. 2005) and global collaboration across time zones (Herbsleb et al. 2003), it is important that we develop a better understanding of how time separation affects team performance.

While time separation can be caused by several reasons (e.g., difference in work schedules, mobile workforce, differences in holidays and vacation), we focus here specifically on the effect of time zones. The essence of the problem with time zones is the amount of time the team has available to work synchronously. There have been attempts in the research literature to articulate this. For example: Griffith et al. (2003) proposed “percentage of time apart in the task” as one of the dimensions of “virtualness”; Kirkman and Mathieu (2005) proposed the concept of “synchronicity” to distinguish between “real-time” (i.e., synchronous) and “lagged-time” (asynchronous) interaction; and O’Leary & Cummings (2007) created a time overlap index based on the fraction of the work day that overlaps between two sites.
In an earlier discussion of our research (Espinosa et al. 2007), we posited that both speed and product quality would decrease monotonically with time zone differences increased. We briefly discuss these arguments and re-state our hypotheses here to provide a complete overview of our theoretical foundations. Espinosa and Carmel (2004) developed a dyadic model with two actors, a task requestor (R) and a task producer (P) with a single task at hand and the work of R depends on P completing a requested task. This model suggests that there are inherent delays due to time separation in that P may be producing while R is sleeping (i.e., negative delay) or that R has to wait because P is sleeping when the request was sent (i.e., positive delay). In addition, further delays can be incurred due to miscommunication that requires either further communication or even re-work. Repairing such miscommunication is costly in time separated environments because one often has to wait until P starts his or her workday. Cummings and Espinosa (in press) have also found that time zone differences among the various dyads in a team affect their coordination through increased task delay. Similarly, we argued that teams with more time separation would have more difficulty identifying and repairing miscommunication on a timely manner because their communication is more asynchronous and therefore less interactive. Because team members often have time pressures to complete a task they may overlook mistakes made by their teammates, or they may consciously decide to trade quality in favor of production speed, depending on the economic incentives for one or the other. This led us to formulate the following two hypotheses.

**H1:** As the inter-site time difference increases (time overlap decreases) production speed will decrease.

**H2:** As the inter-site time difference increases (time overlap decreases) production quality will decrease.

We now briefly discuss the aspects of our experimental design, which are common to all three phases. We then briefly discuss the experimental task and preliminary findings for Phase 1, which are explained in more detail elsewhere (Espinosa et al. 2007). We then elaborate on these findings and augment them by analyzing the team communication logs. We then formulate additional hypotheses associated with task effects based on these preliminary findings and further theoretical development. We then describe our experimental design for Phases 2 and 3 and articulate our next steps in this research.

**Experiment Research Design**

In our experiment we varied the degree of time zone overlap (full time overlap, 2/3 time overlap, 1/3 time overlap and no time overlap). Each dyadic team was assigned to one of these four time zone overlap conditions. Participants were paid $20 for their participation in the study and were promised a performance bonus of $40 for each member of the best performing team in each condition (based on speed and accuracy). Our goal was to simulate a task that resembled collaborative software development but because the subject pools available were primarily non-technical we decided to use a fictional map task used in prior studies (Veinott et al. 1999) to eliminate possible confounds due to the software programming abilities among the participants. This task mimics three important aspects of global software engineering teams: (1) shared goals, (2) interdependent skills, and (3) the need for effective communication. For Phases 1 and 2 one team member played the role of a map designer (D) and the other played the role of a map maker (M). For Phase 3 both team members played the role of map designers. Each map designer had a set of 13 maps (see Figure 1 for an example) while each map maker had a set of 13 blank Microsoft PowerPoint slides. The first map was for practice and training and the remaining 12 maps were for the actual task. A correct map involved the identification of three elements: (1) one map background – out of eight provided; (2) two additional icons – out of 12 provided – and their correct positions on the background; and a (3) path consisting of five connected arrows. In Phases 1 and 2 D’s task was to give precise instructions to M about how to replicate the maps. D had all the maps on paper and M had all the necessary map elements in a PowerPoint file. Thus, rather than drawing a map from scratch M had to identify the correct elements and insert them into blank slides at the correct location. For Phase 3, both designers had to collaboratively produce precise descriptions of how to draw the maps.

Each experimental session included four imaginary workdays. Each workday lasted 15 minutes with short breaks (i.e., off work hours) between workdays. In the full overlap condition team members worked synchronously and had 5-minute breaks between work days. In the 2/3 (10-minute) and 1/3 (5-minute) overlap conditions D started working first followed by M during the overlap period and then M would work alone for the remainder of the work day. In the no overlap condition team members worked asynchronously a full work day by themselves and then left for the day when their teammate came to work at the end of their day. Participants were only allowed to
communicate using a chat software system we provided to the participants to simulate geographically distributed collaboration to eliminate confounds with distance, and to capture all their communication. Participants didn’t know who their teammates were. Using a single communication channel also helped us rule out potential confounding effects of media richness. During the overlap time, subjects could “chat” with their teammates whenever they wanted. On the other hand, during the non-overlap time, subjects could add instructions or comments through the chat facility, but they had to wait until their colleagues came to work to receive a response.

We collected comparable speed and accuracy data, exit survey responses, and chat log text in each of the three phases. The two key performance measures were processed as follows. Speed was calculated based on the number of maps a team could replicate divided by the total number of possible maps (i.e., 12) to normalize the scale from 0 to 1. Accuracy was measured simply by counting the number of correct elements (backgrounds, icons and arrows) in the map and their correct position in the picture. The score was computed by counting the number of correct elements and positions and dividing this by the number of correct elements and positions for a perfect map (i.e., 15), to normalize the scale from 0 to 1.

At the end of each experiment session participants completed an individual exit survey on demographics and perceptions of process and outcomes (i.e., communication, coordination processes and coordination outcomes). The five variables we constructed with this procedure are for perceptions of: (1) communication quality (e.g., “I received accurate (e.g. correct or precise) information from my teammate”); (2) mechanistic coordination (i.e., use of non-communication means to coordinate activities in a programmed way – e.g., “we established ground rules, routines and/or procedures to facilitate our team's work”); (3) communication delay (e.g., “typically it took a long time to get a response from my teammate”); (4) miscommunication problems (e.g., “our communication with my teammate required frequent clarification”; (5) coordination process problems (e.g., “we had many problems due to confusion and misunderstanding [by me or my teammate] about our task requirements”).

Finally, all the chat communication between team members was captured for analysis (recall that no verbal communications were allowed). The chat communication text was entered into a database with a single record for each chat log entry. Each entry included time stamp, team member role (D or M), entry time, and actual text. The researchers then reviewed all the entries to identify recurring themes using open coding as prescribed by Grounded Theory (Glaser et al. 1967).

**Phase 1 – Simple Task**

A total of 84 subjects participated in this Phase 1 of our experiment study arranged into 42 dyadic teams. In this task M had a total of 8 backgrounds and 12 icons that could be selected to reproduce the task maps.

**Data Analysis**

Accuracy for each map was evaluated independently by an external rater and one of the experimenters – with a reliability of 90.5%. The differences between these two raters were reconciled by another experimenter. The perceptual data consisted of 25 survey items, which were factor analyzed with Varimax rotation, which yielded 6
factors explaining 68.7% of the total variance. The factor groups were tested for reliability and all variables had a Cronbach-α reliability of 0.7 or greater. We analyzed the data using regression analysis controlling for all variables that could affect performance, including: (1) experiment location – using a binary variable for each location; (2) age group; (3) gender; (4) educational level; and (5) team member ratings of skills (for self and the teammate). Time separation was modeled with binary variables for 3 of the 4 conditions (full overlap was left out of the model as the baseline condition – i.e., the intercept). Consistent with our first hypothesis, compared to full overlap, speed declined with a small time zone difference. But interestingly, and contrary to our first hypothesis, speed increased slightly with more time zone difference (1/3 overlap, non-significant compared to full overlap) and increased even more with no overlap exceeding the speed for full overlap. Finally, as we anticipated in our second hypothesis, teams with less work time overlap (1/3 and no overlap) had significantly lower levels of accuracy although a small amount of time separation (i.e., 1/3 overlap) had no effect on accuracy. Again, further details and statistical results are described elsewhere (Espinosa et al. 2007).

**Analysis of Team Communication Logs**

In order to better understand our preliminary results we analyzed the communication themes in the team chat logs. We identified three main theme categories with various associated themes: task related (e.g., task instructions, acknowledgements, task questions, task status information, workflow organization); communication issues (e.g., evidence of miscommunication, communication repairs, evidence of rework) and other (e.g., social, technical issues). The themes were then given to an external coder with the necessary instructions and training. The external coder then coded each chat log entry. Some entries required more than one code. A second external coder was then asked to code a small sample of the same data. After inspecting for initial reliability and resolving coding conflicts the second coder coded the rest of the data achieving a 71% reliability, which is acceptable (Miles et al. 1994).

We found no differences in the number of chat log entries across time zone conditions. When analyzing communication by themes, we found that time zones reduced the number of acknowledgments ($\beta=-0.383$, $p=0.001$), requests for task status ($\beta=-0.475$, $p=0.004$), task completion confirmations ($\beta=-0.463$, $p<0.001$), evidence of miscommunication ($\beta=-0.254$, $p=0.041$), clarifications and communication repairs ($\beta=-0.530$, $p<0.001$) and evidence of rework ($\beta=-0.373$, $p=0.009$). There were no significant differences in other types of communication. Table 1 shows the specific time zone conditions that had significant reductions in these types of communication. Taken together, these results suggest a degradation of communication quality as more time zones are added. While certain types of communication (acknowledgements and request for task status) are negatively affected with small time zone differences, others are affected only when time zone differences are large (task completion confirmations, evidence of miscommunication, communication repairs and evidence of rework).

<table>
<thead>
<tr>
<th>Table 1: Communication Patterns across Time Zones (based on text analysis)</th>
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</thead>
<tbody>
<tr>
<td><strong>Significant Changes</strong>&lt;br&gt;<strong>by Overlap Condition</strong>&lt;br&gt;<strong>Compared to</strong>&lt;br&gt;<strong>Full Time Zone Overlap</strong></td>
</tr>
<tr>
<td><strong>Communication Theme</strong></td>
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<tr>
<td><strong>Task Related</strong></td>
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<tr>
<td>Acknowledgements</td>
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<tr>
<td>Requests for Task Status</td>
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<tr>
<td>Task Completion Confirmations</td>
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<tr>
<td><strong>Communication Issues</strong></td>
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<tr>
<td>Evidence of Miscommunication</td>
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<tr>
<td>Clarifications/Communication Repair</td>
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<tr>
<td>Evidence of Rework</td>
</tr>
<tr>
<td><strong>Notation:</strong> SR = significant reduction; blank cell = not significant</td>
</tr>
</tbody>
</table>

**Phases 2 and 3 – Complex and Equivocal Tasks**

Because of the surprising results on the effects of time separation on speed we reasoned that this happened because of the simplicity of the task, which made it easy for team members to effectively batch instructions and write them.
during the non-overlapping period. More complex tasks require individuals working on the task to process more information cues (Wood 1986), which reduces their performance (Argote et al. 1995, Reagans et al. 2005). We added complexity to the task by increasing the number of information cues that the team had to process to successfully finish the maps. More complexity makes it more difficult for individuals to articulate the information they need to transmit to their teammates. We anticipated that because more information cues needed to be transmitted from D to M, this would exacerbate the negative effects of time zones on delay, resulting in a steady decline in speed and steeper decline in accuracy as time zone differences increased. Thus, we posit:

H3: the negative effects of time separation on production speed will be stronger for complex tasks, compared to simple tasks.

H4: the negative effects of time separation on production quality will be stronger for complex tasks, compared to simple tasks.

Next, we turn from structured tasks to equivocal tasks. Equivocal tasks are ambiguous and subject to multiple interpretations. More equivocal tasks also require collaborators to exchange more information cues (Dennis et al. 1998). In equivocal tasks team members often hold different information, some of which is shared and some is unshared. Studies have shown that members tend to focus discussion on shared information, often neglecting to bring to bear unshared information (Stasser 1992), making it more difficult to discover “hidden profiles.” Hidden profiles are solutions that require the pooling of unshared information by team members because individual members do not have sufficient information to complete the task correctly (Stasser et al. 1989). Thus, we posit:

H5: the negative effects of time separation on production speed will be stronger for more equivocal tasks, compared to simple tasks.

H6: the negative effects of time separation on production quality will be stronger for more equivocal tasks, compared to simple tasks.

**Phase 2 – Complex Task**

In order to increase task complexity while retaining the ability to compare results with the simple task, we used the same 12 map figures used in the simple task, such that speed and accuracy scores could be computed on the same basis across experimental phases, but increased the number of available backgrounds to M from 8 to 20 and the number of icons from 12 to 40. The path elements were unchanged. A total of 90 subjects participated in 45 teams in the complex task. We collected the same data as for Phase 1, namely survey, performance and team communication logs. We computed speed and accuracy scores similarly to Phase 1 and we are presently coding the chat log data using the same coding scheme we used for Phase 1.

**Phase 3 – Equivocal Task**

We created an equivocal task that involved two map designers D1 and D2 who worked collaboratively to provide map drawing instructions to a fictitious map maker. We retained the level of complexity used in Phase 2 – i.e., complex task – by using the same maps and the same number of backgrounds (20) and icons (40). In addition, we created a “hidden profile” by providing each team member only 12 backgrounds – eight uniquely held by each member and four shared by both members – and only 24 icons – 16 uniquely held by each member and 8 shared. This way, no team member could produce correct map drawing instructions individually, but both members had collectively all the information needed. Team members had to communicate with each other to accurately describe each map and agree on a joint description of the maps. They were instructed to record this description in a GoogleDocs template we provided to them. Since we used the same maps, speed and accuracy scores could be computed on the same basis across experimental phases. A total of 88 subjects participated in 44 teams in the complex task. We collected the same data types as for Phase 1 – survey, performance and team communication logs. We also computed speed as in to Phase 1. We computed accuracy scores by having one external coder use the map descriptions submitted by each team to draw the maps and then using these maps to compute accuracy similarly to Phase 1. A second coder is presently doing the same drawing and coding so that we can compute reliability statistics for speed and accuracy. We are also presently coding the chat log data. We are using the same coding scheme for Phase 1, but because the task is quite different than phases 1 and 2 we anticipate having to expand the codes needed.
Discussion and Next Steps

Our results from Phase 1 point to a “U” shaped effect of time separation on speed and a negative monotonic effect on accuracy. A relatively small time zone difference of 2/3 overlap between dyads resulted in lower speed but accuracy was unaffected. We speculate that this reduction is due to the fact that individuals need to make constant adjustments as they shift from synchronous to asynchronous interaction, thus creating additional cognitive load compared to full overlap. In addition, valuable task time is utilized due to synchronous chatting, which combined with the switching in communication mode becomes disruptive. However, the ability to communicate synchronously during the larger part of the work day helped teams maintain similar levels of output quality than full overlap.

As the time difference increases to just 1/3 overlap speed improves but accuracy continues to decline. We speculate that the speed improvement is due to the larger chunk of uninterrupted work time, which more than compensates for the need to adjust to the change in communication mode during the work day. Finally, and interestingly, the highest speed is attained in the no overlap condition – even higher than full overlap. Because individuals can work without interruptions for a full day they can work faster, but this clearly comes at the cost of lower accuracy. Our chat log communication analysis suggests that this accuracy reduction is probably due to deteriorated communication quality evidenced by a significantly reduced communication in important categories associated with mutual understanding: acknowledgments, requests for task status, task completion confirmations, evidence of miscommunication, clarifications and communication repairs, and evidence of rework.

Naturally, we have only scratched the surface here and we are impatient to see whether our results hold once we analyze our data from Phase 2 and from Phase 3 as the task becomes more complex and more equivocal. As we mentioned earlier, we partially attribute our surprising results to the fact that the task in Phase 1 is simple and expect a more marked decline in both speed and accuracy as time zones increase.

Our study represents an important contribution for practice and research. The main implication for practice is that there are tradeoffs on the effect of time separation between speed and accuracy and managers need to evaluate this carefully when making work assignments and outsourcing decisions based on geography. Partial time separation has detrimental effects on speed because teams need to learn and adjust to this dual interaction mode (i.e., synchronous-asynchronous) and monitor time differences carefully, but it has little or no effect when time separation is large. In contrast, output quality (i.e., accuracy) does not suffer with small amounts of time separation, but it is substantially affected as time separation is increased.

Our study also has interesting implications for research. No prior study has teased out the effects of time separation from geographic distance or media richness. Our controlled experimental environment has enabled us to learn the nuances of working across time boundaries and it is a first of its kind. As with any laboratory experiment, our study has limitations. First of all, the fictional map task does not fully capture the complexity of software development. While this simplified task enables us to minimize confounding effects inherent to the task of software development, future work can seek to test the time separation effects in more realistic settings. Second, duration of the lab experiment is significantly shorter than real-world collaboration. Although this short time span has already yielded many interesting insights into the effect of time separation, it may prevent us from seeing long-term development of the effect. A possible opportunity to extend our research is to develop field experiment to trace the impact of time separation in the long run. Naturally, we expect our results from phases 2 and 3 to contribute to our knowledge on how the effect of time separation on speed and accuracy is moderated by task complexity and task equivocality, which will also represent an important contribution to fill this knowledge gap in the literature.

References


