Leadership's Effect on Overall Temporal Patterns of Global Virtual Teams

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***Abstract*—The goal of this paper is to examine the overall temporal response activities of global software learning teams and understand how these temporal activities are affected by the presence (and absence) of a team leader. Results from 24 teams enrolled in global software development courses at Universities in Turkey, Panama, and the US reveal that the presence of a team leader resulted in shorter time intervals between communication activities. Moreover, a teams pacing style (e.g., less time between communication activities) was also correlated with better team performance. Specifically, the affect of the rate of a teams temporal communications on team performance was more positive under conditions of the presence of a leader than under those with weaker team leadership. Leadership also had a positive effect on team performance. These results, we believe, further theoretical and methodological research on temporal issues and leadership.**

***Index Terms*—Global Software Development, Leadership, Virtual Teams, Communication Frequency, Temporal Patters, Team Pace**

I. Introduction

The rapid rise of the global economy coupled with recent advances in communication technology has led to an increased use of large international teams that can develop software for multi-national corporations. These large virtual teams, however, pose many problems for the individuals who must work in these environments. These problems include loss of coordination among group members [1], difficulties in understanding tasks developed off-site [2], and misunderstandings over schedules and deadlines [3]. One of the key factors in overcoming such difficulties is the presence of a strong leader. Yet, a majority of the research concerning online leadership in global virtual teams is only prescriptive in nature [4]. Moreover, a number of researchers have noted that most of the literature on global work teams tends to focus on only static leadership qualities (e.g., personal traits) while ignoring other important variables such as the temporal processes that are important in understanding how global virtual teams operate [5]. However, global work teams are, by definition, groups who are constantly aware of both distance and time. Thus, the inclusion of temporal factors, in addition to leadership qualities, provides a more comprehensive view of the features that influence global virtual team performance [5].

The difficulties and problems that exist within global software teams in industry can also be found in groups within university settings. Responding to industry demands for students with international experiences, universities have begun offering distributed learning courses that include international exchanges. These courses generally utilize some type of computer-supported collaborative learning (CSCL) environment to support efforts that allow for easy communication among participants. Students who are enrolled in distributed learning courses are usually assigned large software projects that include all phases of the software development life cycle. While some members of these teams may be co-located, others reside in different countries throughout the world. These global experiences have been well documented in papers such as [6]–[9]. These studies suggest that leadership and temporal factors impact the way students coordinate their efforts and work toward solutions to problems. Thus, educational researchers have found that student groups face the same temporal and leadership challenges as their industrial counterparts [10]. However, the actual relationship between temporal factors and leadership has been less explored. Researchers, instead, tend to concentrate on only specific leadership qualities that promote the management of student projects [11]; thus, motivating a more detailed examination of the real function of temporal factors within a global learning setting.

The goal of this paper, therefore, is to understand the temporal factors that relate to leadership and how such factors affect global software learning teams. More specifically, we explore the temporal variations and patterns in the communication activities among students engaged in a global software development project. Student communication activities include chatting, posting to a forum, uploading code, posting to a wiki, scheduling items on a calendar, and sharing documents. Each of these activities was recorded and time stamped for each project. These quantitative measures were then used to analyze groups with and without leaders with the goal of understanding the impact of the time intervals between communications within each group and determining whether the length of these time intervals varied during the lifecycle of the project. While similar analysis has been done elsewhere, this paper focuses on the question of how a teams leader can affect a teams pace during a project. A teams pace is defined as the length of time between different communication activities within a group. We propose that teams with a leader have less time

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between communication activities (which leads to an increase in team performance), whereas teams without leaders have more time between communication activities (which tends to lead to a decrease in team performance).

Our study furthers theoretical and methodological research on temporal issues and leadership in teams in three ways. First, our results clarify the complex relationship between temporal factors and leadership by specifying the condition (i.e., pace) under which temporal factors can maximize team performance. Second, our results have prescriptive value in specifying a temporal behavior that a leader might use in order to maximize team performance. Finally, we develop a procedure for examining the temporal factors that affect group performance. Such a measurement can prove of value to future studies of global software teams.

II. Related Work

This section represents a sampling of the literature on leadership within global virtual teams, temporal behaviors, and the relationships between these two research areas. Previous work has demonstrated that people have temporal patterns in the workplace, and that these rhythms can help coordinate interactions [12]. As a result, efforts to understand time and its effect on individuals and teams have grown considerably in the past several years. Leadership studies have also increased, as the research community struggles with understanding how team performance can be improved [13]. While the connection between leadership and temporal patterns is not a completely novel topic of research, there are considerably fewer works that consider how these factors interact and connect to group processes. Thus, we discuss the leadership and time literature and provide a relational perspective of how these two areas merge.

A. The Role of Leadership in Global Virtual Teams

The importance of leadership in a global virtual team cannot be understated. As [14] points out, "Leadership issues in Computer Mediated Communication are vital today because of the increasing prevalence of the virtual organization, the flattening of organizational structures and the corresponding interest in managing virtual groups and teams." Advances in communication technology have made the use of global virtual teams (i.e., teams whose members are not physically collocated) more practical and prominent in industry. These technological advances have meant that team members need to operate more adaptively when coordinating their actions. Thus, as several researchers suggest [15], leaders play an important management role by providing the group with a structure that is often loose or missing in these global environments. Additional research [16] shows that leaders often demonstrate particular work skills that allow groups to establish processes for successful team work. At the team level, these skills include specific leadership activities that are likely to affect group success [17]. Thus, group effectiveness can be theoretically defined in particular contexts and circumstances as a function of specific leadership actions. A critical task for researchers in team leadership, then, becomes validating the exact context in which these leadership actions can occur.

In addition to management skills, leaders must also provide a sense of urgency for the completion of a task [18] and create a social environment for individuals within the team [19]. Keeping a team on task is an important factor for teams because it is essential that the project remain on schedule [20]. Another role for the virtual team leader is building trust among team members [18]. This is usually accomplished by establishing extensive communication protocols that ensure that all team members receive the appropriate information. Such communication mechanisms facilitate project control and enable global virtual teams to function more effectively [1]. Research shows that these various roles or skills can have positive impacts on a teams performance [21] [22]. All of these skills are particularly critical in global software teams because team members rarely, if ever, meet [23] [24]. Thus, most effective leaders in virtual teams recognize the importance of communication and how it can affect the teams performance.

While leadership in virtual teams remains one of the most studied topics in management research, the role of leadership in global virtual student teams has received less attention. One reason may be the fact that collaborative learning teams are normally composed of members who have relatively equal knowledge and status; thus, they are more likely to have informal leaders or multi-leaders distributed over time [11]. The fluid nature of leadership within collaborative learning teams makes them much more challenging to study. In this type of environment, a leader is much more likely to emerge, as opposed to being assigned. Emergent leaders can be found in industry, particularly in global virtual teams, but they are far more likely to occur in collaborative learning environments. Researchers on emergent leadership within global learning environments have been interested in differences in the behaviors of emergent leaders and other group members, and in understanding the ways in which emergent leaders influence group actions [14]. The fact that these influences can be linked to temporal behaviors is far less understood. A discussion of temporal issues that are of concern in this area now follows.

B. Temporal Communication Patterns of Global Virtual Teams

As cited above, rapidly changing technologies and client needs have created temporal challenges for teams in the form of complex and dynamic coordination of workers in multiple locations with constantly fluctuating tasks and goals [25]. These challenges require careful management of temporal resources in teams [26], making the topic of time a much more important issue for those interested in studying teams. As a result, a growing number of researchers have identified temporal issues as a key agenda item for team research [27] [28] [29]. Through this research, there has come the discovery that there are a number of different time-based characteristics that are relevant to team tasks and team performance. For example, there are temporal factors such as a persons preferences towards morningness/eveningness [30], punctuality/lateness [31], and future/past [32]. There is also

the more recognizable dimension of clock time, which is both linear and divisible into distinct units [33]. There is also the idea of pacing, [34] which captures how individuals distribute their effort over time in working toward deadlines. Although generally associated with individual work styles, each of these temporal factors can be used to explain work-related cycles or rhythms for a team or group. For example, members of a work team that do not have regular patterns of communication may develop work priorities and pacing behaviors that are inconsistent with the needs and comfort levels of others in their team. This conflict of temporal rhythms can create tensions and dissatisfaction among team members [35], which can translate into lower team performance.

Temporal dimensions have also been used to characterize global software development teams in industry, although these discussions are generally in the context of a teams distance and location [2]. For example, [3] propose a list of temporal indices that are linked to factors such as a teams size, distribution, use of technology, and its organizational structure. Researchers in [36] suggest similar measures in studies that examine the impact of mode of interaction and work overlap on different costs associated with software development. More recently, researchers in [37] examined the effect of various tools that support teams faced with the challenge of working with people in different time zones. Their time zone distance measures account for factors such as the amount of non-overalapping work schedules, which can then be used to determine the cost of working in a different time zone [1]. Controlled experimentation on the effects of proximity on work teams is slowly determining that teams that work in different time zones are forced to spend much of their work time seeking information about when to complete a task or who is managing a particular part of a project [38]. Hence temporal differences coupled with geographical distance have become a major problem in distributed software projects [39].

Researchers in education have also explored the issue of time and how it relates to the collaborative learning process [40]. For the most part, they try to characterize the interactions that have occurred within a project by coding and then sequencing the different communication activities [41]. Researchers in [42] applied Time Series Analysis to data coded from student online tasks in order to characterize changes in students emotions. Researchers in [43] implemented timeline analysis in their research design to track the changes in student participation over time, and in [44] introduced Lag-sequential analysis in conjunction with a coding scheme to show that temporal patterns were significantly related to variations in group performance. Although most of these studies acknowledge the importance of temporal behaviors within collaborative learning teams, they have not examined the role of leaders in initiating or sustaining those temporal behaviors. Below is a discussion of some of the research that is looking at temporal leadership issues.

C. Time and Leadership

Leadership scholars have always been interested in how leaders spend their time at work. Early work by [45] and others showed that leaders spent about 70% to 90% of their time communicating with subordinates [19]. In a related study, [17] suggest that leaders often balance forecasting activities against time demands. For example, in [17], the authors suggest that time demands do indeed impact a leader's ability to lead by affecting the overall decision-making processes.

Researchers in this area are also interested in knowing whether a leader exhibits the correct behaviors at the appropriate time. [46] argues that the temporal ordering and time interval of task versus socio-emotional behaviors can affect performance outcomes. This multi-study work suggests such timing and ordering of behaviors is important, and that socio-emotional behaviors should be displayed by leaders just prior to displays of task-oriented behaviors. [46] suggests that rather than a sum total, or mean approach to the display of leadership behaviors, scholars need to consider if those behaviors are delivered at the appropriate time.

Thus, the literature on teams and leadership suggests that leaders are often the persons who are most responsible for shaping the time-related activities that occur within a team [47]. These time-related activities can include such things as scheduling and reminding team members of deadlines and tasks, creating rapport and trust among team members, and blending the skills of team members in order to achieve better performance. Indeed, both leadership and team researchers are beginning to explicitly link temporally related activities to the leadership role. For example, [33] and [48] have all coined the term temporal leadership to describe various leadership activities such as looking at a leaders reaction time to decisions and actions. Similarly, [49] suggest that temporal leadership activities such as managing temporal activities, adjusting tempo, recognizing time-related differences, and synchronizing the abilities of members should be looked at more intently in order to identify how these factors impact a teams performance. Despite these calls, the formal use of temporal variables in the leader and team literature is still small [49]. Addressing this need, we present a study that looks at the intersections among time, leaders and teams.

D. Current Context

Like many of the researchers cited in the previous section, the authors have looked at a number of different issues related to leaders and temporal behaviors within global virtual teams. In a recent study [50], we explored the question of whether a leader could increase the effectiveness of globally distributed software student teams, particularly student programming teams that are composed of individuals who live in different countries and time zones. Communication data from student teams enrolled in a global software project was analyzed in hopes of identifying teams with leaders and those without leaders. Similar to [51] [11] [14], we found that the person who had the most communications was generally the individual who was the leader in our teams. For our

study, we defined a leader as a person who was responsible for at least 30% of the communication activities within the group. Since our teams were, for the most part, composed of students with equal knowledge and abilities, we used the term emergent leader to characterize the leadership role. As stated previously, an emergent leader is a person who is not necessarily assigned the role of leader, but rather emerges as the individual who take gradually takes on that particular role [52]. The results from this study show that teams with leaders had more communication, performed better, and used different word categories than teams with no leaders.

This study was then followed by an exploration of the communication behaviors that occur among groups with and without leaders at different stages of the software development life cycle [50]. The communication transmissions between the teams were hand coded into one five categories: Social, Reflection, Seeking Input, Contributing, and Planning. A description of these categories can be found in [53]. Once the communication data was classified, we compared the proportion of communication behaviors that occurred in each category for each 10% percent-of-project completion. Surprisingly, leaders and non-leader teams displayed similar overall temporal patterns in terms of their usage of different categories of communications. However, the proportion of the different communication behaviors varied considerably between leader and leaderless teams as well as between leaders and their followers [50]. The work intensity of leaders pushed their teams to start earlier and actually complete their projects on time by using more contributing behaviors. Teams without leaders on the other hand, waited longer to start, participated in more social communication, and were less likely to stay on task. This later result is similar to what has been found in other research literature [54]. One unexplored aspect of this prior research is an investigation into exactly why the different communication behaviors of the leader impacted the team performance. In particular, these previous results prompted us to clarify the temporal conditions under which certain communication behaviors occur. More specifically, we wondered whether the teams with leaders (as opposed to teams without leaders) had more or less time between communication activities and, if less time, how might this time interval pattern affect team performance. We also wondered whether the pace of communication activities among teams with and without leaders varied at different stages of the software development life cycle. In order to answer these questions, we posed the following hypotheses:

1) There is no significant difference between a teams performance and the length of time between a teams group communication activities.
2) Teams with and without leaders have similar time-interval patterns between their communications.
3) Teams with and without leaders have similar time-interval communication patterns during different phases of project development.

Thus, the logical next step was to empirically explore some of the associations that leadership has with the time-interval communication patterns of global software development student teams and determine if the intersection of time-interval behaviors and leadership has an effect on team performance. In the next section, we describe our methodology for representing different types of time-interval communication patterns and examine how these patterns are linked to teams with and without leaders.

III. Methodology

The data for this study was generated from a globally distributed project between third-fourth year students enrolled in software development courses at the University of Atilim (Turkey), Universidad Tecnolgica de Panam, and the University of North Texas (USA). Although the subjects for this study were all students, they completed tasks that were similar to those found in industry. Before each project, researchers met to determine the overall requirements of the programming assignments, as well as how the different projects would be integrated into existing curriculum. The projects were completed over multiple weeks, and all online interactions between the students were captured using a common online collaboration tool. Once the projects were completed, the data was extracted, filtered, and processed.

1) Subjects: The students who participated in this study were enrolled in a junior level computer science or information technology courses during either fall 2009 or spring 2010 semesters. There were a total of 114 students from the following universities: Atilim University (Turkey), University of North Texas (US), and Universidad Tecnologica de Panama (Panama). There were 60 students in the first project and 54 students in the second project. The average age of the participants was 19.5 years. There were no significant differences in either the programming experience ($t = -0.52$, $p = .60$) or grade point average (GPA) ($t = -0.15$, $p = .87$) of the students who participated in the study.

According to survey responses, 99% of the students stated that they had previously worked in a collaborative team, and only 1% of the students stated that they had never worked on a team project. Regardless of their experience, all students received training on the online collaboration tool and teaming skills. The common language used by all the students for team communication was English, which was a project requirement.

2) Time Zone Issues: The Turkey-based students were ”generally” eight hours ahead of the US-based students and seven hours ahead of the Panama-based students. The US and Panama based students were ”generally” separated by an hour, depending on whether countries changed to daylight savings times. Times sometimes differed when countries were (or were not) changing times because of the shift to Daylight Savings times.

3) Team Composition: Each team was composed of at least one student from each of the three universities. The team members were randomly assigned to a group, and they were not allowed to switch teams once the projects began. In the first project (Fall 2010), 12 teams were created. In the second

project, 10 teams were created. Team size for both projects varied from six to nine members. In general, two to three team members from each university were assigned to each team.

4) Project Descriptions: Two separate, but very similar, global software development projects were assigned to student groups who participated in the study. The specific software development tasks were determined, in part by the content of the courses that were participating in the research for that semester. In Spring 2009, groups were asked to design, code, and test a Database Management System (DBMS) for scheduling car rentals. Students were given one month to complete the assignment. In Fall 2010, groups were asked to design, code, and test a DBMS to keep inventory of a bookstore. These students were given six weeks to complete their respected assignment. To complete the assignment, the groups were required to include a number of deliverables pertaining to the DBMS such as code, ER diagrams, and a working prototype. All deliverables were submitted to the collaboration project management system that is described in the following subsection.

Following the training, students were introduced to their team members (either through a teleconference or synchronous chat) and were provided information about the task as well as the management of their teams. Students enrolled in these courses received about 10 percent credit as part of their overall course grade for completing the project. To further motivate team participation, students were awarded prizes for their participation and performance.

5) Collaboration Software: Over the course of the project, a common collaborative software system Sakai [55] was used by all of the students. This system allowed the students to manage and organize the deliverables for their project. It also provided a wide variety of communication tools (synchronous or asynchronous) that students could use to communicate with one another. Synchronous communication was provided through a group chat and direct messaging, while asynchronous communication was provided through forums, emails, wikis, file sharing. The collaborative software was augmented with a series of scripts that stored communication activities in a centralized database. Thus, the recorded data included information about each chat, forum posting, file upload, and wiki entry, along with the date, time, and author of each online activity.

A. Team Performance Measures

A teams performance was evaluated by averaging the individual grades on each of the assignments. Projects were evaluated based on four criteria accuracy, efficiency, thoroughness, and style. A design or a program was considered accurate if it satisfied the users functional requirements and contained no errors. A projects efficiency score was evaluated by examining the number of program modules. A programs thoroughness was scored on whether the design or program included all the necessary elements. Finally, good programming style was judged by the examining the style (e.g., variable naming conventions, indentation, etc.) of the code. Researchers from each university graded their own student projects as well as those from the other participating countries. A mean grade for the project was then assigned to each student.

B. Data Collection and Processing

After the projects were completed, the communication activities (chat, wiki, etc.) were extracted from the independent database. As previously stated, a single communication activity was defined as a single asynchronous post to a forum, a message sent, a wiki posted, or a file uploaded, etc. Synchronous communications were also captured and labeled as chats or chat room activities. All of these communication transmissions were selected and organized by team and then listed in chronological order.

An elapsed time, or time interval between communications, was then computed for each transmission based upon the start time for a particular team. For this study, the time interval between communications was determined by computing the total time that it took for one team member to respond to another team members posting, chat, wiki post, etc. Team members responding to their own posts were not included in these counts. The rationale for this decision was that a self-response was not really indicative of group interactions and teaming so it should not be included in our statistics. These self-responses also occurred within the wiki data because students' initial postings were often followed by quick edits. Thus, all self-responses were eliminated from the time-interval temporal data.

Since the total amount of time for each project differed (4 weeks versus 6 weeks), we calculated the communication activities that occurred during each percent of project completion; that is, dividing the total number of minutes per project by 100 and then adding up the totals for each communication behavior that occurred during a 20% percentile. This normalization procedure allowed us to compare work patterns between the two projects. The response times for each team's time segment were then averaged and compared to one another.

IV. Results

After extracting all the transmissions from all the groups, we performed a number of experiments to determine the interactions between leadership and a teams temporal communication behaviors. Since one of our hypotheses suggests that there is a relationship between the time interval between a groups communications and performance, a Pearson product-moment correlation coefficient was computed to assess the relationship between the mean time intervals between communication activities and team performance. As seen in Table I, there was a strong negative correlation between the mean time between communication and team performance ($r = -.5262$, $n = 24$, $p = .0008$). The negative correlation between time-interval and team performance indicates that the less time that there was between a teams communications, the better the team performed. That is, student teams who responded more quickly to their peers, performed better on the project.

TABLE I
CORRELATION BETWEEN TIME INTERVAL OF GROUP COMMUNICATION ACTIVITY AND TEAM PERFORMANCE

	Time-Interval	Team Performance
Time-Int Pearson Correlation	1.000	.5262*
Sig. (2-tailed)	.	.0008
N	24	24
Team-Per. Pearson Correlation	.5262*	1.000
Sig (2-tailed)	.0008	.
N	24	24

*Correlation is significant at the 0.01 level

The team data was then separated into two groups; those that had leaders and those that did not. As per [56], teams were designated as having a leader if there was an individual who could be identified as generating, at least, 30% of a group's total transmissions, a figure which is similar to that found in [57]. Based on these criteria, we determined that there were 13 teams that had leaders, and 11 teams that appeared to have no single leader. An independent t-test was performed to compare the average time interval between communications between groups with a leader as opposed to those without leaders $see Table\ II$. The groups with leaders spent significantly less time between communication activities (M = 21.5, SD = 15.84) than groups without leaders (M = 70.63, SD = 25.6). Overall, groups with leaders tended to engage in significantly more frequent communications with one another than groups without leaders (M = 43.77, SD = 12.69), t(1) = -2.1, $p < .05$.

TABLE II
COMPARISON OF TIME INTERVAL BETWEEN GROUP COMMUNICATION ACTIVITIES

	N	Mean	SD	T	Sig
Leaders	13	21.05	15.84	-2.1	0.0477
Non-Leaders	11	70.63	25.26		

Knowing that teams with leaders tended to communicate more frequently, we then compared performance scores between the Leader and No-Leader groups (see Table III). An independent t-test shows that teams with leaders (M = 81.01, SD = 9.84) report significantly higher performance levels than teams without leaders (M = 70.72, SD = 12.69), t(1) = 2.27, $p < .05$.

TABLE III
COMPARISON OF MEAN PERFORMANCE BETWEEN LEADER AND NON-LEADER TEAMS

	N	Mean	SD	T	Sig
Leaders	13	81.15	9.84	2.27	0.03354
Non-Leaders	11	70.72	12.69		

Thus, the null Hypothesis 1 and 2 are not supported by the data collected for our experiments. The data clearly shows that groups with leaders had significantly less time between communications than groups with no leaders. Groups with leaders also performed better than no-leader teams. Thus, groups with leaders not only had better performance, but they also had more rapid communications among group members.

But global software projects are not completed in a hour, day, or even week. Most software development projects have phases and milestones that correspond to the software life cycle, which consists of requirements gathering, designing, coding, and testing. Thus there appears to be a temporal side of the software development life cycle which also can affect how a leader interacts with a team. In order to better understand this relationship between leadership and communication frequency over the course of a project, we calculated the time between communications for each percent of project completion; that is, we divided the total number of minutes between communication activities per project by 100 and then averaged the total interval time between communications for each 20 percentile. This normalization procedure allowed us to compare the pacing patterns of leader versus no-leader teams. More specifically, we were interested in determining if teams with leaders had faster rates of communications over the entire course of the project than teams without leaders, or if these rapid communications were localized in one particular part of the project.

Table IV shows the average time intervals between communications for each 20 percent of project for both leader and leaderless teams. Except for the first 20% of the project, time intervals between communications were much shorter for teams with leaders than for teams without leaders.

TABLE IV
TIME SEGMENT AVERAGES (VALUES ARE HOURS:MINUTES:SECONDS)

Time Segment	Leaders	Non-Leaders
0%-19%	55:59:47	56:17:25
20%-39%	21:04:51	57:53:22
40%-59%	36:59:17	72:08:36
60%-79%	21:23:09	92:33:13
80%-100%	68:44:26	140:28:21

A t-test was then used to compare leader versus non-leader teams for each of the 20% percent of project. As shown in table V, except for the first 20% of the project, every percent-of-time period shows significant differences in the temporal response patterns of teams with leaders as compared to those teams without leaders.

Because teams with leaders showed that they had less time between communication activities than teams without leaders, we rejected the third hypothesis, which was also a null hypothesis. Our data clearly show that teams with leaders were responded more rapidly to their peers than those teams without leaders.

V. DISCUSSION

Most individual workers develop, at least, are aware of not only their own temporal behaviors, but also the larger temporal contexts in which they live and work. Regardless of whether these temporal contexts are a work or student environment,

TABLE V
COMPARISON OF TIME INTERVAL BETWEEN GROUP COMMUNICATION BY PERCENT OF PROJECT

Time-Period	Team Designation	N	Mean	df	F	P
0%-19%	Leader	13	55.79	12	-0.012	0.49
	Non-Leader	11	56.10	10		
20%-39%	Leader	13	20.89	12	9.19	0.0003*
	Non-Leader	11	57.58	10		
40%-59%	Leader	13	36.84	12	4.64	0.007*
	Non-Leader	11	71.94	10		
60%-79%	Leader	13	21.23	12	27.12	0.0001**
	Non-Leader	11	82.37	10		
80%-100%	Leader	13	68.59	12	8.35	0.0005*
	Non-Leader	11	140.25	10		

$*p < .05$ and $**p < .0001$

they develop and influence the people who interact in those environments. Thus, it is important to recognize how these different patterns emerge and their implications for leaders and followers. This particular study sought to address this issue and determine the impact that leaders had on the temporal behavioral patterns within groups.

Our study yielded three major results. First, teams that had shorter time intervals between communications were more positively related to good performance than those who had longer time intervals. Second, team leadership exerted a strong influence on this performance since teams with leaders had shorter time intervals between communications AND better performance. Third, team leadership also seems to have had an effect throughout the length of the project. Teams with leaders had less time between communication in every time 20% time period (except the first 20%) throughout the length of the project. We now discuss these results in more detail.

Temporal pacing and team performance. Our research complements and extends temporal research in several ways. Literature, for example, has documented the problems that arise within teams when temporal resources are not attended to in a timely manner [12]. This study suggests that pacing between communications is critical to the success of a global software development project. The correlation between time interval between communication activities and team performance (see Table I) found that the smaller the interval time between group communication activities, the better a team performed. The results of this research indicate that it is important to maintain frequent and constant communications among group members. The lack of timely communication is particularly problematic in global software teams since members are often separated by large distances and many times zones. The results of this paper suggest that team members need to pay particular attention to communication interruptions that might be delayed because workers in one time zone have already left for home. Moreover, time lapses between communications seem to affect a teams rhythm throughout the project.

Team leadership and temporal pacing. Our results also indicate that a team's leader is a key player in maintaining and synchronizing the communication among group members. Based on the results presented in tables IV and V, we can conclude that teams with leaders responded much more quickly to each other than teams without leaders. By acknowledging that time-based issues in teams are often affected by the team leader is similar to what others have found in the leadership literature [17]. Our findings also suggest that strong temporal leaders are more likely to improve performance in distributed teams (see Table III). By acknowledging that the management of time-based issues in teams is often the responsibility of a leader, we believe that our data shows the relationship between effective leaders and a teams pacing activities.

Team leadership and project management. The results of the current research also point to the relevance of understanding how temporal communication activities lead to better managed group projects. For example, this study found that teams with leaders had more frequent communication during almost every phase of the software development life cycle than teams without leaders. The results in tables IV and V show that, with the exception of the first time segment (0%-19%), there is a significant difference in the time-interval activity between leader and leaderless teams in all phases of development. Teams with leaders are much more active in almost every phase of the software development life cycle. These frequent communications, coupled with better team performance scores, seem to highlight the importance of leaders within global virtual teams.

We were somewhat concerned that our data did not show significant differences between leader and no-leader teams during the first 20% if the project. A previous study [50], showed that teams with leaders had significantly more communication activities in every time period throughout the project. Given the increased communication numbers among teams with leaders, we were left to wonder why there weren't differences between the two groups in the 20% time period?

After reviewing our previous study, we concluded that the lack of differences in the 20% time interval was due to the way we calculated the time interval data. For example, the current experiment measured the time between communications as occurring only when the subsequent communication was performed by a different team member. Our measures ignored instances where a single team members communication activity was followed by their own posting. Since many of the initial communications were done by the teams leader, the time-interval activities in the first 20% time period would probably not show the anticipated differences.

VI. CONCLUSION

In this paper we set out to determine the relationship between the presence of a leader and their effect on a global virtual team's temporal patterns during project development. After analyzing the group communication activities of student software development projects, we found that leaders have a profound effect on the temporal behaviors of their

teams. Teams with leaders have smaller interval times between communication activities, which leads to higher performance as compared to non-leader teams. While all of the teams displayed similar interval times in the first 20% of time in development, there were significant differences between groups during the rest of the project. Combined with our previous research, we believe that leaders are active during the first section of development, often establishing a presence with the team, developing a structure or protocol for future team development, and setting the team's pace. After the first 20% of development, team members with a leader show more frequent group communication activity then their leaderless counterparts. This faster pace leads to increased communication among team members, better task management, and eventually increased team performance. We believe these positive attributes can be directly attributed to the presence of a leader.

The results of this study should help inform practitioners about effectively managing global virtual software teams. Although many people acknowledge the importance of synchronizing team communication, specific temporal variables often remain unnoticed by practitioners in the field. Our results highlight the importance of explicitly considering how frequently a team communicates. Proactively discussing how these different temporal factors affect team performance can facilitate the way different members deal with temporal issues within their teams. Moreover, by recognizing the importance of communication frequency, organizations can select leaders who know how to leverage temporal factors and maximize team performance.

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