TEAM DYNAMICS IN LONG-STANDING TECHNOLOGY-SUPPORTED VIRTUAL TEAMS

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ABSTRACT

This paper examines team dynamics in a virtual team that has been developing and issuing updates to open source software code for a period of at least eight years. Our study seeks to extend the applicability of behavioral leadership theory to the broader examination of team dynamics in virtual teams. We developed and use a content analysis framework deductively-derived from the literature on behavioral leadership to examine discourse, task-oriented, relationship-oriented, change, and network/boundary spanning communication behavior at two points in time in the ongoing interaction of the virtual team.

Our findings support the notion the derived behavioral framework can be appreciably used to study emerging team dynamics over the lifecycle of virtual team interaction. Shifts in team dynamics not found in previous studies of virtual teams were found. In particular, relationship-oriented behavior, which was not found to be common in prior studies, was the most prevalent form of communication with in the team at the two points in time at which interaction was examined. Additional shifts were observed in the proportion of process and substance communication related to the team's task that were not found in earlier studies.

Although preliminary, these findings suggest that team dynamics in long-standing technology-supported virtual teams differ from those found in virtual teams that focus on the completion of a single task within a relatively short-timeframe, which have been the focus of the majority of studies of virtual teams. Directions and implications for future research are discussed.

Team Dynamics in Long-Standing Technology-Supported Virtual Teams

INTRODUCTION

Many studies of virtual teams have focused on leadership rather examining team dynamics more broadly. Recent studies of emergent and assigned leadership and attendant group dynamics in virtual teams have examined the relationship between task-oriented and relationship-oriented communication behavior and team leadership. Task-oriented behaviors are behaviors that move teams forward in accomplishing the task at hand while group maintenance behaviors are those that demonstrate a concern for others and for the well-being of the team or group (Bass, 1990; Lord, 1977; Yukl, 2005); group maintenance behaviors have also been called relationship and/or social behaviors in the literature. Authors of these studies have noted that proportionately, virtual team interaction can be characterized as being dominated by task-oriented communication, and that perceptions of which team members assumed leadership roles is associated with their task-oriented but not with relationship-oriented communication.

However, the majority of these studies of leadership in virtual teams have examined leadership and group dynamics in a relatively compressed timeframe ranging from minutes during which a team was required to complete a task to approximately 15 weeks (Balthazard, Potter, & Warren, 2004; Carte, Chidabaram, & Becker, 2006; Cogburn, Zhang, & Khotule, 2002; Kayworth & Leidner, 2002; Misiolek & Heckman, 2005; Sarker, Grewal, & Sarker, 2002; Sudweeks & Simoff, 2005; Tyran, Tyran, & Shepherd, 2003). Given the relatively brief time period in which team members interacted in these studies, it is possible that task-orientation assumed precedence over group maintenance behavior of necessity given the time-boundedness of the tasks assigned to the teams. Absent in the literature are studies that examine emergent leadership and group dynamics within relatively stable virtual teams that interact with one

another over longer time periods during which it might be possible to examine the evolution of virtual team dynamics and leadership (Ortiz de Guinea, Webster, & Staples, 2005).

This purpose of this paper is to examine task- and relationship-oriented behaviors as a part of a larger study of team dynamics in an open source virtual team that has been developing software computer code for a period of eight years. Members of open source teams initiate and participate in voluntary cooperative activity focused on a common purpose. The term is most commonly associated with the development and distribution of computer source code that is published and made available to the public to use and modify without charge such as the Mozilla Firefox web browser and the Linux operation system. However, the open source concept has been applied in other areas and constitutes and important model of user-centered innovation (Von Hippel, 2006). These teams are similar to other types of virtual teams in that team members interact predominantly through a socio-technical infrastructure. These teams differ from the majority virtual teams that have been studied in the literature which have largely consisted of undergraduate and graduate student teams that interacted on an assigned task during a finite time period .

LITERATURE REVIEW

Studies of team dynamics in virual teams have examined a variety of structural, cognitive, attitudinal, and process factors such as temporal coordination and conflict management (e.g., Jarvenpaa, Knoll, & Leidner, 1998; Montoya-Weiss, Massey, & Song, 2001; Rico & Cohen, 2005). Only one study investigating virtual team dynamics – in this case, conflict and its effect on team performance – utilized a behaviorally-based theoretical framework that distinguished between relationship, task, and process dynamics (Martinez-Moreno, Gonzalez,-Navarro, Zomoza, & Ripolli, 2009).

Our literature review focuses on that subset of the literature on leadership in co-located and in virtual teams that discusses and examines the relationship between task-oriented and relationship-oriented behavior and team leadership. We focus on this subset of the virtual teams literature in this review because of the scarcity of behaviorally-based research on team virtual dynamics beyond leadership.

We believe that this is a curious omission in terms of the extension and applicability of theory to the investigation of new phenomena. In the study of team dynamics in virtual teams, the artifacts of communication are under a primary data source consisting of the communication behaviors of virtual team members. The behavioral perspective has been used to examine a variety of forms of leadership and their attendant dynamics in virtual teams, including emergent and shared leadership. As such, we believe that behavioral leadership theory can be productively applied to the examination of team dynamics in virtual teams more generally.

Task- and Relationship Oriented Communication in Co-Located Teams

Much of the research conducted using the behavioral perspective has followed the pattern of research established in studies conducted at The Ohio State University, the University of Michigan, and Harvard University in the 1950s (Bass, 1990; House & Aditya, 1997; Yukl, 2005). The Ohio State studies identified two broad categories of leader behaviors that were associated with subordinate perceptions of who had been a leader: (a) consideration and (b) initiating structure. Consideration was characterized as "acting in a friendly and supportive manner" (Yukl, 2005, p. 50). Initiating structure was characterized as "leaders defining and structuring his or her own roles and the roles of subordinates toward attainment of the group's formal goals" (Yukl, 2005, p. 50).

The research program being conducted at the University of Michigan at the same time compared effective and ineffective managers in field settings and found that they differed on three dimensions. Effective managers engaged in more task-oriented behavior, relationship-oriented behavior, and behaviors associated with participative leadership leaders than ineffective managers . Task-oriented behaviors are similar to initiating structure found in the Ohio State studies and include task-oriented functions such as "planning and scheduling work, coordinating subordinate activities, and providing necessary supplies, equipment, and technical assistance" (Yukl, 2005, p. 53). Relationship-oriented behaviors correspond to consideration in the Ohio State studies and are those behaviors that emphasize a concern for subordinates such as "showing trust and confidence, acting friendly and considerate, trying to understand subordinate problems, helping to develop subordinates and further their careers, keeping subordinates informed, showing appreciation for subordinates' ideas and providing recognition for subordinates' accomplishments" (Yukl, 2005, p. 53). Participative leadership involves the setting of goals and general guidelines and allowing subordinates to determine how to accomplish them (Yukl, 2005). This third set of behaviors found in the Michigan but not the Ohio State studies has not been a subsequent focus in behavioral leadership research.

The Harvard studies were experimental in nature, consisting of researchers making observations of leaders in laboratory settings (House & Aditya, 1997). These studies found that leaders engaged in the same two types of behaviors – task-oriented (instrumental) and relationship-oriented (expressive) – and that these differentiated leaders from non-leaders. Leaders engaged in more task-oriented and relationship-oriented behaviors than non-leaders. In addition, researchers at Harvard identified a third factor associated with leadership – individual

prominence – that did not receive much attention in the later leadership literature (House & Aditya, 1997).

Subsequent research on task-oriented versus relationship-oriented behaviors and emergent leadership found an association between being perceived as an emergent leader and the level of task-oriented but not relationship-oriented behaviors (Bass, 1990; Yukl, 2005). Emergent leaders carried out a greater amount and variety of task-oriented behaviors than non-leaders. Specifically, in these studies emergent leaders performed significantly more behaviors that were oriented toward identifying and proposing solutions to problems; seeking information, opinions, or suggestions for structuring the task; giving information, opinions, or suggestions; setting expectations and clarifying goals; and initiating procedures for accomplishing the group's task or for structuring the group's interaction (Bass, 1990, p. 107).

Two possibilities have been advanced to account for the lack of a stable association between emergent leadership and relationship-oriented communication (Bass, 1990). One possibility is that emergent leaders may engage in a combination of task- and relationship-oriented communication early in the development lifecycles of groups but later in the lifecycle shift to a task-orientation in order to focus the group on the task at hand. A second possibility is that different individuals within groups assume the roles of relational leader and task leader, but that it is only the latter role that is associated with being identified as an emergent leader (Bales & Slater, 1957; Sheard & Kakabadse, 2002, 2004).

In regard to the findings lack of an association between leadership perceptions and relationship-oriented behavior, Pescosolido (2002) has proposed that emergent leaders in self-managing groups or teams function as managers of group emotion rather than as maintainers of intra-group relations. He suggests that these individuals manage group emotion by resolving

ambiguity and by moving the group toward action by modeling appropriate behaviors and by providing certainty and direction. This allows different individuals to enact different leadership roles that set the "emotional tone" for the group as a whole (Pescosolido, 2002, p. 584).

This conceptualization of emotional management as a role enacted by emergent leaders in these types of teams is not without its problematic aspects from a theoretical perspective. On the one hand, it muddies the distinction between task- and relationship-oriented behavior. Actions that ordinarily would be viewed as "task-oriented," such as clarifying and initiating, could have multiple implications for the group or team since they can be interpreted as attempts to manage group emotion by resolving ambiguity and moving the group forward toward a solution. On the other hand, it is not unreasonable to speculate that the reason for the strong association between task-related behavior and emergent leadership lies in the multiple interpretations that team members have of actions that serve these functions. Providing direction, resolving ambiguity, and initiating action that moves the group forward may have the secondary impact of promoting feelings of well-being, accomplishment, and satisfaction among group members. These behaviors may be more "valued" by non-leaders because they serve multiple purposes, and individuals who engage in these types of behaviors may be more likely to be perceived as emergent leaders than other.

However, it is also worth noting that it may not simply be the nature, but the timing of the behaviors, that is important in reducing ambiguity and moving the group forward (Gersick, 1988, 1989; Sheard & Kakabadse, 2002, 2004). Studies of co-located teams have suggested that teams reach an equilibrium point at which interaction dynamics shift toward a process-orientation, and that the ability of teams to make this shift is a critical to moving them forward in process and in task work (Gersick, 1988, 1989; Okhuysen & Eisenhardt, 2002).

Task- and Relationship Communication in Virtual Teams

While the behaviorally-based empirical studies of leadership in virtual differed in terms of study characteristics, their findings suggest some tentative patterns of findings with respect to the behaviors in which virtual team leaders engage. Emergent leaders appear to engage in more communication than non-leaders. Further, findings suggest that the content of communication is also important. In three of the studies of emergent leadership, investigators found that emergent leaders engage in both more task-oriented and relationship-oriented communication than non-leaders, but that it is only task-oriented communication that is associated with being identified as an emergent leader (Sudweeks & Simoff, 2005; Tyran et al., 2003; Yoo & Alavi, 2004). Yoo and Alavi's (2004) investigation of emergent leadership further suggests that when types of task-oriented communication are examined, only those related to logistics (e.g., scheduling) are significantly related with being identified as an emergent leader. Although Carte and colleagues (2006) do not make this distinction, it would appear form their findings that both process and product task-oriented communication are associated with emergent leadership and team performance.

Misiolek and Heckman (2005) distinguished between two types of task-oriented communication in their study of emergent leadership in virtual teams. Task substance communication was communication related to the content (substance) of the task assigned to teams in their study. Task process communication was communication related to the processes and procedures developed by teams to complete their task. A higher level of both task process and task substance communication was associated with being identified as an emergent leader in teams in which emergent leadership was centralized in one or two team members in their study. The level of relationship-oriented communication was not associated with being identified as an emergent leader, although it is instructive to note that proportionately little of the total communication in the virtual teams was group maintenance.

Examination of the relationship between the level of task-oriented communication and leadership in virtual teams suggests that the relationship may be present in virtual teams in which leaders are appointed as well (Weisband, 2002). In virtual teams in which leaders were appointed as well as in those in which no team member was appointed as the team's leader, leader perceptions were positively associated with task-oriented, but not relationship-oriented, communication (Weisband, 2002; Tyran et al., 2003; Yoo & Alavi, 2004). In discussing their findings, Yoo and Alavi (2004) suggest that this may be because relationship-oriented behaviors are more evenly distributed among team members, with no single individual assuming the role of socio-emotional group leader. However, Yoo and Alavi (2004) also provide an alternative explanation based on the results of Hart and McLeod's (2003) field study of virtual teams. Hart and McLeod (2003) suggested that socio-emotional relationships in virtual teams are not built though messages containing personal content. Rather, they are built though frequent and intense task-related messages. This is consistent with Pescosolido's (2002) notion that emergent leaders in co-located teams manage team emotion by adopting a task-orientation that reduces ambiguity and uncertainty among team members and provides direction for completing the task at hand.

In leader-appointed virtual teams, Weisband (2002) found that there was a positive relationship between leaders initiating task-oriented pressure on team members early and subsequent team performance. She takes this as evidence that initiating pressure early in the stages of a team's interactions shapes the norms for team interaction, noting that initiating pressure on team members in the later stages of their task has a negative effect on team performance.

Summary

The behaviorally based literature on leadership dynamics in virtual teams suggests that task-oriented and relationship-oriented communication behaviors play a role in shaping the

collaborative environment of virtual teams that extends beyond accounting for leadership dynamics. We contend that in addition to shaping the environment for leadership emergence, these type of communication behaviors in which team members engage also shape the context for team interaction and the structure of teamwork in virtual teams. This leads us to pose the following the following broad research question and sub-questions:

What communication behaviors can be observed in the ongoing interaction of long-standing, technology supported virtual teams?

- Specifically, how are relationship- and task-oriented communication behaviors manifested in the ongoing actions in these types of teams?

Drawing from this literature, we developed a content analytic framework that integrates behavioral categories used in previous studies of both co-located and virtual teams (Carte et al., 2006; Misiolek & Heckman, 2005; Yukl, Gordon, & Taber, 2002; Yukl & Lepsinger, 2004) The framework is contained in Table 1. The content analytic framework contains six behavioral meta-categories: Discourse, Process, Substance, Dual Process and Substance, Change, and Networking/Boundary Spanning. Each meta-category contains associated behaviors The Dual Process and Substance Category captures those behaviors that can contain both process and substance communication behavior such as asking a question. These behaviors were coded based on whether they referred to process or substance communication in order to preserve the distinction for future analysis.

METHODOLOGY

Data Sources

The data analyzed in study consisted of email threads and messages sampled from two points in the lifecycle of an open source virtual team engaged in the developing and issuing new releases of software that detects and filters unsolicited email (i.e, spam). This virtual team was chosen to be the focus of this study because of the duration of team interaction (at least 8 years), public availability of email archives of team interaction, the innovative nature of the team's work, and the active and ongoing nature of the team's development activities. The team released the first software code for its software in 2001. Shortly thereafter, in 2003, it joined the Apache Software Foundation, an organization composed of open source developers and users that supports the development of open source software code of which it is still a member; the organization currently hosts over 100 open source development projects. Since joining Apache, the team has issued four new releases of software code and is currently working on producing its next release.

The first set of email threads and messages were sampled from 2003-2004, shortly after the team moved to Apache (Time 1). The second set of email threads and messages were sampled from 2010-2011, after the team had successfully and continuously developed and released multiple versions of the open source code that it had developed (Time 2). The sample of email threads from 2003-2004 consisted of 97 email messages. The sample of email threads from 2010-2011 consisted of 67 email messages. These two points in time were selected in order to examine how team dynamics might have changed between these two points in time.

Data Analysis

The email messages were analyzed by two coders using a content analysis framework discussed earlier in this paper The coders worked independently and met weekly to reconcile the coding of the email threads.   Codes were collapsed and redefined as necessary, and new codes were added to capture phenomena observed in the data that did not correspond to existing coding categories.   When reconciled the coding scheme consisted of 18 Group Maintenance/Social codes, 19 Task Process codes, 19 Task Product codes, 4 Change Behavior Codes, 4 Discourse Codes, and 1 Networking/Boundary Spanning code.   Task Process and Dual Task Process and Task Product and Dual Task Product codes were combined in the final analysis.

FINDINGS

Communication Content

Table 2 summarizes the content of team communication.   Independent sample t-tests were conducted to assess the underlying variability of the codes in order ensure that their distribution among messages at both time periods was similar to what would be expected by chance.   Process codes and Dual Process codes were collapsed into one Process category. Substance and Dual Substance codes were also collapsed into a one Substance category. Within the Substance coding category, the code Phatics/Salutations was removed from the analysis because our analysis indicated that he greetings and closures that were being coded were more a matter of individual communication style of the sender of the email message. We concluded that its inclusion would artificially inflate the frequencies of relationship-oriented codes.

Unlike the results of previous studies that examined the prevalence of relationship-oriented communication, the quantity of relationship-oriented communication was similar at Times 1 and 2. Team communication at both points in time was characterized by proportionately

more relationship-oriented communication than process or substance communication. However, substance communication was similar in frequency at Times 1 and 2. Substance communication declined as a proportion of total communication between Times 1 and Time 2, while Process communication almost doubled during the same time period. Proportionately little communication content pertained to Networking/Boundary Spanning and Change at either point in time.

Patterns of Team Member Communication

Patterns of team member communication were examined at Time 1 and Time 2 in order to determine whether communication patterns were similar or dissimilar at these two points in the team lifecycle (Tables 3-5).

Relationship-oriented Communication. Two individuals within the team were responsible for 40% of all relationship-oriented content at Time 1, with 48 and 32 relationship-oriented contributions. One team member did not engage in any relationship-oriented communication, with 11 the average number of relationship-oriented contributions among remaining team members. The most common relationship-oriented category was emotional expression, followed by use of inclusive pronouns. These two categories jointly accounted for 52% of all relationship-oriented communication.

At Time 2, a single individual different from those who contributed the most relationship-oriented communication in the prior time period dominated in contributing relationship-oriented content with 84 contributions accounting for 34% of all relationship-oriented communication. Two team members did not engage in any relationship-oriented communication, while the remaining team members averaged 10 relationship-oriented contributions. The most common relationship-oriented category was the use of inclusive pronouns which accounted for 28% of all

relationship-oriented communication, followed by emotional expression, use of vocatives, and opinion/preference. The latter three categories jointly accounted for 34% of all relationship-oriented communication.

Process Communication. A single individual different from those who contributed the most relationship-oriented content was responsible for 34% of all process communication at Time 1, with 27 process contributions. Three team members did not engage in process communication, with 6 average process contributions by the remaining team members. Provide information and query/question were the most common process contributions, accounting for 52% of process communication content.

Two team members different than the one who had contributed the most process content at Time 1, engaged in the most process communication at Time 2, jointly accounting for 58% of process communication with 47 and 38 process communications. One of these individuals was the same team member who had also engaged in the most relationship-oriented communication. The average process contribution among the remaining team members was 4, with three team members not engaging in any process communication. Query/question was the most common process code, followed by explanation/rationale/background, provide information, and update. These codes jointly accounted for 72% of process communication.

Substance Communication. One team member engaged in substantially more substance contributions that other team members, making 30 contributions accounting for 20% of total. This team member differed from those who engaged in the most relationship-oriented and process communication. Seven team members were comparable in substance communication, averaging 13 contributions each. Two of these team members had also made the most relationship-oriented contributions, and one had made the most process contributions. The

average number of contributions among remaining team members was 3. Provide information was the most common substance communication behavior, accounting for 20% of substance communication. Four communication behaviors were equivalent in frequency – update, query/question, suggest, and explanation/rationale/background – jointly accounting for 74% of substance communication.

Three team members contributed substantially more substance contributions that the remaining team members at Time 2. These three individuals were different than those who made substance contributions at Time 1. One of the three was the same team member who had made the most substance and relationship-oriented communication, engaging in 27% of all substance communication (34). The two other team members jointly contributed 30% of all substance communication contributing 27 and 19; one of these two team members was the other individual who had made the most process contributions. Five team members did not engage in substance communication. The average substance contribution of the remaining team members was 3. Query/question, update, suggest, and objection/disagreement were the most common substance codes, accounting for 65% of all codes.

DISCUSSION

The findings from this study yield insights into the nature of virtual team dynamics that differ from studies of virtual teams that have examined teams composed of students that interact for shorter periods of time. This study found that relationship-oriented communication behavior was the most observed of the three types of communication behaviors at both points of time examined. This differs from results of previous studies that proportionately found virtual team interaction to be characterized by an absence of relationship-oriented communication. There are several possible explanations for these findings. First, the voluntary nature of open source

collaboration may lead to more relationship-oriented communication than is found in teams to which members are assigned to complete a specific task since team members must find means by which to retain contributors. Second, the team's work is ongoing in that team members are engaged in the development of updated software releases rather than confined to the completion of a single assigned task as is the case with the majority of studies of virtual teams. More relationship-oriented communication may be necessary to establish and maintain feelings of cohesiveness and connectedness among team members, which may increase the likelihood that they remain active and contribute to subsequent software releases. Third, members of open source virtual teams lack alternative means by which to interact and communicate, while other types of virtual teams may have access to other means of communication such as conference calls or even face-to-face meetings.. It is possible that more relationship-oriented communication takes place via these other means of communication and that it has not been captured because of a lack of access to these data.

It should also be noted, many of these studies did not clearly distinguish between process and substance communication, examining task-oriented communication as a whole rather than as comprised of two distinct sets of activities. Considering task-oriented communication as whole rather than as consisting of two distinct activities would have led to the conclusion that it was consistent over time and that the team engaged in more task-oriented than relationship-oriented communication, which was not the case in our study.

Relationship-oriented communication was not equally distributed among team members in either time period. One or two individuals were responsible for the majority of relationship-oriented content. This is counter to suggestions that team members share in this activity. It suggests that one or two team members shaped and "managed" the relationships with the team,

suggesting that in virtual teams that interact for longer periods of time than have been observed in the literature to date, relationship-oriented communication is more likely to be centralized on one or two team members.

The amount of process communication nearly doubled between the two periods of time during which the team was observed, however, process communication was not the predominant communication behavior observed in the team. This differs from the results of previous studies of virtual teams in which process communication was the most common form of communication. It is also somewhat counterintuitive. Since the earlier time period was shortly after the team joined Apache, it seemed logical that process-oriented communication would be more prevalent in that time period as the team learned the foundation processes, policies, and procedures (i.e., "the Apache Way") for structuring work, scheduling releases, obtaining appropriate approvals, testing code, and the like; the individual who engaged in the most process communication during this period was a member of the Apache Foundation responsible for the team's transition to the organization. Alternative explanations exist. It is possible that as the team members became more familiar with Apache Foundation policies and procedures over time, more team communication focused on ensuring that those policies and procedure were being followed in determining how to proceed with producing the next release of the software. It is also possible that during the intervening time period, more policies and procedures were implemented by the Apache Foundation, so that the team discussion in this later period emphasized process over substance.

However, a process shift in the orientation and communication content of the team members is also consistent with Gersick (1988; 1989) and Okhuysen and Eisenhardt's (2002) work on temporal sequencing teamwork and process shifts. It is conceivable that data reflect a

18

shift toward a process-orientation as the team moves closer to a release date, which would be consistent with the literature on team dynamics in co-located teams.

Substance communication behavior declined over time, however, the early time period was characterized substance communication that was more equally distributed among team members. This could reflect the emergence of individuals as content experts on whom the team came to rely for expertise over time. This dynamic was not observed in previous studies of virtual teams suggesting that the nature of work assigned to the teams studied may have played a role or that the shorter time periods during which the teams interacted precluded the emergence of content experts who could be called on to contribute their expertise. However, the emergence of content experts over time is consistent with discussions of the role of technical knowledge about a project area can be a source of legitimacy among open source team members (Mateus-Garcia & Steinmueller, 2008). It is also possible that the increase in process communication coupled with a decrease in more broadly distributed substance communication reflects an increase in the formalization of the development environment leading to a decrease in participation among team members as suggested by Mateus-Garcia & Steinmueller (2008).

The communication patterns of team members over time provides evidence that a single team member emerged in the second time period whose contributions across all three categories of communication exceeded those of other team members. Different team members were responsible for engaging in the majority of relationship-oriented and process communication behaviors in the initial time period, while substance communication was more uniformly distributed as noted. This raises the possibility that leadership dynamics shifted over time, such that a single centralized leader emerged over the course of team interaction as the team successfully released subsequent versions of code.   This is consistent with observation s that

more distributed forms of interaction characterize virtual teams in earlier stages of development, but that teams shift to a more centralized interaction later in their lifecycle (Carte et al., 2006; Heckman, Crowston, & Misiolek, 2007).

In terms of the research question posed, relationship-oriented and task-oriented process and substance communication behaviors were the most prevalent in our study. Few change and networking/boundary spanning communication behaviors were observed. This suggests that virtual team interaction is characterized primarily by relationship-oriented and task-oriented communication, as suggested by behavioral leadership theory, and that these account for team dynamics beyond leadership dynamics. That the proportion of relationship-oriented communication behaviors remained stable over time, while the proportion of process and substance communication behaviors shifted suggests a fluidity to virtual team dynamics that was not captured in prior studies.

The current study is not without its limitations. Email messages were sampled from two points in time in team lifecycle. It is possible that examination of a more extensive sample across the life of the project would yield additional insights into team dynamics at the formative and mature stages of the team lifecycle. Also, we have only examined a single project. Although this project does not appear to be unusual, it would be premature to claim that our findings describe all intact virtual teams or even all open source projects more generally. To address both of these limitations will require coding of more email messages from a broader time range and more groups. Now that we have a usable content analysis scheme, we plan to extend our coding to provide more generalizable results. .

The coding scheme used in this study was deductively derived. On the one hand, this is a strength of the study because the content analysis scheme is drawn directly from and builds on

prior behavioral studies of team leadership in co-located and virtual environments. On the other hand, observers have suggested that inductive analysis of leadership dynamics in virtual teams could yield additional insights not readily captured by deductively-derived coding schemes (Sarker, Lau, & Sahey, 2001; Yoo & Alavi, 2004).

CONCLUSION

The findings of this study differ from those of studies of virtual teams to date on several important dimensions discussed above. Although additional research is needed, the findings suggest that virtual team dynamics differ in teams that interact for longer periods of time than have been studied previously and that are engaged in work that is characterized by continued product development and innovation. This suggests studies of team dynamics in virtual teams to date may have not captured aspect of teams dynamics that are important to team development and dynamics over time and that additional studies that examine these phenomena in long-standing technology-supported virtual teams will further advance our understanding of team dynamics in these types of teams.

TABLE 1

Content Analysis Framework

Category	Code
Discourse	Speaker ID Target ID- [Member Name] Target ID-Group Date
Process	Assignment/Delegating Procedure Remind Schedule
Substance	Editor/Integration Evaluation/Feedback Generate New Idea/Introduce new content Provide Information
Dual Process and Substance	Approval Commit/Assume Responsibility Confirm/Clarify Correction Explanation/Rationale/ Background Informing Issue Directive Monitoring Objection/Disagreement Offer/Provide Assistance Query/Question Request Suggest Update
Change	Encouraging Innovative Thinking Envisioning Change External Monitoring Taking Personal Risks to Implement Change
Networking	Network/Boundary Spanning

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Process	Assignment/Delegating Procedure

	Remind
	Schedule
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	Generate New Idea/Introduce new content
	Provide Information
Dual Process and Substance	Approval
	Commit/Assume Responsibility
	Confirm/Clarify
	Correction
	Explanation/Rationale/ Background
	Informing
	Issue Directive
	Monitoring
	Objection/Disagreement
	Offer/Provide Assistance
	Query/Question
	Request
	Suggest
	Update
Change	Encouraging Innovative Thinking
	Envisioning Change
	External Monitoring
	Taking Personal Risks to Implement Change
Networking	Network/Boundary Spanning

TABLE 2

Distribution of Coding Categories at Times 1 and 2

Coding Category	Time 1 Frequency	Percent of Total	Time 2 Frequency	Percent of Total
Relationship-Oriented	207	.454	219	.430
Process	87	.191	153	.301
Substance	149	.327	130	.255
Change	6	.013	0	.000
Networking/ Boundary Spanning	7	.015	7	.014

TABLE 3

Distribution of Relationship-Oriented Codes among Team Members

Time 1

Relationship-Oriented Codes	Team Members													Total
	M1A*	M1B*	M1C*	M1E	M1F	M1G	M1H	M1I	M1J	M1K	M1L	M1M	M1N	
Agreement	2	1	1	0	0	0	0	3	1	3	0	3	3	17
Apology	0	0	0	0	0	0	1	0	0	2	0	0	1	4
Appreciation/Thanks/ Recognition	0	0	1	0	0	0	0	2	0	0	0	1	1	5
Coaching	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Consulting	1	1	1	0	0	0	0	1	0	1	0	0	0	5
Criticism (negative)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Duplicate Text	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emotional Expression (positive and negative)	12	1	7	2	0	4	1	0	3	16	1	8	4	59
Empowering*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Humor	0	0	1	1	0	0	0	0	0	0	0	0	0	2
Inclusive Pronoun	11	3	6	0	0	6	0	0	0	8	1	7	2	44
Managing Conflict	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Motivating	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Opinion/Preference	2	1	2	2	0	1	0	2	1	6	2	4	2	25
Phatics/Salutations	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Proactive Informing	1	0	0	0	0	0	0	1	0	3	0	0	0	5
Problem Solving	1	0	1	0	1	3	0	1	0	0	0	0	2	9
Self-disclosure	0	1	0	0	0	0	1	4	0	5	0	0	3	14
Supporting	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Team Building	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vocative	2	0	0	0	0	0	0	1	0	4	0	1	1	9
Total	32	8	20	5	1	15	3	15	5	48	4	24	19	199

*Denotes member contributed in Time 1 and Time 2

Table 3 (continued)

Distribution of Relationship-Oriented Codes among Team Members

Time 2

Relationship-Oriented Codes	Team Members													
	M2A*	M2B*	M2C*	M2D	M2E	M2F	M2G	M2H	M2I	M2J	M2K	M2L	M2M	M2N
Agreement	0	0	0	2	0	1	6	1	0	1	4	1	2	6
Apology	0	0	0	0	0	0	0	0	0	0	2	0	0	3
Appreciation/Thanks/Recognition	0	0	0	0	0	0	2	0	0	0	1	0	0	2
Coaching	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Consulting	0	0	0	0	0	0	3	0	0	0	1	0	0	1
Criticism (negative)	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Duplicate Text	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emotional Expression (positive and negative)	3	0	2	2	2	1	2	1	0	1	3	0	3	10
Empowering*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Humor	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inclusive Pronoun	0	3	0	7	0	1	9	7	0	2	1	0	6	29
Managing Conflict	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Motivating	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Opinion/Preference	1	0	0	0	0	0	3	1	0	0	0	0	0	6
Phatics/Salutations	2	6	1	0	0	0	0	5	1	0	1	0	0	11
Proactive Informing	0	0	0	1	1	0	1	0	0	0	0	0	0	1
Problem Solving	2	1	0	1	0	0	3	0	0	0	0	0	0	4
Self-disclosure	0	0	1	0	0	0	2	1	0	0	0	0	0	0
Supporting	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Team Building	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vocative	0	2	0	1	0	0	6	0	0	0	1	0	1	8
Total	8	13	4	14	3	3	37	16	1	5	14	1	12	84

*Denotes member contributed in Time 1 and Time 2

Table 3 (continued)

Distribution of Relationship-Oriented Codes among Team Members

Time 2 (continued)

Relationship-Oriented Codes	Team Members				Total
	M2Q	M2R	M2S	M2U	
Agreement	5	0	0	0	29
Apology	0	0	0	0	5
Appreciation/Thanks/ Recognition	0	0	2	0	7
Coaching	0	0	0	0	0
Consulting	0	0	0	0	5
Criticism (negative)	0	1	0	0	3
Duplicate Text	0	0	0	0	0
Emotional Expression (positive and negative)	0	1	2	0	33
Empowering*	0	0	0	0	0
Humor	0	0	0	0	0
Inclusive Pronoun	4	0	1	2	72
Managing Conflict	0	1	0	0	3
Motivating	0	0	0	0	0
Opinion/Preference	3	0	0	0	14
Phatics/Salutations	0	0	3	3	33
Proactive Informing	0	0	0	1	5
Problem Solving	0	0	1	0	12
Self-disclosure	0	1	0	2	7
Supporting	0	0	0	0	1
Team Building	0	0	0	0	0
Vocative	1	0	0	0	20
Total	13	4	9	8	249

Table 4

Distribution of Process Codes among Team Members

Time 1

Process Codes	Team Members										Total
	M1A*	M1B*	M1C*	M1F	M1G	M1I	M1J	M1K	M1M	M1N	
Approval	0	0	0	0	0	0	0	0	0	0	0
Assignment/Delegating	0	0	0	0	0	0	0	0	0	0	0
Commit/Assume Responsibility	0	0	0	1	0	0	0	0	2	1	4
Confirm/Clarify	1	0	1	0	1	0	0	0	4	0	7
Correction	0	0	0	0	0	0	0	0	0	0	0
Explanation/Rationale/Background	2	0	2	0	2	3	0	0	2	0	11
Informing	0	0	0	1	1	0	0	0	0	0	2
Issue Directive	0	0	0	0	0	0	0	0	1	0	1
Monitoring	0	0	0	0	0	0	0	0	0	0	0
Objection/Disagreement	0	0	0	0	0	0	0	0	0	0	0
Offer/Provide Assistance	0	0	0	0	0	0	0	0	2	0	2
Procedure	0	0	0	0	0	0	0	0	1	0	1
Query/Question	2	1	2	0	2	2	0	6	5	2	22
Remind	0	0	0	0	0	0	0	1	0	2	3
Request	0	0	0	0	0	0	1	0	2	1	4
Schedule	0	0	0	0	0	0	0	0	0	0	0
Suggest	4	1	0	0	1	0	0	0	3	1	10
Update	1	0	0	0	0	1	0	3	5	2	12
Total	10	2	5	2	7	6	1	10	27	9	79

*Denotes member contributed in Time 1 and Time 2

Table 4 (continued)

Distribution of Process Codes among Team Members

Time 2

Process Codes	Team Members										
Process Codes	M2A*	M2B*	M2C*	M2D	M2E	M2F	M2G	M2H	M2J	M2K	M2M
Approval	0	0	0	0	0	0	1	0	0	0	0
Assignment/Delegating	0	0	0	0	0	0	0	0	0	0	0
Commit/Assume Responsibility	0	0	0	0	0	0	2	0	0	2	0
Confirm/Clarify	0	0	0	0	1	0	3	0	0	0	1
Correction	0	0	0	0	0	0	0	0	0	0	0
Explanation/Rationale/Background	0	1	0	0	0	3	7	5	0	2	4
Informing	0	0	0	0	0	0	0	0	0	0	0
Issue Directive	0	1	0	0	0	0	0	0	0	0	0
Monitoring	0	0	0	0	0	0	0	0	0	0	0
Objection/Disagreement	0	0	0	0	1	0	0	3	0	0	0
Offer/Provide Assistance	0	0	1	0	0	0	0	0	0	0	0
Procedure	0	0	0	0	0	1	2	0	0	0	0
Query/Question	3	1	1	3	0	2	22	2	1	2	1
Remind	0	0	0	0	0	0	2	0	0	0	0
Request	0	0	0	0	0	0	0	0	0	0	0
Schedule	0	0	0	0	0	0	3	0	0	0	0
Suggest	1	0	0	0	0	0	4	3	1	0	0
Update	0	0	1	0	0	1	1	0	0	0	0
Total	4	3	3	3	2	7	47	13	2	6	6

*Denotes member contributed in Time 1 and Time 2

29

Table 4 (continued)

Distribution of Process Codes among Team Members

Time 2 (continued)

Process Codes	Team Members					Total
	M2N	M2Q	M2R	M2S	M2U	
Approval	1	0	0	1	0	3
Assignment/Delegating	0	0	0	0	0	0
Commit/Assume Responsibility	2	0	0	0	0	6
Confirm/Clarify	4	2	0	0	0	11
Correction	0	0	0	0	0	0
Explanation/Rationale/Background	9	0	1	0	0	32
Informing	0	0	0	0	0	0
Issue Directive	1	0	0	0	0	2
Monitoring	0	0	0	0	0	0
Objection/Disagreement	2	0	0	0	0	6
Offer/Provide Assistance	0	0	0	0	0	1
Procedure	3	0	0	0	0	6
Query/Question	5	0	0	0	2	45
Remind	0	0	0	0	0	2
Request	1	0	0	0	0	1
Schedule	0	0	0	0	0	3
Suggest	8	2	0	1	1	21
Update	2	1	0	0	1	7
Total	38	5	1	2	4	146

TABLE 5

Distribution of Substance Codes among Team Members

Time 1

Substance Codes	Team Members														Total
	M1A*	M1B*	M1C	M1D	M1E	M1F	M1G	M1H	M1I	M1J	M1K	M1L	M1M	M1N	
Approval	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Commit/Assume Responsibility	1	0	0	0	0	0	0	1	0	0	2	0	0	1	5
Confirm/Clarify	1	0	1	0	0	0	0	0	0	0	0	0	4	1	7
Correction	0	0	1	1	0	0	0	0	0	0	0	0	0	0	2
Editor/Integration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Evaluation/Feedback	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2
Explanation/Rationale/ Background	1	2	1	0	1	0	0	0	2	1	2	1	2	6	19
Generate New Idea /Introduce new content	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Informing	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Issue Directive	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Monitoring	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Objection/Disagreement	0	1	0	0	0	0	1	0	0	0	0	0	1	1	4
Offer/Provide Assistance	0	0	0	0	0	1	0	0	0	0	0	0	1	0	2
Provide Information	3	1	10	0	0	0	3	1	1	3	4	0	13	1	40
Query/Question	2	1	0	0	0	0	3	0	2	1	5	1	3	2	20
Request	0	0	0	0	0	0	1	0	1	0	0	0	1	0	3
Suggest	4	2	1	0	1	0	0	0	2	1	0	1	4	3	19
Update	4	3	1	0	0	0	2	3	5	0	4	0	0	0	22
Total	16	10	16	1	2	1	12	5	14	6	17	3	30	16	149

*Denotes member contributed in Time 1 and Time 2

TABLE 5 (continued)

Distribution of Substance Codes among Team Members

Time 2

Substance Codes	Team Members														
	M2A*	M2B*	M2D	M2E	M2F	M2G	M2H	M2I	M2J	M2K	M2L	M2M	M2N	M2O	M2Q
Approval	0	1	1	0	0	0	0	1	0	0	0	0	1	0	1
Commit/Assume Responsibility	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
Confirm/Clarify	0	0	1	2	0	3	0	0	0	0	1	0	0	0	0
Correction	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Editor/Integration	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Evaluation/Feedback	0	0	0	0	0	3	0	0	0	1	0	0	1	0	0
Explanation/Rationale/ Background	0	0	0	0	0	0	0	0	0	6	0	0	3	0	0
Generate New Idea /Introduce new content	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Informing	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Issue Directive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Monitoring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Objection/Disagreement	0	3	0	0	0	4	1	0	0	3	0	0	3	0	0
Offer/Provide Assistance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Provide Information	2	1	1	4	2	6	0	0	0	0	0	2	4	1	0
Query/Question	1	1	1	0	0	6	1	0	0	4	0	0	6	0	0
Request	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Suggest	0	2	3	1	0	2	0	0	1	2	0	0	4	0	0
Update	0	2	0	0	0	2	0	0	0	1	0	0	9	0	1
Total	3	10	7	7	2	27	2	1	1	19	1	2	34	1	3

*Denotes member contributed in Time 1 and Time 2

TABLE 5 (continued)

Distribution of Substance Codes among Team Members

Time 2 (continued)

Substance Codes	Team Members			Total
	M2R	M2S	M2U	
Approval	0	0	0	5
Commit/Assume Responsibility	0	0	0	2
Confirm/Clarify	0	0	0	7
Correction	0	0	0	1
Editor/Integration	0	0	0	0
Evaluation/Feedback	0	0	0	5
Explanation/Rationale/ Background	0	0	0	9
Generate New Idea /Introduce new content	0	0	0	1
Informing	0	0	0	1
Issue Directive	0	0	0	1
Monitoring	0	0	0	0
Objection/Disagreement	0	0	0	14
Offer/Provide Assistance	0	1	0	1
Provide Information	1	0	0	24
Query/Question	0	0	1	21
Request	0	0	1	2
Suggest	0	0	0	15
Update	0	1	0	16
Total	1	2	2	125

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