Communication Differences in Virtual Design Teams: Findings from a Multi-Method Analysis of High and Low Performing Experimental Teams

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Acknowledgments

Partial funding for this research was provided by the National Science Foundation grant 9015236. Additional funding was provided by the Leir Foundation. The opinions expressed are those of the authors. We would like to thank three anonymous reviewers for their insightful comments which greatly helped to improve this paper.

Abstract

This multi-method study distinguishes between four high performing and four low performing fully distributed virtual design teams, through an analysis of their asynchronous communication. Results indicate that these teams were similar in terms of the number of messages exchanged, the amount of communication devoted to aspects of design, and the amount and proportion of communication spent on team coordination, supportive commentary, and "other" topics. However, high performing teams were more verbose—they communicated more words. They also spent less time in brainstorming activities. Rather, high performing teams engaged in more critical commentary and active debate, compared to low performing teams. High performing teams conducted more in-depth discussions in the form of argumentation, as ideas were developed through an interactive debate of the pros and cons of issues. This debate resulted in the need for summaries, which served a dual role as they became intermediate steps in the process of writing the report deliverable.

ACM Categories: H.5.3, K.4.3

Keywords: Computer-Mediated Communication, Creativity, Distributed Software Development, Innovation, Software Design, Software Requirements Analysis, Virtual Teams

Introduction

Upstream software development—requirements determination and software design—is fundamentally a collaborative process of communication where designers "figure out what to build" (Holtzblatt & Beyer, 1995). When the goal is the creation of an innovative software application, upstream development is the front-end activity of the innovation process where idea generation and idea development occur (Couger, 1996; Couger et al., 1990). Upstream development is an inherently creative process (Glass & Vessey, 1994; Ocker, 2007) that occurs during the initial phase of the development process. It is where ideas are conceptualized to create a high-level definition and design of the software to be developed (Couger, 1996).

Although the use of virtual teams is now commonplace in downstream development (e.g., programming) (Carmel & Agarwal, 2001; Herbsleb & Grinter, 1999), the ability to conduct upstream development in a virtual environment is becoming increasingly important as firms strive to remain competitive in a global economy (Audy et al., 2004). A

virtual team (VT) can be defined as a group of people who interact through interdependent tasks guided by a common purpose, in which the majority of the communication occurs online through computer-mediated communication systems (Lipnack & Stamps, 1997).

Research over the last decade points to a set of key challenges faced by virtual teams. These include difficulty establishing trust (Coppola, Hiltz & Rotter, 2004; Jarvenpaa & Leidner, 1999; Jarvenpaa et al., 2004) and a shared team identity (Armstrong & Cole, 2002; Cramton, 2001); managing conflict (Hinds & Bailey, 2003; Hinds & Mortensen, 2005; Montoya-Weiss, Massey & Song, 2001), maintaining awareness of members' activities (Hinds & Mortensen, 2005); coordinating team member efforts (Maznevski & Chudoba, 2001; Malhotra et al., 2001; Sarkey & Shay, 2002), effective leadership (Bell & Kozlowski, 2002; Kayworth & Leidner, 2001), knowledge sharing (Cramton, 2001, Griffith et al., 2003), and determining the appropriate task-technology fit (Qureshi & Vogel, 2001) (for reviews, see Hertel et al., 2005; Martins et al., 2004; Pinsonneault & Caya, 2005; and Powell et al., 2004).

As communication is the core of VT interaction, many of these challenges are rooted in team communication behaviors and processes (Connaughton & Shuffler, 2007; Powell et al., 2004). Frequent communication has been found to enhance shared team identity and to moderate the distance-conflict relationship (Hinds & Mortensen, 2005) as well as to increase trust (Jarvenpaa et al., 1998). Predictable communication with regular feedback has been associated with improved team performance (Jarvenpaa et al., 1998; Jarvenpaa & Leidner, 1999; Kayworth & Leinder, 2000; Maznevski & Chudoba, 2001). These research studies provide critical understanding of the relationship between communication activity (e.g., frequency, rhythm, immediacy of reply) and virtual team performance.

We extend research on VT communication by delving into the *content* of task-related communication (Connaughton & Shuffer, 2007; Gibbs et al., forthcoming). Through a multi-method analysis of the communication transcripts of eight experimental virtual design teams (VDTs) working on upstream development, we conducted an exploratory study to address the research question: *Are high performing virtual design teams distinguishable from low performing virtual design teams in terms of the content of task-related communication?*

The remainder of this paper is organized as follows. The next section reviews literature related to team performance for teams working on the initial stages of an innovation, and presents the research model. Following that is a description of methods, where a comparison of two experiments is made and the methods for the current study are described. Analyses and results are provided next, which contain both quantitative and qualitative findings. The paper ends with conclusions, study limitations and suggestions for future research.

Design Team Performance and Team Climate for Innovation

With the advent of teams as the fundamental work unit in organizations, the performance of teams, and more recently, the performance of virtual teams, is of primary importance. Team performance is multidimensional (Hackman, 1983; McGrath, 1990). In terms of task-related performance, quality of the team work product is the traditional measure of performance (Koze & Masciale, 1993). However, when the goal is the creation of a software innovation, the creativity of the product conceptualization generated during upstream development is a fundamental component of the team work product. Indeed, creativity is considered the starting point for innovation (Rosenfeld & Servo, 1984). The importance of both creativity and quality performance aspects for teams working on the early stages of an innovation (e.g. high-level software design) has been emphasized (West, 1990).

Generally speaking, in an organizational context, climate refers to a shared perception regarding a work environment. With respect to work teams, climate pertains to the environment within the team itself. To be meaningful, the concept of climate must be associated with a referent, such as a climate for innovation (Anderson & West, 1998; Schneider & Reichers, 1983). Research on "traditional" co-located teams indicates that a climate for innovation promotes team performance with regard to innovativeness (Bain et al., 2001). Thus, with regard to design teams, a team climate for innovation enhances design team performance in terms of both creativity and quality of design, as shown in Figure 1.

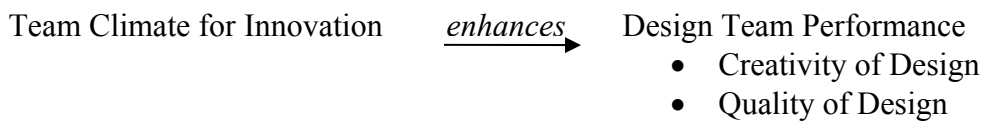

Figure 1. Relationship between Team Climates for Innovation and Design Team Performance

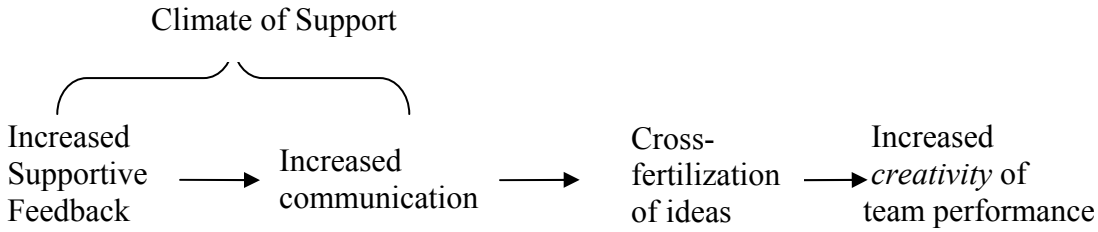

Figure 2. Relationship between a Team Climate of Support and Performance Creativity

Osborn (1950) recognized that proffering novel (and perhaps outlandish) ideas to others is a scary proposition for many people. Apprehension associated with a fear of ridicule or appearing silly in front of one's colleagues is detrimental to the production of novel ideas. For this reason, during the idea generation phase of brainstorming, participants are instructed to withhold judgment and evaluation of others' ideas.

In one of the most studied models of team climate for innovation (cf. Mathisen et al., 2006), West (1990) introduces the notion of participative safety. As the term denotes, participation and safety are linked. When a member perceives the team as a supportive, non-threatening unit, he/she is more likely to communicate with other members, which leads to increased information sharing, the exchange of ideas, and the amount of new ideas offered (West & Wallace, 1988). West (1990) describes these linkages as follows:

> "Interaction between the two parties undertaken with the ultimate aim of reaching agreement over a decision, requires and results in an exchange of information and increased intercommunication" (Wall and Lischeron, 1977:37). A group member is less likely to take the risk of proposing a new idea when he or she feels that the proposal might lead to an attack, or to being censored, ridiculed or penalized..." (p. 312).

Thus, West argues that a supportive team climate leads to increased communication, as group members are more likely to risk proposing new ideas when they do not feel threatened. This amplified information sharing increases members' knowledge bases due to the cross-fertilization of ideas from other team members, which heightens the likelihood of creative achievements (Mumford & Gustafson, 1988). These relationships are depicted in Figure 2.

An integral part of a team climate for innovation is a shared concern for a high-quality outcome, such as a design innovation (West, 1990). A tolerance for diversity of opinion, debate and constructive conflict are hallmarks of a climate that fosters high-quality outcomes, as opposing opinions are not only offered, but also debated and critiqued by team members (King & Anderson, 1990). West (1990) argues that in a team context where "underlying assumptions are challenged, ideas and practices are monitored and appraised, and opposing opinions are encouraged and explored, it is likely that flawed innovative ideas will be rejected prior to their application" (p. 318).

A supportive team environment, by itself, is more likely to generate potentially damaging innovations than teams characterized by constructive conflict (West, 1990). Teams that value the critical debate of ideas are better able to tolerate diversity which should, in turn, reduce the likelihood of groupthink (Janis, 1972). These relationships are depicted in Figure 3.

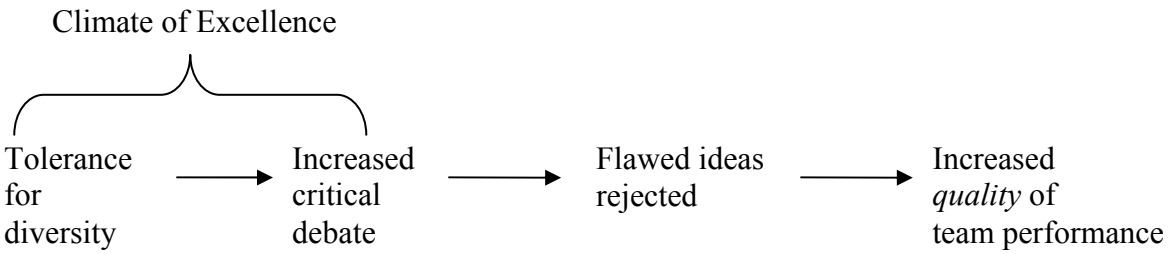

Figure 3. Relationship between a Team Climate of Excellence and Performance Quality

West proposes that active interaction of team members is a key component in the performance of innovative teams. However, the question arises as to the *content* of team interactions within the domain of upstream development. That is, are there certain topics of discussion that distinguish high performing from low performing virtual design teams?

In the domain of upstream development, Olson et al. (1992) investigated the content of design team discussions. They conducted an in-depth field study of ten face-to-face design meetings stemming from four projects in two organizations. The design teams were working on upstream development where small teams discussed the design of systems which would be built later, usually by others. The teams were working from a general description of the type of software to be designed.

Originally, the meetings appeared quite chaotic. However, upon detailed content analysis, they found that the meetings were very similar across the teams. Team discussions contained a mixture of both requirements and high-level design.

They found that the vast majority of communication fell into three categories—design, reviews and summaries, and coordination. Design discussions focused on requirements and issues related to the design of the system. Reviews and summaries pertained to reviewing the current state or progress of the design. Coordination activities related to organizing the work of team members.

Research Model

Based on the premise that the key to understanding team performance is to focus on the manner in which team members interact when working on a task, Hackman and Morris (1975) view the team interaction process as a mediator of team input-output (i.e. performance) relationships. As such, it includes all observable interpersonal behavior occurring between two arbitrary points in time (t_1 and t_2). Hackman and Morris explain that, given some groups (input at t_1) that perform better than their counterparts on a task (outcome at t_2),

> "it should be possible to explain the performance difference by examining the difference between the interaction processes of the *high* and the *low*…groups. That is, the 'reason' for obtained input-performance relationships always is available—albeit sometimes well-hidden—in the interaction process itself; by appropriate analysis of the interaction process it should be possible to develop a rather complete understanding of input-output relationships in any performance setting" (p. 50, emphasis added).

The research model for the study of VDT communication is presented in Figure 4. In line with prior research on virtual team communication, we investigated whether the levels of communication activity differ between high and low performing VDTs. Based on the discussion of a climate for innovation, we explored VDTs in terms of supportive communication and critical debate. Stemming from the discussion of FtF design teams working on upstream development, we explored VDTs in terms of communication pertaining to design, summary and coordination. Our goal was to uncover distinct differences in communication patterns between high and low performing VDTs.

Method

In order to explore communication differences between high and low performing virtual design teams, we chose to study a rather vanilla instantiation of VTs to reduce "noise."

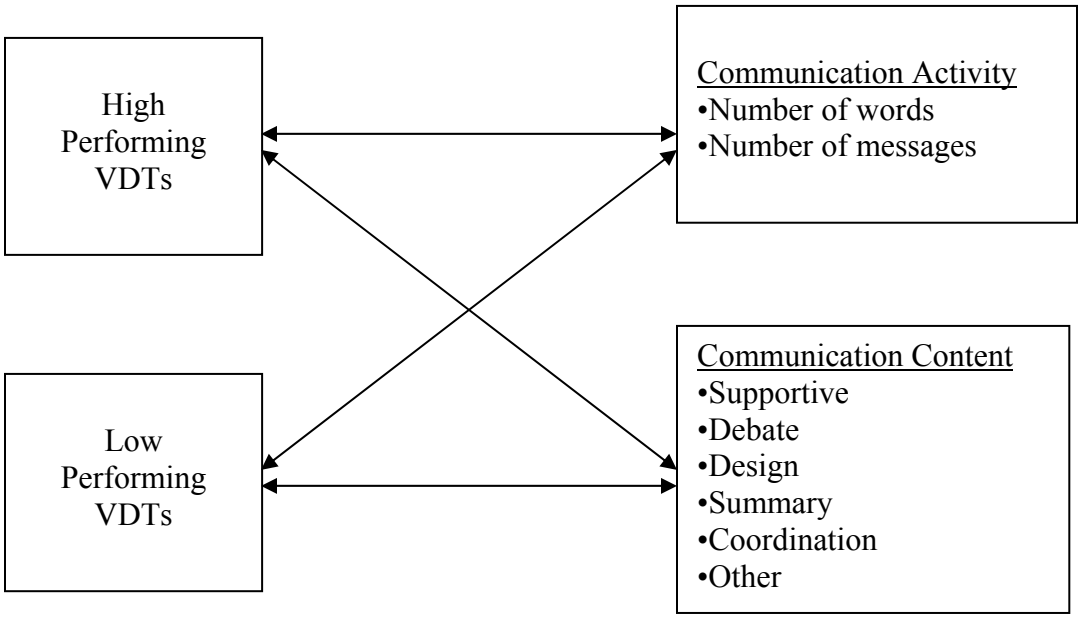

Figure 4. Research Model

The configuration of the teams in this study was fully distributed; team members did not interact face-to-face, but rather communicated, collaborated, and otherwise interacted with one another solely via *asynchronous* computer-mediated communication (CMC). Team members were distributed within the same geographic region, so that teams did not experience time differences. Furthermore, members within a given team were drawn from the same university.

Method for Asynchronous Communication Teams in Experiments A and B

Teams comprising the asynchronous communication condition from two related experiments, referred to as Experiment A (Ocker & Fjermestad, 1998) and Experiment B (Ocker, 2001) comprised the pool of potential teams to be explored. Following is an overview of the methods for both experiments.

Experiments A and B are similar, as discussed below and high-lighted in Table 1.

Subjects. Subjects consisted of graduate students in IS courses within the business schools of two mid-Atlantic universities; subjects in Experiment A were drawn from University A and subjects in Experiment B from University B. For their participation, all subjects received course credit. Subjects were randomly assigned to teams. However measures were taken to assure that no teams had previous experience working together (i.e., zero history).

	Experiment A	**Experiment B**
Communication condition	Asynchronous	Asynchronous
Length	14 days	17 days
Subjects	graduate students from IS courses at University A	graduate students from IS courses at University B
Computer conferencing system	Web-EIES	FirstClass™
Training task	Entertainment for Dutch Visitors	Entertainment for Dutch Visitors
Training procedures	detailed script of procedures developed and followed	same script but with minor modifications to reflect difference in user interface
Experimental task	Computerized Post Office	Computerized Post Office
Experimental procedures	detailed script of procedures developed and followed	same script with minor modification to reflect 17 day experiment length
Rating of quality and creativity	panel of judges	panel of judges

Table 1. Comparison of Experiments A & B

Task. The Computerized Post Office (CPO) was the task used in both experiments. This task was adapted from Goel (1989) and Olson et al. (1993). Teams were asked to determine the high-level requirements and design for the CPO (e.g, what services would be offered to customers, delineate the top levels of menu/service choices). Additionally, teams were to describe the advantages and disadvantages of the CPO, as well as any major implementation concerns. Each team submitted a report which addressed these aspects.

Olson et al. (1993) characterize the task as incorporating planning, creativity, decision-making, and cognitive conflict (McGrath, 1984). This task is also classified as integrative and thus complex (Olson et al., 1993, Steiner, 1972), resulting from interdependencies (e.g., decisions on services impact the user interface). The CPO task is presented in Appendix A.

Length. Experiment A ran for 14 days, while Experiment B ran for 17 days.

Technology and Facilitation. Asynchronous VDTs communicated only via CMC, either using Web-EIES (Experiment A) or FirstClass™ (Experiment B). The feature set of these systems, as instantiated in these experiments, was fundamentally the same. Subjects could compose, reply, and thread through conferencing messages, using a GUI interface. Each team communicated in its own computer conference. The conferences were minimally facilitated. The facilitator's role was that of a technical assistant, helping teams with equipment problems and answering questions of a technical nature.

Training. Subjects met within their classes for training on the essential aspects of their respective conferencing system. Trainers followed essentially the same training script, modified to fit the particular conferencing system. Training was completed within one hour. All subjects were trained using the same practice problem, a modified version of "Entertainment for Dutch Visitors" (Olson et al., 1993).

Procedure. All subjects completed a Consent Form and the Background Survey prior to the start of the experiments. All teams had access to their computer conferencing system throughout the entire experimental period. The teams were not given a process to follow. Subjects were instructed to communicate only within their team's computer conference, using asynchronous messaging. Teams were self-managing and team leaders were not assigned. However, at the end of the training session in Experiment A, the experimenter requested that a member from each team volunteer to be the team leader. No such request was made in Experiment B.

Measure of Performance. At the conclusion of each experiment, expert judges rated the quality and creativity of each team's solution, as contained in its report deliverable. Three judges were used in Experiment A and two in Experiment B. In each experiment, judges consisted of professors and doctoral candidates in IS, all with academic and/or professional experience in software design.

Quality Measure: The quality of each team's CPO solution was judged based on a consideration of the (1) functionality, (2) interface layout, and (3) coherence of these ideas (Olson et al., 1993). For each expert judge, ratings of the three categories were added together to calculate the judge's quality rating for each team. This quality rating was averaged across judges to calculate the team's quality rating.

Creativity Measure. The level of creativity contained in each team's solution was also measured by the panel of judges. Founded upon her extensive research on creativity, Amabile (1983) advocates that a "product or response is creative to the extent that appropriate observers independently agree it is creative" (p. 359). Furthermore, there is scant agreement on subcategories that are appropriate in rating creativity. Thus, the expert judges were not provided with explicit rating categories for creativity; rather, they were instructed to judge the creativity of each teams' solution using the general category of "Creativity of Solution."

Study of Communication

High performing asynchronous VDTs were compared with low performing asynchronous VDTs to explore differences in communication. Eight asynchronous VDTs from Experiment A and ten asynchronous VDTs from Experiment B constituted the pool of potential teams. To select high and low performing asynchronous VDTs for this study, we relied on a theoretical sampling approach. A cluster analysis was conducted to classify teams according to performance. Teams within a given cluster exhibit high within cluster homogeneity while teams in different clusters exhibit high between-cluster heterogeneity. To perform the cluster analysis, judges' ratings of creativity and quality served as the cluster variables. A hierarchical clustering method incorporating a Euclidean distance measure as a measure of similarity was used. Two separate cluster analyses were performed, one for each set of asynchronous teams from Experiments A and B. A four-cluster solution resulted for Experiment A asynchronous teams, while a five-cluster solution

resulted for Experiment B asynchronous teams. In both cluster analyses, two teams clustered in what represented the high-performing team cluster and f

two teams clustered in the low-performing team cluster. Thus, the study is based on an analysis oeight teams—two high performing and two low performing teams from each experiment.

Content Analysis

Content analysis is "a research technique of selective reduction, whereby text is associated with content categories based on explicit rules of coding, which are defined in a coding scheme" (Krippendorff, 2004, p. 18). Specifically, as all team communication occurred in the form of text, this study employs transcript analysis (Anderson et al., 2001).

Coding Scheme

A coding scheme for transcript analysis of team communication was formulated based on the research model. This resulted in the six codes shown in Table 2. *Design* includes the initial (i.e., first) conveyance of an idea pertaining to the CPO functionality (i.e., services), interface design, advantages and disadvantages of the design concept, and implementation considerations. *Summary* encompasses communication which summarizes or reviews prior discussions or decisions.

Coordination pertains to communication related to project management (i.e., schedules, responsibilities, status of work), problem solving approach, or an individual's intentions.

Debate encompasses opposing arguments and different perspectives concerning ideas or topics previously communicated. Debate includes both simple communications (e.g., "I don't really think we should accept packages.") as well as statements indicating the reasons against an idea (e.g., "Accepting packages really increases the complexity – for example, we'll have to handle different sizes, and we'll need some sort of bomb detection."). Supportive communication indicates agreement with a team member's idea or suggestion, and includes both simple statements (e.g., "Great idea! I agree that we should include voice recognition.") as well as statements indicating the reasons for support (i.e., "Great idea – it will encourage the not so computer-savvy to utilize the facility too."). A sixth code, *other,* captures communication which does not fit into any of the preceding coding categories. The six codes are mutually exclusive and account for all of the teams' discussion content.

Coding Procedures

As team members communicated only via asynchronous electronic messaging in their computer conferencing system, these messages constitute the team communication transcripts.

Code	Explanation	Example
Design	*Initial* suggestion, idea or assumption pertaining to the functionality and services, user interface, advantages and disadvantages, and 5 year plan (see task description).	Computerization should provide accessibility to existing communication procedures-including E-mail, EDI, and general document transfer over VANS
Coordination	Any reference to project management (i.e., schedules, responsibilities, status of work), problem solving approach, or an individual's intentions	Any ideas or comments you want included in Saturday's finished product please have transmitted to me by tomorrow at 6:00 PM. I'll check back later tonight to see how things are coming along.
Summary	Summarizes or reviews prior discussions, debates or decisions.	I've collected and listed all of the functions and services we have been discussing. They are…
Debate	Opposing argument or different perspective regarding an idea previously communicated; includes reasons for disagreement	I don't agree with e-mail as a part of our CPO service because everyone can send their e-mail using internet...
Supportive	Agreeing with members' comments, positive feedback; includes reasons for agreement	I agree with Vineet, I think that we should locate this at all train stations along with the post offices.
Other	Communication that does not fit into any other category	

Table 2. Coding Scheme

The first author refined the coding instrument by coding the transcripts of two asynchronous VDTs not included in this study, but drawn from Experiments A and B. The unit of coding was each message posting, or "communication incident" within each respective team transcript (De Wever et al., 2006; Massey et al., 2003).

The first author then trained a coder, using the same two transcripts. The first author and the coder compared results and discussed differences. Coding definitions were modified to enhance clarity and precision. After the training was completed, the coder, who was blind to the performance category of each VDT, coded all eight team transcripts. A second coder served as a reliability coder, coding four of the eight transcripts.

Analysis & Results

A multi-method analysis was conducted to uncover relationships. Coding of the asynchronous transcripts was conducted and an ANOVA was performed on the coding results. To comprehend how quantifiable differences impacted team performance, a qualitative analysis was also conducted. This section begins with data on team demographics and tests for the equivalency of the two experiments. Quantitative findings are presented next, followed by qualitative findings.

Team Demographics

Table 3 contains team demographics, while Table 4 contains demographics aggregated for the high and low performance categories. Teams one through four comprise the high performing teams, while teams five through eight comprise the low performing teams. The eight teams consisted of a total of 39 members. In terms of team size, the high teams included one six-member team, one five-member team and two four-member teams for a total of 19 participants or 49% of the total, while the low performing teams included one six-member team, two five-member teams, and one four-member team for a total of 20 participants or 51% of the total.

				AGE (years)				SEX	EMPLOYMENT (years)			
Team	Exper-iment	Category	Number of members	under 23	23-30	31-35	Over 35	FEMALE	0-2	3-5	6-10	>10
1	A	H	6		5	1		0	2	3	1	
2	A	H	5		5			1	3	2		
3	B	H	4	1		2	1	1	1	1	1	1
4	B	H	4		2	2		0	3			1
5	A	L	5	1	2	1	1	1	2	1	1	1
6	A	L	6	3	2		1	0	5			1
7	B	L	5	1	2	2		1	1	2	2	
8	B	L	4		1	1	2	2		2		2
		Total	39	6	19	9	5	6	17	11	5	6

Table 3. Demographics by Team

		AGE (years)				SEX	EMPLOYMENT (years)			
Performance Category	Number of members	under 23	23-30	31-35	Over 35	FEMALE	0-2	3-5	6-10	>10
High	19	1	12	5	1	2	9	6	2	2
Low	20	5	7	4	4	4	8	5	3	4
Total	39	6	19	9	5	6	17	11	5	6
Percent of Total	1.00	0.15	0.49	0.23	0.13	0.15	0.44	0.28	0.13	0.15

Table 4. Demographics by Performance Category

Regarding age distribution, approximately half of the participants were between the ages of 23 and 30, while nearly a quarter were between 31 and 35. The high performing teams had a higher concentration of members in the 23-30 bracket, while members of the low performing teams were more evenly distributed across age brackets. There were a total of six female participants. Two high and two low performing teams each had a single female member, while one low team had two female members. In terms of years of employment, over 40% of participants had between zero and two years, nearly 30% had between three and five years, while the 6-10 and over 10 brackets 13% and 15% respectively. The split across employment brackets between the high and low performance categories was virtually the same.

Equivalency of experiments. As another means of comparing the equivalency of the two experiments, beyond similarity of experimental research methods, T-tests were conducted within performance categories *between* experiments. That is, high performing VDTs in Experiment A were compared with those of Experiment B and low performing VDTs in Experiment A were compared with those of Experiment B. T-tests were conducted regarding communication activity (number of messages and number of words) and code category ratios. No significant differences were found within performance categories between experiments.

Coding Results

Inter-rater reliability was calculated using the percent agreement method, which is the ratio of the number of codes agreed upon to the total number of codes for a given coding category (De Wever et al., 2006; Massey et al., 2003). Inter-rater reliability between the primary and reliability coders was acceptable (.86 for design, .82 for coordination, .86 for summary, .81 for debate, .95 for supportive and .87 for other) (De Wever et al., 2006; Neuendorf, 2002; Rourke et al., 2001). Based on these results, we concluded that the primary coder correctly applied the codes as per the coding instrument.

Each message (i.e., posting) was coded using the coding scheme. Coding was accomplished using the software package Atlas.ti. Two sets of results are presented. One set is based on the raw data, that is, the number of words attributed to each code. A second set of results is based on proportions. The proportion of each message attributed to a given code was calculated using the number of words attributed to a code divided by the number of words in the message. Thus, if the message length was 100 words, and 80 words were coded as design and 20 words were coded as coordination, then the proportions would be 80% and 20% respectively. Then, for each team, the average proportion of communication for each coding category was calculated across all of the team's communications. For example, Team One spent 43% of its communication on design, 21% on coordination, 9% on summaries, etc. The coding results for each team based on number of words and proportions are presented in Tables 5A and 5B respectively.

Results of Quantitative Analysis

Given the exploratory nature of this study, ANOVA was chosen to test for quantitative communication differences as no assumption is made regarding the nature of the regression function in terms of causality. In presenting results, significance levels of .05 or better will be considered "statistically significant." Levels between .10 and .05 indicate findings that suggest a relationship may exist and will be considered "marginally significant."

TEAM	Design	Coord.	Summary	Debate	Supportive	Other	Total
1 (H)	2002	956	403	888	369	34	4652
2 (H)	1889	949	858	1960	520	328	6504
3 (H)	1397	2037	533	3622	231	111	7931
4 (H)	826	1012	428	759	322	42	3389
5 (L)	1656	744	209	344	335	75	3363
6 (L)	2940	626	0	505	289	13	4373
7 (L)	591	948	0	195	84	381	2199
8 (L)	1435	1092	120	319	131	14	3111

H- high performance, L – low performance

Table 5A. Coding Results by Team (in words)

TEAM	Design	Coord.	Summary	Debate	Supportive	Other
1 (H)	0.43	0.21	0.09	0.19	0.08	0.09
2 (H)	0.29	0.15	0.13	0.30	0.08	0.13
3 (H)	0.18	0.26	0.07	0.46	0.03	0.04
4 (H)	0.24	0.30	0.13	0.22	0.10	0.11
5 (L)	0.49	0.22	0.06	0.10	0.10	0.12
6 (L)	0.67	0.14	0.00	0.12	0.07	0.07
7 (L)	0.27	0.43	0.00	0.09	0.04	0.21
8 (L)	0.46	0.35	0.04	0.10	0.04	0.05

Table 5B. Coding Results by Team (in proportions)

Communication Activity. Two measures of communication activity were analyzed: (1) the total number of words exchanged within each team and (2) the total number of messages exchanged within each team. Table 6 shows the team word and message counts, Table 7 contains the means and standard deviations and Table 8 contains the ANOVA results.

TEAM	# Words	# Messages
1 (H)	4652	48
2 (H)	6504	59
3 (H)	7931	72
4 (H)	3389	29
5 (L)	3363	34
6 (L)	4373	44
7 (L)	2199	52
8 (L)	3111	32

Table 6. Team Communication Activity

	Performance Category	N	Mean	Std. Dev.
# Words	High	4	5621.0	2004.23
	Low	4	3261.5	893.92
# Mssges	High	4	52.0	18.20
	Low	4	40.5	9.29

Table 7. Mean and Std. Deviation for Team Communication Activity

The high and low VDTs did not differ significantly with regard to the number of messages exchanged (52 messages for high VDTs vs. 40 messages for low VDTs, p = .30). However, the high teams exchanged more words (5,621 high vs. 3,261.5 low, p = .08).

Communication Content: Tables 9A and 9B contain the means and standard deviations while Tables 10A and 10B contain the ANOVA results in words and proportions, respectively.

		Sum of Squares	df	F	Sig.
# Words	Between Groups	11134481	1	4.64	0.08
	Within Groups	14448057	6		
# Mssgs	Between Groups	264.50	1	1.27	0.30
	Within Groups	1253.00	6		

Table 8. ANOVA Results for Team Communication Activity

Code Category	Perform. Category	N	Mean	Std. Dev.
Design	High	4	1529	537
	Low	4	1655	972
Coord.	High	4	1239	533
	Low	4	853	208
Summary	High	4	556	209
	Low	4	82	102
Debate	High	4	1807	1324
	Low	4	341	127
Supportive	High	4	361	121
	Low	4	210	121
Other	High	4	129	137
	Low	4	121	146

Table 9A. Coding Mean and Standard Deviation (words)

Code Category	Perform. Category	N	Mean	Std. Dev.
Design	High	4	.2851	.1076
	Low	4	.4737	.1653
Coord.	High	4	.2267	.6600
	Low	4	.2866	.1290
Summary	High	4	.1030	.3120
	Low	4	.0252	.3060
Debate	High	4	.2931	.1184
	Low	4	.1022	.1100
Supportive	High	4	.0708	.2870
	Low	4	.0615	.2820
Other	High	4	.0918	.3700
	Low	4	.1123	.7330

Table 9B. Coding Mean and Standard Deviation (proportions)

Code Category	Grps	Sum of Squares	df	F	Sig.
Design	Betwn	32258	1	0.05	0.83
	Within	3696682	6		
Coord.	Betwn	297992	1	1.82	0.23
	Within	982076	6		
Summary	Betwn	447931	1	16.53	0.01
	Within	162546	6		
Debate	Betwn	4301245	1	4.86	0.07
	Within	5309104	6		
Supportive	Betwn	45451	1	3.11	0.13
	Within	87748	6		
Other	Betwn	128	1	0.005	0.95
	Within	149348	6		

Table 10A. Coding ANOVA Results (words)

Although not significant in terms of words (1529 high vs. 1655 low, p = .83), the low performing VDTs spent a marginally significant higher proportion of communication devoted to aspects of *design* (28.5% high vs. 47.3% low, p=.10). There were no differences regarding *coordination, supportive communication*, or *other* categories in terms of eitherwords or proportions. However, high performing VDTs communicated significantly more regarding *summaries*, both in terms of words (556 high vs. 82 low, p = .01) and proportions (10% high vs. 2.5% low, p = .01). High performing VDTs exhibited marginally significantly more *debate* in terms of words (1807 high vs. 341 low, p = .07) and a significantly higher proportion of communication (29% high vs. 10% low, p = .02). These results are summarized in Table 11.

Findings from the Qualitative Analysis

To gain an understanding into how these quantifiable differences were manifested in the high and low performing teams, we conducted a qualitative analysis of the team communication transcripts. Each team was treated as a separate case (Yin, 1998). Similar to Jarvenpaa et al., (1998), we followed the guidelines espoused by Eisenhardt (1989) to uncover within-case and between-case patterns.

Design

Compared to high performing VDTs, low performing VDTs spent more communication on idea generation. However, these members neglected to build upon or question others' ideas, instead opting to contribute by suggesting more ideas. This resulted in seemingly endless brainstorming where members worked in parallel *on the same activity* rather than as a team, each espousing his or her own ideas with little questioning of, or integration with the ideas of others. It was not unusual for one member's ideas to remain unacknowledged by other team members.

Code Category	Groups	Sum of Squares	df	Mean Square	F	Sig.
Design	Between	0.071	1	0.071	3.659	0.10
	Within	0.117	6	0.019		
Coordination	Between	0.007	1	0.007	0.685	0.44
	Within	0.063	6	0.010		
Summary	Between	0.012	1	0.012	12.667	0.01
	Within	0.006	6	0.001		
Debate	Between	0.073	1	0.073	10.309	0.02
	Within	0.042	6	0.007		
Supportive	Between	0.000	1	0.000	0.214	0.66
	Within	0.005	6	0.001		
Other	Between	0.001	1	0.001	0.247	0.64
	Within	0.02	6	0.003		

Table 10B. Coding ANOVA Results (proportions)

Code Category		Relationship	Significance
Communic. Activ.	words	High VDT > Low VDT	**Marginal**
	messages		non-sig.
Design	words		non-sig.
	proportions	High VDT < Low VDT	**Marginal**
Summaries	words	High VDT > Low VDT	**Significant**
	proportions	High VDT > Low VDT	**Significant**
Coordination	words		non-sig.
	proportions		non-sig.
Supportive	words		non-sig.
	proportions		non-sig.
Debate	words	High VDT > Low VDT	**Marginal**
	proportions	High VDT > Low VDT	**Significant**
Other	words		non-sig.
	proportions		non-sig.

Table 11. Summary of Results

This engendered a team atmosphere of talking past each other, reminiscent of face-to-face meetings where people talk without listening to the suggestions of others. Thus, extended brainstorming, while good for generating many ideas, precluded an in-depth interactive discussion or critique concerning the merits of the ideas being contributed.

Debate

High performing virtual teams continually assessed their members' contributions. Constructive conflict and deliberation was the norm as members actively participated in frequent, and often intense and direct debate of ideas and issues. This often blunt, critical examination resulted in the back and forth exchange of opposing ideas, which frequently spanned several or more days. Even in Team 4, which exchanged the lowest amount of communication within the high Performing teams, critical argumentation was prevalent. While the members of this team were not as verbose as the other high performing teams, they were adept at asking pointed questions, detailing possibilities and providing substantive feedback as they debated key issues. These characteristics are high-lighted in the following excerpts extracted from a lengthier debate concerning the scope of the CPO:

> Sam writes: "Considering the 'COMPUTERIZED Post Office I have a strong vision of a link to the WEB. This would allow people to log into the CPO and check anything imaginable in regards to their mail or packages…"
>
> Less than an hour later, Winston replies with: "What exactly is a CPO? Are we talking about computerizing the existing US Mail system?...There definitely are possibilities to computerize here but I look at the computerized services as largely a premium service…"
>
> Two days later, Heinz replies: "I was thinking the same thing as Winston. The background on exactly what kind of CPO we were talking about was sketchy. I'm assuming that it is a physical rather than virtual USPS station of some type that mimics as many functions of a full service PO as possible..."
>
> An hour later, Sam asks Heinz: "Are you saying that you don't think that an online interface to the CPO is worth considering?...I was under the assumption that anything was fair game versus sticking to one or the other…"
>
> The following day, Ted enters the debate by stating: "I'm envisioning a combination of the two…" and then continues by detailing his thoughts.

Note that all four team members participated in this debate. Indeed, in the high performing teams, it was not unusual for several members to actively engage in opinion giving and argumentation. In Team 3, for example, three members participated in most debates such that, typically, there was a single member on

opposing sides of an issue, with the third member debating the pros and cons of the arguments presented by the other two.

While argumentation tended to be direct, members were adept at diplomacy as their critical comments were often peppered with supportive remarks.

> For example, in response to a member's proposal of a framework to follow,Victor from Team 1 stated, "Prashant's idea involving a framework to start with is quite good, but it can be improved upon. I feel we should first define the problem properly…"

Thus, members exerted effort to maintain a professional and positive demeanor as they offered opposing opinions.

The critical argumentation of the high teams is in harsh disparity to the convergent behavior which was dominant in the low performing VDTs. While all teams strived to reach consensus on a design solution, the low performing teams enacted a more streamlined approach that was, for the most part, devoid of critical feedback and back-and-forth debate. Thus, if an idea was questioned, it was usually done so by a single individual. While this was expedient, it did not foster active debate. This scenario is typified in the following excerpts exchanged between two members of the five-members in Team 7:

> Mark writes: "I was considering the scope of our project and wondered if we should consider handling only electronic documents…However,…that may be too limiting…Please let me know if anyone disagrees…"
>
> Three days later, the following exchange takes place:
>
> Jean: "Actually, I completely ignored the electronic aspect of this—not on purpose, but simply because it did not come to mind. Is this something w*e* want to include??"
>
> Mark: "In my opinion, as it is a computerized Post office it seems like a natural fit."
>
> Jean: "You're right...this could complicate things, though! :) However, it does make sense. I'll expound upon my previous work."

The above exchange highlights the entire discussion in Team 7 concerning the central issue of the CPO scope.

Summarization

Asynchronous communication can be challenging, particularly since multiple topics are active at once and the lapse in time between messages can make any interactive exchange of ideas seem disjointed. Moreover, the sheer volume of communication can result in information overload. As the high performing teams engaged in significantly more back-and-forth critical debate, it is likely that members experienced these coordination and overload difficulties. However, these teams incorporated two emergent structures pertaining to knowledge management to counter these drawbacks of asynchronous interaction: (1) reviewing the knowledge repository created as a result of their electronic communication, and (2) summarizing content.

In the high performing teams, typically a member sifted through the team's communications in order to summarize discussion content on a given topic. These summary messages often amounted to lists of ideas (e.g., features of the CPO), but could also contain detailed elaboration of content. In essence, the summaries provided a structuring mechanism that organized the team's work and progress-to-date on a topic. The summaries also served to bring all members up-to-date and thus helped to keep a team on the same "virtual page."

Furthermore, summaries also served a "check and balance function," as members made certain their ideas were included and accurately represented. When this was not the case, a quick message was made to the effect of "Here are my thoughts on the summary, which looks great, BTW. First, I think you forgot one of my ideas*"* The summaries were an intermediate step to the actual report writing, as their content was "cut and pasted" to create the team's final report deliverable. Thus, the existence of accurate and complete summaries directly impacted the content of the resulting report.

In severe contrast, knowledge management activities were almost non-existent in the low performing teams. Only one member summarized the team's discussion of functionality. In the remaining teams, summary comments were either absent or only re-capped a single individual's input. Since the means of communication was asynchronous and spanned two weeks, the content of design communications was often disjointed and lacking in coherence. When it was time to produce the final report deliverable, the low performing teams were at a disadvantage as there were few summaries from which to directly draw report content.

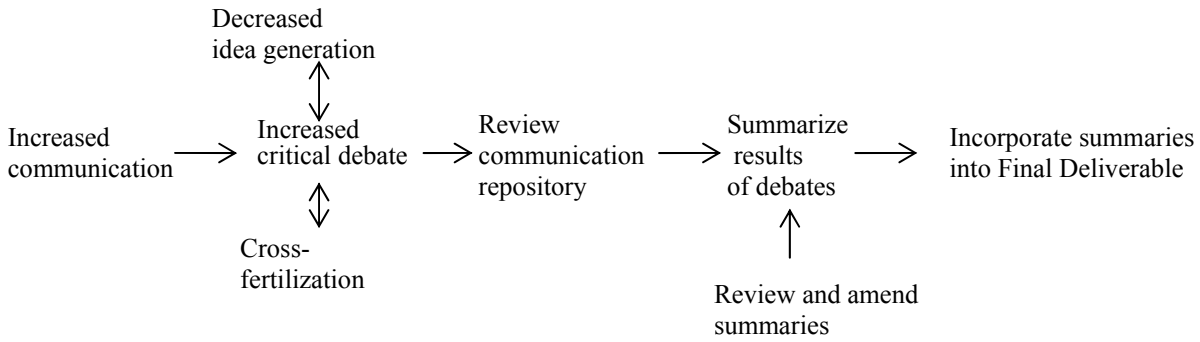

Figure 5. Virtual Team Climate for Innovation

Conclusion

The objective of this study was to distinguish between high and low performing fully distributed virtual design teams, through an analysis of their (asynchronous) communication. Results indicate that these teams were similar in terms of the number of messages exchanged, the amount of communication devoted to aspects of design, and the amount and proportion of communication spent on team coordination, supportive commentary, and "other" topics. In terms of a supportive team climate, high and low performing teams were indistinguishable.

However, differences were found in several key areas. High performing teams were more verbose—they exchanged more words. They also spent less communication in brainstorming activities. Rather, while remaining professional and diplomatic, high performing teams engaged in more critical commentary and active debate, hallmarks of a climate for excellence. They conducted more in-depth discussions in the form of argumentation, as ideas were developed through an interactive debate of the pros and cons of issues. This debate resulted in the need for summarization, as multiple viewpoints were deliberated concerning a given issue, and members needed to be clear on the outcome of the debate. Members reviewed and amended these summaries to ensure their completeness and accuracy. These summaries became intermediate steps to creating the final report deliverable, and thus served a dual purpose. Figure 5 depicts these findings in a model of virtual team climate for innovation.

Although the quantitative analyses show correlation but not causality – that is, we cannot make the claim that the statistical findings caused differences in performance – the qualitative analysis provides an understanding of the reasons behind the quantitative differences. However, we cannot discount other explanations. For example, differences in motivation or effort may cause both low communication and low performance, or perhaps it is the act of documenting throughout the project rather than summarization per se that distinguishes performance. Furthermore, the study analyzes a limited number of virtual teams, drawn from two experimental settings using graduate students. With a small sample, it is easy for results to be swayed by a single anomalous group. However, the increased understanding of quantitative results afforded by the qualitative analysis helps to place the results within the context in which they were generated, and thus increases comprehension. Furthermore, the fact that both similarities and differences between high and low performing teams were supported by the multi-method analysis lessens the likelihood of false claims. Nevertheless, generalization of results must be done cautiously.

An understanding of communication differences between the high performing and low performing virtual design teams paves the way for future research to test causality. Research by Tan et al. (2000) indicates that training virtual team members in a dialogue technique can improve team performance. Critical debate can be uncomfortable for some people, even in a virtual context of communication. Virtual team members may benefit from training on argumentation, and how to undertake such debate in a virtual team environment. A key future study would be to manipulate communication practices, such as summarization and argumentation, in an effort to analyze the effect on team performance and test for causality. Additionally, a larger study of VDT communication might more clearly indicate whether marginal differences are truly significant.

It is noteworthy that the high teams were quite effective in the absence of any technological support designed to aid knowledge management, and that the rather simple act of summarizing appeared quite

effective. Indeed, others have found that, when provided with tools such as powerful navigation and search functionalities, virtual teams did not make use of them (Malhortra et al., 2001). This suggests that actively attending to the management of knowledge, perhaps by designating the role of knowledge manager within the team, may be a simple means of reaping the benefits of knowledge management without increasing the complexities of the communication technology. Future research should be explicitly directed at exploring the role of a knowledge manager within a virtual team.

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