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Studies in Distributed Software Requirements Engineering

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Abstract

Nowadays, scientific advances in communication technologies enable the creation of work environments that cross organizational and national boundaries, allowing customers and developers to define requirements while working in separate physical locations. This paper reports on our ongoing research in the area of human factors in distributed requirements engineering. It outlines our exploratory approach and presents preliminary results of our investigation of the effects of communication medium on group performance and behavior in software requirements negotiation situations. The traditional setting of physical co-location of stakeholders is compared to four different distributed communication settings with multimedia facilities. The results suggest that the distributed groups perform better compared with the face-to-face groups. They also suggest that distributed groups are more task-oriented and less concerned with the interpersonal aspects of the interaction. These results not only provide new insights into the controversial issue of negotiating software requirements at a distance, but should also help managers better evaluate the potential impacts of computer-mediated environments for dispersed settings, and assist them in choosing the appropriate communication technology for an effective communication in distributed requirements negotiation.

1. BACKGROUND AND MOTIVATION

The present decade is characterized by rapid technological advances and the ability to work collaboratively in environments that cross organizational and national boundaries. Furthermore, the globalization of companies results in geographically and temporally dispersed development. Thus, there is a need for rigorous studies of the issues of computer-mediated interaction of task-oriented groups.

New and highly sophisticated electronic meeting support is widely available to organizations and includes three generic categories of meeting technologies: (1) teleconferencing that enables meetings to be held through audioconferencing and videoconferencing systems, (2) computer conferencing that allows multiple participants to interact by contributing to a pool of computer files that is accessible to all, and (3) group support systems (GSSs) that supplement computer conferencing with information management capabilities, decision support tools, graphics displays, and meeting process management software.

Clearly, we experience an era in which technological opportunities for distributed human interaction are overwhelming, where advanced communication technologies give rise to potential

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collaboration among teams and organizations that would otherwise not be considered. These new communication technologies enable multidisciplinary project teams to overcome significant distance barriers. Whilst such technological innovations are impressive the usefulness of the various modes of communication remains a fundamental question. Yet what is required is a careful examination of the relative strengths and weaknesses of different alternatives. In addition, the effects of new technologies on group work, and the value of support of the various channels of communication need to be investigated further.

This paper reports on a laboratory experiment that is part of our ongoing research in distributed requirements engineering, which is an area of software engineering where the use of advanced technology for collaboration at distance is becoming not only a necessity but also a reality. It has become common practice that customers and developers define software requirements from different parts of the world. Supporting requirements engineering at distance is not only possible nowadays, rather the use of teleconferencing has become very common in any organization. New business environments are considering teleconferencing as an alternative to travel for face-to-face meetings. The RE community would therefore benefit from more experimentation (Ryan 1995) and evaluation of these communication media, as well as from a better understanding of their roles in facilitating social processes in requirements engineering.

Our research is mainly targeted towards conflict resolution in requirements engineering. In our previous studies, we conducted investigations into the use of existing groupware systems for distributed requirements negotiations (Herlea 1998a), and outlined a set of design requirements for virtual environments to support user involvement in requirements engineering processes (Herlea 1998b). Currently we focus our attention towards multimedia integrated meeting systems (audio/video conferencing and shared electronic files) and seek to evaluate their usefulness in supporting software requirements negotiation situations.

Although theories of media effects argue that face-to-face meetings are the richest communication medium for complex human processes (such as negotiation) as they allow the transmission of a full range of social cues (Short, Williams and Christie (1976); Daft and Lengel (1984)) some empirical studies indicate that these processes are actually improved when individuals are physically separated and communicate through less rich communication media (Kinney and Dennis 1994). Questions in requirements engineering that need further investigation are whether the group performance improves when the design team communicates through a less rich communication medium that integrates video, audio and shared electronic files. From a socio-psychological perspective, do stakeholders with different (conflicting) requirements/perspectives manage conflict differently when physically separated or co-located? These unanswered questions illustrate that, although the technology may be impressive, little systematic research exists on its social and psychological significance in requirements engineering.

We start the paper by discussing the place of the laboratory experiment reported in this paper which is part of our larger exploratory investigation into distributed requirements engineering. A short review of the relevant research on media effects with an emphasis on theories and studies of group performance in negotiation situations follows. The need to turn our attention to the socio-psychological aspects related to the employment of communication technology in requirements engineering meetings is then discussed. The rest of the paper presents our laboratory experiment: its settings, method, procedure and the results on the efficacy of video-conferencing meeting systems for software requirements negotiations, as compared to the

traditional face-to-face meetings.

2. OUR INVESTIGATIVE APPROACH

This section provides the large picture of our current research and discusses the place of the laboratory experiment reported in this paper as part of our exploratory investigation of media effects in requirements engineering. The methodological issues of our approach are also addressed.

Our research is concerned with group performance and behavior in distributed requirements engineering, with a focus on requirements negotiation. We build our research on existing theoretical streams in group research and social psychology of telecommunications, theories that will guide the disciplined inquiry into technology-mediated groups that negotiate requirements. These theories are used for providing concepts and for guiding the research, especially in guiding observations, i.e., in knowing what to look at and what to look for, in drawing interpretations based on those observations and giving meaning to them.

Given the complexity of human interaction in general and of conflict resolution in particular, we are conducting an exploratory investigation outlined by the following steps (Figure 1):

- Stage I: We start by conducting (1) observational sessions of groups negotiating software requirements and (2) interviews with experienced industry software engineers to identify critical success factors of requirements negotiation sessions. Insights from this phase inform the design of the laboratory experiment:

- Stage II: We design and conduct a formal laboratory experiment in which the communication medium is varied, from the face-to-face setting to the teleconferencing setting. During the experiment, the group performance is measured and behavior is observed. The group type/size and task type/complexity will be controlled. Findings of the laboratory experiment represent pilot information for and inform the design of the field validation phase:

- Stage III: A field validation follows the laboratory experiment in order to further investigate any findings of the laboratory experiment in a real industrial environment.

This paper reports preliminary results (from pilot sessions) of the laboratory experiment, the second stage in our exploratory investigation (Figure 1).

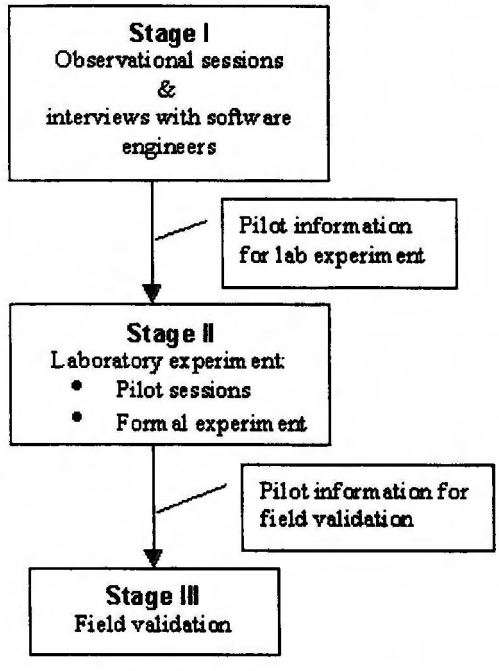


Figure 1. Stages of the exploratory investigation

2.1 Methodological issues in our exploratory investigation

The study of groups grew out of the work of sociologists and social psychologists of the late nineteenth and early twentieth centuries. The central feature of groups lies in the interactions of its members. McGrath (1984) presents a general model of group performance, while Bales and Cohen (1979) develop a system for the observation of interpersonal behavior. McGrath (1984) models the group interaction and performance as taking place under and being linked to a number of conditions - the properties of the group members, properties of the group structure, properties of the task/situation and the surrounding environment.

A wide range of research methods for the study of groups is outlined in McGrath (1984), from obtrusive research strategies (e.g. laboratory experiments, experimental simulations and field experiments) to unobtrusive ones (e.g. surveys, computer simulations and field studies).

The experimental method has been the most commonly used method in investigating the effects of media within mediated negotiations. Although empirical research based on experiments has been criticized for having an acontextual orientation (Fulk and Collins-Jarvin 1998), there is a good reason for favoring laboratory experiments over field studies. Conflict management and negotiation situations are recognized as complex human tasks and careful observation of their intimate details is often inaccessible in field settings. Experimental methods make possible the careful observation and precise manipulation of independent variables (e.g. communication media), allowing for greater certainty with respect to cause and effect, while holding constant other variables that would normally be associated with it in field settings. They also encourage the investigator to try out novel conditions and strategies in a safe and exploratory environment before implementing them in the real world (McGrath 1984).

One way of dealing with the lack of realism in laboratory experiments is to use multiple methods (McGrath 1984) so that strengths of some compensate weaknesses of others. Simulated laboratory negotiations could be complemented by field studies or validations (whose strength is realism), if the lack of realism is an issue. In our research therefore, we plan to complement the findings of our laboratory experiment with field validation sessions to be conducted at local software companies (Stage III, Figure 1).

3. RELEVANT RESEARCH

This section reviews previous research that is relevant to the study presented in this paper. The case of technology-mediated group session approaches to distributed requirements engineering is placed in the context of previous work in (1) requirements engineering and (2) media effects and group performance in negotiation situations.

3.1 Human factors and conflict in requirements engineering

As groups and teams are important features of the modern organization, the impact of technology on group communication and behavior patterns is a major area of research (Short et al. 1976, McGrath and Hollingshead 1994, Fulk and Collins-Jarvis 1998). However, little if no research has paid attention to the socio-psychological aspects related to the employment of communication technology in requirements engineering meetings. Aspects of the social process in requirements engineering have been largely overlooked (Goguen 1984), both in traditional face-to-face and distributed meetings.

The source of the problem is that defining requirements is inherently a human process. The organizational roles and the nature of work itself give the stakeholders diverse and sometimes

even conflicting views of the system to be developed which can result in a communication breakdown (Al-Rawas and Easterbrook 1996). The system stakeholders disagree over how to interpret features of the application domain, what the requirements for a new system are, and how to meet those requirements. There are various reasons for disagreement: (a) Different uses of the system by different types of users cause different interpretations of the customers' problem (Easterbrook 1994), (b) the knowledge of requirements is socially situated in the world of customers while it has formal and technical aspects in the world of developers (Goguen 1994), (c) field studies reveal user resistance to accept the development of the specific system, due to a lack of understanding of the benefits brought by the introduction of the new system (Macaulay 1996; Robinson 1990) and (d) defining requirements of an information system is a natural occasion for power struggles (Macaulay 1996).

Previous research recognizes conflict resolution and negotiation as an integral part of requirements engineering (Easterbrook 1994, Robinson 1990). It is recognized that emerging conflicts (e.g. cognitive conflicts or conflicts of interests) are to be resolved through a consideration, exploration and discussion of multiple viewpoints, i.e, by negotiation (Easterbrook 1994, Robinson 1990, McDermid 1994).

At the same time, there is an increasing recognition of the importance of the communication mechanisms for requirements engineering as they are provided by group session approaches (Macaulay 1996; Wood and Silver 1995; Crawford 1994). Examples of group session approaches include: Joint Application Development (JAD) (Wood and Silver 1995; Crawford 1994), Participatory Design (Floyd, Mehl, Reisen, Schmidt and Wolf 1989); Quality Function Deployment (QFD) (Sullivan 1986) and Cooperative Requirements Capture (CRC) (Macaulay 1993). Generally, these approaches involve stakeholders playing diverse roles in meeting situations during which they share a common workspace, share information, coordinate and control shared objects, analyze and make decisions (Macaulay 1996). A feature common to most group session approaches is the well-defined role of the facilitator in the meeting. The facilitator is the key person in managing the social process and guiding the team through the process. The facilitator monitors the group dynamics and intervenes whenever the relationships among the group members are dysfunctional.

Limitations of the current research. Research done in distributed requirements engineering focuses mainly on studies of asynchronous electronic communication during requirements elicitation (Matsuura, Takada and Nakakoji 1998), the use of groupware systems in supporting the management of meeting artifacts (Hrones, Jedrey and Zaaf 1993), or automated support for conflict management (Robinson 1990; Easterbrook 1994; Boehm and Egyed 1998). Only limited attention is paid to the social process of group interaction.

Group dynamics and especially the role of the facilitator in distributed requirements engineering processes are poorly understood (Dubs and Hayne 1992). Moreover, since face-to-face meetings seem to have more intense and richer interaction, the distributed setting is intuitively perceived as not effective for requirements negotiation. The idea of facilitating requirements negotiation meetings at distance has been challenged by a panel of professional meeting facilitators at the International Conference on Requirements Engineering 1998.

The fact that the social issues at the root of many difficulties cannot be modeled by the usual technical methods suggests that novel approaches be needed (Goguen 1994). In our research we use methods from behavioral and social sciences to investigate the case of technology-mediated

group session approaches to distributed requirements negotiation.

3.2 Perception of media and media effects

People have studied information transmission through various media well before the advent of the computer. Various studies compared the reception of information presented aurally and visually as different teaching methods (see, for example, the reviews by Day and Beach (1950) and Mowbay and Gebhard (1961)).

Then the era of computers opened new paths for the study of man-computer communication. Chapanis' work in interactive communications (Chapanis et al. 1972) pioneered a series of studies concerned with how people naturally communicate with each other and how their natural communication is affected by the devices through which they converse. This direction of research has been continued for decades. This section outlines two main theoretical streams on technology-mediated interaction developed over time and relevant to the study of media effects on group interaction and performance: Social Presence theory and Media Richness theory, classified often under the heading of Media Capacity theories. The core premise of media capacity theories is that media have different capacities to carry communicative cues.

Social Presence theory (Short et al 1976) was developed as a theory of media effects in the 70's, when the era of experiments done with audio and video conferencing systems began. The "social presence" concept was linked to nonverbal signals (e.g. facial expression, direction of gaze) and addressed the difficulties of developing predictions based on the presence or absence of such cues in complex human interaction. It was defined as a quality of a communication medium as perceived by the individual, and used in predicting the medium effects in situations that require group cooperation. The theory proposes that technology-mediated interaction would be less effective for highly interpersonally involving tasks (e.g. negotiation), in proportion to the decreasing amount of social presence of the medium. For example, it is hypothesized that conflict and negotiation situations, in which maintaining personal relationships is important, require high social presence media while low social presence media would be sufficient for information transmission and cooperative problem-solving activities in which interpersonal relationships are fairly unimportant (Short et al 1976).

Media Richness theory draws on organizational information processing premises and defines the medium's richness as its information-carrying capacity, in terms of feedback, channel, source and language (Daft and Lengel 1984). Five communication media (face-to-face, telephone, letters, written documents and numeric documents) have been fit on a continuum, with face-to-face being the 'richest' and numerical documents the 'leanest'. MRT argues that organizations process information to reduce uncertainty (lack of information) and equivocality (ambiguity, multiple and conflicting interpretations). Its fundamental claim is that the task performance improves when a medium with the appropriate richness is selected: equivocality reduction requires rich media, while uncertainty reduction occurs best in lean media. Over the years, extensions to MRT adapted this continuum to include newer communication forms such as computer-mediated and video-based media (e.g. Kydd and Ferry 1991; Rice 1992) face-to-face however, remained the "richest" communication medium.

Overall, however, empirical tests have not provided strong and convincing support for MRT. Recent empirical studies indicate the poverty of MRT to account for the media choice between newer media such as electronic mail and voice mail in organizations (El-Shinnawy and Markus 1997). One critique of media capacity theories is that much of the empirical research that

supports its predictions has focused on media perception or media choice, not on the effects of media on objective task performance. Although McGrath's Time, Interaction and Performance (TIP) theory (McGrath and Hollingshead 1994) considers this issue, it still includes a mapping between task performance requirements and media richness in a manner consistent with that of MRT.

Empirically however, when the objective performance for equivocal and cognitive conflict tasks has been tested (Kinney and Dennis, 1994), little or no support has been found for the claims of MRT or McGrath's TIP. While the theory indicated that "tasks requiring groups to negotiate and resolve conflicts of views or conflicts of interests may require the transmission of maximally rich information" (McGrath and Hollingshead, 1993, pg. 92), in practice the objective performance for the face-to-face condition was lower than in other media used (e.g. video phone, telephone and computer-mediated communication) (Kinney and Dennis, 1994).

In the area of group decision making in particular, reduced socio-emotional communication can in fact enhance group work (Walther, 1996). Complementing the findings on task performance, research into the socio-psychological aspects of telecommunications and computer-mediated communication (CMC) (Kiesler, Siegel and McGuire, 1984; Short et al, 1976, Walther, 1996) provide some insights into these controversial empirical findings. It was found that computer-mediated decisions are less influenced by social norms and pressures than face-to-face group decisions (McGuire, Kiesler and Siegel, 1987), and group decision support systems appear to achieve useful group-level outcomes by dampening interpersonal communication. Interpersonal relationships are seen as critical in conflictual situations (Short et al, 1976) and represent another testing ground for theories of media effects.

The greater task orientation of CMC (for a review see (Walther 1996)) is seen as a potential boon for the medium, where "computer conferencing ... promotes rationality by providing essential discipline (task orientation, coordination, equality of participation, etc.), by filtering out affective components of communication and emphasizing the content, minimizing social influences (influence of status, interpersonal 'noise', and so on)" (Dubrovski 1985, p. 381).

In face-to-face RE, we expect that socio-emotional concerns such as conflict or relationship management among the design team members would take time and effort away from task resolution. The question is then, would a less rich media (such as computer-mediated) act as a mechanism to reduce the need to expend effort in managing interpersonal relationships and therefore enhance the group performance during requirements negotiation.

4. LABORATORY EXPERIMENT

In order to address this question we designed a laboratory experiment to investigate the effects of communication media on group performance in requirements negotiation. We designed a simplified scenario that illustrates the conflict between requirements scope and resource constraints. It involves the communication between a system analyst and two representative customers, socially mediated by a facilitator. The two customers are from two different organizational units and have different perspectives of the system to be developed. The system analyst represents that it is not possible to implement the system in the given time frame. Therefore the customers need to agree on a subset of the original requirements to accommodate the time constraints. This triggers the need to resolve conflicts between the requirements of the two customers.

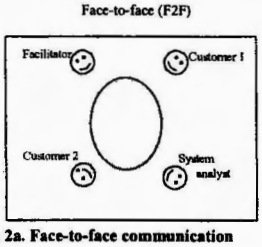


Figure 2a. Face-to-face communication

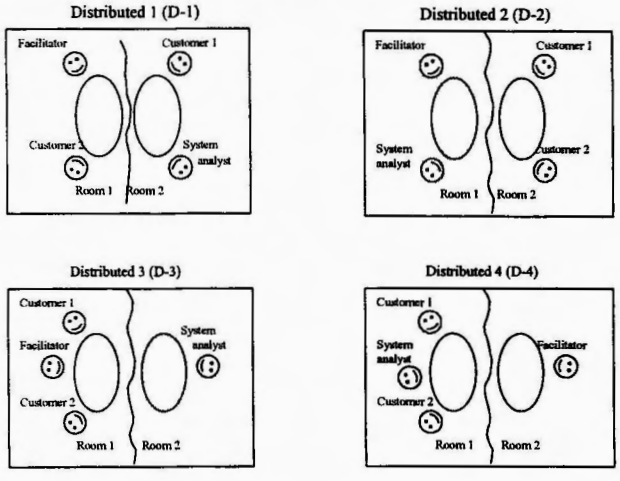


Figure 2b. Four physical group configurations within the distributed communication setting

In order to evaluate the efficacy of computer-conferencing systems for requirements negotiation and their effects on interpersonal relationships we compared the face-to-face with distributed, computer-conferenced meetings, using the scenario described above. Within the distributed condition, we defined four "group settings" distinguished by different physical configurations (figure 2b, D-1 to D-4). These were chosen to vary the relative location of the two customers, the system analyst and the facilitator. Our purpose in including the facilitator is to examine potential changes in the facilitator's behavior in distributed conditions compared to face-to-face meetings. Future work will report on media effects on the facilitation style in such group settings.

In describing and analyzing the quality of group performance (resolution of conflicting perspectives) we used general concepts from negotiation literature (Pruitt, 1981). Negotiation behavior can be distributive or integrative. While distributive behavior reflects the situation "your loss is my gain" (here: only one customer perspective is supported by the system), integrative behavior consists of incorporation of opposing proposals, communication of goals and constraints, as well as searching through extreme alternatives and multiple issues (Pruitt, 1981; Robinson 1990) (here: the incorporation of both customer perspectives to support the overall business goal). In exploring the potential for an integrative behavior, numerical weights were used to account for the relative importance of each issue in discussion.

The perception of medium, i.e., the participants' mental set towards the medium, is an important key to understanding person-to-person telecommunications (Short et al 1976). Thus, the participants' perceptions of media, and concern with "irrelevant" interpersonal information and focusing objectively on the task at hand are also investigated and analyzed in an attempt to interpret the results on group performance.

4.1 Sample

Forty-two volunteers from the student population of the University of Calgary took part in this study, 11 (26.1%) females and 31 (73.8%) males. The participants ranged in age from 19 to 41. The prerequisite for their participation was experience in software engineering and/or negotiation. They gave informed consent and were paid for their participation. Three professional facilitators volunteered to mediate these meetings.

4.2 Materials and Design

Equipment· In designing any experiment of this nature a large number of decisions have to be made concerning the equipment used. As the goal of this study was to investigate the effects of multimedia meeting systems currently used by the software industry in remote collaborations, this study used widely available meeting technology (Microsoft's NetMeeting system with full video/audio and shared files facilities).

Figure 3 depicts the equipment configuration in the distributed conditions. The two rooms were connected such that the images and sounds from one room were transmitted with high quality to the other via audio/video conferencing facilities (an 100Mb Ethernet link was used). Further, the

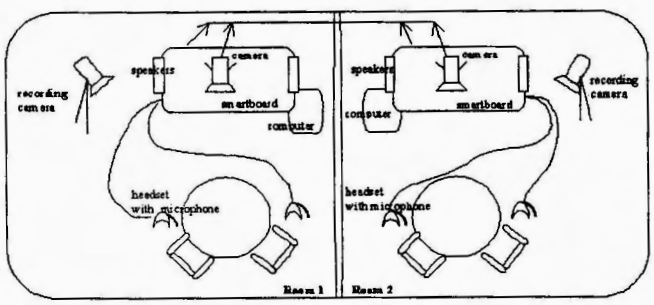


Figure 3. Equipment used in the distributed condition

task was electronically mediated through a shared editor to reflect the results of the negotiation and displayed on both electronic displays. Therefore, all groups (including F2F, figure 2) used the shared editor in completing the task.

Task. The scenario proceeds as follows. Two customer representatives and one system analyst are involved in defining a set of functional requirements for a banking management system. The overall business goal in using the system is to provide efficient face-to-face service to the bank's clients. The system development time is non-negotiable and fixed at 23 weeks. The customers, a Teller and a Personal Banking Representative (PBR), are given an initial list of requirements (all 12 requirements in figure 5) elicited at a previous meeting in no particular order of importance. An analysis of the requirements by the system analyst has shown that the implementation of all 12 requirements is not feasible given the fixed development time.

The Teller and PBR are each presented with a description of their own job responsibilities at the

bank summarized in figure 4. As can be observed, the customers represent business units that perform different operations on the clients' accounts: the Teller provides services to the bank's clients on a "walk-in" basis, with respect to banking (chequing/savings) accounts; while the PBR provides services on an "appointment", more personal basis, being concerned with credit (loan/mortgage/credit card) accounts.

The system analyst is given only the information on the number of weeks (in brackets, figure 5) required for the implementation of each of the 12 initial requirements. The system analyst suggests that the implementation be limited to only the first 9 requirements (see dotted line in figure 5). The group is then asked to consider the requirements selected by the analyst: if these nine requirements are not agreed upon as being helpful in aiding both customers to do their jobs efficiently, they are asked to agree on another set of requirements.

	Customers	
	Teller Representative	**Personal Banking Representative**
Critical operations	TC1. Browse client's list of accounts TC2. Access client's banking accounts profile (owner, date created, balance) TC3. Access client's credit accounts profile (owner, date created, balance) TC4. Pay bills, deposit/ transfer/withdraw funds	LC1. Open/inactivate accounts LC2. Update terms of credit accounts LC3. Browse client's list of credit accounts LC4. Obtain history of transactions on client's credit accounts
High priority operations	TH1. Obtain history of transactions on client's banking accounts TH2. Obtain list of due dates on client's credit accounts TH3. Order new cheques	LH1. Access client's credit accounts profiles (owner, date created). LH2. Access the balance on the client's credit accounts. LH3. Obtain credit rating from an external agency
Medium priority operations	TM1. Obtain history of transactions on client's credit accounts TM2. Obtain list of client's liabilities on credit accounts	LM1. Access client's banking accounts profile (owner, date created, balance) LM2. Obtain a list of client's banking accounts.
No authority/ responsibility to perform	TN1. Open/inactivate accounts TN2. Update terms of credit accounts	LN1. Pay bills, transfers, deposits. LN2. Order new cheques

Figure 4. Job descriptions of the teller and PBR sorted according to priority.

(1) R1. The system shall enable the open/deactivate accounts (**banking/credit**) operations.
(2) R2. The system shall display a screen showing history of transactions on **banking** accounts for the last 3 months.
(3) R3. For each **credit** account, the system shall display detailed information on the account: owner(s), date created, and balances.
(2) R4. The system shall enable the ordering of cheques on line.
(2) R5. The system shall automatically provide **credit** rating from an external agency.
(3) R6. For each **banking** account, the system shall display detailed information on the account: owner(s), date created and balance
(3) R7. The system shall enable transactions such as: deposit/withdraw/transfer/payment.
(4) R8. The system shall display a screen with a profile of *all* accounts with information on owner(s) and date created.
(4) R9. The system shall enable the updating of terms of **credit** accounts (e.g. grant credit, change payment terms).

(3) R10. The system shall display a screen with information on client's due dates, liabilities (for all **credit** accounts) and assets (for all **banking** accounts).
(2) R11. The system shall display a screen showing history of transactions on *all* accounts a client holds, for the last month.
(3) R12. The system shall display the list of *all* accounts a client holds.

(the system analyst was informed that the implementation of R3&R4 together require only 3 weeks)

Figure 5. The list of 12 initial requirements

Each requirement in figure 5 refers to one or more operations in figure 4, and each operation can be completely fulfilled by the implementation of one or more requirements. For instance, operation TC2 (which is the same as LM1) can be fulfilled by the implementation of either requirement R6 or both requirements R8 and R10. On the other hand, requirement R11 refers to both operations LC4 (which is the same as TM1) and TH1.

We aimed for a real-life task that is highly equivocal, in which each customer has detailed domain knowledge of only the operations performed by his/her own business unit. The only common piece of knowledge the participants had was the initial list of 12 requirements, and only through discussion did they discover the complex interrelationships between operations and requirements. There was the need to exchange information to understand the relative importance of requirements (e.g., R6 is regarded as very important by Teller while not important at all by PBR), and to explore alternatives in order to reach a mutual agreement.

The system analyst was the only one with the ability to estimate the development time for each requirement. Any subset of requirements chosen by the customers had to be discussed with the system analyst in order to determine the feasibility of implementation, given the time constraint.

Before the pilot sessions, the task was validated with a bank officer to confirm the validity of the task and was refined with three experienced software engineers to ensure a sufficient level of conflict.

4.3 Procedure

Participants were informed of the nature of the task prior to the study. A one-page set of instructions on the role was distributed and the need to become familiar with the role was explained. During the briefing period the understanding of the role was validated with each participant. They were introduced to their partners and completed a warm-up task designed to familiarize the participants both with each other and with the medium. Then they started the software requirements session, which was presented as a scheduled meeting of 40 minutes. Each facilitator mediated groups in each setting in figure 2a/b. Each group participated in only one negotiation session. The sessions were ended after 40 minutes and the final list of requirements was recorded. The participants then completed a post-session questionnaire.

4.4 Variables and measures

The independent variable in our exploratory investigation was the *communication media,* varied from face-to-face (figure 2a) to distributed communication (figure 2b).

Dependent variables were: (a) *group performance*, (b) *media perception* and (c) *perceived concern with interpersonal relationships.*

(a) The key variable was group performance, measured by the objective negotiation outcome.

We define the *objective negotiation outcome* as a measure of the final agreement from the bank's perspective. It illustrates the extent to which the needs of both customers are considered equally in a way that is most beneficial to the overall business goal.

We define a scoring system to measure the *objective negotiation outcome.* We use the following notations for weights given to operations and scores received by requirements:

- $w_{T\ \{PBR\}}$ (O) = weight of the operation O from the Teller's {PBR's} perspective
- $score_{T\ \{PBR,\ B\}}$ (R) = score of requirement (or list of requirements) from the teller's {PBR's or bank's respectively} perspective

To calculate the *objective outcome*, weights of 6, 3 and 1 points are given to operations of critical, high and medium priority respectively to either customer. If both customers require an operation of different relative importance, the higher weight is considered. Each requirement receives a score that is the sum of the weights of the operations it helps to achieve. The overall objective outcome is determined by the sum of scores of the requirements that are part of the final specification.

The scoring system accounts for both cooperative and competitive negotiation behavior.

Cooperative behavior in this case results in both customers defending their positions equally strong and the agreement illustrates the implementation of requirements that consider the operations of both customers equally. This situation is characterized either by an exploratory

search through alternatives and selection of an optimum subset of requirements, or by an expedient resolution by abandoning goals early and missing the implementation of critical requirements.

Competitive behavior in this case results in one customer being stronger on his/her own position, and the agreement illustrates the implementation of requirements that favor the operations of one customer over the other. The objective measure in this case is reduced to a score that takes into consideration the difference between the two customers' positions.

(b) The media perception variable was evaluated in the post-session questionnaire. The participants were asked to rate the communication media on a series of five point, bipolar scales such as: impersonal-personal, unsociable-sociable, insensitive-sensitive, formal-informal, unemotional-emotional, cold-warm, good-bad, easy-difficult, and complex-simple. The instrument was developed primarily from the work of Short et al [24] on the comparison of media.

(c) The perceived concern with interpersonal relationships was evaluated in the post-session questionnaire. The participants reported whether or not they were concerned with the presentation of self (interpersonal matters) and/or how well they could focus objectively on the task at hand.

4.5 Collection of data

The usage of the electronic shared editor has been recorded for groups in all experimental conditions. The final list of requirements that the group agreed on was analyzed and scored as described above. The post-session questionnaire was used in collecting both quantitative data on media perception and concern with interpersonal relationships, and qualitative data on the aspects of videoconferencing that helped/hindered the negotiation process (using open-ended questions). The sessions were video recorded for future analyses of group behavior.

5 RESULTS

Due to the small sample size in each experimental condition, we used non-parametric tests to analyze the results. These tests included the Mann-Whitney test for the analysis of results on the group performance variable (Siegel, 1956).

Before describing the results some technical details concerning their statistical analysis is required. As explained above, the study had five experimental conditions. This paper reports on the performance of groups in two interaction settings: (1) physical co-location of all stakeholders (Figure 2, Face-to-face&D4) and (2) distributed communication from two separate sites when the communication between some stakeholders was restricted to the video connection (Figure 2, D1&D2&D3). The outcomes of the negotiation are reported for each experimental condition in Table 1. For inferential statistical analysis purposes the face-to-face condition and the fourth distributed condition are collapsed under the "face-to-face" heading henceforth (since in both conditions all stakeholders are co-located), while the remaining distributed conditions are collapsed under the "distributed" heading.

5.1 Group performance

The group performance variable was measured by the objective negotiation outcome. Thirteen out of fourteen groups reached an agreement. The outcomes were scored with values ranging from 51 to 48 points and the groups with no agreement were scored 30 points. Table 1 illustrates

the distribution of these scores across all five experimental conditions (F2F, D-1, ..., D-4). Their significance is explained below.

I. 51 points: two different combinations of requirements resulted in an optimal objective outcome; the final agreement favored the requirements of both customers equally

II. 50 points: two different combinations of requirements resulted in a suboptimal objective outcome; the final agreement favors either the PBR's requirements or the teller's requirements

III. 48 points: the final agreement did not include the specification of a particular critical requirement for the bank; it resulted in a suboptimal objective outcome but favored both customers' requirements equally

IV. 30 points were given if the group could not come to any agreement within the allocated time

	F2F (all co-located)	D-1 (customers separated)	D-2 (customers co-located, sys. analyst and facilitator at a distance)	D-3 (customers and facilitator co-located, sys. analyst at a distance)	D-4 (customers and sys. analyst co-located and facilitator at a distance)
Facilitator 1	30	48	51	51	50
Facilitator 2	48	50	50	48	48
Facilitator 3	48	51, 50	51		

Table 1. Negotiation outcomes for each facilitator and experimental condition

A Man-Whitney analysis of the two types of interaction settings, "face-to-face" (F2F together with D4) and "distributed" (D1 together with D2 and D3) found that groups in the distributed condition reach a significantly higher-quality agreement than the groups in the face-to-face condition ($U = 6.5, p < 0.05$).

5.2 Perception of media

Factor analyses were carried out on the nine "communication media perception" scales, the method used being principal component analysis. The four factor solutions which gave the most meaningful results are shown in Table 2. Differences between the face-to-face and distributed conditions were tested with an analysis of variance on these four factor scores and the results are shown in Table 3. The communication medium has no significant effects on the first three factors, but there is a significant result effect on Factor 4 "perception of emotion" ($F(1,58)=6.613, p<.02$). The face-to-face communication medium (mean factor score = 3.54) was perceived as more emotional and sensitive than the distributed communication medium (mean factor score=3.33).

Factor 1 (Formality)		Factor 2 (Sociability)		Factor 3 (Easiness)		Factor 4 (Perception of emotion)	
good	.818	personal	.583	easy	.848	emotional	.580
informal	.581	simple	-.554			sensitive	.563
sociable	.769						
warm	.587						
25.8% of variance		19.9% of variance		15.4% of variance		12.1% of variance	

Table 2. Factors and loadings

Factor	Mean	SD	F	p
Factor1 F2F vs. Distributed	14.79 vs. 14.33	2.41 vs. 2.49	.459	.50
Factor 2 F2F vs. Distributed	7.12 vs. 6.88	1.26 vs. 1.25	.039	.844
Factor 3 F2F vs. Distributed	6.58 vs. 6.33	1.17 vs. 1.26	.256	.615
Factor 4 F2F vs. Distributed	3.54 vs. 3.33	.58 vs. 1.06	6.613*	.013

Table 3. Effects of communication medium on the Perception of Media factors

5.3 Perceived concern with interpersonal information and focus on the task

Analyzing the responses on the two-item session in the questionnaire in all five experimental conditions it was found that the percentage of perceived concern with interpersonal information in face-to-face condition (Figure 5, 100%) was higher than in any other distributed condition (Figure 5, D1: 33.3%; D2: 11.1%; D3: 66.6% and D4: 88%), while the participants were predominantly concerned with focusing objectively on the task at hand (F2F&D1&D3&D4:100%; D2: 88.8%).

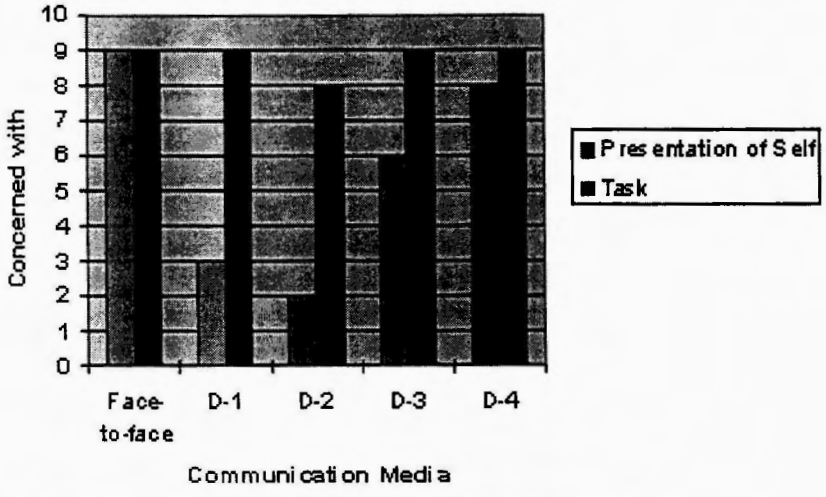


Figure 5. Perceived concern with interpersonal information and focusing objectively on the task

6. DISCUSSION

The results of this study suggest that agreements in the negotiation of software requirements are of a higher quality when groups are distributed (when the communication among the two customers and the software developer was mediated by the video link) than in face-to-face settings. Drawing on Media Richness Theory (MRT), videoconferencing is a less rich communication medium than face-to-face due to a reduced 'human touch'; and it would be perceived as being ineffective when used for negotiation tasks. Thus someone would expect the performance of groups to decrease, in comparison to face-to-face settings. However, our results challenge the claims of MRT. A discussion of the findings on the other variables helps us interpret this result.

The results on the four factors of perception of media are not easy to interpret. Drawing on the Media Capacity theories, we would have expected significant effects on the 'formality' and 'sociability' factors which were not affected by the communication medium in this experiment. This suggests that these theories may not be appropriate any longer in the context of today's advanced communication technologies and that new theories that accommodate recent findings should be developed.

However, the statistically significant difference found on the "perception of emotion" factor requires some consideration. The lowered ability to perceive emotions and be sensitive to emotional cues in the distributed condition together with a lower focus on interpersonal aspects

of interaction may explain the results of the higher-quality outcome. Post hoc explanations of this result include that higher-quality solutions would be reached using media which impede the full transmission of interpersonal affective information. A decrease in the transmission of affective cues would lead to a decrease in importance of "irrelevant" personal emotional considerations and thus enhance the chances of a more task oriented and objective interaction in the meeting.

Before we analyze data on the perception of the communication medium, it is important to remind the reader that participants in the distributed conditions (except in D3) interacted both with a local and a remote partner. The post-session questionnaire gave them the opportunity to report on perceived aspects of both face-to-face and distributed communication that helped or hindered their ability to achieve their objective in the meeting.

Although numerous participants commented on the positive aspects of the face-to-face communication (e.g., the increased ability to "communicate more easily with the other customer") some individuals reported on the increased ability to manipulate the partner in face-to-face negotiation situations ("body language allowed the other customer to persuade me easier (to some detriment)").

At the same time, a common theme could be observed on the advantages of distributed setting: the participants' heightened ability to focus on the task and remain objective, even detached during the debate. Numerous comments stress these points. Just a few examples are provided below:

[Developer:]	[Customers:]
• "... yeah, I felt a certain distance that made me able to be firm yet polite".	• "it is easier to be more objective to someone that is not right next to you - less prone to feelings of sympathy/compassion"
• "... maintained emotional distance"	• "... feel better and think better when I know someone is not in room waiting for me to say something"
• "... focused better on objective"	• "it helped me get personal with my co-worker on issues while ignoring the developer, although not seeming to ignore him"
	• "helped to not obsess about what the developer was doing or thinking and just get down to business"
	• "it's good for people who are shy and uncomfortable around others"

Considering the theory of Argyle and Dean (1982) we can provide a reasonable post hoc explanation for the preference of the video condition in requirements negotiation situations. Argyle and Dean proposed an intimacy equilibrium model, in which 'intimacy' is a function of proximity, eye contact, smiling, topic of conversation and other factors. They hypothesize that immediacy has a $\cap$ -shaped relation to liking, so that either too high or too low intimacy is avoided. This suggests that with tasks of very high intimacy - perhaps personal or conflictual ones - the least immediate medium available would lead to more positive evaluations (similar results were found in part in Williams 1975). Then it is only necessary to consider the requirements negotiation situation, in which the two customers had to decide on the relative importance of particular requirements that were often critical for one customer but not important at all for the other customer; or explaining to the customer that the developer cannot implement all requirements in the given time frame - and the results become more understandable. It is relevant to tie this aspect to the fact that all the distributed conditions in this study (D1+D2+D3) involved at least one of the customers or the developer at the remote site. On the one hand, this forced the "heavy" communication link that would appear in a face-to-face setting to be "re-

shaped" in the group distributed interaction. On the other hand, it revealed surprising evaluations of video-conferencing settings as (1) limiting the stakeholders' ability to manipulate the others into accepting a solution which favors only one side in the negotiation, and thus (2) allowing an increased ability to objectively evaluate one's own position in the negotiation.

7. LIMITATIONS OF THE STUDY

As with any laboratory experiment, caution should be exercised in extrapolating the results from this study to all users of such communication media in software enterprises. The small sample size used in this study makes any generalization of results difficult. However, our study had an exploratory nature, with the intent to investigate the use of computer-conferencing systems in several meaningful group configurations in requirements engineering. Although only three groups performed in each experimental condition, we believe that the random assignment of participants to conditions and facilitators minimized the effect of uncontrolled variables that might have confounded the results (i.e. personality characteristics and level of acquaintance). This study still makes a contribution to our better understanding of groups' performance and behavior in computer-conferenced requirements meetings.

8. CONCLUSIONS

This paper reported work in progress on our exploratory investigation of the effects of communication media on groups performance and behavior in requirements negotiation. Specifically, the laboratory experiment has been described: its motivation, setting, procedure and results. Its findings have been presented along with a post-hoc explanation. Also, the limitations of it have been discussed.

Despite these limitations, the preliminary results of our laboratory experiment point to the efficacy of videoconferencing for distributed requirements engineering meetings, specifically the ability of videoconferencing settings to enable a more task-oriented environment for requirements negotiation meetings. It has been found that groups using distributed meeting systems reach higher-quality requirements agreements, which means that software enterprises can augment the traditional face-to-face mode of communication with the introduction of videoconferenced meetings with their customers, while saving time and money for travel.

Although we believe that the controlled nature of the setting and the use of student subjects limits the applicability of our results to other settings and populations, the field validation (Stage III, Figure 1) of our exploratory investigation will extend the scope of the study to more realistic settings: arrangements have been made with a major industry partner to carry out a similar but a less controlled investigation in the field, to see whether there is sufficient continuity between laboratory and field setting to which we wish to generalize for a particular effect to be found in both arenas. We believe that the laboratory experiment represents a first step in building a model of distributed requirements negotiation situations and hope that complementing it with a field validation will help us enrich this model of group performance and behavior in these circumstances.

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