The Effects of Communication Mode on Distributed Requirements Negotiations

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Abstract

Videoconferencing is generally considered as the most appropriate medium to conduct requirements negotiations between remote stakeholders. To improve the effectiveness of distributed requirements negotiations, drawing upon the postulates of theories on media selection, we argue that a combination of lean and rich media is needed. In this paper we empirically test the hypothesis that the early resolution of uncertainties through an asynchronous lean medium can shorten the list of open issues to be negotiated over a synchronous rich channel.

1. Introduction

Requirements negotiation is one of the most complex and communication intensive practice of software engineering, especially in distributed scenarios, where arranging collocated meetings is often impractical. Previous studies in the field of Requirement Engineering [5] [9] indicate that videoconferencing is the most appropriate medium for effectively conducting distributed negotiations, thanks to its synchronicity (i.e., the capability of conveying information in a timely manner) and richness (i.e., the ability to convey the sense of physical presence of individuals, as well as a number of visual and verbal cues). However, while videoconferencing sessions come with an additional overhead (e.g., the costs of infrastructure setup and maintenance), even when everything runs smoothly [11], it is still hard to conduct a long-running and productive discussion during a videoconference, especially when more than a few people are involved. In contrast, asynchronous lean media, such as email or discussion forums, lacks all these abilities (e.g., one cannot see people nodding in text-based communication). Thus, to improve the effectiveness of distributed requirements negotiations, drawing upon the postulates of theories on media selection, we argue that a combination of rich synchronous media and lean asynchronous media is needed.

The Media Richness theory [1] [2] is one of the most prominent in the field of computer-mediated communication (CMC) studies. It posits the existence of two complementary forces, namely uncertainty, which act on individuals when they process the information exchanged to execute a task. *Uncertainty* represents the lack of required information, whereas *equivocality* represents the existence of multiple and conflicting interpretations of available information However, during the execution of a complex task like requirements negotiations, communicating and agreeing on requirements involves a constant interplay between both collecting further information about requirements and their context (i.e., uncertainty reduction), and resolving ambiguities, misunderstandings, or conflicts in requirements (i.e., equivocality reduction) [10]. In addition, the Media Switching theory [12], a more recent theory on CMC, has analyzed communication from a cognitive perspective, arguing that while rich media are useful in ensuring commitment to the task execution, they allow individuals a substantially lower ability to properly (re)process information at will, as compare to lean media. Thus, from the consistent combination of these two theories we argue that, on the one hand, rich synchronous communication is better suited for resolving the ambiguities that may arise in the discussion of requirements issues. On the other hand, when discussing issues or inspecting requirements documents, stakeholders may also need time to process information properly and sift through the issues outside of the meeting, at will and in a less interactive manner. Hence, lean asynchronous communication can more effectively support stakeholders in thoroughly analyzing issues, as well as in resolving issues of uncertainty by conveying missing information.

In two of our previous studies [3] [4], we have already shown that asynchronous discussions improve the effectiveness of synchronous requirements negotiations. Instead, in this paper we aim at

investigating the hypothesis that the resolution of uncertainties through an asynchronous discussion, conducted before the synchronous negotiation meeting, can shorten the list of requirements with open issues to be negotiated in a real-time manner. Rich media negotiation meetings will thus be mostly focused on reducing ambiguities (equivocality) in requirements. In this way the overall effectiveness of the requirements engineering process can be increased by cutting down the number of issues that remain open after the final synchronous negotiation.

The remainder of the paper is organized as follows. Section 2 describes the experiment in detail, including the design, the variables and hypotheses, and the threats to validity. Section 3 describes the results whereas Section 4 discusses the findings from the experiment. Finally, conclusions and future work are presented in Section 5.

2. The Empirical Study

The study was performed during a software engineering course, held in Spring 2005, and organized by three universities: University of Bari (Italy), University of Victoria (Canada), and University of Technology, Sydney (Australia).

Thirty-two students (10 Italians, 12 Canadians, and 10 Australians) were divided into six international project teams. Each team was formed by a client group and a developer group, interacting remotely. All the members of each group were, instead, always collocated.

As shown in Table 1, each Canadian and Australian group was involved in two different projects, playing the role of client (C) and developer (D), respectively. Instead, each of the two Italian groups was involved in only one project, either as a client (Gr6cl) or as a developer (Gr6dev).

The study used three distinct projects, each with two instances. Project A (A1 and A2 in Table 1) was to design a Global software development system to facilitate GSD collaboration. In project B (B1 and B2) the students designed the interface for a "iMedia" software to allow users to purchase movies online, organize and play their movies. Finally, project C (C1 and C2) involved the design of a real estate system.

The outcome of each project was a software requirements specification (SRS) resulting from the mutual agreement reached by the client group and the developer group. This mutual agreement was developed through a series of scheduled activities. First, a Request for Proposal (RFP) was produced by the client group and discussed during the requirements elicitation meeting, held in a videoconference by the entire team (both clients and developers). Then, the SRS was developed by the developer group in each project, with the client team providing feedback. This feedback had been provided earlier, through an inspection entirely performed online with the help of the IBIS tool [8]. The inspection was carried out individually by each member of the client team, who participated in the Discovery stage by reading the SRS and recording issues in the system. Each recorded issue was classified according to the IEEE standard taxonomy for good requirements documents (i.e., as omission, ambiguous info, incorrect fact, inconsistent info, not verifiable, or not modifiable) [7]. One of the researchers collected all issues and merged duplicates (i.e., issues found by more than one client) into a unique list of collated issues.

Table 1. Groups of clients (C) and developers (D) allocated to course projects

Country	Group	Project A (A1, A2)		Project B (B1, B2)		Project C (C1, C2)	
		PT1	PT2	PT3	PT4	PT5	PT6
Ca	Gr1	C					D
	Gr2		D	C			
	Gr3				D	C	
Au	Gr4	D			C		
	Gr5		C			D	
It	Gr6cl						C
	Gr6dev			D			

After the inspection, three teams out of six participated in a four-day asynchronous discussion using IBIS (i.e., in the Discrimination stage), and the other three teams jumped into the negotiation without asynchronous discussion. The purpose of the asynchronous discussion was to reach an understanding of each issue and identify those issues that could be closed online (i.e., where resolution could be reached without further negotiation) or remained open issues (everything else, which had to be further negotiated in real-time discussion). The process of closing issues used two mechanisms in IBIS: a discussion thread consisting of messages with respect to a certain issue was created, and voting as to whether it is still an open issue or is resolved and thus could be closed.

Finally, all six teams attended the requirements negotiation, which was held in a one-hour videoconference meeting session involving the remote developers and clients. The three teams that asynchronously discussed prior to the negotiation had to resolve only those issues that could not be closed during the asynchronous discussion and thus, remained

open issues. The other three teams entered the negotiation with the entire list of issues collated from the inspection.

2.1. Study Design

As shown in Table 2, we manipulated as independent variable the *communication mode*, with the following two treatments: (1) *mixed media* and (2) *rich media-only*.

Clients and developers in the *mixed media* teams used the IBIS tool to asynchronously discuss and store threaded discussions on requirements issues. The aim was to come to an understanding of each issue by exchanging messages and to reach an early resolution through a common agreement expressed by voting. Those open issues that could not be closed during asynchronous discussion were then left for the synchronous requirements negotiation.

Rich media-only teams skipped the asynchronous discussion and all issues found at the discovery stage were thus considered as open issues to be dealt at the negotiation.

Table 2. Study design

project team (client/developer)	communication mode
A1 (gr1/gr4)	rich media-only
B1 (gr2/gr6dev)	rich media-only
C1 (gr3/gr5)	rich media-only
A2 (gr5/gr2)	mixed media
B2 (gr4/gr3)	mixed media
C2 (gr6cl/gr1)	mixed media

2.2. Variables and Hypotheses

To conceptualize the elements in our research hypothesis, we defined the construct of the type of issues being discussed during the asynchronous and synchronous discussions. Our intention was to distinguish between elements of uncertainty and equivocality in the conversations. When an issue indicated the absence of sufficient information in a specific requirement and thus, implied a request of explanation in form of *extra information*, it was classified as *uncertainty*. Conversely, when an issue indicated multiple and possibly conflicting interpretations of a specific requirement and thus, implied a request of explanation in form of *clarification*, with no additional information, it was classified as *ambiguity* (or *equivocality*). Therefore, we measured the number of uncertainties and ambiguities in all asynchronous and synchronous discussions.

To count uncertainties and ambiguities, we parsed all the issues identified during the IBIS-based discovery stage performed by clients. We included in the *uncertainty set* all the issues classified under the category "omission" of the IEEE taxonomy. Similarly, we included in the *ambiguity set* all the issues classified under the category "ambiguous info" of the IEEE taxonomy. The issues classified in the remaining categories of "incorrect fact", "inconsistent info", "not verifiable" and "not modifiable" were also analyzed and counted as part of the one of the two sets depending on whether they required additional information (i.e., could be resolved by removing uncertainty and thus, classified in the uncertainty set) or clarifications (i.e., meaning was ambiguous and had to be clarified and thus, classified in the ambiguity set). Thus, we formulated the following two hypotheses:

H_1 *During asynchronous discussions of mixed media teams the uncertainties percentages of closed are higher than the percentages of closed ambiguities.*

H_2 *During synchronous negotiations of all teams the percentages of closed ambiguities are higher than the percentages of closed uncertainties.*

To investigate the H_1 and H_2 hypotheses, we collected the following dependent variables:

% closed uncertainties during async discussion = the ratio of closed uncertainties after async discussion to uncertainties after discovery.

% closed ambiguities during async discussion = the ratio of closed ambiguities after async discussion to ambiguities after discovery.

% closed uncertainties during sync negotiation = the ratio of closed uncertainties after sync negotiation to uncertainties before sync negotiation.

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Where *closed issues* (uncertainties or ambiguities) are issues for which a consensus was reached between developers and clients during discussions, either asynchronous or synchronous.

Furthermore, to investigate the presence of *extra info* and *clarifications* related to issues in the conversation, we performed the content analysis (or coding) on the transcripts of the video recorded synchronous negotiations. One of the researchers

identified thematic units[1] within negotiations' transcripts, then two coders performed the coding separately, and finally we counted the number of thematic units classified as *extra info* and *clarifications*. An *extra info* is a category specific for issues classified as uncertainties which raises new information about the issue that has not been elicited yet. A *clarification* is a category for issues classified both as uncertainties and ambiguities which states explanation without adding new information about the issue. Both categories do not include any form of agreement or disagreement expression.

According to the previous hypothesis (H_2), during synchronous negotiations, mixed media teams were more focused on closing ambiguities. Thus, we expected that they provided more clarifications than rich media-only teams. Conversely, because mixed media teams closed most of the uncertainties asynchronously (H_1), during synchronous negotiations they were expected to provide less extra info than rich media-only teams. Therefore, we formulated the following other two hypotheses:

H_3 *Mixed media teams use fewer clarifications than rich media-only teams to reach a consensus.*

H_4 *Mixed media teams use fewer extra info than rich media-only teams to reach a consensus.*

2.3. Threats to Validity

One of the key issues in experimentation is evaluating the validity of results [14]. Thus in the following we report the threats that are relevant for our study.

Threats to *internal validity* influence the conclusions about a possible causal relationship between the treatment and the outcome of a study. The following rival explanations for the findings have been identified. Because in this study there were three different project topics, we cannot exclude that the topic and project complexity could have been a confounding factor. Another threat to internal validity occurs because we were not able to completely randomize the selection and participants' assignment to the different groups. Indeed, while Australian and Canadian students were exposed to both levels of the independent variable, although with different roles (clients or developers), Italian students were not able to work on two projects and had the chance to choose the experimental treatment.

External validity describes the study representativeness and the ability to generalize the results outside the scope of the study. We identified the following threats to external validity. Involving students as subjects of the study (both as clients and as developers) may not be representative of the population of professional stakeholders. However, this threat is partially mitigated by the presence of Canadian students, who were attending a specific course on global software development and then were trained on meeting protocols and negotiation techniques for requirements engineering. Some students had also previous working experience in the software business.

Finally, *conclusion validity* concerns the relation between the treatments and the outcome of the experiment, regarding statistical methods, reliability of measures and treatment implementation. In our study an issue that could affect the statistical validity is the size of the sample data (6 projects, 32 subjects), and for this reason we performed non-parametric tests [13].

3. Results

To validate the $H_{1\text{-}4}$ hypotheses we performed the Wilcoxon matched pairs test as a nonparametric alternative for dependent samples [13].

In testing H_1, we compared the percentages of closed uncertainties to that of closed ambiguities during the asynchronous discussion for the three mixed media teams. In testing H_2, we compared the percentages of closed uncertainties to that of closed ambiguities during the synchronous discussion for all teams.

With regard to the H_1 hypothesis, Figure 1 shows that asynchronous discussions were more useful to close uncertainties than ambiguities. Although participants had a high number of uncertainties to be discussed during the asynchronous discussion, they were able to close many of them. The percentages of closed uncertainties during async discussion (0.53%, 0.91%, and 0.53%, respectively for A2, B2 and C2) were always higher than the percentages of closed ambiguities during async discussion (0.33%, 0.82%, and 0.0%, respectively for A2, B2 and C2), for all three mixed media teams. The Wilcoxon test was significant at the 10% level (Z=1.603, p=0.10).

With regard to the H_2 hypothesis, Figure 2 shows higher percentages of closed ambiguities than closed uncertainties during sync negotiation for each of the six projects. Also in this case the difference is statistically significant at the 10% level (Z=1.603, p=0.10).

With regard to the H_3 and H_4 hypotheses, we performed the content analysis on the negotiations'

[1] A single thought unit or idea unit that conveys a single item of information extracted from a segment of content [6].

transcripts. The inter-coder agreement between the two coders was measured by Cohen's kappa and ranged from 0.84 (for project A2) to 0.94 (for project A1). Our interest was in observing any differences between the numbers of *extra info* and *clarifications* recorded for the rich media-only vs. mixed media teams. In testing the H_3 and H_4 hypotheses we found the following results (see Table 3):

(1) the mixed media teams had significantly higher numbers of clarifications per issue (Z=1.963, p=0.04) than the rich media-only teams;
(2) the number of extra info per uncertainty were significantly lower for the mixed media teams (Z=1.963, p=0.04).

4. Discussion

The quantitative analysis of data indicates that, as compared to the synchronous discussions, in the asynchronous discussions participants closed more uncertainties than ambiguities. Consequently, participants who had already run an asynchronous discussion (i.e., belonging to mixed media teams) could start the videoconference negotiation meeting with a shorter list of open issues to be discussed (mostly ambiguities). Instead, for rich media-only teams more ambiguities than uncertainties were closed during the videoconference negotiation meeting (i.e., the only media participants used). Moreover, results of the content analysis indicate that a lower number of extra info units were recorded consistently for the mixed media teams. In other words, participants of mixed media teams in the negotiations did not provide additional information for those uncertainties already discussed asynchronously but that remained still open.

Our findings are consistent with the predictions of media selection theories described [1] [2] [12], since asynchronous discussions resulted more effective for reducing the uncertainty in requirements, whereas synchronous discussions more effectively reduced the ambiguity in requirements. In particular, while rich media high in social presence – such as synchronous videoconference meetings – are needed for converging to a shared agreement, lean media low in social presence – such as asynchronous text-based discussions – are valuable in providing an early mechanism to structure the discussion of requirements issues before synchronous negotiation sessions. Although synchronous videoconferencing meetings ensure project stakeholders' motivation and attention in the discussion of possibly conflicting requirements, the high social presence, important in supporting the social relationships, may also impede unbiased or prompt decisions. Asynchronous text-based communication medium emerges as a useful complement in preparation for such meetings: they allow the group participants to process information and consider requirements issues and provide missing information (reducing uncertainty) at their own time and pace. Moreover, asynchronous discussions allowed shortening the duration of synchronous negotiations that were effectively carried out in a one-hour videoconference session.

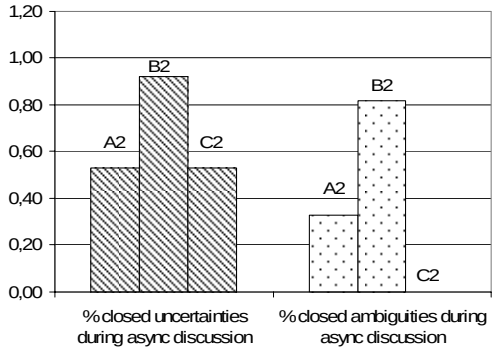

Figure 1. Uncertainty and equivocality reduction during async discussion

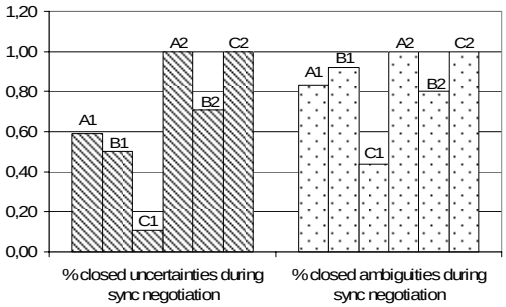

Figure 2. Uncertainty and equivocality reduction during sync negotiation

Table 3. Results from the content analysis

	rich media-only			**mixed media**		
	A1	B1	C1	A2	B2	C2
discussed issues	34	50	31	12	12	13
thematic units	350	245	298	174	141	125
extra info per uncertainty	1.81	1.09	2.00	**0.63**	**0.86**	**0.44**
clarifications per issue	3.03	1.66	3.32	**5.42**	**4.67**	**3.62**

5. Conclusions & Future Work

In this paper we have presented an empirical study on the effects of rich-media synchronous communication (i.e., through videoconferencing) and lean-media asynchronous communication (i.e., through a web-based discussion forum) in distributed requirements negotiations. The study was conducted in collaboration of three universities in three countries (Australia, Canada, and Italy).

Our findings have shown that, during rich synchronous discussions, remote stakeholders closed a statistically significant higher number of ambiguities than uncertainties. Conversely, during lean asynchronous discussions, stakeholders were able to close a significantly higher number of uncertainties than ambiguities.

These results have a practical impact in the design of a new toolset, which has to include a combination of synchronous/asynchronous media for effectively supporting distributed requirements negotiations. Then, such toolset would be capable of shortening the duration of a synchronous negotiation, conducted over a rich-medium, by running first an asynchronous discussion over a lean medium to cut down the number of issues left open to discuss.

As future work, in order to gain a more in depth understanding of ways in which structured asynchronous discussions can support remote teams resolve open issues prior to negotiations, we are analyzing the broader context in which this causal relationship was observed. In particular, we are analyzing the negotiation meetings behavior, by measuring the conversational efficiency in terms of speaking turns and words, and the process, by classifying the types of turn (e.g., questions, agreements), exchanged to reach mutual agreement on issues. This will enable us to understand which factors in the computer-mediated collaborative process contributed to these results. We thus hope to draw more detailed guidelines on conducting structured asynchronous discussions in support of expensive but important synchronous requirements negotiations.

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