Requirements Eng (2010) 15:397–417
DOI 10.1007/s00766-010-0105-9

ORIGINAL ARTICLE

A framework to improve communication during the requirements elicitation process in GSD projects

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Received: 10 July 2009 / Accepted: 21 April 2010 / Published online: 21 May 2010

Abstract Achieving a shared understanding of requirements is difficult in any situation, even more so in global software development projects. In such environments, people must deal not only with the lack of face to face communication, but also with other issues such as time difference, cultural diversity and a large amount of information originating from different sources throughout the world. Obtaining the right requirements therefore implies extra effort. In order to minimize such problems, we propose a framework that focuses on analyzing the factors that may be problematic in global software development and which suggests a set of strategies to improve the requirements elicitation process in such environments. In this paper, we describe the different phases of our framework and present the results of an experiment that test part of this framework. The results indicate that applying some of the strategies proposed in the framework seems to positively affect the stakeholders' satisfaction with regard to communication. Moreover, the quality of the written software requirements specifications seems to be better as well when using those strategies.

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Keywords Requirements elicitation · Global software development · Cognitive informatics

1 Introduction

Failures during the elicitation process are usually attributed to the fact that teams experience difficulties in working on a cooperative basis [56]. Additionally, there is a trend which has arisen in the past decade, called Global Software Development (GSD), which involves the geographic distribution of modern software development organizations' employees. In such environments, a series of new problems emerge, particularly when stakeholders are distributed throughout distant countries. These new problems include:

1.1 Inadequate communication

Face-to-face interaction in globally distributed environments is severely reduced and usually takes place between very few people. This practice causes misunderstandings due to communication restrictions which are a key problem for requirements engineering activities [23, 51]. Furthermore, tackling communication difficulties in GSD projects is crucial. If communication difficulties can be clarified as soon as possible during the requirements elicitation phase, they are not spread over the different software development phases and the cost of solving them is lower.

1.2 Time difference

Another kind of problem appears when sites are distributed in different time zones, which usually means that timetables do not overlap or only overlap for a short time, thus signifying that synchronous collaboration is not possible and that some delays may occur in the project [23]. These kinds of delays may also occur because of cultural issues such as different work hours, lunch breaks, weekends or holidays [29].

1.3 Cultural diversity

People from different sites in different countries usually have different religions and customs. Furthermore, when the native language is not the same, the different levels of knowledge of a common language (usually English) may also be a problem. These differences may be a source of misunderstandings caused by the use of ambiguous words, expressions that can be misunderstood, body language that gives a wrong impression, etc. [23, 45]. As was previously explained, it is better to detect misunderstandings as soon as possible so that their consequences can easily be prevented.

1.4 Knowledge management

In any project, it is necessary to deal with a huge amount of information originating from multiple sources, and this is particularly true for engineering requirements activities [23]. Unfortunately, the distance between sites usually makes this problem worse than in traditional requirements elicitation processes.

Within all the problems related to global software development projects, complexity can also be added to the traditional problems of the requirements elicitation process [14, 44]. Therefore, although GSD involves many different stages, we have focused our research on the requirements elicitation phase for the following reasons:

1) The importance of correctly communicating the requirements, which is fundamental to the success of any software under construction.
2) The fact that the requirements elicitation phase is crucially based on the communication between analysts and clients, which is continuously challenged by the characteristics of global environments.
3) The importance of minimizing misunderstandings during the requirements elicitation, in order to avoid their being propagated to the rest of the project phases, so as to reduce project costs and time.

Doing so, we have focused our work on answering the following question: Is it possible to improve the requirements elicitation process in a GSD project by means of strategies that take the virtual team characteristics into account?. With such an idea in mind, we present a framework for requirements elicitation, which is adapted to geographically distributed environments, and we present an experiment we have carried out to validate part of it. This framework proposes a series of strategies to minimize the most common problems that affect communication in GSD projects, considering not only the environmental features but also the stakeholders' cognitive characteristics which may affect the virtual team's performance. Finally, we present the results of an experiment in which our framework is applied.

The remainder of the paper is structured as follows: in Sect. 2, we introduce the motivation behind our work. In Sect. 3, we present our proposal. In Sect. 4, we discuss the experimental design and its implementation, in addition to reporting its results. In Sect. 5, we discuss these results and threats to their validity. Lastly, we present our conclusions.

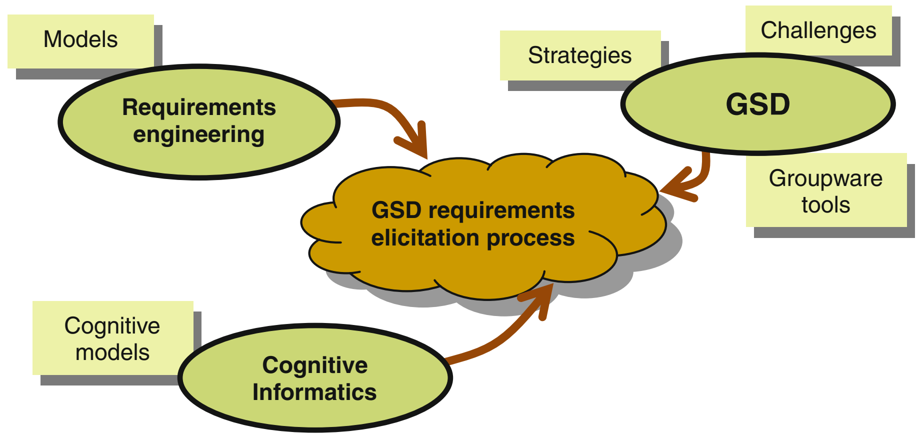
2 Background

In order to minimize some of the problems mentioned in Sect. 1, particularly those related to communication and cultural diversity, we focused our research on a set of areas (shown in Fig. 1), which are introduced as follows:

First, as the stakeholders in GSD projects principally communicate by means of *groupware tools*, we analyzed the characteristics of those groupware tools that are the most frequently used in GSD projects, i.e., e-mails, newsgroups, mailing lists, forums, electronic notice boards, shared whiteboards, document sharing, chat, instant messaging, and videoconferencing [23, 33, 36]. We then analyzed the different ways in which groupware tools have been classified, for instance with regard to time and space characteristics: synchronous or asynchronous [28, 40], their purpose: messaging, conference, decision support, etc. [28] or according to their richness with regard to visibility, audibility, reviewability, etc. [21, 22]. Furthermore, we also examined a series of works that analyzes the way in which some groupware tools or a combination of them affect team communication or performance in software engineering activities [25, 35], and others which focus on the differences between face-to-face communication and communication by means of groupware tools [24, 53].

Although groupware tools had been analyzed in many different ways, we believed it would be interesting to analyze how groupware tools can be affected by stakeholders' innate cognitive characteristics and vice versa. Therefore, we focused on the Cognitive Informatics research area, which aims to use cognitive theories to investigate informatics, computing, and software engineering problems [58], and we sought works that had applied cognitive style models for groupware tools selection. We did not find any works that had related both topics previously, so we decided to research this and began studying how to classify people according to their cognitive characteristics. To do this, we analyzed different

Fig. 1 Related research areas



cognitive style models which classify people according to the way in which they perceive and process information [27, 31, 42], and looked for works that related them with informatics or software engineering activities. This led us to realize that most of the works regarding cognitive aspects in informatics were focused on educational purposes [10, 13, 48, 55, 60]. However, we found one work centered on cognitive style models and software engineering processes. This work [47] specifically relates software inspection teams selection and analyzes its performance with regard to the cognitive style of its members. Miller and Yin did this by classifying inspection teams as homogeneous or heterogeneous, regarding the cognitive style of its members, and demonstrating that heterogeneous groups tend to confront more problems than homogeneous groups. They then suggest selecting the people that would make up a more successful software inspection team. There is, however, a difference between Miller and Yin's approach and ours, since we aim to choose the most suitable groupware tool for a given group of people.

Furthermore, in order to analyze stakeholders' cognitive characteristics, we studied five cognitive models [46] and we found that every item in the other models was included in the learning style model proposed by Felder and Silverman [31]. In addition, the model by Felder and Silverman has been widely used for cognitive classification in engineering fields [32]. As learning style models (LSMs) are used to analyze relationships between instructors and students, we considered that during the elicitation process, everybody "learns" from others. Elicitation is about learning the needs of the users [37], and also because users and clients learn from analysts and developers (for instance, they learn how to use a software prototype or new vocabulary, etc.), which means that stakeholders play the role of student or instructor alternatively, depending on the moment or the task they are carrying out [46]. For further details on learning styles, we refer the reader to [30, 31]. Section 3 describes how the Felder and Silverman learning style model is used in our proposal.

We have also analyzed works that attempted to minimize GSD problems related to inadequate communication, time difference, cultural diversity and knowledge management in the different stages of the software development process. For example, in the minimization of cultural problems, different strategies have been used in companies to improve awareness, such as cultural mediation [18, 34]. Other examples specifically related to requirements engineering are the Easy Win–Win methodology and the groupware tool to support the process [12] or the web-based collaborative tool proposed by [16, 24, 25]. The common aspect of these approaches is that they focus on the requirements negotiation phase, which is subsequent to the requirements elicitation phase. However, we have only found two works dealing with the global requirements elicitation process. The first of these is a preliminary comparison between different requirements elicitation techniques in GSD environments [43], and focuses on how groupware can be used to aid requirements engineering activities and analyze groups' performance by considering the application of different requirements elicitation techniques. The experiment performed in this work found that the Question and Answer method, Use Cases, Brainstorming, and Requirements Management were the most effective requirements elicitation techniques. Since not all the requirements elicitation techniques were used for the same number of people, these results are not conclusive. It is worth noting that this work did not consider cultural differences, since all the students were from the same country. This brings us to the second work that focuses on global requirements elicitation [8], which studies cultural differences related to context sharing and analyzes different levels of training with regard to cultural behavior. According to the case study presented in this work, context sharing can be perceived differently depending on people's cultural context. The main topics of both works (the use of groupware tools to assist requirements elicitation and cultural differences) have been considered in our work in order to propose strategies with which to improve the requirements elicitation process in global environments. Furthermore, since communication during requirements elicitation is also affected by the way in which people understand and deal with the world that surrounds them [15, 50], our proposal also considers the role that stakeholders' cognitive characteristics play in such environments.

As mentioned previously, Fig. 1 summarizes the different research areas of which part of our research is formed.

3 Our proposal

Our proposal consists of a framework for requirements elicitation processes in global environments, called RE-GSD (Requirement Elicitation for Global Software Development projects). This framework is a basis for adjusting or extending co-located requirements elicitation methodologies to GSD environments. It not only takes into account the characteristics of GSD projects but also their stakeholders' cognitive characteristics with the goal of making them feel more comfortable in the elicitation environment. To do this, we have studied various models for the requirements elicitation process and have selected those proposed by Christel and Kang [20] and Hickey and Davis [37, 38] as a basis for our proposal. This selection is due to the fact that both models share a generic view of the selection of requirement elicitation techniques that fits our intention of defining what to use according to stakeholders' personalities, which is not the intention of other models, such as the WinWin Spiral Model [11], which is based on a specific groupware tool.

Having considered the importance of communication during requirements elicitation and the special characteristics of a GSD environment, we have extended the framework methodology proposed by Christel [20] and have furthermore adapted its earlier stages. RE-GSD focuses on the first two phases of the Christel framework and also adds a phase between them (called *Virtual team definition & problem detection and solution*), which has been specially created for the global setting of teams. As Fig. 2 shows, phase 1 in the Christel framework is equivalent to phase 1 in RE-GSD, but it has been extended in order to offer templates with which to collect information from people on different sites and in different countries. On the other hand, phase 2 in the Christel framework is equivalent to phase 3 in RE-GSD. The difference is that strategies which help to improve communication in a distributed environment have also been included in the

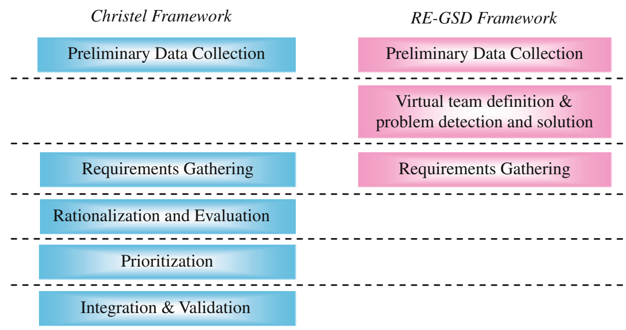


Fig. 2 Christel and RE-GSD methodology framework comparison

RE-GSD framework. Furthermore, phase 2 in RE-GSD has been added to implement the analysis of information, in order to detect the factors that negatively affect global requirements elicitation and to suggest strategies that will help to improve communication during such a process, avoiding or decreasing the negative effects previously detected. We shall now present the main characteristics for each phase in RE-GSD.

3.1 PHASE 1: Preliminary data collection

Similar to Phase 1 in the Christel model, the main goal of Phase 1 in RE-GSD is to discover as much as possible about the requirements elicitation scenario, which includes the people, sites, and organizations involved in the process. In order to organize this information correctly, we have defined categories to classify the information concerning the stakeholders and the environment in which the requirements elicitation takes place. The main difference between this phase in RE-GSD and the methodologies designed for collocated development is that RE-GSD not only focuses on the stakeholders' distribution on the sites but also on any cultural information relating to them, along with the technology that they are most familiar with or that they are able to use. In our proposal, this information is used to select the most suitable technology, as will be explained later.

To help gather this information, we have created a specially designed set of forms that has been presented in [7], which focused on stakeholders' personal data like cultural issues, academic background and previous experience, together with cognitive information. For example, stakeholders are asked to complete a psychological test[1] to discover their cognitive profile according to the Felder and Silverman model. Section 3 explains why such information is useful for our research and how it is applied in our proposal.

[1] Available on the www: http://www.engr.ncsu.edu/learningstyles/ilsweb.html.

Table 1 Factors evaluated in Phase 2

Factor	Question	Linguistic tags
Time overlap	How much time do stakeholders share for synchronous collaboration?	Low, medium, high
Cultural difference	How different are the cultures of stakeholders taking part in the process?	Low, medium, high
Level of knowledge about a common language	What is the level of knowledge with regard to the chosen common language?	Low, low-intermediate, medium, high-intermediate, high
Group cognitive type	What type of cognitive style does each stakeholder in the team have, and how do all the stakeholders' styles combine?	Type 1, type 2, type 3

On the other hand, such forms are also used to collect information about stakeholders' contact information, considering their timetable and the groupware tools are available. All this information is then arranged to be used in the various procedures of the following phase. For example, during the second phase, this information is used to detect possible problems and to define the strategies to be applied in order to minimize them by applying the remaining phases of our methodology. Gathering this information does not take much time in comparison with the benefits that it represents for the rest of the process. In addition, we have designed the forms in such a way that they are easy to understand and complete in order to facilitate this task.

3.2 PHASE 2: Virtual team definition & problem detection and solution

Previously mentioned, Phase 2 has been added in RE-GSD in order to specifically focus on recommending strategies to minimize the problems caused by geographical dispersion.

With such an aim in mind, we propose analyzing the information gathered in phase 1, identifying the possible sources of problems, and then recommending strategies to improve the requirements elicitation process. In order to do this, we propose two main tasks:

- Evaluating the factors that may be a source of future problems.
- Determining the strategies to be applied in order to minimize the detected problems

3.2.1 Evaluating the factors that may be a source of future problems

First, we have analyzed the information gathered during the previous phase and detected which factors affect a given virtual team's performance. This analysis has been carried out by focusing on the most common problems referred to in literature related to this topic. Four factors which can be measured in any virtual team have been defined. They are: *time overlap, cultural difference, level of knowledge about a common language,* and *group type regarding stakeholders' cognitive aspects*. For each of these factors, we have determined a set of linguistic tags, which are easy both to remember and to refer to. They also provide us with the possibility of reusing our functions in various projects. In Table 1, each factor is presented with the question that it attempts to answer and its linguistic tags.

We explain how the different linguistic tags are obtained for each factor below.

3.2.1.1 Time overlap evaluation This factor is calculated by analyzing the information gathered by means used in Phase 1, which between other questions ask about arrival and departure times and lunch breaks (if needed), and convert them into Greenwich Mean Time (GMT). We then calculate how much time is available for synchronous interaction per day and we estimate the percentage over the daily working time to define the tag for the time overlap factor.

In order to define the tags "low", "medium", and "high" for the overlap factor, we propose a formula based on n hours working day, as it has been presented in [6]. For example, let us consider a three stakeholders' virtual team (Jane, Joe, and Antonio). Jane and Joe are in New York and Antonio is in Madrid. Since the time zone for New York is −5 and the Spanish time zone is +1, according to GMT, we recalculate the timetables for the GMT standard as follows: if Jane works from 8 to 16, it would be 13 to 21 GMT; if Joe works from 10 to 18 in New York, it would be 15–23 GMT, and if Antonio works from 10 to 14 and from 16 to 20 in Madrid, it would be 9–13 GMT and 15–19 GMT. This information is then drawn as is shown in Fig. 3, and the overlap is calculated. As a result, the total overlap is 4 h, which corresponds to a "medium" level for the time overlap factor according to the fuzzy function presented in [6].

3.2.1.2 Cultural difference evaluation This factor is estimated by using the Hofstede model [39], which is most frequently used to analyze cultural differences in GSD projects [26, 45]. Such model defines five dimensions: power distance (PDI), individualism (IDV), uncertainty

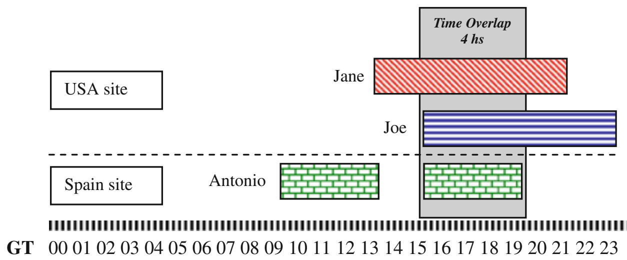


Fig. 3 Time table overlap evaluation form

avoidance index (UAI), masculinity (MAS), and long-term orientation (LTO), which are indicators of the cultural behavior in each country. These values have been defined by means of surveys in 53 different countries, while the fifth dimension was defined by means of a later survey in 23 countries [39].

In order to obtain a value for the cultural difference between two countries on a scale (low, medium, high), we have proposed formula $D_{A,B}$ for the cultural distance between countries A and B [6]:

$$D_{A,B} = \sum_{i=1}^{5} |v_i(A) - v_i(B)|$$

where i is a dimension in the Hofstede model: 1 = PDI, 2 = IDV, 3 = UAI, 4 = MAS, 5 = LTO, and v_i (X) is the value for the ith dimension of country X.

For example, we can calculate the cultural difference between Belgium and Spain, as follows:

	V_1	V_2	V_3	V_4
Belgium	65	75	54	94
Spain	57	51	42	86
$\|v_i(A) - v_i(B)\|$	8	24	12	8

Therefore $D_{\text{Belgium,Spain}} = (8 + 24 + 12 + 8) = 52$

This formula was applied repeatedly to obtain an indicator for the cultural difference between each pair of countries in the Hofstede model, and as a result, we defined a range of values for each linguistic tag (low, medium, high) accordingly, as it is presented in [6].

3.2.1.3 Evaluation of level of knowledge about a common language In this case, rather than using a scale to evaluate the language difference, we preferred to evaluate the degree of knowledge of a common language. In this scale, the tag "High" is the best choice, which means that there is no language difference. The other tags are: High-Intermediate, Intermediate, Low-Intermediate, and Low. To evaluate this factor, we propose a diagram (shown in Fig. 4) to gather the information related to knowledge about a given language and propose a scale to classify the difference. For this classification, we have considered the following cases:

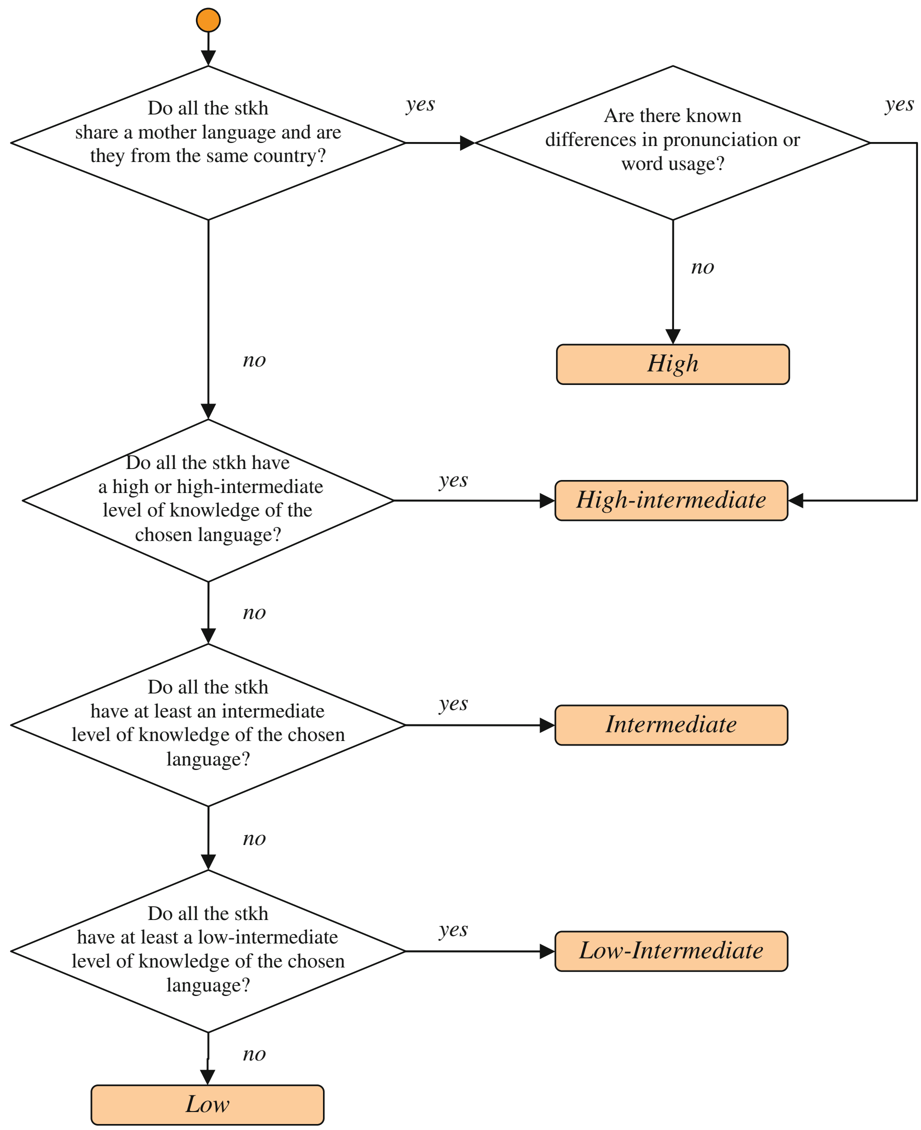
- People from the same country may not share the same mother language (for example, in Canada, there are two official languages: English and French. In Spain, there are also different languages in different regions: Castilian which is commonly known as Spanish, Catalan, Valencian, Basque, etc.)
- People who share a mother language, usually from different countries or regions, may have differences regarding pronunciation, word usage, etc.

Each language that can be considered as a possible common language for the virtual team should be analyzed following the diagram in Fig. 4. The information gathered by the means used during Phase 1 must be analyzed, specifically considering the level of knowledge regarding each language stakeholders in the team are familiar with. Therefore, the language that obtains the highest mark (or tag) should be chosen as the best common language for the team.

3.2.1.4 Group cognitive-type evaluation As explained in Sect. 2, we studied different cognitive models and chose the Felder-Silverman (F–S) learning style model [31] as a basis for our research. We thus propose the use of the F–S model to obtain stakeholders' cognitive profiles and use this information to choose the most suitable technology for a particular team. By doing this, we aim to make the environment closer to the stakeholders' cognitive profiles. When applying the F–S model, the stakeholders' learning styles are obtained by means of a test that catalogs their preferences with regard to four categories (perception, input, processing, and understanding) as slight, moderate, and strong in two opposite subcategories. For instance, in the "input" category, the scale catalogs people as being verbal or visual (slight, moderate, strong). Verbal people would therefore prefer to perceive information by means of spoken word, while visual people would prefer graphics. When preferences are strong, people may have difficulty in learning in an environment that does not support their preference. We have therefore decided to classify teams and assign them a tag, according to the occurrence of strong preferences, as follows:

- **Type 1**: There are no strong preferences within the team.
- **Type 2**: There are strong preferences but not at opposite ends of the same category. For instance: if there are strongly visual people on the team and no strongly verbal people, communication should be based on diagrams and written words that will increase the involvement of visual people. It is easy for those people

Fig. 4 Evaluating language difference factor



with slight and moderate preferences to become accustomed to these communication methods.

- **Type 3**: If there are strong preferences at opposite ends of the same category, then there is a conflict of preferences. For example, if there are one or more strongly visual people and also some strongly verbal people, communication should support both kinds of styles, as we discuss later.

Figure 5 clarifies the process of the team cognitive-type factor evaluation.

3.2.2 Proposing strategies to minimize communication problems

Once all the factors have been measured for a team, we obtain a characterization that is useful to analyze the strategies which minimize the problems that may occur.

As we have previously explained, the main focus of our work is suggesting strategies to solve or minimize the main problems that appear in GSD projects during the requirements elicitation process [17, 23]. The previously measured factors have therefore been used to distinguish those factors that may be a source of problem and to enable us to propose a set of strategies with which to minimize them. Our suggested strategies are:

- **Strategy A**. Training with regard to cultural diversity.
- **Strategy B**. Using ontologies as bridges to facilitate communication.
- **Strategy C**. Selection of suitable technology, according to both the environmental features and the stakeholders' cognitive characteristics.

Table 2 shows how each strategy is related to the factors evaluated in Phase 2.

As Table 2 shows, the three strategies are related to improving problems related to language difference. For instance, when focusing on improving stakeholders' knowledge of the foreign culture, which is naturally related to problems regarding cultural diversity, this will also affect knowledge of the foreign language to some extent. Similarly, by using ontologies to minimize problems caused by language differences, we are reducing conceptual ambiguities [57] and clarifying the structure of knowledge [19], which will be helpful when time difference makes synchronous communication difficult. Finally, technology selection is focused on time difference, since communication can occur via synchronous and asynchronous communication groupware tools. However, technology selection is also related to the language difference factor, since we consider that people with the lowest levels of knowledge about a language need more time to think about what they read or want to express. Furthermore, technology selection is also related to communication channels, and here we refer to written texts, audio, and other visual mediums, which are connected to stakeholders' cognitive characteristics. Figure 6 shows the relationship between the strategies and the obtained values for the previously measured factors. Note that Strategy A (which involves training with regard to cultural differences) is recommended when the cultural difference is medium or high, while Strategy B (using ontologies as a communication facilitator) is recommended when knowledge of a common language is not high.

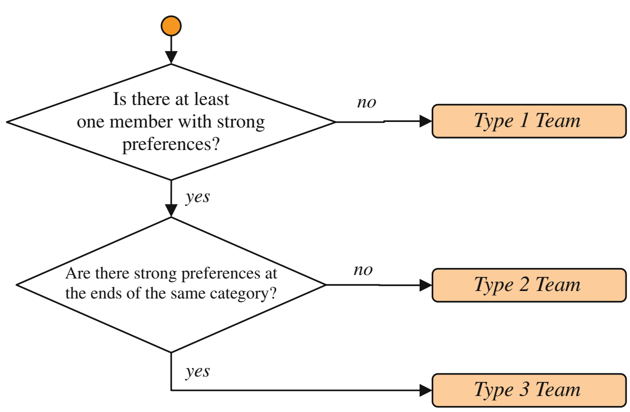


Fig. 5 Evaluating team cognitive type factor

Each strategy is presented in greater detail as follows.

3.2.2.1 Strategy A: Learning about Cultural Diversity Cultural differences cannot be avoided, but it is possible for stakeholders to learn about the differences between other cultures and their own. Being trained in cultural diversity is crucial if stakeholders are to be both aware of normal behavior in other cultures and conscious of their own behavior, especially with regard to that which might be offensive or could be misunderstood. In order to improve the dissemination of such knowledge, we propose using an innovative strategy called "virtual mentoring". This strategy is based on simulation and virtual actors, and it is a potentially interesting manner through which to motivate stakeholders in foreign language training and cultural familiarization [54]. Specifically, there is research in progress which focuses on simulation for requirements elicitation activities, regarding cultural and languages differences [52].

In addition to cultural diversity, GSD projects must also deal with language differences. Language difference can occur on a wide variety of levels, depending upon whether or not stakeholders share the same mother language. When people do not share the same mother language, English is usually the language chosen for interaction, and a clear understanding of domain concepts and relationships is vital.

However, a situation may arise in which people share the same native language but originate from different countries, and their idiomatic differences might also cause difficulties in communication. For example, the native language of both Argentina and Spain is Spanish, but pronunciation may vary, and many words may have different meanings in each country. Since a common understanding of the system domain is crucial during the requirements elicitation process, our strategy to minimize the idiomatic differences consists of using ontologies to help communication, as follows:

3.2.2.2 Strategy B: Using ontologies as communication facilitators Although stakeholders may share the same mother language, if they are not from the same country of origin, misunderstandings may occur as a result of the fact that some words have more than one meaning, or different words refer to the same concept, etc. Sharing a common vocabulary is crucial, especially when it refers to

Table 2 Factors and strategy relationship

	Time difference	Cultural diversity	Language difference	Group Cognitive Type
(A) Training with regard to cultural differences		√	√	
(B) Use of ontologies	√		√	
(C) Technology selection	√		√	√

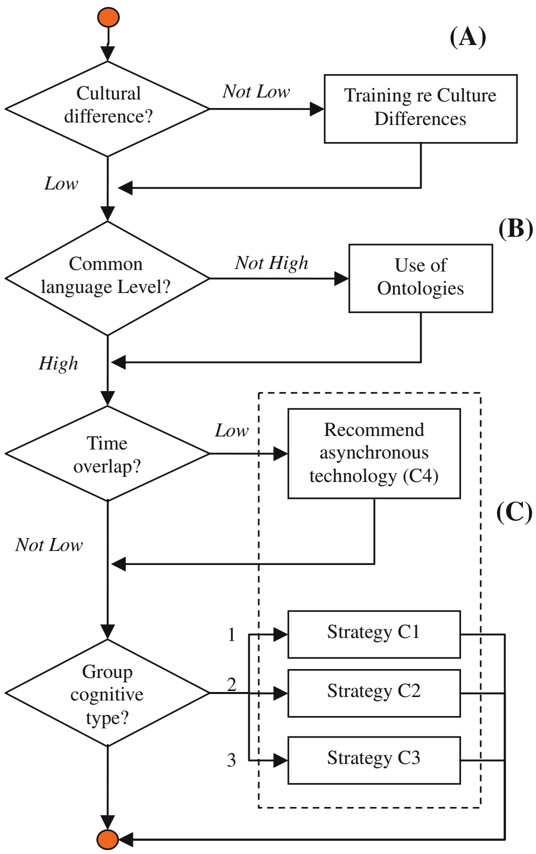


Fig. 6 Applying strategies according to factors measured in virtual teams

the domain components. Our proposal is concerned with attempting to build this vocabulary through the use of a domain ontology. Ontologies also play a natural role in supporting knowledge management, which is highly important during requirements elicitation in which a considerable amount of data is collected from many distant sources. Ontologies thus make it possible to clarify the structure of this knowledge and permit a clear specification of the concepts and the terms used to represent it [19].

Finally, we have considered the fact that people in GSD projects apply requirements elicitation techniques by means of groupware tools. Therefore, in order to improve people's communication, we have focused on analyzing how technology selection can influence people's performance. We propose a third strategy based on this analysis:

3.2.2.3 Strategy C: Selection of suitable technology Two types of technology are used during requirements elicitation: groupware and requirements elicitation techniques. By analyzing the factors measured in Phase 2, we aim to choose the most suitable technology according to the characteristics of each virtual team.

Various factors are involved in the selection of technology. The first factor is time overlap. In this case, it is obvious that when the time overlap is low, synchronous interaction will be difficult. Therefore, we recommend using asynchronous groupware tools and avoiding requirements elicitation techniques based on synchronous interaction (such as brainstorming). Furthermore, when the stakeholders' mother language is not the same, and the degree of knowledge of a common language is intermediate or less, we propose restricting communication to asynchronous tools in order to give people time to read and write attentively.

Lastly, we propose using knowledge of the stakeholders' cognitive characteristics for the technology selection. As was explained previously, one of the factors that is possible to study in a virtual team is the cognitive characteristics, which are innate to people and are related to the way in which they perceive and understand information. Since communication in GSD projects takes place by means of groupware tools and requirements elicitation techniques, we have proposed a model to obtain preference rules at the individual level [2]. After applying this model in a number of surveys [5], we obtained a preliminary set of preference rules [4]. In addition, we propose a set of strategies to combine technology according to the type of virtual team (type 1, 2, or 3). These strategies are designated as C1, C2, and C3, depending on the occurrence of people with strong preferences in the virtual team, using Strategy C1 for group type 1, C2 for group type 2, and so on.

In Fig. 7, we illustrate this process supposing that we have three stakeholders:

- First, we obtain the stakeholders' cognitive profiles by using the Felder and Silverman test. Cognitive information might also be retrieved from a "Cognitive Style DB", if stakeholders have participated in other GSD projects, and such information has been previously saved in the DB.
- Once we know the stakeholders' cognitive style, we apply our set of preference rules and obtain a set of suitable groupware tools for each stakeholder.
- Finally, we combine the personal preferences using strategies C1, C2, or C3, in order to obtain the technology which is most suitable for the whole team, according to the strategy that corresponds with the group cognitive type.

Strategies C1, C2, and C3 for personal preferences combination in a team are applied in each case, depending on the stakeholders' cognitive profiles and on the existence of strong preferences with or without conflicts. Further details about C1, C2, and C3 strategy definitions and examples that illustrate them can be found in [4].

3.2.2.4 Strategy application Strategies A, B, and C, are specifically related to the problems caused by geographical dispersion. They can be applied to any project, but we

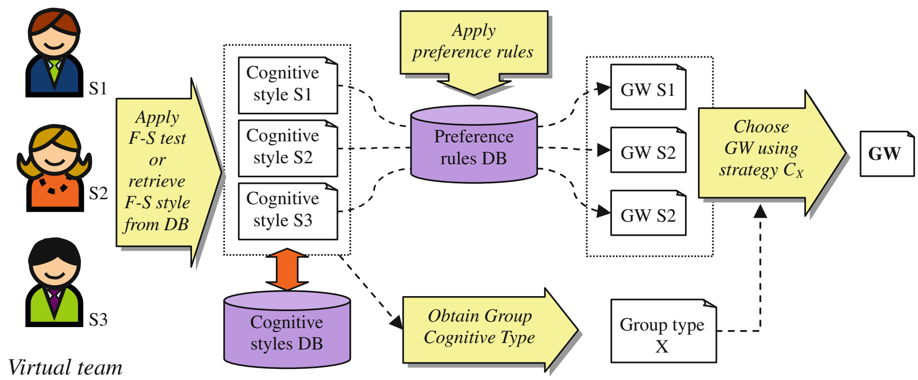


Fig. 7 Groupware selection process for a given virtual team

strongly recommend doing so when factors indicate that they are necessary.

For instance, as shown in Fig. 6, training with regard to cultural difference is suggested when cultural difference is medium or high, while the use of domain ontologies is recommended when people from different countries take part in the global requirements elicitation process. The technology selection strategy is recommended in most of the cases, but especially when virtual teams are type 2 or 3, thus signifying that people with strong cognitive preferences can increase their performance.

3.3 PHASE 3: Requirements gathering

Once the strategies to help communication in GSD have been defined for the project in hand, it is necessary to apply the requirements elicitation techniques and to obtain a list of requirements that answer the question of "*what*" is to be built [20].

The activities in this phase have been represented through an adaptation of the requirements elicitation model proposed by Hickey and Davis [38], taking into consideration both the factors introduced by geographical dispersion and the stakeholders' preferences regarding their cognitive styles.

In Fig. 8, the gathering phase begins by searching for a set of requirements elicitation techniques (RET; [49] that are applicable in the current situation S_i, and when the current state of requirements is R_i. Moreover, we have extended the Hickey and Davis model also taking into account factors T_i and L_i, which represent the time overlap and language difference, which are inherent to a GSD project [3]. One of these RET is chosen (t_i), considering the RET preference rules and the virtual team type (1, 2, or 3). Next, a groupware tool which is suitable for the application of t_i is chosen with regard to groupware tool (GW) preference rules. Finally, t_i is applied and a new state of requirements (R_{i+1}) and a new project situation (S_{i+1}) are attained.

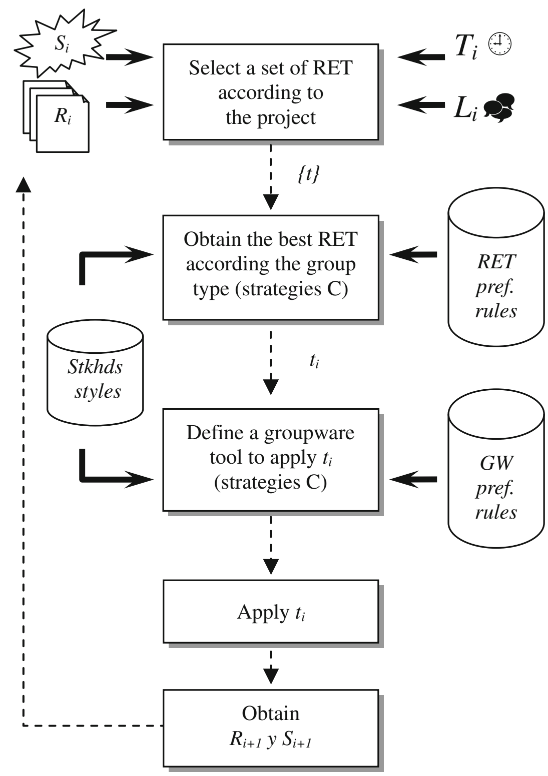


Fig. 8 Requirements gathering model for GSD projects

4 Experiment design

In order to evaluate our framework and the use of factor measurements and strategies definition in particular, we have carried out a controlled experiment by following the different stages described in [59]. This is explained in the following sections.

4.1 Definition

As suggested in [59], we followed the GQM template [9] for goal definition as follows:

Analyze	Application of RE-GSD framework
For the purpose of	Evaluating
With regard to	Stakeholders' satisfaction as regards communication with their colleagues.
From the point of view of	Researchers
In the context of	Simulation of a requirements elicitation process in a global environment.

4.2 Planning

Once the experimental goal was defined, the following step was to *plan* the experiment, which implied a description of *how* the experiment would be conducted and involved the following activities:

4.2.1 Context and subject selection

The selected context for our experiment was an academic environment. In order to carry out the experiment with a homogenous set of people, it was conducted with a set of Software Engineering students from the University of Castilla-La Mancha (Spain) and Software Engineering teachers from the University of Comahue (Argentina). Our reason for choosing subjects from Spain and Argentina is due to the fact that this was the first experiment that we carried out, and the authors work at these universities. Therefore, it was easier to carry out the experiment at these universities rather than at others, due to regulations and difficulty obtaining permission at other universities. Moreover, the variables of this choice were suitable to test our methodology since we needed countries where the cultural difference was not marked.

4.2.2 Hypothesis formulation

As our framework was specially designed to improve communication during the requirements elicitation process, we decided that one important factor to measure was the stakeholders' satisfaction with the communication in the virtual team. Our goal was to test the following:

Using the RE-GSD framework increases stakeholders' satisfaction regarding communication with their team colleagues

Since the subjects came from two countries (Argentina and Spain) whose cultural differences were low, according to the Hofstede model [39], we considered that strategy A (minimize cultural differences) was not applicable. Although the mother language in both countries is Spanish, we considered it important to apply strategy B (the use of ontologies to facilitate communication and knowledge sharing), because the subjects from both countries do not share the same pronunciation and use many words in different ways. It was also necessary to apply strategy C (selection of technology according to the stakeholders' cognitive style, specifically groupware tools selection).

We determined the following hypotheses:

- $\mathbf{H_{0,1}}$ Using a domain ontology does not affect the stakeholders' satisfaction with regard to communication during the requirements elicitation process. $H_{1,1} = \neg H_{0,1}$
- $\mathbf{H_{0,2}}$ Using groupware tools which are in accordance with the stakeholders' cognitive profiles does not affect stakeholders' satisfaction with communication during the requirements elicitation process. $H_{1,2} = \neg H_{0,2}$
- $\mathbf{H_{0,3}}$ There is no interaction effect between the use of a domain ontology and groupware tools chosen according to the stakeholders' cognitive profile regarding their satisfaction with communication during the requirements elicitation process. $H_{1,3} = \neg H_{0,3}$

4.2.3 Variables selection and experiment design

According to the characteristics of the subjects who would take part in the experiment, we defined two independent variables (strategy B, strategy C) and four treatments, combining the existence or absence of a domain ontology (strategy B) and the use or absence of a suitable groupware tool according to the subjects' cognitive style (strategy C) as follows:

T1: using an appropriate groupware tool and using a domain ontology
T2: using an appropriate groupware tool without using a domain ontology
T3: using a non-appropriate groupware tool and using a domain ontology
T4: using a non-appropriate groupware tool without using a domain ontology

With regard to the experiment design, we considered the possibility that an intra-group design [1], in which each team participated in each treatment, would provide us with the opportunity to analyze the differences regarding satisfaction and performance in each treatment. However, as four different treatments had to be covered, we realized that the maturity and the knowledge gained in each application of the experiment would influence the final results. We, therefore, believed that a design that did not involve repetition would be the most appropriate.

4.2.4 Instrumentation

During this phase, it was necessary to define the quantity and size of the teams. The size was defined according to the number of people available to participate in the experiment. There were 24 people at our disposal, and we needed to apply four different treatments. The participants were divided into eight teams of three. In order to avoid educational and background differences, we decided that participants from the same country and with similar backgrounds should play the same role in each team. The Spanish students were asked to play the role of *analyst,* and the Argentine teachers were asked to play the role of *client*.

Domain under study: we decided to choose a domain that was well known to the subjects playing the role of *client*, in order to make interaction with the analysts easier. Since those playing the role of *client* were Software Engineering teachers and researchers, we believed that a tool to organize their activities as researchers would be appropriate for all of them. It would also facilitate the explanations of their requirements to the analysts.

A series of documents were also designed, such as instructions for the different kinds of stakeholders and a pre-experiment questionnaire in which the subjects were asked about their previous experience in requirements elicitation processes and the groupware tools they had used before. They were also asked to fill in the Felder-Silverman test [31], which is available on the Internet.[2] A post-experiment questionnaire was similarly designed to collect stakeholders' opinions and assessments of the experiment.

4.2.5 Evaluation of validity

In order to avoid other factors affecting our results, we ensured that the remaining variables were fixed for all the treatments. For instance, requirements elicitation techniques were reduced to interviews and use case models for all the teams, and more experienced people were assigned to teams first, in order to avoid them being on the same team.

Subjects were assigned to teams by ensuring that the same roles were played by people from the same country, i.e., the Spanish students played the role of analyst and the Argentine teachers played the role of user. Finally, we ensured that each team had to overcome the same challenges: a time difference of 4 h, the same difference in timetables, and the cultural difference was the same (low according to the Hofstede model, [39]. Since there were two Spanish participants and one Argentine on each team, we ensured that each team had the same idiomatic differences regarding pronunciation and vocabulary.

4.3 Experimental procedure

The main activities carried out during the experiment are explained as follows.

4.3.1 Preparation

Before beginning the experiment, the students were asked to complete the pre-experiment test. Upon analyzing the collected information, we noticed that there was a high percentage of strongly visual people, and there were no strongly verbal people. Therefore, we assigned the subjects to Type 2 teams. To do this, we assigned the strongly visual people first, using a random criteria (a die). We later assigned the non-strongly visual people by using the method. Next, the teams were randomly assigned to one of the four treatments (as shown in Fig. 9).

Once the teams were formed, we applied the rules which had previously been defined by means of machine learning algorithm [2, 4] and obtained the most suitable tool for each stakeholder. We then obtained the most suitable groupware tool for each team by using strategy C2, since all the teams were Type 2. The teams in treatments T1 and T2 were then assigned the groupware tool suggested by our preference rules, but the teams in treatments T3 and T4 were assigned a different groupware tool.

Table 3 shows the most suitable groupware tool for each team (according to their members' cognitive characteristics), and the groupware tool they were assigned.

The team members were told to use only a single groupware tool during the entire duration of the experiment. However, they were not told that the groupware tools had been assigned by considering their cognitive profiles, so they did not know which groupware tool was appropriate for them. Similarly, the team members in treatments T2 and T4 did not know that the other teams were able to consult a domain ontology, since that information was revealed only to the teams that had it available to them for use.

	Using a Domain Ontology	Not Using a Domain Ontology
Appropriate groupware tool	**G4 G8** T1	**G6 G3** T2
Non- Appropriate groupware tool	**G1 G7** T3	**G2 G5** T4

Fig. 9 Team distribution in treatments

[2] http://www.engr.ncsu.edu/learningstyles/ilsweb.html.

Table 3 Groupware tools used by each team

Team	Suitable GW tool	Assigned GW tool	Suitability
G1	IM	Email	–
G2	Audio	IM	–
G3	Audio	Audio	+
G4	IM	IM	+
G5	IM	Email	–
G6	IM	IM	+
G7	Audio	IM	–
G8	Audio	Audio	+

4.3.2 Execution

While carrying out the experiment, each client was provided with general indications about a desired system (the same for all the teams), and he/she had to communicate the requirements of this system to the analysts by means of the recommended groupware tool and then transmit the system requirements. The team members were able to communicate freely for a week. After that time, each team presented us with the requirements specification that the analysts had written with the clients' approval.

Finally, upon receiving the requirements specification, we asked the team members to fill out a post-experiment questionnaire in order to obtain their personal opinions about the requirements elicitation process and the requirements specification they had written. The following section shows our results from the analysis of these post-experiment questionnaires.

4.3.3 Data Validation

The obtained requirements specifications and post-experiment questionnaires were considered valid since all subjects had similar knowledge and experience in the requirements elicitation process.

4.4 Analysis and Interpretation

The results of our experiment regarding the stakeholders' satisfaction with communication and the quality of the software requirements specification (SRS) are presented below.

4.4.1 Analyzing stakeholders' satisfaction about communication

In order to analyze the stakeholders' satisfaction with regard to communication in the virtual team, we included a question in the post-experiment Questionnaire (question 21A) which stated: *Assign a value that represents your evaluation concerning communication with the members of your team (using the following scale):*

Very bad	Bad	Acceptable	Good	Very good
0	1	2	3	4

The data from the 24 post-experiment questionnaires were analyzed by using SPSS 15.0 for Windows, applying non-parametric methods, as suggested in [41].

We analyzed the first hypothesis formulated, which concerns the use of an ontology as a communication facilitator as follows:

$\mathbf{H_{0,1}}$; Using a domain ontology does not affect stakeholders' satisfaction regarding communication during the requirements elicitation process.

We then introduced the stakeholders' answers into the SPSS system, designating this variable as *comun21A*, an ordinal variable with values in the interval of 0,1,2,3, and 4. The grouping variable, designated as *ontology*, was a nominal variable that took the values of 0 (for stakeholders that did not use the domain ontology) or 1 (for stakeholders who did). The non-parametric applicable methods used for the two independent samples were the Mann–Whitney U-test and the Wilcoxon W-text, whose results are shown as follows:

Ranks

	Ontology	*N*	Mean ranks	Rank sum
comun21A	0	12	12.96	155.50
	1	12	12.04	144.50
	Total	24		

Test statistics[b]

	comun21A
Mann–Whitney *U*	66.500
Wilcoxon W	144.500
Z	−.357
Asymp. sig. (2 tailed)	.721
Exact Sig. [2*(1-tailed sig.)]	.755[a]

[a] Not corrected for ties

[b] Grouping variable: ontology

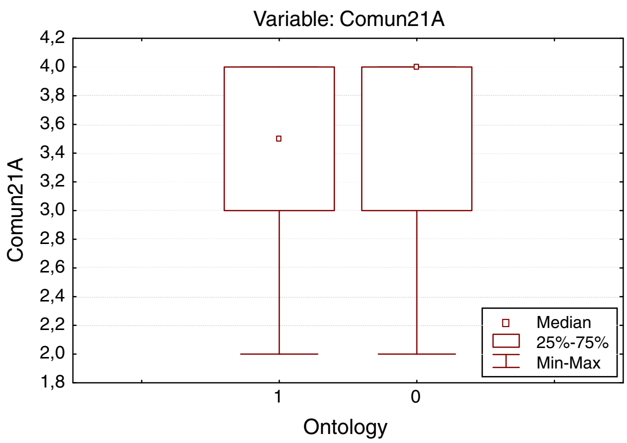


Fig. 10 Median analysis for stakeholders' satisfaction regarding communication in the team, according to the use of a domain ontology

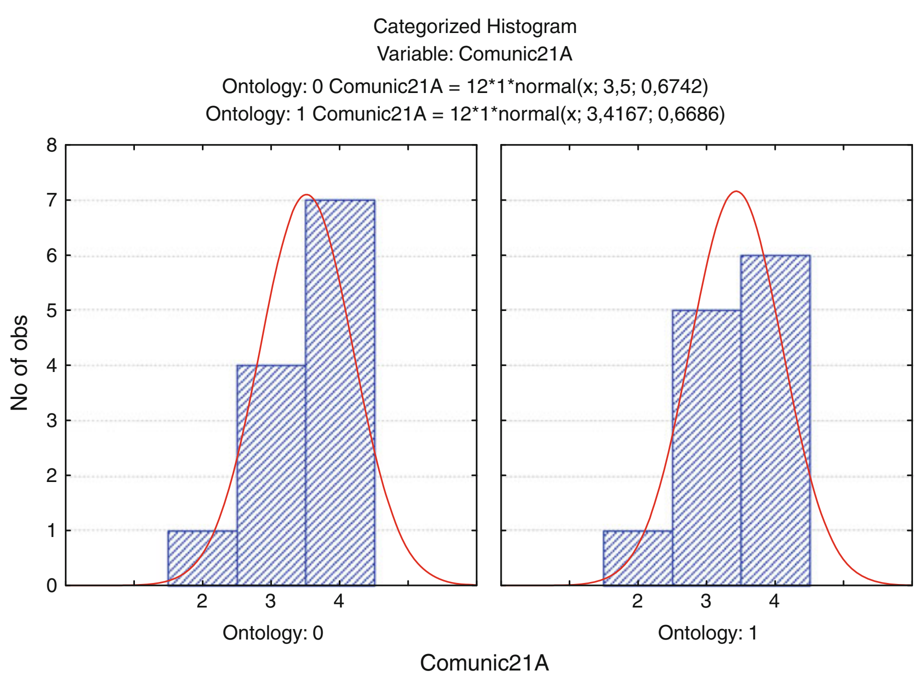
Since the exact *p*-value (0.755) is greater than the specified α level (.05), we cannot reject $H_{0,1}$. This means that using an ontology during the requirements elicitation process in a global environment does not seem to affect the stakeholders' perception of communication in the team.

When analyzing the answers concerning the median for the stakeholders' satisfaction with communication (as shown in Fig. 10), we realized that satisfaction with communication in group 0 (stakeholders that did not use the ontology) is higher than satisfaction with communication in group 1, which is contrary to our previous expectations. Upon analyzing the number of answers for each value in the ordinal scale for satisfaction (shown in Fig. 11), it is clear that the same amount of people answered 2 (*acceptable*; only one in each group) and that the difference is related to the values 3 (*good*) and 4 (*very good*).

As this result was unexpected with regard to our previous expectations, we believed it was necessary to search for other factors that might have affected the stakeholders' perception of communication. We analyzed a set of questions in the post-experiment test, specifically concerning the ontology and the stakeholders' perception of it. We realized that they generally considered the ontology to be "useful" and "very useful", with the exception of two people from the same team (G1) who ranked the ontology as "indifferent". They were also the only two people to rank communication as "acceptable" rather than "good" or "very good". In order to attempt to explain these answers, we analyzed the conversations that we had previously recorded for all the teams in the experiment. We discovered that the other three teams that had used an ontology (G3, G7, and G8) mentioned that they needed to check some words or relationships in the ontology. However, G1 never mentioned it. Although it is impossible to state whether they used the ontology or not, it would appear that G1 team's behavior was not the same as the other teams'. This difference may have affected their perception of communication during the experiment. It may also have affected the general results with regard to the stakeholders' perception of communication.

We shall now analyze the second hypothesis, which concerns the use of groupware tools selection according to stakeholders' cognitive styles as follows:

Fig. 11 Answer distribution for stakeholders' satisfaction as regarding communication in the team, according to the use of a domain ontology



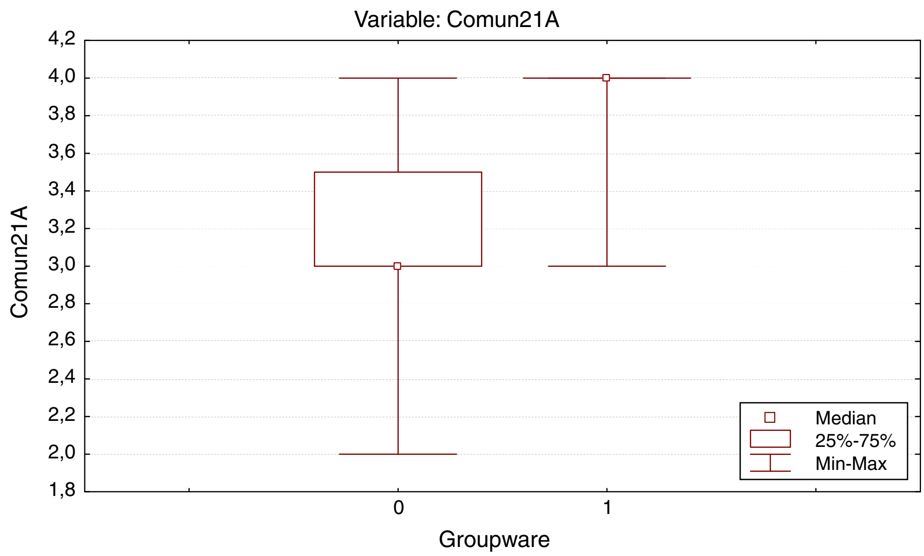


Fig. 12 Median analysis for stakeholders' satisfaction with communication in the team, according to the use of groupware regarding stakeholders' cognitive profile

$\mathbf{H_{0,2}}$ Using groupware tools according to the cognitive profile of stakeholders does not affect the stakeholders' satisfaction with regard to communication during the requirements elicitation process.

In order to analyze this hypothesis, we also used the answers from question 21A in the post-experiment Questionnaire. In this case, the grouping variable *groupware* was a nominal variable that took the values of 1 (for stakeholders that used the groupware tool according to our set of preference rules) or 0 (for stakeholders who used a different groupware tool). We also applied the non-parametric Mann–Whitney U-test and the Wilcoxon W-text methods, whose results are shown as follows:

Ranks

	Groupware	*N*	Mean ranks	Rank sum
comun21A	0	12	8.83	106.00
	1	12	16.17	194.00
	Total	24		

Test statistics[b]

	comun21A
Mann–Whitney *U*	28.000
Wilcoxon *W*	106.000
Z	−2.860
Asymp. sig. (2 tailed)	.004
Exact sig. [2*(1-tailed sig.)]	.010[a]

[a] Not corrected for ties

[b] Grouping variable: groupware

In this case, the exact *p*-value (0.010) is lower than the specified α level (.05). Therefore, we can reject $H_{0,2}$ meaning that using groupware tools, which are closer to the stakeholders' cognitive styles (according to our set of preference rules), seems to improve the stakeholders' perception of communication during the requirements elicitation process in a global environment.

Furthermore, after analyzing the answers by considering the median for stakeholders' satisfaction with communication (as shown in Fig. 12), we realized that it is much higher for those who used the groupware suggested by our set of preference rules (group 1). As Fig. 13 shows, it is obvious that the stakeholders' satisfaction in group 1 is concentrated on the values of 3 (*good*) and 4 (*very good*) and that most of the answers for group 1 are 4 (*very good*).

In conclusion, the analysis of the data collected during our experiment would appear to indicate that using groupware tools that are closer to the stakeholders' cognitive styles (according to our set of preference rules) improves the stakeholders' perception of communication during the requirements elicitation process in a global environment.

Lastly, we shall analyze the third hypothesis which considers the interaction between the use of an ontology and the groupware tools selection according to stakeholders' cognitive styles as follows:

$H_{0,3}$ There is no interaction effect between using a domain ontology and groupware tools which agree with the stakeholders' cognitive profile regarding their satisfaction with communication during the requirements elicitation process.

In this case, we also analyzed the answers to question 21A in the post-experiment Questionnaire by using the grouping variable *treatment*, which was a nominal variable that took the values of 1, 2, 3, and 4. Since the number of independent samples was higher than 2, the non-parametric applicable method used was the Kruskal–Wallis test, whose results are shown as follows:

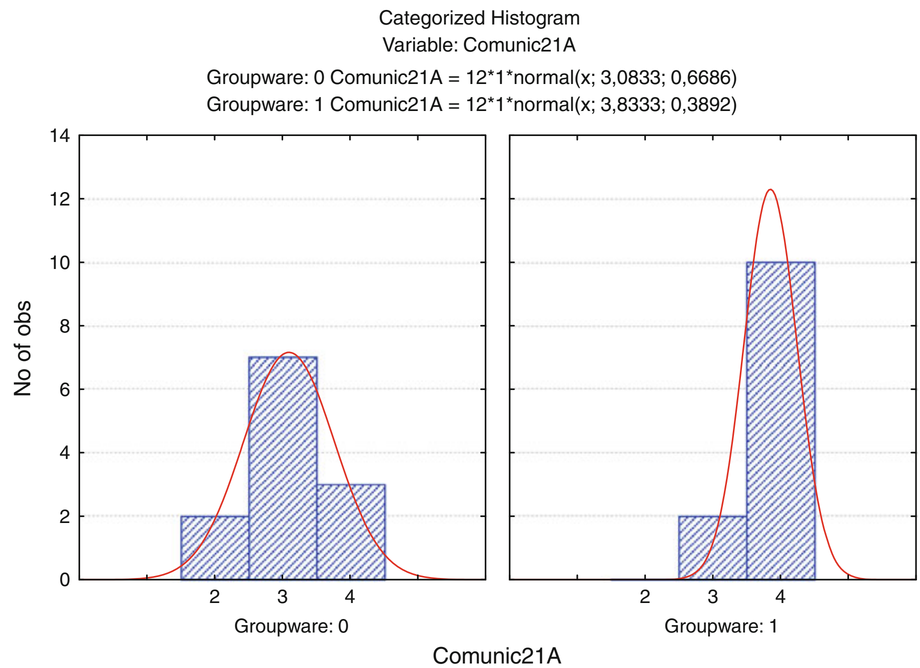


Fig. 13 Answer distribution for stakeholders' satisfaction with communication in the team, according to the use of groupware regarding stakeholders' cognitive profile

Descriptive statistics

	N	Mean	SD	Minimum	Maximum
comun21A	24	3.46	.658	2	4
Treatment	24	2.50	1.142	1	4

Ranks

	Treatment	*N*	Mean rank
comun21A	1	6	16.17
	2	6	16.17
	3	6	7.92
	4	6	9.75
	Total	24	

Test statistics[a,b]

	comun21A
Chi-square	8.433
df	3
Asymp. sig.	.038

[a] Kruskal–Wallis test

[b] Grouping variable: treatment

In this case, since the *p*-value (0.038) is also lower than the specified α level (.05), we can reject $H_{0,3.}$ This means that there is a significant difference between the stakeholders' perception of communication when using an ontology and selecting the groupware tools which are closer to the stakeholders' cognitive styles (according to our set of preference rules).

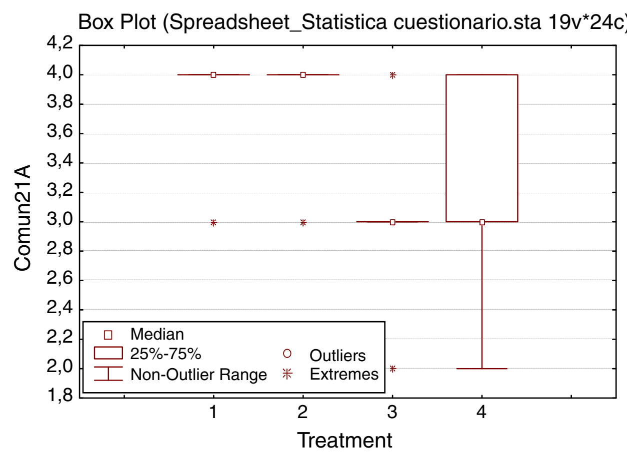


Fig. 14 Median analysis for stakeholders' satisfaction with communication in the team, according to the treatment

Furthermore, upon analyzing the answers by considering the median for stakeholders' satisfaction with communication (as shown in Fig. 14), it is clear that it is higher for subjects in treatments 1 and 2 (who used the most suitable groupware according to their cognitive profile). However, it is contrary to what was expected. The stakeholders in treatment 4 (who did not use the ontology) seemed to be more satisfied with communication than the stakeholders in treatment 3. This is confirmed in Fig. 15 where the answers for treatment 4 are a little higher in value 4 (*very good*). This experiment must be replicated in order to confirm this tendency.

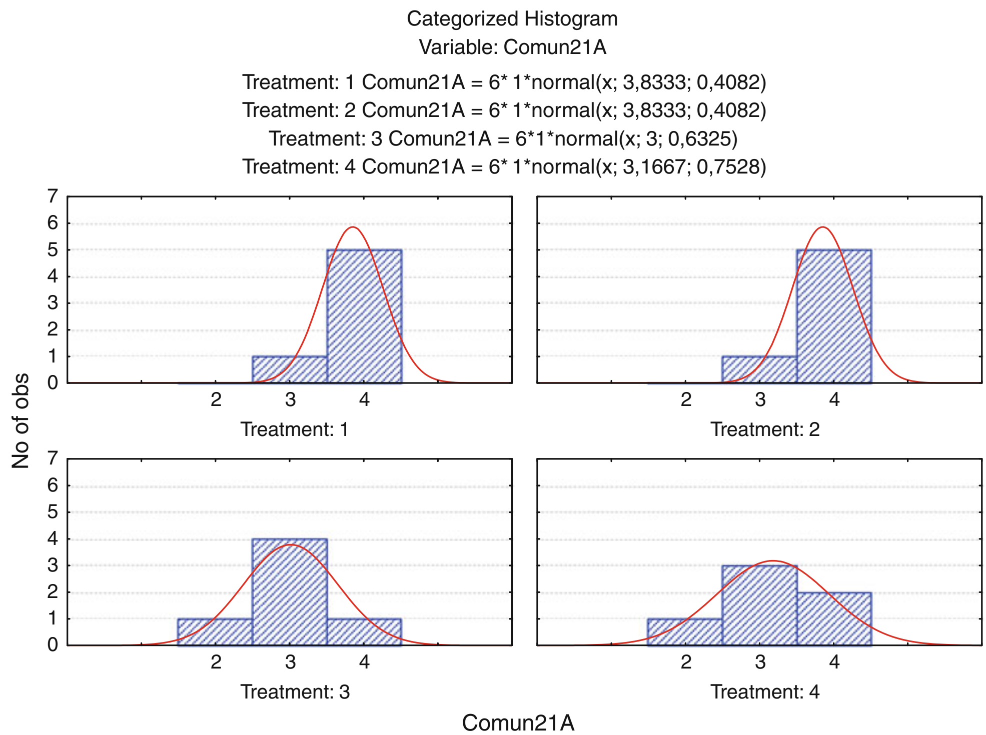


Fig. 15 Answer distribution for stakeholders' satisfaction with communication in the team, according to the treatment

4.4.2 Analyzing the software requirements specification quality

To complement the stakeholders' satisfaction with communication during the requirements elicitation process, we also focused on software requirements specification (SRS). We attempted to answer whether or not considering the stakeholders' cognitive style and providing a domain ontology would make a difference to SRS quality.

In order to evaluate this question, we asked four experts to check all the SRS obtained during the experiment and give them a score from 0 (very bad) to 10 (very good). The experts were Software Engineering teachers at the University of Castilla-La Mancha (Spain), who had not participated in the experiment and had previous experience in checking SRS and use case models. The evaluation scores for each team are shown in Table 4.

When analyzing the scores, we realized that experts 2, 3, and 4 showed a similar tendency toward all the teams. However, expert 1 had some notable differences, particularly with regard to teams G6 and G7 (as shown in Fig. 16). We, therefore, decided to analyze the results without considering the evaluation by expert 1.

We first analyzed the scores considering the use of a domain ontology as a communication facilitator. To do so, we considered two groups: Group 0 which is made up of teams G2, G3, G5, and G6 (did not use a domain ontology), and Group 1 which is made up of teams G1, G4, G7, and G8 (did use a domain ontology). Figure 17 shows the mean for the scores is quite similar in both groups. However, when analyzing the median and standard deviation (Fig. 18), we discovered that the median for Group 1, which used the ontology, is higher than the median for Group 0, which did not use it. This difference appears to indicate that SRS quality seems to improve when using a domain ontology, which agrees with our previous expectations. Furthermore, when analyzing the standard deviation, the minimum and maximum values are in closer range for Group 1, which would indicate that scores for Group 1 teams are more stable according to the experts' opinion.

We then analyzed the mean scores, considering groups according to the use of groupware regarding stakeholders' cognitive profile. This was done by defining two groups:

Table 4 Scores for each team according to expert evaluation

Team	Exp1	Exp2	Exp3	Exp4
G1	6	6	6	6
G2	3	5	7	6.5
G3	5	6	7	7
G4	6	8	8	8
G5	8	9	9	9.5
G6	9	6	7	7
G7	4	7.5	8	8
G8	4	6	7	6

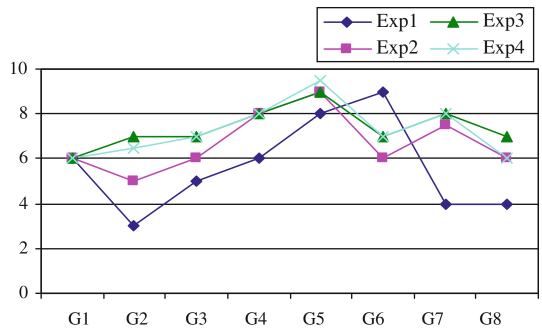


Fig. 16 Expert evaluation comparison

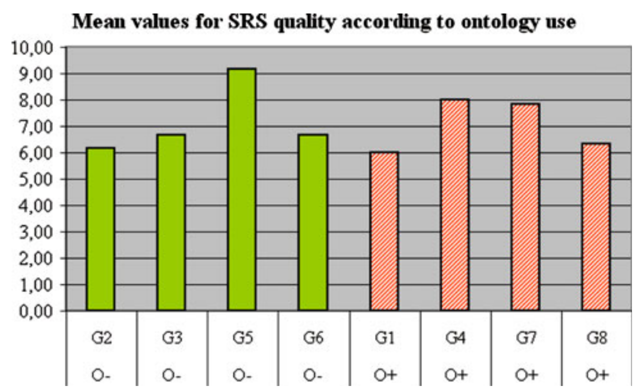


Fig. 17 Mean value for SRS quality according to the use of a domain ontology

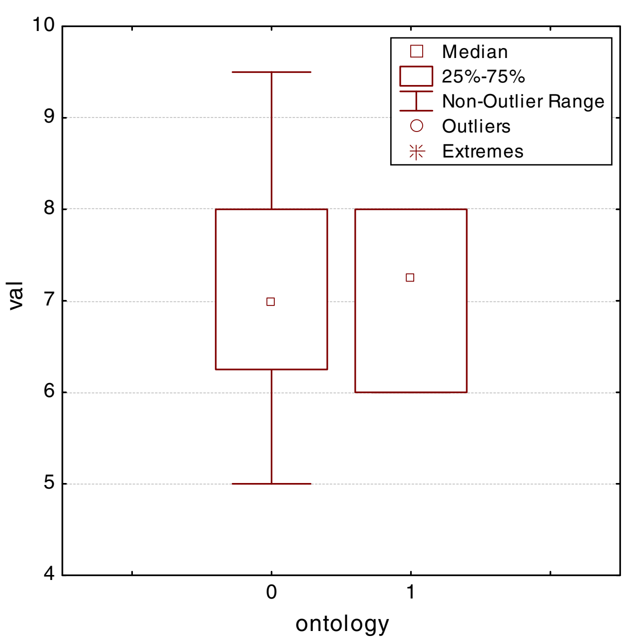


Fig. 18 Median and standard deviation analysis for SRS quality, according to the use of a domain ontology

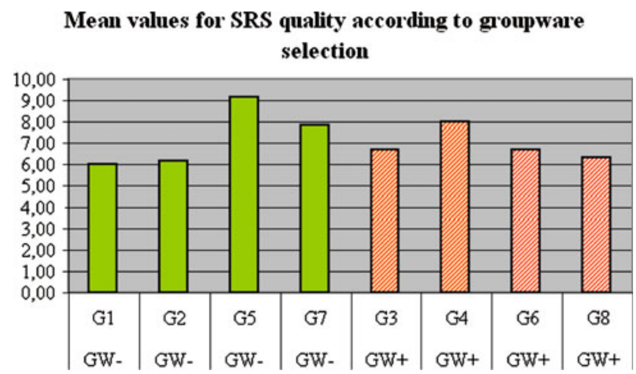


Fig. 19 Mean value for SRS quality according to the use of groupware regarding stakeholders' cognitive profile

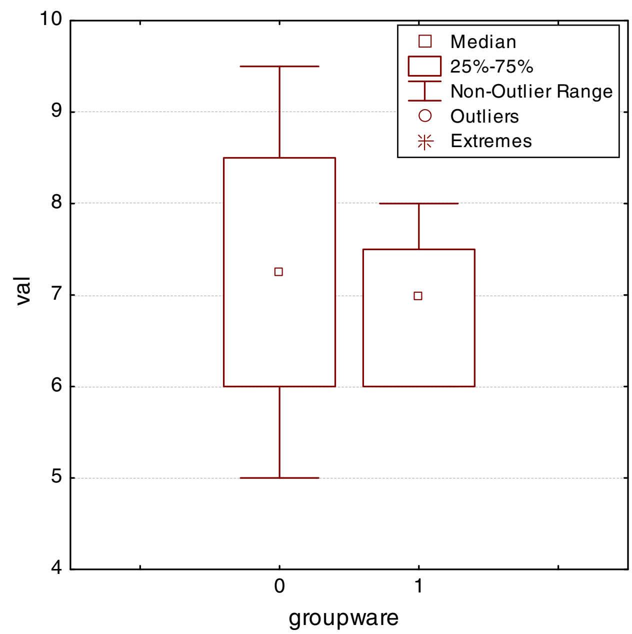


Fig. 20 Median and standard deviation analysis for SRS quality, according to the use of groupware regarding stakeholders' cognitive profile

Group 1 for teams that used a groupware tool according to our set of preference rules, and Group 0 for teams that used a groupware tool not according to our set of preference rules. After comparing both groups' scores, we noted that they were similar for both groups (Fig. 19). However, when analyzing the median and standard deviation, it will be observed that the median is higher in Group 0, which is an unexpected result according to our previous expectations (see Fig. 20).

The scores for team G5 are quite higher than the rest of the teams, which increases the mean for Group 0, even when most of the remaining scores are below the mean score. Unfortunately, we only have 8 teams, so we cannot consider G5 as an outlier, which would be possible if we

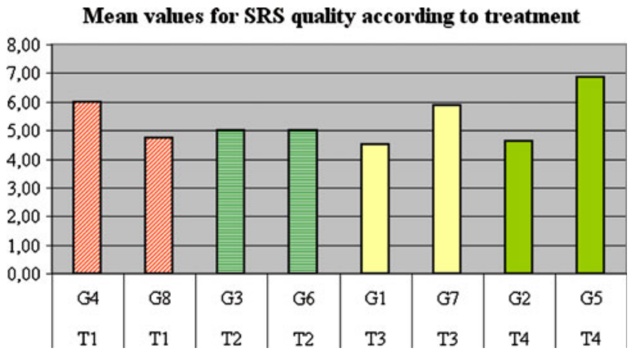


Fig. 21 Mean value for SRS quality according to the treatment

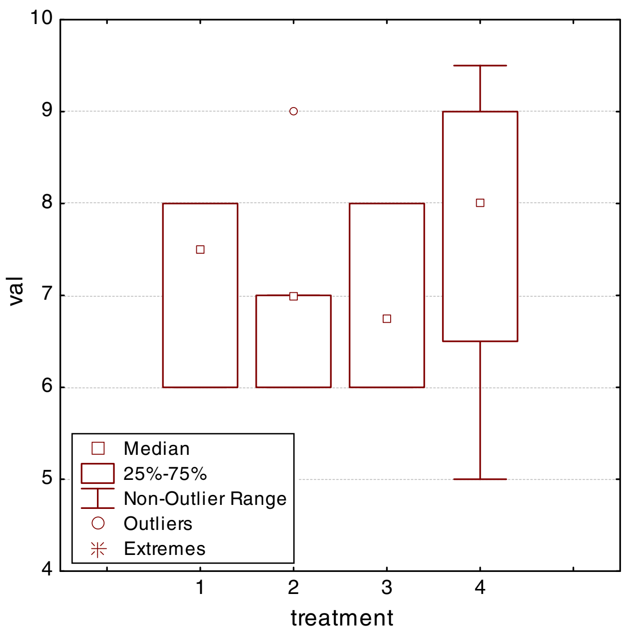


Fig. 22 Median and standard deviation analysis for SRS quality, according to treatment

had more teams. We, therefore, consider that it is necessary to replicate the experiment in order to refute such results.

Finally, we compared the scores by considering the treatment applied. Figure 21 shows that the distribution is again quite similar in each of the four treatments.

The median for treatment 4 is the highest (Fig. 22), but as we already noted, this is due to the fact that the G5 score is the highest and, therefore, the standard deviation is also the highest for treatment 4.

Furthermore, upon analyzing the graph for treatments 1, 2, and 3, it is noted that the deviation does not have such a wide range. In addition, the median for treatment 1 is higher than the median for treatment 2, and the median for treatment 2 is also higher than the median for treatment 3. Treatment 1 used the groupware tool according to our set of preference rules and also used a domain ontology. Treatment 2 used the groupware tool according to our set of preference rules but did not use a domain ontology. Treatment 3 did not use a groupware tool according to our set of preference rules and did use a domain ontology. The difference between the medians in each treatment would appear to indicate that groupware selection might also have an effect on SRS quality. The experiment should, however, be replicated in order to validate these results.

5 Discussion

The previous sections show the results of a controlled experiment for a global requirements elicitation process. From the analysis of the post-experiment questionnaire given to the stakeholders, we concluded that using a domain ontology does not seem to improve stakeholders' satisfaction with regard to communication. Although the results do not coincide with our previous expectations, we believe that it is important to discuss what the possible causes of such results may be. For instance, the language difference between the stakeholders in our experiments should be noted, since both countries (Spain and Argentina) have different pronunciation and vocabulary, and many ambiguities may occur. Both countries share a mother language (Spanish) and, therefore, the language difference is not so great. We conclude that the experiment should be repeated in a scenario with a higher degree of difference between the stakeholders' language and culture, in order to verify if the usage of a domain ontology improves stakeholders' satisfaction with communication.

On the contrary, when the stakeholders' satisfaction with regard to communication was analyzed by considering the groupware tools they used (which were selected according to the stakeholders' cognitive characteristics), the results corresponded with our previous expectations. They showed that the stakeholders seemed to be more satisfied when the groupware tools were selected by means of the set of preference rules, defined by considering stakeholders cognitive characteristics. The statistical analysis confirms this.

In order to validate the results of our experiment, we believe that it is fundamental to prove: i) that the differences between the treatments are significant; ii) the quality of the requirements specifications is obtained. In order to avoid any subjectivity that may have occurred if the specifications were reviewed by the subjects who carried out the experiment, we asked four software engineering professors at the University of Castilla-La Mancha to evaluate the requirements specifications written during the experiment. When analyzing SRS quality according to the expert evaluations, the results confirmed our expectations and showed that SRS from teams that used a domain ontology as a communication facilitator seemed to obtain a higher score than those that did not use it.

6 Conclusion

Business globalization has led organizations to adopt a distributed structure for software development, which lies beyond the limits of a single country. This is called global software development or GSD. It means that software development projects are affected by many factors that complicate communication. Requirements elicitation and development processes, therefore, need to be rethought to consider the main difficulties they have to confront.

We have proposed a framework for requirements elicitation processes in global projects, focusing on problem prediction and different strategies to avoid or decrease their impact on GSD project performance. The suggested strategies are centered both on the characteristics of the environment in which the requirements elicitation process takes place and on the stakeholders' cognitive characteristics for the technology selection.

To evaluate part of our methodology, we have performed a controlled experiment whose preliminary results are shown here. The results show that the use of a domain ontology does not seem to improve stakeholders' satisfaction with regard to communication during the requirements elicitation process. On the contrary, according to the statistical analysis, the selection process we proposed for a groupware tool by considering stakeholders' cognitive characteristics seems to affect stakeholders' satisfaction with regard to communication in a positive way. Furthermore, when analyzing the quality of the written software requirements specifications, we found that the use of a domain ontology as a communication facilitator seems to affect SRS quality in a positive way. In the future, we plan to replicate the experiment in other academic environments before applying it to an industrial scenario. However, since it is not easy to synchronize students from different universities and countries, this replication will not be carried out in the short term. Nevertheless, we are currently working on its preparation and seeking universities that are willing to collaborate with us.

Acknowledgments This work has been funded by the PEGASO/MAGO project (Ministerio de Ciencia e Innovación MICINN and Fondos FEDER, TIN2009-13718-C02-01). It is also supported by MEVALHE (HITO-09-126) and ENGLOBAS (PII2I09-0147-8235) projects, funded by Consejería de Educación y Ciencia (Junta de Comunidades de Castilla-La Mancha), and co-funded by Fondos FEDER, as well as the MELISA project (PAC08-0142-3315), Junta de Comunidades de Castilla-La Mancha, Consejería de Educación y Ciencia in Spain and also by the 04/E072 project from Universidad Nacional del Comahue, in Argentina.

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