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A COGNITIVE-BASED APPROACH TO IMPROVE DISTRIBUTED REQUIREMENTS ELICITATION PROCESSES

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Abstract

Technology used by virtual teams during a distributed requirement elicitation process is usually selected according to predetermined business politics, personal criteria of managers, etc. However, when technology is not appropriate for all members of the team, it is possible that some stakeholders would not feel completely comfortable, and hence influence their participation negatively. In order to mitigate these effects during a distributed requirements elicitation process, we propose a model based on psychology theories to identify suitable elicitation techniques according to cognitive aspects of most stakeholders in the group.

1. Introduction

Global software development is becoming a common practice these days because it allows organizations counting with skilled resources at lower cost [10] but, as a result, stakeholders in such scenarios must deal with a number of problems that are currently a matter of study and discussion. For example, problems during traditional requirement elicitation processes have been detected and analyzed by many authors [5, 15] and a number of strategies have been settled; but when participants are distributed, distance affects their possibilities of communication, coordination and control, and has consequences along all the software development process [3], specially during requirements elicitation, which is critically based on communication between stakeholders [18].

To minimize these problems we propose to use concepts from CSCW (Computer-Supported Cooperative Work) and Cognitive Informatics.

On the one hand the CSCW studies human behavior when working in groups, as well as the technical support they need to work in a more productive way. On the other hand Cognitive Informatics is a profound interdisciplinary research area that combines cognitive science and informatics in a bi-directional way: (1) using computing techniques to investigate cognitive science problems like memory, learning, and thinking; and (2) using cognitive theories to investigate informatics, computing, and software engineering problems [19]. Related to this second point of view, our work applies concepts from cognitive psychology to enhance interpersonal communication during a distributed requirement elicitation process. Particularly, we are interested in some techniques called Learning Style Models (LSM), which classify people according to the way they perceive and process information [6].

Having this in mind, in the following two sections we present some notions about the selection process of groupware tools and requirement elicitation techniques. In section 4 we introduce concepts from cognitive informatics and learning style models and present the Felder-Silverman Model. Following, we bring in a model to support stakeholders' personal preferences in geographically distributed processes, and propose a selector function for requirements elicitation techniques according to the cognitive aspects of most stakeholders in a group. In the last sections we present related works and address conclusions and future work.

2. Groupware Tools

Groupware is defined as software that enables communication between cooperating people who work on a common task. Since it refers to different communication technologies, from simple plain-text chat to advanced videoconferencing; to avoid ambiguities we refer to every simple piece of communication technology as a groupware tool, and to the systems that combine them as groupware packages [9].

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The most common groupware tools used during multi-site developments are [4, 14]:

- E-mails
- Newsgroups and mailing lists
- Electronic discussion or Forums
- Electronic notice or Bulletin boards
- Asynchronous Shared Whiteboards
- Document sharing
- Synchronous Shared Whiteboards
- Chat
- Instant Messaging
- Videoconferencing

At a first glance, groupware tools can be divided into *synchronous* and *asynchronous*; depending on whether the users have to work at the same time or not [13]. Synchronous tools are, for instance, chat and instant messaging, while e-mails and forums are examples of asynchronous tools.

A second classification of groupware tools can be made according to the way in which they show the information. Some of them are based primarily on images, figures, and diagrams (shared whiteboards, videoconferencing), while others do it by predominantly using words (chat, instant messaging, e-mails, newsgroups, mailing lists, forums).

Distributed teams usually choose a combination of groupware tools according to their possibilities. They can choose between using a groupware package (that offers a combination of tools) and using individual tools in an ad-hoc way. Respect to using synchronous or asynchronous tools in group work, some authors note that both types of communication are important [4], while others reinforce the idea that using only synchronous communication is better [14]. According to the first approach, asynchronous collaboration allows team members to construct requirements individually and contribute to the collective activity of the group for a later discussion, while real time collaboration gives the stakeholders the chance of getting instant feedback. However, according to cognitive aspects of personality, we think that people would have preferences for one or the other, in the same way that some people would prefer working with tools based on visual or verbal characteristics.

3. The Elicitation Technique Selection Process

Requirement elicitation techniques are methods that analysts use to capture and understand the needs of clients and end-users in order to build systems that fit their expectations [18].

There are some requirement elicitation techniques that are commonly used in distributed environments, such as question and answer methods, interviews, brainstorming, use cases, storyboards, prototyping, and questionnaires [14]. But, why analysts decide using one technique or another? According to [11] there are four main reasons:

- It is the only one that analysts know,
- It is their favorite one, so they use it for all situations,
- They follow a methodology that suggests using that technique,
- They think (intuitively) that the technique would be the most effective in that situation.

Even when these reasons are understandable, it is a fact that a technique cannot be appropriate for any situation, and also that the techniques employed during the requirement elicitation process influence on the quality of the requirements that are obtained. So, by improving how techniques are selected, it is possible to improve the success of the products [11]. With such an idea, in [12] it has been presented a general model of the elicitation process, which is shown in figure 1.

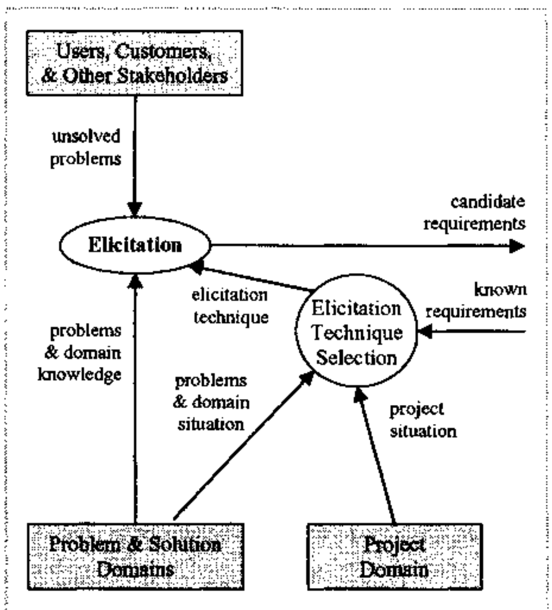

Figure 1: Elicitation activities model

The model, proposed by Hickey and Davis, is a generalization for all requirement elicitation methodologies and techniques, so that each iteration *i* of the elicitation process is defined as:

$$elicit_i(R_i, S_i, t_i) \rightarrow R_{i+1}, S_{i+1}$$

where t_i is the elicitation technique that is applied in step i when R_i is the current state of knowledge about requirements and S_i is the current situation. After applying t_i, new state of knowledge R_{i+1} and a new current situation exist.

Then, the elicitation technique selection process, is modeled as a selector function σ:

$$\sigma(R_i, S_i, \chi(T)) \rightarrow \{t \in T \,/\, t \text{ is applicable in situation } S_i \text{ when the current state of requirements is } R_i\}$$

The selector function identifies the best possible techniques given a current state of knowledge and a particular situation.

There is also a personal selector function π:

$$\pi(\{t\}, P) \rightarrow t_i \in \{t\}$$

that analyze personal preferences of analysts.

That means, given a particular situation and a particular knowledge state about requirements, the selector function will suggest a set of best techniques {t}. Then, the selector π will look for an intersection between the techniques suggested and the personal preferences (P) of the analyst.

Following we will propose a cognitive approach to define the π selector function, based not just on the analyst personal preferences but on preferences of all stakeholders who participate in the requirement elicitation process.

4. Cognitive Informatics

Cognitive informatics definition says that it is "an extension of contemporary informatics into the study of the brain and its information processing mechanisms" [22]. Then, it is related to activities of information processing in the brain such as information acquisition, representation, memory, retrieval, generation, and communication [20].

Many research areas in computer sciences contribute to cognitive sciences, like artificial intelligence, knowledge management, neural networks, etc. In software engineering there are also processes that can be related to cognitive informatics, especially those that concern software complexity and program comprehension processes [22].

There are some basic characteristics that determine the complexity of software development from the point of view of cognitive informatics that have been presented in [21]. The most important ones, which have some relation with the requirement elicitation process, are the difficulty of establishing and stabilizing requirements; the necessity of varying domain knowledge; the dependability of interactions between software, hardware and human beings.

Cognitive psychology studies the thinking mind and the mental processes concerning the way people attend and gain information, and how these information processing mechanisms affect human behavior [22]. Part of cognitive psychology are cognitive styles, which are based on Jung's theory of psychological types published in 1921, and classifiy people preferences about perception, judgment and processing of information [17]. This classification can be used to analyze and understand differences in human behavior and, based on that theories, different instruments have been designed to measure human characteristics and explain their differences.

Similarly to cognitive styles, learning style models (LSM) classify people according to a set of behavioral characteristics, which are used to improve the way people learn a given task [7]. There are two different steps during a learning process: (1) in the first step (called *reception*), people receive external information through their senses, and also internal information which emerges from introspection. Once information is perceived, people select part of it to be processed, and ignore the rest. (2) The second stage, called *processing*, involves memorization or reasoning (inductive or deductive), reflection or action, and introspection or interaction with others [6, 7].

Even when LSM have been discussed in the context of analyzing relationships between instructors and students, we can take advantage of this kind of models and adapt them to improve virtual teams, considering an analogy between stakeholders and roles in LSM. For example, in [11] it is mentioned that elicitation is about *"learning the needs of the users"*. From our point of view, also users and clients learn from analysts and developers (for instance, they learn how to use a software prototype or a new vocabulary) so, as Figure 2 shows, we consider that during the elicitation process everybody "learns" from others, and stakeholders play the role of student or instructor alternatively, depending on the moment or the task they are carrying out [16].

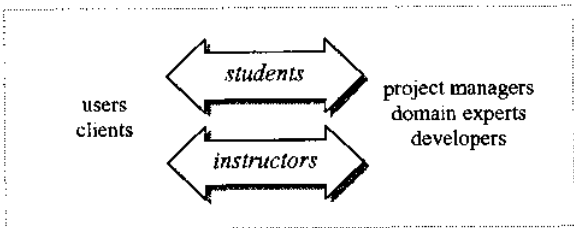

Figure 2: Student/instructor and stakeholders roles analogy

After analyzing five different LSM in [16], we found out that the model proposed by Felder-Silverman [7] was wide enough to build a complete reference framework choosing it as a foundation. This LSM classifies people into four categories, each of them further decomposed into two subcategories, as follows:

- Sensing / Intuitive
- Visual / Verbal
- Active / Reflective
- Sequential / Global

Characteristics of each subcategory are:

- *Sensing people* prefer learning facts. They like solving problems by well-established methods and dislike complications and surprises. Sensors tend to be patient with details and good at memorizing facts and doing hands-on (laboratory) work.
- *Intuitive people* often prefer discovering possibilities and relationships. They like innovation and dislike repetition. They tend to work faster and to be more innovative than sensors. Intuitors do not like work that involves a lot of memorization and routine calculations.
- *Visual people* remember best what they see (such as pictures, diagrams, flow charts, time lines, films, and demonstrations). They prefer visually presented information.
- *Verbal people* get more out of words, and written and spoken explanations. They prefer verbally presented information.
- *Active people* tend to retain and understand information by doing something active with it (discussing or applying it or explaining it to others). "Let's try it out and see how it works" is an Active 's phrase.
- *Reflective people* prefer to think about information quietly first. "Let's think it through first" is the Reflective's response.
- *Sequential people* tend to gain understanding in linear steps, with each step following logically from the previous one. They tend to follow logical stepwise paths in finding solutions. They may not fully understand the material but they can nevertheless do something with it (like solve homework problems or pass a test) since the pieces are logically connected.
- *Global people* tend to work in large jumps, absorbing material almost randomly without seeing connections, and then suddenly "getting it". They may be able to solve complex problems quickly or put things together in novel ways once they have grasped the big picture, but they may have difficulty explaining how they did it.

People obtain a classification in the Felder-Silverman model by filling a multiple-choice test that gives them a rank for each subcategory. According to the test proposed by Barbara Soloman and Richard Felder, (available at http://www.engr.ncsu.edu/learningstyles/ilsweb.html), people may fit into one category or the other depending on the circumstances, being for instance, "sometimes" active and "sometimes" reflective, so preference for each category is measured as *strong, moderate*, or *mild*. Only when there is a strong preference, a person can be classified as a member of a certain group.

5. A Cognitive-Based Approach to Select Groupware Tools and Elicitation Techniques

In order to make the problem we face more concrete, we have defined a model, depicted in Figure 3, whose key concepts are briefly described in Table 1. They represent the main elements we need to reason about the process of selecting groupware tools and elicitation techniques in a distributed environment. Of course, several instantiations of this model might be possible, by extending it for each particular case.

Relationships among the elements are explained below. For further details, we refer the reader to [2].

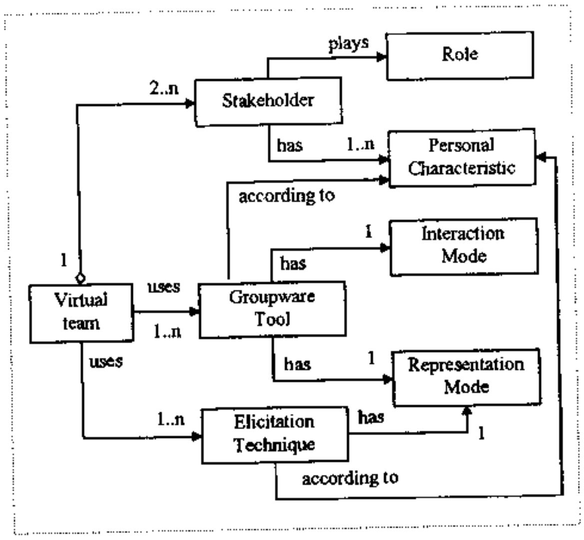

Figure 3: A cognitive-based model to support personal preferences in distributed elicitation

Table 1: Primary concepts of our model

Concept	Description
Virtual Team	A group of people who work together on a project. Their main characteristic is that people are distributed over many sites, and they use information technology to communicate and coordinate efforts.
Stakeholder	Typical stakeholders are users (those who will operate the system), customers (those who have commissioned the system), system developers, etc. [18]
Groupware Tools	Software to enable communication (email, chat, videoconferencing, etc).
Elicitation Techniques	Elicitation is fundamentally a human activity where communication plays a transcendental role [18]. Since face-to-face interaction is not possible, techniques have to be adapted to be used in combination with groupware.
Representation Mode	The way groupware tools and elicitation techniques present the information. For instance, it can be based on images or based on words.
Interaction Mode	The way people interact with others depends on the characteristics of the groupware tools. For instance, interaction can be synchronous or asynchronous.
Personal Characteristics	Personal characteristics and preferences of stakeholders. The result of the classification of Felder-Soloman test is information about their preferences when perceiving and processing information.
Role	It represents information about the role that stakeholders play during the requirement elicitation process. Examples of *roles* are end-user, client, analyst, project manager, etc.

Relationships between concepts on Table 1 can be expressed generally as:

- A **Virtual Team** represents a group of **Stakeholders** that work cooperatively on a common task (which in our case is the Elicitation Process).
- **Stakeholders** play **Roles** that imply rights and responsibilities that have to do with their job.
- **Stakeholders** communicate with each other using some **Groupware Tools** and build different models of a problem using a set of **Elicitation Techniques**.
- **Groupware Tools**, as well as **Elicitation Techniques**, are supposed to be chosen according to the stakeholders' **Personal Characteristics**, in order to make them feel comfortable and improve their performance.
- Each **Groupware Tool** has a **Representation Mode** (verbal or visual) and an **Interaction Mode** (synchronous or asynchronous), which are important in deciding the suitability for a stakeholder's personal preferences.
- In a similar way, each **Elicitation Technique** has a predominant **Representation Mode** (verbal, visual, or a possible good combination of both) that we will take into account to suggest their use or non-use.

5.1 Applying learning styles to support personal preferences in distributed elicitation

In order to support personal preferences about groupware tools, in [1] we have presented a model based on fuzzy logic and fuzzy sets, which aims at obtaining rules from a set of representative examples that tell us which preferences stakeholders show in their daily use of groupware tools, according to their classification in the F-S model.

The model takes four inputs (X_1, X_2, X_3, X_4), which are the ranks for each category of the F-S Model, and an output variable (Y) that is the preference for one of a given set of groupware tools.

As a part of a pilot experiment, we have chosen a set of people that use email and instant messaging in their daily work and asked them to fill the Felder and Soloman test and choose the groupware tool they feel more comfortable with during a collaborative task.

Using a machine learning algorithm we could obtain rules such as *Ro: if X_1 is VAc and X_3 is VVi then Y is IM;* which is interpreted as: *"If a user has a strong preference for the Active subcategory and a strong preference for the Visual subcategory, the tool that this person would prefer is Instant Messaging"*, but as the quantity of examples was too small we have not obtained definitive results yet.

In a similar way we propose to find a suitable set of elicitation techniques according to the preferences for each category of the F-S model.

The input variables will be the four categories that correspond to the F-S model as follows:

I = {Sensing-Intuitive, Visual-Verbal, Active-Reflective, Sequential-Global}

We have defined a domain (DDV) for each input variable using the adverbs (and their correspondent abbreviations): Very (*V*), Moderate (*M*) and Slight (*S*).

These adverbs correspond to *strong*, *moderate* and *mild*, respectively, in the F-S model, but we have changed their names to avoid confusion with respect to the use of the first letter.

For instance, the definition domain for the category Reflective-Active, which is graphically shown in Figure 4, would be: Very reflective (VRe), Moderately reflective (MRe), Slightly reflective (SRe), Slightly active (SAc), Moderately active (MAc), Very active (VAc).

For convenience, we show the results of the F-S test with a negative sign for the categories that appear firstly on the presentation of the characteristics (sensing, visual, active and sequential) and with a positive sign for the later (intuitive, verbal, reflective, global).

$$DDV_{Active\_Reflective} = \{VAc, MAc, SAc, SRe, MRe, VRe\}$$

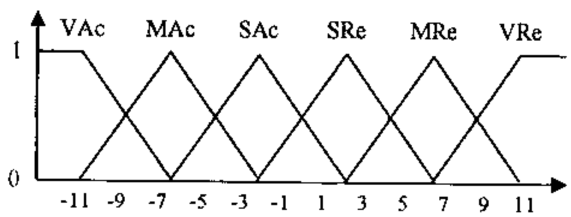

Figure 4: Definition domain of the variable Active-Reflective

The same definition domain and functions have been used for the other three categories: Visual-Verbal, Sensing-Intuitive and Sequential-Global.

The output variable will be the elicitation technique a person would prefer.

$$O = \{Elicitation\ Technique\}$$

In that case the definition domain of the output would be:

$$DDV_{Elicitation\_Technique} = \{interview, prototype, brainstorming, \ldots\}$$

The selection about which groupware tool users feel more comfortable using seems quite straightforward: people use email, instant messaging, and chat quite normally in their life and even if they have never used videoconferencing or shared whiteboards they can easily imagine how they would feel about them, so a simple question is enough to get the output variable. However, selecting a requirement elicitation technique does not seem so easy. Analysts usually know a couple of techniques and users and clients usually do not know any. In order to get a ranking of preferences we need to develop an experiment so as, after some training in a set of requirement elicitation techniques, it would be possible to ask stakeholders about their experience with each one.

Of course, particular notations should be used according to background of analysts and users – i.e. knowledge about diagrams may widely differ among stakeholders.

Then, given a set of examples $\theta = \{e_1, e_2, \ldots, e_m\}$, each example would have the form $e_i = \{(x_{i1}, x_{i2}, x_{i3}, x_{i4}), y_j\}$, where :

and $x_{i1} \in DDV_{Sensing\text{-}Intuitive}$
and $x_{i2} \in DDV_{Visual\text{-}Verbal}$
and $x_{i3} \in DDV_{Active\text{-}Reflective}$
and $x_{i4} \in DDV_{Sequential\text{-}Global}$
and $y_j \in DDV_{Elicitation\_Technique}$

For instance {(SIn, VVi, VAc, VSq), prototype} would be a possible instantiation.

Using the same machine learning algorithm, that represents a sample of stakeholders, we aim to obtain rules such as:

Ro: if X1 is VAc then Y is Prototype

which is interpreted as: *"If a user has a strong preference for the Active subcategory, the elicitation technique that this person would prefer is Prototype"*.

Once we have obtained a set of rules like the previous one and the personal preferences for each person that will work in a virtual team, we propose choosing the best elicitation technique (equivalent to the π personal selector function) analyzing the preferences of each stakeholder and choosing the one that have more adherents We are assuming here that the selected option is suitable for the project itself too, that means {t} (for example, by analyzing relationships between elicitation and particular life cycles). In that way we propose an extension of the π function, called π^*, which is defined as follows:

$$\pi^* (\{t\}, \{PS_1\}, \{PS_2\}, \ldots, \{PS_n\}) \rightarrow t_i \in \{t\}$$

where PS_i represents a set of techniques that fit the *i-th* stakeholder's preferences, {t} is the set of appropriate requirement elicitation techniques obtained by calculating the function σ, and t_i is a technique that belongs to {t} and appears in most of the PS_i.

With the aim of automating the selection processes, in [2] we have presented a prototype tool based on the model previously explained. Its mechanism can be simply explained as follows:

- Stakeholders are asked to fill in a multiple-choice test so as to know their preferences. This information is maintained throughout the cooperative process.
- Once a group of stakeholders is defined, the tool analyses their personal preferences using the sets of rules previously generated.
- As a result, the tool returns the most suitable groupware tools and elicitation techniques for that group of people.

5.2 Case study

To illustrate how our function selector π^* works, let us consider the results of the Felder-Soloman test applied to three stakeholders:

$$S_1 = (MAc, SSe, MVe, SGl)$$

$$S_2 = (SRe, VSe, VVi, VSq)$$

$$S_3 = (SRe, SSe, SVe, SGl).$$

Assuming that S_1 is the analyst, S_2 and S_3 are users, and {t} is the set of the appropriate requirement elicitation techniques obtained by calculating the function σ, there are two possible scenarios:

<u>Case 1</u>: *Application of personal function selector* π
In this case, as it is presented in Figure 5, only the personal preferences of the analyst (S_1) would be taken into account. That situation would make stakeholders S1 and S_2 not feeling comfortable and therefore not committed enough with the collaborative task.

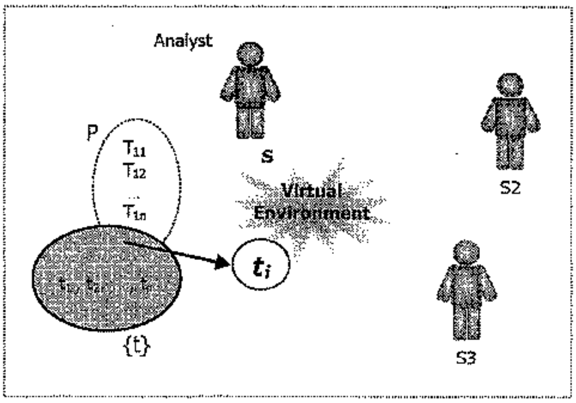

Figure 5: Application of selector function π

<u>Case 2</u>: *Application of personal function selector* π^*
In this case, we suppose that, by the application of the rules we have previously determined according to personal preferences, we obtain a set of "appropriate" elicitation techniques for each stakeholder, called E_1, E_2, and E_3. Then the most appropriate technique t_i would be chosen from those that are repeated in most of the E_i sets. That would give the chance of using elicitation techniques that could make most people in the group (instead of just the analyst) feel comfortable, as it is shown in Figure 6.

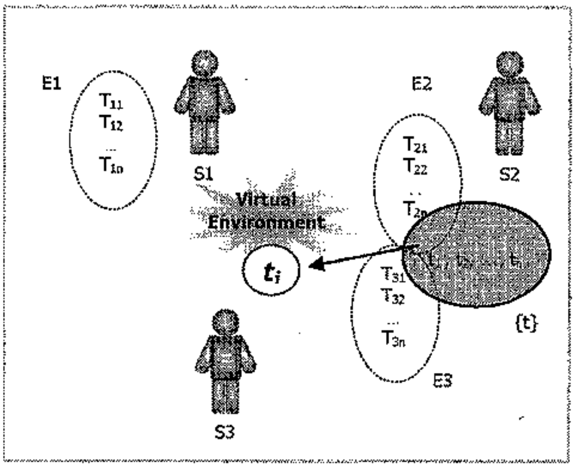

Figure 6: Application of selector function π^*

6. Related works

As related works on the use of psychological techniques to solve problems in Software Engineering we can cite the use of the psychotherapeutic approach known as Neuro-Linguistic Programming (NLP), by the Sophist group, in requirements elicitation. They have developed a set of rules for analyzing requirements linguistically, which can be applied within interviews, when writing requirements, and for checking written requirements. The main aspects these rules can help avoid are the under-specified process words (deletions); the use of universal and usually problematic quantors all, each, never (generalizations); and finally the nominalizations (distortions) [8].

Another work in this direction is the use of cognitive styles as a mechanism for software inspection team construction [17]. This work describes an experiment that aims at proving that heterogeneous software inspection teams have better performance than homogeneous ones. The heterogeneity concept is analyzed according to the cognitive style of participants. During the experiment, 33 software inspectors were asked to analyze some code. Then they were classified using the MBTI method, an instrument similar to Felder and Silverman Model. Later, the quantity of detected errors and their types were compared individually and arranged into groups of different sizes and homogeneity/heterogeneity conditions (homogeneity = same cognitive style vs. heterogeneity = many different cognitive styles). Authors conclude that heterogeneous groups worked better than homogeneous ones.

Even when they also used the concept of cognitive styles to classify people, our approach is not the same. As we have explained previously, we aim at choosing the best strategies to improve communication for a given group of people, which means we do not try to set which people seem to be more suitable to work together, but to give the best solution for an already chosen group of people.

7. Conclusions

Virtual teams became a common way of developing software. To save costs, many organizations have adopted a distributed structure where members communicate through groupware tools.

The selection of appropriate technology and elicitation techniques in such environments is a subject of research, since when stakeholders feel comfortable with the technology and methodologies they use, information gathered during elicitation is expected to be more accurate. Stakeholders might feel more comfortable expressing their ideas and describing facts when using a tool closer to the way they perceive and reason about the world.

In this paper, we have proposed a model to relate stakeholders' learning preferences to requirement elicitation techniques which would be more suitable according to those preferences. To do so we focused on instruments from the field of psychology called Learning Style Models.

As an extension of this work we are analyzing the possibility of weighting stakeholder's preferences to indicate their relative importance. For instance, if some stakeholders' preferences are strong and the rest of the stakeholders are moderate or mild, the preferences that should be primarily considered are those of the first group of stakeholders. Then, different weights might differentiate the type of preferences we have, but also might be used to prioritize them according to different stakeholder's roles.

Future work is needed to solve conflicts when stakeholders' preferences seem to be opposite, and we are aware of the necessity of empirical results to validate our approach.

Acknowledgements

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