COGNITIVE INFLUENCES IN PRIORITIZING SOFTWARE REQUIREMENTS

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Abstract: In software development, the elicitation process and particularly the acquisition of software requirements are critical success factors. Elicitation is about learning the needs of users, and communicating those needs to system builders. Prioritizing requirements includes negotiation as an important issue, which becomes extremely difficult, as clients often do not know exactly what they need. To overcome this situation, aiming at improving stakeholder's negotiation, we propose reducing the gap of misunderstanding between them by the use of cognitive science. Particularly, we suggest using cognitive styles to characterize people from the way their process information. In this paper, we introduce a case study showing that cognitive profiles may affect requirement understanding and prioritization. Our controlled experiment shows that considering cognitive profiles when performing elicitation might increase stakeholders' satisfaction and prioritization accuracy.

1 INTRODUCTION

In spite of the highly technical and formal nature of software, creating it remains a very people-intensive activity. Regardless of our cultural and educational backgrounds, most of us have at least an intuitive understanding that some people are more scientific, logical, and orderly in their thought processes whereas others are more artistic, intuitive, and spontaneous. The system analyst (broadly defined) also has a dual task: he or she must be a communicator who can understand and respond to what is found in observing and talking with those who are commissioning a new system or who will be the end-users of it; above all the system analyst must be able to *perceive correctly what is needed*. In this context, elicitation is about learning the needs of users, and communicating those needs to system builders (Hickey and Davis, 2003). And although the literature suggests the elicitation as a simple process, experience in real projects turns it in rather complicated as stakeholders have different viewpoints. As understanding involves aspects of human processing mechanisms that are analyzed by the cognitive sciences, we decided to look for references into the Cognitive Informatics (CI), an interdisciplinary research area that applies concepts from psychology and other cognitive sciences to improve processes in engineering disciplines like software engineering (Wang, 2002).

Wang defines CI as "a branch of information and computer science that studies computing by cognitive methodologies and studies cognitive science by informatics and computing theories". CI analyses how natural intelligence processes information, using many sciences and engineering disciplines in this work. CI can be studied from both artificial intelligence and software engineering viewpoints. Artificial intelligence studies the mechanisms of natural intelligence and the architecture of the brain often ignoring psychological aspects of intelligence. Software engineering (Chiew and Wang, 2003) is interested in explaining the mechanisms and processes of memory learning and reasoning. We focus on CI as a software engineering area by considering stakeholders' characteristics, based on cognitive psychology. From this starting point, we have defined design and cognitive aspects as main features to characterize different approaches of elicitation prioritisation, aiming at identifying possible improvements to the elicitation process (Martínez Carod and Cechich, 2007). As related work on the cognitive style direction, we have already proposed a selection function for requirements elicitation techniques according to

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cognitive aspects of most stakeholders in a distributed group (Aranda et al., 2005).

After analyzing varied psychological issues, we set our interest in using some techniques called Learning Style Models (LSMs), which may be useful to select groupware tools and elicitation techniques according to the cognitive style of stakeholders. Few related works use psychological techniques to solve problems in Software Engineering. One work on this direction uses cognitive styles as a mechanism for software inspection team construction (Miller and Yin, 2004), which describes an experiment to prove that heterogeneous software inspection teams have better performance than homogeneous ones, where the heterogeneity concept is analyzed according to the cognitive style of participants. Even when they also used the concept of cognitive styles to classify people, our approach is different because our goal is choosing the best requirements specification to improve understanding of an already given group of people.

In this paper, we introduce a process to associate cognitive profiles to requirements prioritization. The last sections will present the design and results of an interesting case study we have carried out, as well as conclusions and guidelines for future work.

2 RELATING COGNITIVE PSYCHOLOGY AND SOFTWARE ENGINEERING PROCESSES

Part of cognitive psychology theories are cognitive styles, which classify people’s preferences about perception, judgment and processing of information (Miller and Yin, 2004), with the goal of analyzing and understanding differences in human behaviour. With the same idea, learning style models (LSMs) classify people according to a set of behavioural characteristics that concern the ways people receive and process information, while their goal is improving the way people learn a given task.

The model we have chosen as the basis for our research is called the Felder-Silverman (F-S) Model (Felder and Silverman, 1998). This model was selected after studying different LSMs. The analysis showed that the F-S model is the most complete because it covers the categories defined by the most famous LSMs and, additionally, the F-S model has been widely and successfully used with educational purposes in engineering fields (Felder and Spurlin, 2005). The F-S Model introduces four categories (Perception, Input, Processing and Understanding), each of them further decomposed into two subcategories (Sensing / Intuitive; Visual / Verbal; Active / Reflective; Sequential / Global). Characteristics of each subcategory (Felder and Silverman, 1998) are:

- *Sensing people* prefer learning facts and solving problems by well-established methods, while *Intuitive people* prefer discovering possibilities and relationships, and dislike repetition.
- *Visual people* remember best what they see (such as pictures, diagrams, flow charts, time lines, films, and demonstrations). On the contrary, *Verbal people* get more out of words, and written and spoken explanations.
- *Active people* tend to retain and understand information by doing something active with it (discussing or applying it or explaining it to others). In contrast, *Reflective people* prefer to think about information quietly first.
- *Sequential people* tend to gain understanding in linear steps, with each step following logically from the previous one, whereas *Global people* tend to work in large jumps, absorbing material almost randomly without seeing connections, and then suddenly "getting it".

People are classified into the different categories by filling a multiple-choice test, available on the WWW (Soloman and Felder, 2009), which returns a rank for each subcategory. Depending on the circumstances, people may fit into one category or the other, being for instance, sometimes active and sometimes reflective; so preference for one category is measured as strong, moderate, or mild.

3 A PROCESS TO ASSOCIATE COGNITIVE PREFERENCES TO PRIORITIZATION

Previous to introducing our approach, we briefly describe the elicitation techniques we have used, as considered in (Hickey and Davis, 2003):

Interviewing: It is fundamental to gather new projects’ background information, especially in new domains. Interviews are widely used, primarily to surface new information, to uncover conflicts or politics.

Questionnaires: They depend on both the analyst’ domain knowledge and the users’ written expression. It always must be complemented with

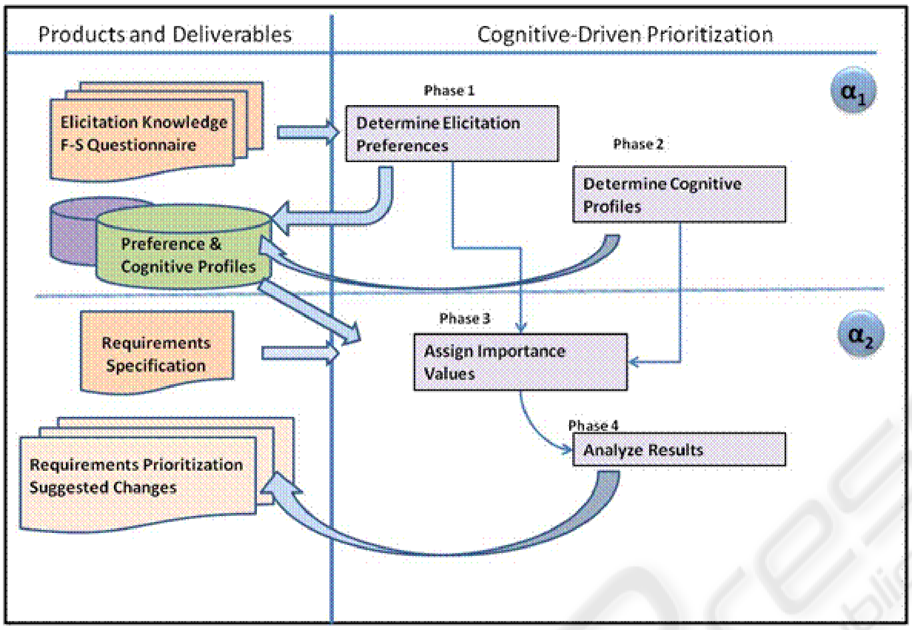


Figure 1: Cognitive-Driven Requirements Prioritization Process Graph.

another technique to obtain more details. Many times the results are not as good as are expected.

Models: DFD diagrams, UML, state charts, Use Cases, scenarios, storyboards. Any model specifies different aspects and some are particular to some applications.

Our technique complements these strategies by focusing on the assessment of cognitive profiles, which would help obtain a set of well-defined requirements. For instance, starting from a goal-oriented method (Kaiya, Horai, and Saeki, 2002), our technique introduced in (Martínez Carod and Cechich, 2007) extends goal graphs by using stakeholders' cognitive characteristics.

Our process schema, shown in Figure 1, can be divided into two sections: α_1 and α_2. As we said, the first one, α_1, is related with *preference management*; the other, α_2, includes specific phases for *requirements prioritization*. In this paper, we have instantiated sections α_1 and α_2 by using two approaches – a use case-driven modelling with a graphical notation, and a textual-based notation following an ad-hoc elicitation.

Section α1. Phase 1 constructs statistical predominant perceptions based on people's preferences about elicitation techniques. In this stage there must be a great number of system analysts to be convenient sampled. Each analyst must response a questionnaire to identify his/her viewpoint about appropriate and inappropriate elicitation techniques. Next, these people must be classified according to the F-S learning model. Thus, the information gained would be the basis for the relation to each elicitation technique. In the second phase, stakeholders' satisfaction levels are obtained based on their F-S category detected by a questionnaire on the Web. Results from this phase define the cognitive preference profiles.

Section α2. Here, results from both previous phases must be combined. Firstly, in Phase 3, each stakeholder assigns an importance value to each requirement according to his or her viewpoints. A cognitive weight is attached to each requirement according to relationships between the cognitive features of the stakeholder and the elicitation techniques' communicational aspects. Then, in Phase 4, results from the prioritization are analyzed and cognitive weights and/or some elicitation techniques might be changed reducing the preference gap. Depending on the discrepancies, the analyst may choose to change his/her elicitation techniques, as it is specified in (Hickey and Davis, 2003).

3.1 Research Hypothesis

Before describing the research, it is important to recognize that analysts' satisfaction can be caused by a variety of conditions from knowledge and experience on elicitation to how comfortable they feel with a particular elicitation technique. To actually see whether there was a relation between

Table 1: Distribution of Cognitive Preferences.

Act-Ref			Sens-Int			Vis-Vrb			Seq-Glo		
Mod-Str		Mod-Str	Mod-Str		Mod-Str	Mod-Str		Mod-Str	Mod-Str		Mod-Str
Act	Mild	Ref	Sens	Mild	Int	Vis	Mild	Vrb	Seq	Mild	Glo
21,74%	47,83%	30,43%	30,43%	60,87%	8,70%	47,83%	47,83%	4,35%	17,39%	69,57%	13,04%

cognitive profiles, elicitation techniques, and requirements prioritization, data from a survey and from a controlled experiment were combined. In order to do so, we surveyed 24 advanced students of the University of Comahue, Argentina and asked them to participate in an elicitation simulation. They had already attended courses about requirements engineering and data base definition; and many of them were employed in industry. So, previous knowledge about elicitation techniques was ensured.

Then, the following hypothesis had been formulated for the validation:

H1: Cognitive profiles do not affect the result of the requirements prioritization.

H2 Cognitive profiles do not affect the understanding of software requirements.

4 A CASE STUDY

The assessment scheme is organized in three phases, each one with a well-defined goal. The Preferences Phase involves the detection of people's preferences according to the F-S learning style model as well as their experience in applying elicitation techniques as students and as practitioners in real projects. The second phase (System X) studies their reaction with a simulated case in a known domain. In this phase we evaluate students' satisfaction in prioritizing requirements from a particular software specification. Finally, in the third phase (System Y) the study is replicated in another case, contemplating opposite preferences. Both Phase 2 and Phase 3 constitute Stage 2.

Stage 1. The preference and knowledge section of the first stage is made up of individual questionnaires. To detect the student experience, we labelled the different levels of experience as extensive, enough, some, little and none. The results for real cases showed that nobody had extensive experience; only 16.66% had enough or some experience and 83.33% had little or no experience at all. The participants' experience with elicitation techniques was practically limited to interviews, modelling cases and document analysis. As an illustration only 4.17 % of students mentioned no experience in interviews, 8.33 % no experience in uses case modelling, and everyone had experience in using models (diagrams, UML, state charts, etc). As a statement, all of them mentioned preferring previously known techniques.

In particular, the students were asked about how they conducted their elicitation activities, about their qualitative experience with the techniques and on quantitative data in order to find out whether the hypotheses held. Most of both questionnaires were subjective, depending on the subjects and the viewpoint from which they are taken. In both cases the students contributed making a sort of judgment. By classifying the preferences of students as strong/moderated (values from 5 to 11 in the ILS) and balanced (values from +3 to -3 in the ILS), we found out the distribution of preferences shown in Table 1. It is important to highlight the Visual preference as the strong and moderate preference with highest percentage 47.83 %,, in contrast to the Verbal preference with 4.35%.

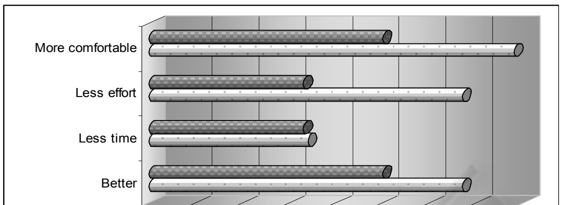
Stage 2. The next two phases involved working with real problem simulation. We worked here with the specification of two applications in the academic domain. In this way, we reduced the understanding gap between domain knowledge and working scenarios students are familiar with. The main goal of the first system (X) was to optimize faculty's classrooms and material resources. The system managed not only the courses' schedules but also resource assignments. Visual SRSs (X1, Y1) were made up of a Graphical Functional Diagram showing system's functions, UML Class Diagrams, Use Case Diagrams, and UML Sequence Diagrams. As opposite, the non-visual SRSs (X2, Y2) described the same system domain using textual notation. Both types of SRSs were tested by software engineering professors to check their similarity. The main goal of the second system (Y) was adding new functionalities to the educational web system support PEDCO (http://pedco.uncoma.edu.ar); and here, SRS's treatments were similar to the case of system X. We use a cross-validation experiment to obtain reliable results. The population was divided in two groups: A and B. We used a dice to assure randomized selection, thereby all the subjects had the same possibility of being assigned to the group A or B. Independently the group that each student was assigned to, he/she was asked to accomplish the activities individually playing the role of system analyst. To overcome some threats, during the case study not only data with respect to performance was collected (time spent in prioritizing), but the student doing process modelling in the case study was also asked about his/her experience in the particular elicitation technique.

Finally, as a first glance, we cannot assume our sample as representative enough. The number of students considered is small, and it is not possible to perform a complex statistical analysis. Therefore, we based our analysis on the comparison of percentages. However, looking at the overview of similar studies given by (Felder and Spurlin, 2005), our results are mostly in agreement with the results of these studies. Thus, we can suppose that our sample is representative enough and can act as basis for further analysis.

5 RESULTS AND SOME LESSONS LEARNED

Although understanding was not a problem, we found some interesting results that motivate us to continue our research line. For instance, 81.8% of respondents with strong visual preferences agreed on feeling more comfortable with visual specifications, as we expected; but 36.4% of respondents with strong non-visual preferences felt more comfortable with visual specifications. Another result showed that few people had problems to understand requirements; but 72.7% of the conflicts appeared when the SRSs were not specified in concordance to their preferences. Another result showed that a high percentage (> 68%) of visual students spent more time understanding non-visual SRSs than understanding visual ones. This clear relation does not appear in the other types of preferences (non-visual). In general, except for an isolate case, respondents did not spend much time in prioritizing requirements; however some people were not sure about how to assign requirements' priorities. In this case we could not find a clear relation with their cognitive preferences.

The last part of stage 2 implied running a post-experiment questionnaire, which associated individual feelings about both applications. By comparing satisfaction (Figure 2), we realized that all people with strong and moderate visual preferences felt more comfortable, spent less effort and better understood specifications aligned to their profiles.



	Better	Less time	Less effort	More comfortable
Non-Visual	50	33	33	50
Visual	67	34	67	78

Figure 2: Comparing satisfaction of visual and non-visual people with respect to understanding a visual SRS.

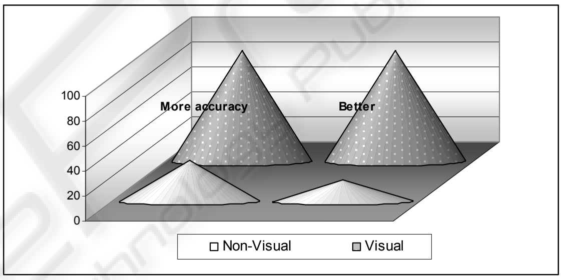


Figure 3: Comparing satisfaction of visual and non-visual people with respect to prioritizing visual SRSs.

On the other hand, as we expected, verbal people did not feel the same satisfaction with the visual SRSs. Time showed an interesting result since both groups felt that there was no difference at dealing with visual or non-visual SRSs. Although further research is needed, it seems that using visual representations might be useful for making understanding faster independently of the cognitive profile (but with different effort for each case). It seems that a better manipulation of specifications might be related to cognitive profiles. This is clear from the impact on prioritization (Figure 3). There is no doubt that visual people perform better with visual SRSs than non-visual people. Visual people felt that accuracy of prioritization was higher when using visual specifications. This fact let us wonder whether a prioritization process does not reach commitment because people consider requirements' value differently, or just because they do not look at the same features similarly when prioritizing.

More experimentation is needed for mild preferences. To clarify the point, Figure 4 shows the results of prioritizing requirements of the system Y, given by visual people using the non-visual SRS. For example the black line represents a moderate visual student, called MVi5, whose priorities for the functional requirements (FR1.1 to FR1.14) and non-functional requirements (NFR1.1 to NFR4.4) were assigned between 5-9 (on a scale 0-10). Notice that only 14 scores are below 6 in Figure 4. Similarly, Figure 5 shows another group of *visual people* scoring the same requirements but using the *visual SRS*; and here, we found 21 scores below 6. Considering that we had taking care of side variables such as people's background and context knowledge, we might suppose there is a relation among cognitive profiles, SRS notation and prioritization values.

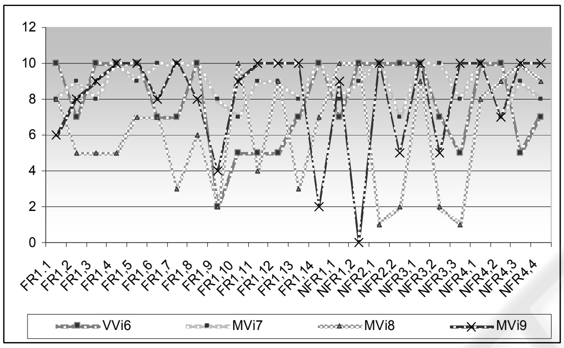


Figure 4: Examples of prioritization given by visual people using the non-visual specification of System Y.

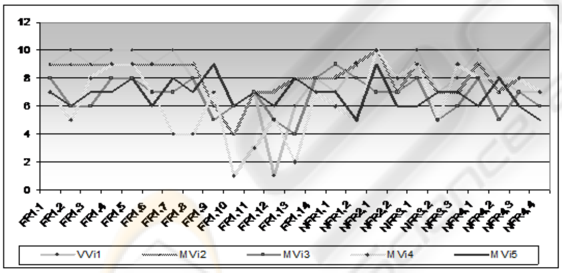


Figure 5: Examples of prioritization given by other visual people using the visual specification of System Y.

6 CONCLUSIONS

From our research, it can be said that cognitive profiles might influence some aspects of process elicitation, as demonstrated in the experiment. However, controlled experiments have their limitations as they cannot be generalized to every situation using that technology or method. Thus, more case studies would be helpful for the validation of the approach. In particular, more experience with the overall method and with concrete techniques (such as goal-oriented graph prioritization) would be helpful. Formulating such cases is part of our future work in the short time.

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