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Author(s): Khanom, Sukanya; Heimbürger, Anneli; Kärkkäinen, Tommi

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Icon Recognition and Usability for Requirements Engineering

Sukanya KHANOM¹, Anneli HEIMBÜRGER and Tommi KÄRKKÄINEN
University of Jyväskylä, Department of Mathematical Information Technology, Finland

Abstract. When we introduce icon-based language into the context of requirements engineering, we must take into account that what users perceive as recognizable and usable depends on their background. In this paper, we argue that it is not possible to provide a single set of visual notations that appeal to all of stakeholders. Instead, we suggest an adaptable preference framework, which generates personalized notations that correspond to personal background. We present and evaluate icon-based language: a new kind of approach to requirements engineering work to explore its possibility and usability. In an initial evaluation of students residing in Finland, results reveal that users are able to recognize a group of icons fairly well. Our findings show that an icon-based language could probably be a positive means in improving awareness of requirements engineering as it tends to take advantages of icons which are intuitively understandable to represent traditional textual requirements.

Keywords. Requirements engineering, icon-based language, stakeholders, culture, visual notation, experimental study

Introduction

Requirements engineering (RE) is recognized as being one of the most difficult engineering tasks. Principally, RE has been categorized in terms of two areas: requirements development (RD) and requirements management (RM) [1,2]. Its merit for RD is primarily examined in this paper. Researchers have perceived that diversity of stakeholder's background can inhibit successful use of the RE process [3]. Although there is a growing body of research pertaining to requirements development and management across borders, information in the area of cross-cultural RE is lacking [3,4]. The tasks involved in RE are essentially collaborative. Various stakeholders participate in these tasks, and it is necessary to obtain all potential requirements from stakeholders. Requirements are commonly high identity risk, and they can be difficult to capture in situations where a communication gap exists between developers and users. Requirements identity depends on the background distance between relevant stakeholders [5]. In practice, it is more problematic for stakeholders to communicate requirements internationally than with local users. Particular types of communication problems that affect and limit shared understanding between developers and non-technical users include so-called ineffective communication channels, restricted notation languages, and cultural and organizational factors [6]. Poor communication can broadly be classified in three different ways: lack of articulation (the ability to

¹ Corresponding author.

express information), misunderstanding (the tendency for various stakeholders to interpret differently the same piece of information), and conflict (multiple perspectives and differences) [7,8].

There may be numerous approaches to solving the problems encountered in RE. This paper introduces one such approach with the help of the following key concepts: preference aspects, RE modelling and icon-based language.

Preference aspects assist in building a user preference framework with adaptive user interfaces that conform to the user's background.

RE modelling provides classes for representing the requirements element. It designates how requirements information is typically structured, as well as the relationship between different elements within a particular project. On a macro-level, we define elements within a project as requirement, attribute, traceability links and people involved in the project. *RE artefacts* are characterized as a static element, which means they are not dependent on preferences. Thus all users visualize requirements features or functions in the same manner.

Icon-based language is designed in visually supporting pieces of RE artefacts that go beyond ordinary textual description. Being dissimilar from RE artefacts that are static, icon-based information is dynamic, depending on the user's background. The divergence of icon presentations that adhere to preferences can be seen, for example, by illuminating icons to represent the information: users from Europe might prefer an interface with only icons while users in Asia may prefer an interface with icons supplemented by text captions.

Our research explores how well respondents are able to recognize a set of icons and how icon-based language can help to enrich RE work. To answer these two questions, this paper evaluates icons that represent RE attributes and surveys respondents' satisfaction. During the evaluation phase, there were two iterations: one with student participants and another with expert participants. The first iteration, presented in this paper, included 48 students in an RE course in the Department of Mathematical Information Technology at the University of Jyväskylä. A Web-based test was implemented in a MediaWiki environment. Our findings have the potential to show whether the use of icons is advantageous in the RE domain. We anticipate that the added functionality of icons could simplify RE tasks for a range of stakeholders.

In the following section, we introduce previous works on which our method for designing a concept of icon-based language has been based. In Section 2, we describe our research approach in terms of the three artefacts – *preference aspects*, *RE modelling* and *icon-based language* – that have been developed. In Section 3, we explain the implementation environment. In Section 4, we offer an empirical evaluation of icon-based information. In Section 5, we discuss our results and recommendations for improvement. In Section 6, we propose areas of future study and present our conclusions.

1. Related Work

Natural language description is a technique that aims at communication which is commonly understandable by all potential users. However, natural language has widely recognized limitations, such as potential ambiguity and inconsistency. Substituting natural language with more structured notations would probably decrease ambiguity [9]. Dozens of requirements engineering visual methodologies and techniques have been

developed and made available for respondents. Unfortunately, some of these lack mechanisms for managing complexity. In the absence of such mechanisms, problems have been represented as single massive diagrams, regardless of their complexity. For example, the ER model that has been used for several decades is still lacking such mechanisms. As a result, ridiculously complex diagrams are often produced in practices that overwhelm end users [10]. The goal-oriented model, a language which was developed more recently and specifically for communication with end users, also lacks these mechanisms [11]. It can be concluded that the lesson has still not been learnt after all this time. Otherwise, only a very small number of tools have been developed to support requirements modelling and requirements management. This suggests that there is room for improvement for those two perspectives [4]. Diagrammatic modelling techniques such as UML [12-14] are a popular approach amongst developers. Nonetheless, end users are at a disadvantage when asked to validate existing diagrams or notations, as they are typically required to translate their knowledge into an unfamiliar language [6,9]. Hence, modelling techniques may be unsatisfactory or even useless when communicating with non-technical users. A good requirements collaborative mechanism is comprised of several crucial influencers. Of these, one type of support is to be able to specify requirements using textual, graphical, and modelling descriptions (with rich visual aids such as images and icons) [9]. Another support feature is the ability to trace backward and forward between requirements [1,2].

As the RE paradigm has shifted from localization to globalization, developing software when team members are located in distributed geographic regions can pose many challenges for developers. A single technique for development of RE within a multicultural organization does not necessarily mean optimization. Likewise, the use of different methods and different uses of the same methods across countries can be problematic, depending on cultural differences. Asian websites, for example, tend to commonly be bright and colourful, with frequent animations that try to attract the user's attention. This degree of high complexity is often perceived as information overload by Westerners, who prefer more structured content. Asian people, in contrast, have been shown to efficiently filter such dense information [15-17]. This fact motivates researchers and developers to realize that adapting the interface to a user's culture is a major strategy to market success [18,19]. While cultural preferences have long been researched, efforts in this direction have been limited only to specific countries or regions [20-22]. The implementation of guidelines related to cultural preferences mostly emphasizes the design of the user interface or navigation system, which is only beneficial for users who belong to the group targeted by the company. Historically, O'Neill-Brown has proposed the idea of developing systems that can automatically recognize and adapt themselves to suit a user's cultural preference [22]. Later, Heimgärtner and Burgmann conducted research in the area of cultural adaptivity in navigation systems [20,21]. Since such adaptations are largely intended to improve the user's learning experience, they did not comprise a full range of user interface components. More recently, therefore, Reinecke [18,19] has suggested an increasingly adaptive approach that takes into consideration all interface components influencing a user's preferences, which vary according to their nation and culture.

Our contribution is novel in the way in which we present an alternative approach that applies icon-based language to represent the context of RD and that enables icon appearance to be adapted to the preferences of users of any culture.

2. Research Approach: Model of Requirements, Icon-based Language and Preference Dimensions

This research follows the research methodology of design science [23,24], which consists of three primary phases: identification of problems and objectives, design solution, and evaluation.

By scrutinizing a vast amount of literature in the first phase (e.g. [5,6,25]), we arrived at three research problems: (1) the difficulty for stakeholders to express their needs explicitly, (2) the difficulty for stakeholders to understand, communicate and review requirements, and (3) the difficulty for stakeholders to make requirements constant. To arrive at a potential solution to these problems, solid objectives of icon-based language must be defined. Three key benefits can be determined: (1) to assist stakeholders to specify and communicate requirements, (2) to support requirements analysts to prioritize and resolve conflicts, and (3) to enable RE stakeholders to investigate changes in requirements and to continue tracking the requirements life cycle.

In the second phase, the design solution stage, we extend three key insights of our approach from [26-29] that is, preference aspects, the requirements engineering context and icon-based language (Figure 1). The details of these three artefacts are explained in the next three sub-sections.

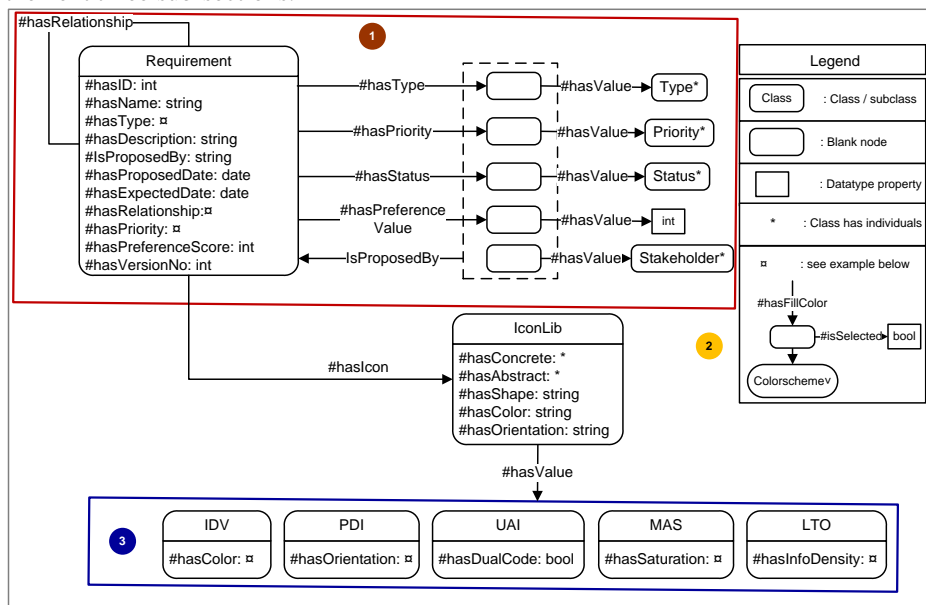


Figure 1. Model of requirements, icon-based language and preference dimensions.

2.1. Requirements Engineering

The central concept of requirement artefacts is correlation between attributes, stakeholders, and relationship (see number 1 in Figure 1). Attributes are the properties that distinguish a requirement from other requirements and establish a context and background for each requirement. Stakeholders refer to the persons or systems that have the purpose and ability to achieve goals. Relationships signify the interaction between two or more requirements. Each requirement is proposed by a stakeholder, and

thus it is essential to record information about associated stakeholders. We categorized the requirements into groupings (a taxonomy), in order to facilitate better organization and management. Eight types were created to delineate software quality and development process quality [30]. All requirements are characterized by a unique identifier (*#hasID*), name (*#hasName*), description (*#hasDescription*), type (*#hasType*), proposed stakeholder (*#IsProposedBy*), proposed date (*#hasProposedDate*), expected date (*#hasExpectedDate*), association (*#hasRelationship*), priority (*#hasPriority*), preference score (*#hasPreferenceScore*), and version number (*#hasVersionNo*).

2.2. Icon-based Language

It was first necessary to derive an icon library of visual notations designed to be attached to the requirement itself, the requirements process and the user interface (see number 2 in Figure 1). To promote scalability and variability, we built libraries for icon-based language to collect icons that relate to attributes that adhere to every requirement. Icons in this library must be designed in accordance with the cultural aspects of Hofstede's dimensions (see number 3 in Figure 1). Other icon syntactic properties are, for example, "position" (which characterizes the icon's orientation on the X and Y axes), "size" (which exemplifies icon size, including 1D iconic elements, such as lines, 2D iconic elements (areas), and 3D graphic elements (volumes)), "style" (which typifies colour and shape), and "link" (which symbolizes link attributes such as curves and dashed lines).

2.3. Preference Dimensions

We ground our preference framework in cooperation with cultural user ontology [19] whose conception was already validated, and the evaluation exposed that preference adaptive method has a competitive advantage over non-adapted version. Participants' preference is relied obviously on their personal background, namely education, gender, age and nationality.

Culture also plays an essential role in the use of information and communication technology. Cultures have different degrees of context: some cultures are determined as high-context while others are considered as low-context. In high-context communication, most of the meaning is found in the context. By contrast, in low-context communication, most of the meaning is in the transmitted message itself. Problems and conflicts frequently emerge when people from high- and low-context cultures communicate with each other [31-33]. In Table 1, we have summarized the rules for a cultural interface based on Hofstede's theory of the five dimensions of human-computer interaction components, such as colour, appearance and contents [34-38]. Power distance (PDI), for example, describes the extent to which hierarchies exist and are accepted by the members in a society. In countries that have been assigned a high power distance score, societal inequalities are much more acceptable than in low power distance countries. People in highly individualist (IDV) countries are usually seen as being more independent; in contrast, people in collectivist countries often see themselves as part of a group. The third dimension, masculinity (MAS), refers to a high preference for competitive achievement (high masculinity) versus low preference (femininity). The degree to which the members of society tolerate uncertainty and ambiguity is inversely reflected by an uncertainty avoidance index (UAI); that is, people from high uncertainty avoidance countries prefer less ambiguity than those in

low uncertainty avoidance countries. The fifth dimension, long-term orientation (LTO), measures how people perceive time. In LTO countries, people are comfortable sacrificing for long-term benefit, but in countries with short-term orientation people are more focused on immediate results. Table 1 illustrates adaptation rules for icon contents that represent an aspect of RE artefacts.

Table 1. Icon adaptation rules divided into high and low according to user preference frameworks.

IL Aspect	Hofstede's Dimension	Dynamic Component (icon)	
		Low Scores	High Scores
Colour	IDV	Icons' display colours correspond to nation's preference.	Homogeneous colours.
Space/Orientation	PDI	The space between each icon element can be close to each other.	The space between each element must be wide and follow hierarchical structure.
Support	UAI	Icon individually shown without text caption.	Icon displayed with dual-coding (text and icon).
Information Density	LTO	Low number of icon details. Limited number of shapes.	High number of icon details. Many kinds of shapes.
Saturation	MAS	Icons' saturation corresponds to nation's preference.	Pastel-coloured icons.

3. Implementation in MediaWiki Environment

Wikis are defined as collaboratively and freely expandable collections of interlinked webpages that allow users to edit the content of a webpage [39]. There are a wide variety of wikis available, including MediaWiki. In order to develop a collaboration tool to communicate requirements, we extended the MediaWiki architecture. Wiki technology facilitates stakeholders to work on the same thread without overwriting each other's modifications, with the added benefit of being able to keep track of each other's contributions. The concept of maintaining multiple versions in a Wiki originated from similar mechanisms implemented in software version control systems [39]. Through wiki-based collaboration, many stakeholders are able to view the newest version, control or manage concurrent write-access, and implement rollback to prior versions. Once requirements have been completed, the page is released for others to see, review and further modify. The basic MediaWiki model does provide for collaboration and distribution, but does not provide support for RE (such as requirements creation, requirements reuse, and requirements evolution analysis). Furthermore, the basic model does not provide details of attributes and properties that should be stored within the model. It is up to developers to take advantage of those and to customize advance supportive features.

Figure 2 describes the technical implementation for an icon-based language prototype. The top level demonstrates the user interface view, which consists of four views: requirement editor, requirement visualization, traceability visualization and management visualization. One important trait of icon-based language is that it is comprised of four layers. In the top layer, a user interface that is kept separate from the system model allows for each tier to be easily modified with minimal impact on the others. The lower level of the framework illustrates the convergence of three main artefacts –user preference framework, icon-based information and RE artefacts – to reach an icon-based information adaptivity process. The icon-based interface is tailored to the user on the basis of adaptation rules (see Table 1). For instance, if a user has a

high score in UAI, then an interface with very simple, clear imagery and limited choices is provided.

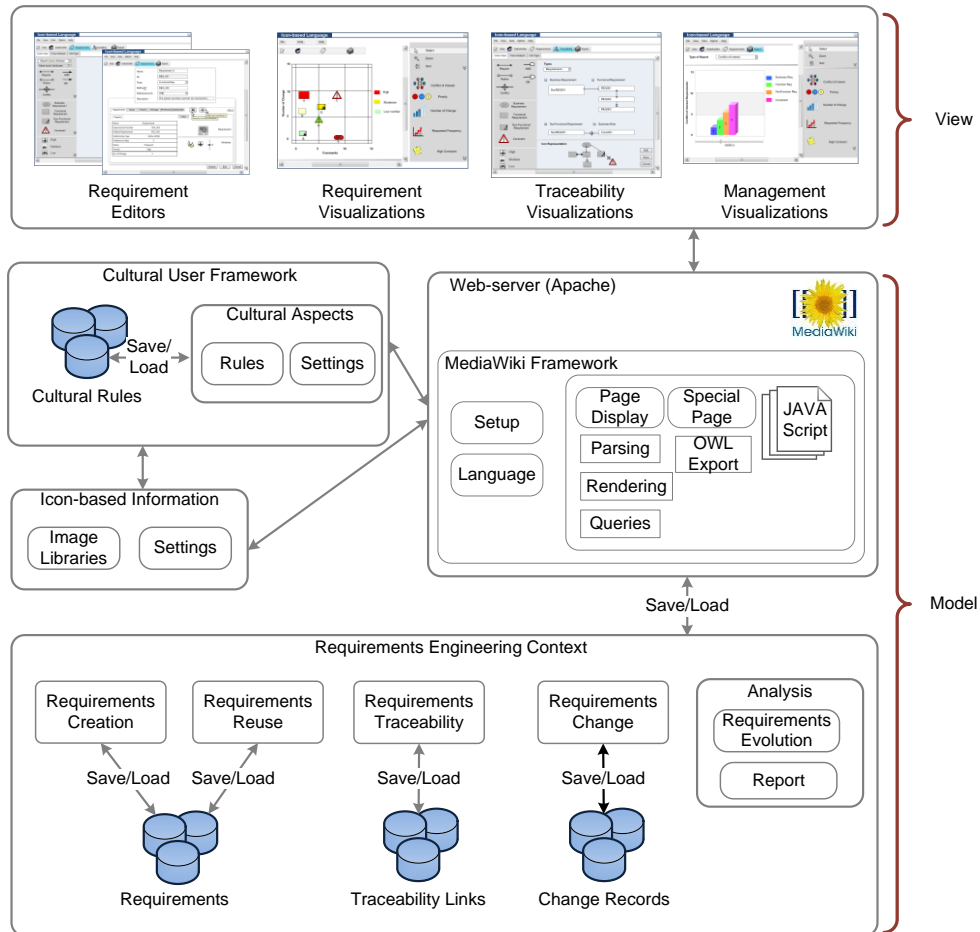


Figure 2. A framework for icon-based language in the RE context for multi stakeholders.

4. Experiments on Icon Recognition and Satisfaction

In order to evaluate the advantage of icon-based language, our experiment was aimed at measuring user recognition and satisfaction. We extended the result [40] by including additional three participants and by supplementing other two facet evaluations, that is, recognition and usability. We hypothesized that the benefit of icon-based language is twofold. First, we expected that icon-based language that uses icons to represent textual improves recognition (Hypothesis 1). Secondly, we assumed that icon-based language increases satisfaction (Hypothesis 2).

4.1. Method

4.1.1. Participants

In order to balance education level, participants had to be students. We invited 48 students attending a RE course at the University of Jyväskylä to participate in the survey.

4.1.2. Apparatus and Procedure

We conducted the experiment on MediaWiki as a web-based survey. The icons were presented to participants on webpages. During the experiment, participants encountered three sections: background information, a form for personal information, and a test on icons. Each section contained a description that helped users to complete the tasks.

On arrival, participants received a verbal explanation about the test procedure, followed by a short questionnaire to solicit information about their background (nationality, education level and work experience). Frequency of computer usage, age and gender were not recorded. Participants were then provided with a short introduction to the purpose and functions of icon-based language, as well as an explanation of its structural categories. The explanation and the questionnaire were provided in English. The test procedure consisted of two subsets: icon recognition and a survey on satisfaction.

The first subset consisted of three tasks: individual icon recognition, multi-icon recognition and compound icon recognition. For individual icon recognition (see Figure 3(a)), participants encountered diagrams on a requirement's life cycle, consisting of five blanks, and a list of potential icons. They needed to select and place the appropriate icon into its corresponding diagram state. For multi-icon recognition (see Figure 3(b)), respondents were confronted with 14 icons of three types: five icons for priority type, five icons for status states and four icons for stakeholder type. All icons were abstract, so that their meaning must be guessed. Icons in each of the three types could be clearly inferred from their characteristics. First, various degrees of vehicles' velocities were utilized to represent how important and urgent a particular requirement is (e.g. the slowest vehicle, a baby carriage, signified very low priority). Secondly, the interrelation between a person and his or her environment was used to represent life cycle states from submitting to verifying (e.g. a person writing a red X sign was representative of a rejection status). Thirdly, different types of actors could be distinguished by various stick figures [11,13] (e.g. a manager was shown by a stick figure wearing a hat). Finally, for compound icon recognition (see Figure 3(c)), respondents were encouraged to construct a sentence from pre-defined icons. We mimicked the goal-oriented model for this test, but rather than using existing goal notations, we defined icons and shapes for our own icon-based language.

The second subset was composed of three questions, plus two freeform areas for opinions and comments. Participants were asked to proceed step by step, beginning with the first task of individual icon interpretation to the last part of the questionnaire.

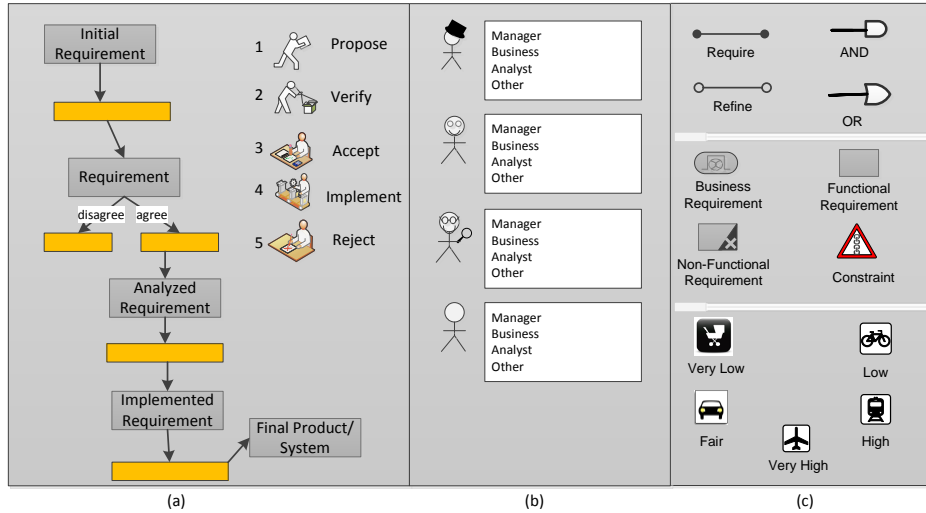


Figure 3. The test tasks: (a) individual icon recognition exemplifying the requirement's life cycle, (b) multi-icon recognition typifying requirement attributes, and (c) compound icon recognition characterizing requirement types and relationships.

4.2. Results

4.2.1. Icon Recognition

To determine icon recognition, we based our evaluation on the frequency of prediction accuracy. For analysis, for each task and participant we coded a correct prediction (success) with a 1 and an incorrect answer (failure) with a 0. To test whether icon-based language reached a significantly higher frequency, we employed the statistical mechanism of binomial confidence intervals (with confidence level 0.95 and $\alpha = 0.05$). Depending on the task, the participants correctly predicted the icons' meaning with a minimum of 25 and maximum of 41 items (mean = 34.67, sd = 10.12), with an overall prediction accuracy of 73 percent. Comparing our obtained data per task (see Table 2), our results show that the number of respondents able to accurately select an icon and drop it into every single blank state obtained the lower limit of 0.3795 and the upper limit of 0.6622.

Table 2. Summary of test results on icon recognition.

Test Type	Test Result
Individual Icon Recognition	The 95% confidence interval for the proportion of potential participants who could predict icons' meaning and correctly place icons in the requirements life cycle stage was .3795 to .6622.
Multiple Icon Recognition	The 95% confidence interval for the proportion of potential participants who could correctly interpret multi-icons' meaning was .7331 to .9306.
Compound Icon Recognition	The 95% confidence interval for the proportion of potential participants who could correctly construct iconic sentence from a given icon was .7543 to .9540.

We observed that multiple icons were recognized fairly well (lower level of 0.7331 and upper level of 0.9306). In terms of recognition of the 14 icons, roughly 17 percent of respondents had misunderstandings. Compound icon recognition achieved a correct prediction accuracy of 0.7543 at the lower limit and 0.9540 at the upper limit.

4.2.2. Icon Satisfaction/Usability

For the aspect of usability, we collected information about satisfaction, effort expectations and attitudes toward using the system [41]. We included scales to describe users' perceived competence in mastering icon-based language tasks. We complemented the dimension of usability with satisfaction opinions [42] (with variables such as complicated/easy or unpredictable/predictable). The experiment ended with three questions on the participants' overall preferences, which directly point to icon-based language usage. The first question, related to the satisfaction of icon-based language, was measured on a 4-point scale (0: no opinion, 1: dissatisfied, 2: satisfied, and 3: very satisfied). The second question regarded attitudes toward using the system and was assessed on a 3-point scale (0: no opinion, 1: will not use icon-based language, and 2: will use icon-based language). The third question, which focused on attractiveness, was appraised by a 5-point scale (0: no opinion, 1: make communication more clear, 2: the structure was presented clearly, 3: intuitively understood, and 4: easy to use). The results in Table 3 describe three primary aspects: (1) satisfaction level, (2) likelihood for further use of icon-based language, and (3) effort expectations.

Satisfaction was based on the degree to which participants perceived that icon-based language is beneficial for developers and other stakeholders. The overwhelming percentage of respondents was "satisfied" (69.57%).

However, icon-based language has significant differences in attitudes when it comes to using the system. According to the figure shown in Table 3, more participants plan to use icon-based language (39.13%) than not (17.39%). However, those with a positive attitude were still less than those with no opinion (43.48%).

The question on effort expectation gauges the degree of ease associated with the use of a system. These results explained subjective perceptions of usability (e.g. "I find icon-based language to be intuitive" or "I find icon-based language easy to use", etc.). The intuitive aspect (32.61%) was perceived to be the highest. According to respondents, making communication clear (28.26%) was the second notable feature supported by icon-based language.

Table 3. Measurement of subjective scales of users' satisfaction (46 replies out of 48).

Measurement Type	Rating	
	Scale	Portion
Satisfaction	0 = no opinion	13.04
	1 = dissatisfied	17.39
	2 = satisfied	69.57
	3 = very satisfied	0.00
Attitude toward using the system	0 = no opinion	43.48
	1 = will not use IL	17.39
	2 = will use IL	39.13
Effort expectation/Attractiveness	0 = no opinion	15.22
	1 = make communication more clearly	28.26
	2 = the structure presented clearly	13.04
	3 = intuitive understanding	32.61
	4 = easy to use	10.87

5. Discussion

The experiments presented in this paper reveal that user can indeed sufficient recognize icons very well when a group of related icons is presented. However, when individual icon is portrayed separately it seems practitioners getting misunderstood.

Here we summarized our experiments by excluding individual icon interpretation. Both of our experiments show promising results, which generally support our approach. In terms of Hypothesis 1, icon-based language proved to be significantly well recognized by participants across all tasks. Specifically, compound icon recognition (which imitated the goal-oriented model) was correctly recognized by a majority of respondents (85%).

Here we reported our experiments by including individual icon interpretation. While derived results are encouraging, they also indicate a need for improvement for individual icon recognition; in practice, training on RE components (such as process, activities and life cycle to users) could advance users' knowledge and skill. Therefore, the findings confirm a prerequisite need for users to capture RE knowledge.

Hypothesis 2 was substantiated by the results of our questionnaire, where participants described icon-based language usability: icon-based language is successful when it comes to making users satisfied, enriching communication, and supporting intuitive understanding. Regrettably, icon-based language fails in terms of perceived ease of use: only 10.58 percent of respondents felt that it is easy to use. This failure to offer stakeholders an easy-to-use approach could have several reasons. First, the survey did not cover icon-based language as a whole, but presented only a part of icons' attributes. As a consequence, respondents might not have been able to comprehend how icon-based language can be used and how it benefits RE stakeholders. Secondly, it was not our intention in this study to emphasize icon designs. Therefore, a limitation was that all visual vocabularies in this paper were gathered from existing ones and only used to represent concepts and ideas. At this stage, we were not concerned with their appearance in terms of what they represented. This task must be taken up by designers, who are experts in that area. Design relies enormously on cultural experience and cognitive effectiveness.

It is worth noting again that the adaptive preference framework (Section 2.3) does not yet implement in this phase because we attempt to make our concept available for only Finnish participants. Only one variable, nationality, was taken into account for pattern presentation, therefore, all practitioners view icon visualization in the same fashion since we assume that all practitioners are Finnish. Nevertheless such framework is needed to precisely define all necessary variables that could be supportive information for acquiring prospective participants as well as for further development.

6. Conclusion

It has long been acknowledged by industry experience and research that RE is a crucial factor that contributes to software success or failure and that icons are frequently used to supplement texts and overcome language barriers. While more and more RE techniques offer visual notations, they often use abstract shapes with clearly conventional meanings, which must be learnt. Additionally, little effort has been made to correlate icons with such techniques. This study set out to determine whether icons are capable of representing RE concepts. One of the more significant findings to

emerge from this study is that icons that characterize requirements attributes such as priority, status and stakeholders can be correctly recognized by users. This study also finds that respondents conceive icons as an intuitive medium for communication.

As with most novel approaches, our study of icon-based language has opened up possibilities for new and exciting future research. It is recommended that further research be undertaken in the following areas: (1) developing user preference framework for other nationalities, (2) implementing demonstrators for icon-based that can be used by multi stakeholders, and (3) assessing implemented tools in terms of their benefit and ease of use for a range of stakeholders.

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