Comparing the Effect of Use Case Format on End User Understanding of System Requirements

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ABSTRACT

The effective analysis and specification of requirements is critical in software development. Faults in the requirements may have significant impact on the quality of the software system. Use cases describe and analyze requirements in many current Object Oriented (OO) development methodologies, and can serve as a means for developers to communicate with different stakeholders. However, issues concerning use case format and level of detail are unclear and debatable. This study uses theories from cognitive psychology on how humans understand text and diagrams to investigate the effect of use case model format on end user understanding. An experiment to assess the performance of novices when using different use case formats indicated that for tasks that required only surface understanding of the use case model, the provision of diagrams along with the textual use case descriptions significantly improved comprehension performance in both familiar and unfamiliar application domains. However, the author found no statistically significant difference in performance between simple and detailed diagrams, suggesting that the provision of simple diagrams along with textual use case descriptions might be sufficient to support the negotiation and communication on system requirements between novice end-users and system analysts.

Keywords: Cognitive Psychology, Laboratory Experiment, Requirements Analysis, UML, Use Case Model, User Comprehension

1. INTRODUCTION

Numerous studies have indicated the importance of identifying correct, adequate and unambiguous requirements for the success of software systems development (Lamsweerde, 2001; Vessay & Conger, 1994; Yeo, 2002; Valenti et al., 1998). Shemer (1983) stated that “Requirements specification should reflect an understanding of a system, guide the subsequent design and programming phases, and serve as a basis for all communications concerning the software system being developed (e.g., users should be able to verify that their needs are answered and to plan acceptance tests”). Various methods and techniques have been developed for requirements specification and many research suggest the need for empirical evidence of the ease of

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interpretation and understandability of these methods (Wand & Weber, 2002).

The unified modeling language (UML) is the modeling language for object oriented systems development. It is widely acknowledged that UML has become the standard for modeling object oriented software systems since its adoption by the Object Management Group (OMG) in 1997 (Kobryn, 2002). Use cases are the technique in the unified modeling language that is used to capture the functional requirements of software and validate them with the system users in the early phases of system development. Use case models serve as basis for deriving other UML conceptual models. Thus, it is important to ensure the quality of these models. Little empirical research is found on how we can make the best use of use case modeling (Dobing & Parsons, 2006).

In order to make full use of these, establishment of communication and understanding between the system developers and the novice users is of paramount significance. This points to the need to investigate how the current formats of use case models assist user’s understanding of system requirements.

There was a variety of formats for use cases (Schneider & Winter, 2001; Cockburn, 2001; Constantine & Lockwood, 2000). Some researchers used use case narratives (either structured or unstructured text) while others used diagrams with the text. The use case diagram does not show the step by step interactions within use cases, but it provides an overview of the use cases and the relationships between them. Little attention has been paid to the role of use case diagrams in supporting user understanding when accompanying the text. Although the effect of pictures on facilitating text comprehension is well known in literature, few empirical work has been undertaken to investigate the cognitive processes underlying the understanding of use case models.

In a survey on UML current usage, Dobing and Parsons (2005) found that use case narratives had the highest score for verifying and validating requirements with client representatives on the project team. Their results also showed that clients were often involved in developing, reviewing and approving use case narratives and the use case diagram, and much more so than for other kinds of UML diagrams. They pointed out to the fact that how UML diagrams were used among non-experts remains unexplored.

Our objective in this paper is to demonstrate how using diagrams with the text description in a use case model can be studied by combining theoretical considerations and empirical methods. To accomplish this, we have chosen to consider an intra-grammar comparison (Wand & Weber, 2002) of three informationally equivalent formats of Use Case model. In one format, a text description is used. In the other two formats, text with diagrams of different levels of detail is used. In this study, we use cognitive considerations to suggest why there are differences in users’ understanding when presented different formats of use case model.

The other objective is to explore whether a simple diagram may be more understandable than detailed one for novice users. There is one independent variable with three levels, corresponding to three different formats of use case model used in this study. The dependent variable is the performance (in terms of effectiveness and efficiency) of subjects performing comprehension and verification tasks using the models.

To explain why differences in performance might exist, we use the Cognitive Load theory (Sweller, 1988), and the Multimedia Learning theory (Mayer, 2001).

Our first hypothesis is that when there are two alternative representations of the requirements (e.g., a text and a diagram) combined in one model, the model viewer can use both types of presentation to improve his/her understanding. The second hypothesis is that using simple diagrams with the text may improve the comprehension and verification task performance of novice users more than a detailed diagram do. The remainder of this paper is organized as follows. Section 2 provides a brief description of the use case models. Section 3 presents related work on the empirical evaluation of UML diagrams comprehension and specifically with regard to use cases. Section 4 provides a
A discussion of cognitive theories that suggest why different formats of use case model might affect task performance and proposes hypotheses. An experiment to test these hypotheses is described in Section 5 and results are presented in Section 6. Section 7 discusses the threats to the validity of the study. Section 8 concludes this report.

2. UML AND USE CASE MODELS

The UML advocates claim that users quickly recognize the advantages of a common modeling language that can be used to visualize, construct and document the artifacts of a software system (Booch et al., 1999) and argue that UML uses simple, intuitive notations that are understandable by non-programmers (Kobryn, 1999). On the other hand, some researchers (Siau & Cao, 2001; Siau et al., 2005; Dobing & Parson, 2006) consider UML complicated as it has large number of diagrams (9 in UML1.2). The Class diagram, the object diagram, the component diagram, and the deployment diagram represent the static view of the system, while the state chart diagram, the use case diagram, the activity diagram, the sequence diagram, and the collaboration diagram depict the dynamic view of the system. Each diagram shows different aspect of the system, and is by itself insufficient (Siau & Cao, 2001). However, the sequence diagram and the collaboration diagram were found redundant as they represent the same behavior in different arrangements (Batra & Satzinger, 2006). Use case model is an important part in the UML. Use cases are intended to aid the analyst to identify and describe the functional requirements for the proposed system. As defined by Malan (2001), a use case “describes the sequence of interactions between an actor and the system necessary to deliver the service that satisfies the goal of the actor”. Use case narratives include specification of use cases, actors and the relationships between them.

A UML use case diagram is a graphical representation of system use cases. Use case diagrams show use case names, actors, relationships between use cases and actors who trigger them. The relationships used in the diagram are <<include>>, <<extend>>, and <<generalization>>. These associations could be mandatory relationship where the included use case is part of the behavior of the base use case and it serves reusable when finding similarity between use cases. They could be optional when it is desirable to extend a use case without changing its original description (Fowler, 1997). Generalization is used when finding similarities in the behavior of the actors or use cases. Thus, one use case or actor would be a special case inherent in the behavior of the parent use case or actor and may add to it. However, some researchers (Schneider & Winters, 2001) argue that these techniques are really of interest to development staff, not end users. Figure 1 shows an example of UML use case diagram, which is also part of the experimental materials described in Section 5.

3. RELATED RESEARCH IN UML

UML is a large and complex language with more than 150 constructs (Dori, 2002) which render it difficult to understand. Empirical research have been undertaken to investigate the comprehension of UML diagrams. Siau and Lee (2004) used verbal protocol technique in an experiment to investigate whether use case diagrams and class diagrams complement each other in requirement analysis. Their findings showed that use case diagrams are easier to interpret than class diagrams. Satron et al. (2006) used a set of controlled experiments to evaluate the role of stereotypes on improving comprehension of class diagram and collaboration diagram. They found that stereotypes significantly supported the comprehension of both students and industry professionals. Lange and Chaudron (2006) developed two controlled experiments to investigate the extent to which implementers detect defects in UML models (sequence, use case, and class diagram) used as basis for implementation and maintenance,
and the effect of defects on the models interpretation. The results showed that defects often remain undetected and cause misinterpretation. Manso et al. (2009) used a set of five controlled experiments to explore the relationship between the structural complexity and size of class diagrams and their cognitive complexity and comprehensibility. They found strong correlation between the associations and cognitive complexity which affects comprehensibility of the models. Cruz Lemus et al. (2007) presented three experiments to investigate the effect of using composite states on the understandability of state chart diagrams. The results showed no effect of the composite states on improving the understandability of simple state chart diagrams.

Burton- Jones and Meso (2008) focused on conceptual diagrams and developed protocol study and an experiment to explain the effect of decomposing and accompanying the diagrams by additional information in an alternative form on user understanding of the domain. They found positive effect of good decomposition and multiple form of information on domain understanding. They used elements of class, use case, and state transition diagrams. Anda et al. (2001) conducted an experiment where three sets of guidelines to construct and document use cases were examined. The results of the experiment indicate that use case models constructed with the support of guidelines based on templates are easier to understand than
those supported by guidelines without specific details on how to document each use case. The literature review described here considers the comprehension as the primary concern in the context of UML modeling, this study tries to compare different formats of use case models and looks at how the detail in use case diagrams affects the viewer’s understanding.

4. COGNITIVE CONSIDERATIONS AND HYPOTHESES

This section provides a discussion of cognitive theories that suggest why different formats of use case model might affect task performance. Based on these theories, we propose two research questions and related hypotheses, which in turn are refined and made operational in the experiment design described in Section 5.

4.1 Dual Coding Theory and Multimedia

Learning from multiple external presentations is a wide area of research. Schnotze and Bannert (2003) point out that the main findings of research in this area are that text information is remembered better when it is illustrated by pictures than that without any illustration. They explain this effect with the Paivio’s dual coding theory (Paivio, 1986). This theory states that verbal material and pictorial material are processed in two different channels in human memory. Consequently, learning from text with pictures leads to better recall for the learned information and to better performance in knowledge acquisition, as Winn (1990) explains information is encoded twice verbally (text) and spatially (picture), which make it easier to retrieve. Richard Mayer has extended the dual coding theory in order to explain the effect of pictures with text (multimedia) on the understanding of technical or physical phenomena, especially for individuals with low prior knowledge of the phenomena, who need pictorial support in constructing mental models (Mayer & Moreno, 2002). He defined multimedia as presenting both words (spoken or printed text) and pictures (illustrations, photos, animations). Mayer assumes that verbal and pictorial explanations are separately processed in verbal and pictorial stores in working memory (Figure 2) and explains that the construction of different mental models in different channels of working memory may reduce the cognitive load on working memory, freeing up more resources in working memory to process new information so active learning could take place. Mayer focuses on active learning or “meaningful learning” that supports problem-solving. Meaningful learning, according to Mayer, occurs when learners engage in active cognitive processing. This includes paying attention to the related words and pictures coming from external sources, organizing them mentally into coherent verbal and pictorial representations, and mentally integrating verbal and pictorial representations with each other and with prior knowledge stored in long term memory. Prior knowledge is organized in schemas which have been constructed as a result of experience over time and stored in long term memory. Schemas are the cognitive structures that make up an individual’s knowledge base (Sweller et al., 1998). They argue that these Schemata can organize information that needs to be processed in limited capacity working memory, thus reducing the load on working memory which makes it unlimited. Mayer (1989) also notices that there is a growing research base showing that well designed multimedia presentations help students learn more deeply than traditional text only instructions. Mayer’s focus was on improving performance on tests of problem-solving transfer that require deep understanding of the problem domain.

Bearing in mind the above theories, the following research question is established for this study.

Research Question 1: Does the format of use case model influence the understanding and the patterns of performance, when individuals have to solve tasks on the basis of their previously acquired knowledge?
And which use case, text only or text accompanied with diagram better support user understanding of the domain requirements?

Based on the above theories, we hypothesize that using a diagram to accompany the text descriptions in a use case model may improve viewers understanding of the functions provided by the proposed software. Two representations may help the viewer integrating the two sources to improve his/her understanding of the domain.

**Hypothesis 1:** Individuals who receive a use case model consisting of both diagrams and text may develop a higher level of understanding of the system requirements faster than individuals who receive a use case model consisting text only.

### 4.2 Cognitive Load Theory (CLT)

This theory was first developed by John Sweller in 1980. The main concepts of the CLT are that human cognitive architecture consists of a working memory (short term memory) which has a limited storage and process of novel information. It can process only about seven elements at a time (Miller, 1956). This working memory becomes unlimited in capacity when dealing with familiar information brought from long term memory (Figure 3). Long term memory holds unlimited number of elements organized in the form of schemas which are treated as a single element in working memory and vary in the degree of complexity and automation (Van Merrienboer & Sweller 2005; Pass et al., 2004; Kalyuga et al., 1997). If schemas repeatedly applied they become automated and processed automatically rather than consciously in working memory, thus, reducing working memory load. Human expertise come from knowledge stored in these schemata, and the difference between an expert and a novice is that a novice hasn’t acquired the schemas of an expert (Van Merrienboer & Sweller, 2005; Kalyuga & Sweller, 2005). The theory is concerned with improving the learning process by encouraging learners to construct new schemas and automate them. According to the CLT, working memory load may be affected by two sources of cognitive load, *intrinsic* and *extraneous*. The intrinsic cognitive load (ICL) is imposed by the number of information elements and their interactivity. The difficulty in learning appears when there is large number of elements that interact with each other within the material and to learn they must be processed simultaneously. This load cannot be altered by instructional manipulation and it is not possible to avoid it with very complex, high interactive element tasks (Paas et al., 2004; Sweller & Chandler, 1994; Sweller et al., 1998).

Extraneous cognitive load (ECL) is the load imposed by instructional procedures and is not necessary for learning, e.g. for the process of schema construction and automation. It is
under the control of the instructional designer and can be reduced by instructional manipulation. Extraneous cognitive load is primarily important when intrinsic cognitive load is high. It must be lowered to keep the total cognitive load within the memory limits because the two forms of cognitive load are additive (Van Merrienboer & Sweller, 2005).

Based on CLT, the following research question which explores a totally new area is set up for this study.

**Research Question 2:** How does the degree of detail in a UML diagram that accompanies text in a use case model affect end user comprehension of the domain requirements?

The UML use case diagram consists of many elements as use cases, actors, advanced relationships which are highly interactive. When novices with little experience in modeling are exposed to such material at once, it imposes a high, intrinsic cognitive load because many elements must be processed in working memory simultaneously to be understood. As it is found that the intrinsic cognitive load of the material is fixed if immediate understanding is the goal of the task (Pollock et al., 2002), the only way to ease understanding is to develop cognitive schemata that incorporate the interacting elements. Because novices lack these schemata, this would hinder their understanding. We hypothesize, therefore, that a simple diagram will support their understanding more than a detailed diagram:

**Hypothesis 2:** Novice users who receive a use case model consisting of text and a simple diagram accompanying the text may develop a higher level of understanding of the system requirements faster than those who receive a use case model consisting of text and a detailed diagram.

### 5. METHOD

To answer the research questions, an empirical study was conducted in the laboratories of the Faculty of Computer Science and Information Systems in the University of Technology (Malaysia). Participants were required to complete two tasks using computer based tests. To assure internal validity, the three models used were assumed to be informationally equivalent with respect to the dependent variables, as it was possible to answer the test questions with any of the three representation formats used as treatments (Parsons & Cole, 2005). Although the three models include the required information for answering questions about the domain requirements they can nevertheless differ in their usefulness.

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*Figure 3. An information processing model (Mayer, 1989)*

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A pilot test was conducted before the experiment to validate the experimental materials and procedures. Six Master students from the Faculty of Computer Science and Information systems in the University of Technology Malaysia participated in this pilot study, which revealed some discrepancies in the materials and thus the procedures and the materials of the experiment were improved.

### 5.1 Experiment Design

A 3x2 factorial between-subject, randomized design is used in this experiment.

- **Independent variable:** The first factor was the use case representation method with three levels:
  1. **Text only** use case model
  2. **Text with simple diagram** use case model
  3. **Text with detailed diagram** use case model.

  The other factor had two levels corresponding to the two cases adapted from two separate sources: simulation of an automatic teller machine (ATM) (Charbonneau, 2003) and home security system (HSS) (Anderson & Polanski, 2001). The use of two cases was to broaden the external validity of the comparison between the use case model formats.

- **Dependent variable:** was the level of user understanding of the use case model being presented in the treatments.

  In this study, we consider the process and product of understanding. The process refers to the activities a user engages in to understand the domain. One aspect of this process will measure the user’s *ease of understanding the domain* (Gemino & Wand, 2005; Burton-Jones & Meso, 2006). Therefore, a post-test was conducted for measuring the perceived ease of understanding by using the ease of use scale of Moore and Benbasat (1991). This scale was originally developed in the context of Technology acceptance and adapted by Gemino and Wand (2005) for the information systems research. For the *product* of understanding, which is the main focus in this study, we distinguish between two levels:

  1. **Surface understanding**, which reflects the understanding of the domain elements and functions.
  2. **Deep understanding**, which concerns the understanding of the actual relationships among elements and how to apply the understanding in problem solving.

  We used a comprehension test to assess surface understanding and a verification test to assess deep understanding. According to Kim and March (1995), comprehension performance reflects *syntactic understanding*, the person’s competence in understanding the constructs of the modeling formalism, while verification performance reflects *semantic understanding*, the person’s ability to apply that understanding. Our comprehension test consisted of 12 multiple choice questions that tested the comprehension of explicit system functionality as depicted by the use case model. The verification test was done by providing the participants with a model having mixed inconsistencies of elements and functions and asked them to identify any fault in the model based on their knowledge of the system requirements gained from the comprehension task, and to explain why they think it is incorrect.

  In defining measures of understanding, we therefore distinguish between:

  - **Comprehension performance:** the ability to answer questions about a use case model (12 multiple choice questions) (Appendix C).
  - **Verification performance:** the ability to identify inconsistencies between a use case model and user understanding of the domain requirements (8 inconsistencies).

Previous study of Bodart et al. (2001) measured the time taken to complete the tasks...
as an indication of the degree of difficulty encountered. Thus, time taken to complete each of the two experimental tasks (comprehension and verification) was measured. Participants were aware that tasks were being timed but no time limit was placed on them. The time to complete the task was collected automatically by the computerized test application.

We also distinguish between two dimensions of performance:

**Effectiveness:** as reflected by the number of total correct answers to the comprehension and verification tasks, respectively.

**Efficiency:** as reflected by the time taken to perform the comprehension and verification tasks, respectively, which represents the effort exerted in completing the tasks.

**Hypothesis 1:** Individuals who receive a use case model consisting of both diagrams and text may develop a higher level of understanding of the system requirements faster than individuals who receive a use case model consisting text only.

**Predictions:**

- **Comprehension Performance**
  - **H1A:** Participants using *text with diagram* model will perform the comprehension task more accurately than those using *text only*.
  - **H1B:** Participants using *text with diagram* model will perform the comprehension task faster than those using *text only*.

- **Verification performance**
  - **H1C:** Participants using *text with diagram* model will perform the verification task more accurately than those using *text only*.
  - **H1D:** Participants using *text with diagram* model will perform the verification task faster than those using *text only*.

**Hypothesis 2:** Individuals who received a **text with simple diagram** Use Case model may develop higher level of understanding of the system requirements faster than individuals who received a *text with detailed diagram* model.

**Predictions:**

- **Comprehension Performance**
  - **H2A:** Participants using *text with simple diagram* model will perform the comprehension task more accurately than those using *text with detailed diagram*.
  - **H2B:** Participants using *text with simple diagram* model will perform the comprehension task faster than those using *text with detailed diagram*.

- **Verification performance**
  - **H2C:** Participants using *text with simple diagram* model will perform the verification task more accurately than those using *text with detailed diagram*.
  - **H2D:** Participants using *text with simple diagram* model will perform the verification task faster than those using *text with detailed diagram*.

**Control Variables**

Data were collected during the experiment to create scale variables that are used as covariates in the MANCOVA analysis. This includes any factors that may confound the results and affect the internal validity of the experiment. In this study, two factors were considered, the level of experience with modeling methods and the level of knowledge of the modeled domains. The main reason to measure the prior knowledge was to ensure that there were no significant differences among three groups of our subjects. A pre-test was used to collect information on participant’s familiarity, confidence, and competence with the modeling techniques, as well as their perceived knowledge of the two domains used in the study (Appendix A).
5.2 Participants

Participants were 84 undergraduate students (49 female and 35 male), drawn from the Faculty of Computer Science at the University of Technology in Malaysia, who had completed a course of software engineering of which use case technique was taught for about two hours. The experiment was administered at least one year after finishing that course for all students. It is claimed in studies (Kalyuga et al., 1998) that although learned conventions of diagrams are clearly critical for understanding and using schematic diagrams, expertise in using these diagrams in scientific material is not gained by only learning their conventions. Rather, domain-specific knowledge within the area of application is required as well. This sample contains individuals without high level of knowledge in both the domains under study and the use case modeling technique which might confound the results. Thus, they represent a group of novices or end users, thus, increasing the validity of this research. Subjects were randomly assigned to three groups of 28 persons corresponding to three experimental conditions (text with simple diagram, text with detailed diagram, text only). The experiment was conducted in a large computer lab in the same university and monitored to assure individuals completed the tests independently.

5.3 Materials and Procedure

The paper material which includes the use case models of two cases, instructions for computerized tests, pre and post tests were provided to participants in closed envelops. Subjects began by registering and filling the pre-test form manually (Appendix A). Then, they rate their experience, familiarity with use case modeling and their knowledge of the two case domains. Each subject then completed two cases, an automatic teller machine (ATM) (Charbonneau, 2003), and a Home security system (HSS) (Anderson & Polanski, 2001) in computerized tests. For each case, subjects received one format of the use case model (text, text combined with a simple diagram, or text combined with a detailed diagram) and completed two tasks in the following order: comprehension task, verification task. Figure 1 shows one of the detailed diagrams used in this experiment. It includes main use cases, include and extend relationships to finer-granularity use cases for the ATM case. The relative textual description is provided in Appendix B. Half of the subjects started with case1 (ATM) and then continued with case2 (HSS), the other half is counter balanced to control for any learning between the two domains. To ensure internal validity of the experiment, first, subjects read the correct use case models and completed the multiple choice comprehension questions on the computer, with the models available (see Appendix C for the ATM case). This serves to assure that the subjects scanned the whole models and understood the domain, so they would be ready to apply this understanding. The models were removed after the comprehension test of each case. The subjects then started the verification test with the correct models away to ensure that the information available to the participant is the cognitive model developed earlier by viewing the original, correct model. For the second test, participants received a new model that contained eight inconsistencies, and asked to identify any inconsistency in the model on the computer. A post-test was provided after the verification task of the second case to measure the perceived ease of interpretation associated with the method (Appendix D).

6. ANALYSIS AND RESULTS

A priori analysis was conducted to determine the effect size ($\eta^2 > .06$), power = .8, alpha level ($\alpha = .05$), total number (N) of subjects needed (Cohen 1988). The statistical method used to analyze the data in this study was multivariate analysis of covariance (MANCOVA). The data collected for all dependent variables in each case was analyzed separately. Figure 4 shows a preliminary descriptive statistics of all dependent variables in the study (ATM and HSS). The data
for the two covariates used in the analysis: (1) Knowledge of use case model (KMETHOD) and (2) domain knowledge (KDOMAIN) for the two cases were collected in the pre-test. Participants were asked if they have used the method and how long they have been familiar with the method. Then they were asked to rate their competence and confidence with the method on a 5-point scale from (very low, 1) to (very high, 5). To assess the participant’s knowledge of the domains, they were asked to rate their level of familiarity with “Automatic Teller Machine” and “Home Security System” case on a 5-point scale from (never, 1) to (very frequently, 5) for the (ATM) case, and from (very low, 1) to (very high, 5) for the (HSS) case. An ANOVA (Figure 5) was conducted to compare the level of the two scales across the three treatments. The results showed no significant differences between the participants on these covariates, which may indicate that the randomization was successful.

The post-test was used to collect perceived ease of use or interpretation of the models. Participants using the text with diagram model rated their perceived ease of use on a 5-point scale slightly higher than participants using the text only model (Figure 5), but this difference was not statistically significant. The control variables were initially added in the MANCOVA analysis done by the SPSS package (Figure 6). In both cases the covariates did not affect the dependent scores significantly, suggesting that prior experience with modeling method and prior domain knowledge had no significant effect on the results of the experiment. Thus, the control variables were excluded from the final analysis. High values of Eta squared η² were observed (η² > .171) in Figure 6 indicating large treatment effect sizes according to Cohen’s definition of effect size (Cohen, 1988).

Pairwise comparisons followed the MANOVA analysis to determine to which DV the observed difference between the three treatments could be attributed. Results of Pairwise comparisons are provided in Figure 7. For the comprehension task, Figure 7 shows that the groups that received a text with diagram use case model (simple or detailed) scored significantly higher than the text only group in both cases (ATM&HSS) and took less time to solve the multiple choice questions than did the text only group for both cases. These results support both hypotheses H1A & H1B and suggest people viewing models created with text accompanied with diagram gain higher level of comprehension of system requirements than participants viewing a model with text description only, which might indicate that the diagram has aided people to understand, and that two representations are better than one.

Figure 4. Descriptive statistics for dependent variables of both cases (ATM & HSS)

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For the verification task, the results in Figure 7 for hypotheses H1C and H1D did not show significant differences between the text with diagram and text only groups with respect to deep understanding. Thus, there is insufficient support for hypotheses H1C and H1D.

The same results in both cases might indicate higher complexity of the verification task, which demand finding any inconsistencies between the presented model and what the participants understood after scanning the original model that show the correct system functionality. Complex tasks usually require more background knowledge in both the domain under study and the method used to model the domain, to be accomplished. As mentioned in Section 4.1, prior knowledge is determined by the extent of schema acquisition, as well
as the degree to which these schemas contain specific information on domain typical problem solutions. These results are consistent with the outcome of Tables 2 and 3, which suggests consistently low level domain and modeling method knowledge among the participants, and might explain why there were small and not statistically significant differences in their performance in the (deep understanding) verification task. For hypotheses H2A, H2B, H2C and H2D, we expected that subjects who received a text with simple diagram use case model would have higher comprehension and verification task performance than individuals who received a text with detailed diagram. The results in Figure 7 show no statistically significant differences in performance between simple and detailed diagrams groups and there is thus insufficient support for hypotheses H2A, H2B, H2C and H2D. However, given the small effect sizes compared with the effect of providing diagrams versus text only (H1A and H1B), there is not much evidence to suggest that the provision of more detailed diagrams would be worth the extra effort in our case. Judging from the effect sizes, both text with simple and text with detailed diagram provide more or less the same (and statistically significant) benefits over text only use case models. There might be many explanations for these results, but it is possible that the manipulation of the difference between the two types of diagrams in the models was not strong enough, or that the effects are moderated by the prior knowledge of the participants.

7. THREATS TO VALIDITY

The better scores of correct answers with less time taken to answer them observed in the comprehension test could not be attributed to difference in the material content or to the characteristics of the participants in the three groups. The similar results observed across two cases support the internal validity of the results. Participants’ apprehension effect which may threat the internal validity was minimized by reducing the interaction between the researcher and the participants and eliminating the interaction between participants. The order
of presenting the cases was alternated to reduce any possible order bias.

To reduce the threats to statistical conclusions validity, the experimental design contributed in minimizing the impact of violations in the assumptions underlying statistical procedures by utilizing a balanced, independent, randomized design, with equal group’s sizes. Meeting the mathematical assumptions underlying the MANOVA analysis is necessary before making inferences from the experiment results. Normal distribution for each dependent variable in each group separately was verified using graphical and non graphical tests. Other tests to ensure no violation of the MANOVA assumptions were also done including check of homogenous co-variance matrices (Box’s M), (Levene’s test) of homogeneity of Covariance and (Bartlett-Box) homogeneity of variance which are produced automatically in the MANOVA procedure with the statistical program for Social Sciences (SPSS).

Normality tests included: Wilks-Shapiro, Skewness & Kurtosis, Kolmogorov- Smirnov test, Histogram, and Q-Q plot. From this analysis we concluded that the dependent variables in the study are not significantly different from normal.

As common in most software engineering experiments, there are some important threats to construct validity. The focus of this study was to investigate the product of understanding which is the cognitive model that an individual has developed as a result of viewing the diagram or description. Since the product is cognitive, it cannot be adequately observed directly. For this reason, participants are asked a set of performance tests, to obtain a picture of the product that each participant has developed cognitively. The extent to which the dependent variables from these tests reflect the cognitive processes (shallow and deep understanding) in individuals with different experiences, cognitive abilities, and levels of motivation is unknown. Furthermore, our moderator variables of prior knowledge of domain and the modeling method are quite subjective and have not been formally validated in information systems research as “valid” measures of experience.

Regarding the external validity, this study uses relatively small cases to enable students to complete the required tasks in a time reasonable for the study. We can not claim that the results could be extended to real world problems. However, this does not discount the differences observed, but might limit the extension of the results to more complex domains. The strong emphasis in this study on existing theories that support our hypotheses partially counters this threat. In regard to our subject’s sample, as mentioned in Section 5.2, we consider undergraduate students to be appropriate representatives of “novice users”, which was our target population.

8. CONCLUSION

This paper focused on studying the usefulness of different representations of use cases in communicating requirements between software developers and novice users, by combining theoretical considerations and a controlled experiment. The objective of this study was both to evaluate alternative formats of use case models, to determine which format performs better with respect to individual’s performance differences, and to understand why these differences occur. To explain “why” requires theory of how the characteristics of a modeling technique affect the understanding of individuals viewing the model. We adopted cognitive theories of learning from diagram and text, and complex information processing to explain why the differences between different formats of use case models can have impact in the actual use of models. We observed that evaluation of use case models understandability can be based on cognitive theories to provide predictions on possible differences and how to test them. The lack of theory to drive empirical tests of conceptual modeling methods has long been noted as a difficulty in advancing research in this area. This study is unique in two aspects. Firstly, it made
comparison between the comprehensibility of use case models which contained text accompanied by simple diagram with the detailed complicated diagram in order to enhance the communication between the system developers and the novice users. Secondly, it demonstrated the use of semantic verification test with use cases in software engineering research.

The experimental results confirm the hypotheses generated through the analysis based on the cognitive theory of multimedia learning. The study indicates that supporting the text description of a use case model with diagram provides for better comprehension of the model semantics, as substantiated by the higher comprehension accuracy results and less time taken to complete the comprehension task. This suggests that when the use cases are applied in requirements analysis, the use of a model that comprises a use case diagram might be preferable. This is particularly important for practitioners, as they need often to choose which technique to use in requirements gathering with little or no comparative information on their performance (Gemino & Wand, 2003).

The impact of the degree of the details of the diagrams is, however, still an open question, as our results were inconclusive in this regard. We thus suggest that future experiments attempt to increase the difference in degrees of details between the diagrams. In future research we will investigate more experienced subjects to assess the effect of expertise on model comprehension and verification performance for both simple and detailed diagrams.

Considering that the requirement specification process must support effective communication between stakeholders (Holtzblatt & Beyer, 1995) and the fact that one of the major reasons of failure of software systems projects is faulty or incomplete requirements (Damian et al., 2006), it is important to ensure the effectiveness of use case models that support communication between users and developers and facilitate early detection and correction of system development errors.

REFERENCES


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APPENDIX A

A.1 Pre-test questions (knowledge of method)

- Prior use of analysis methods.

Have you ever used Use Cases to model a business organization? Y/N

- Familiarity with analysis methods.

For how many months have you been familiar with Use Case Models? ( )

- Competence with Use Case models (Text/Diagram)

  ○ Very weak ○ Weak ○ Average ○ Good ○ Very good

- Confidence in Use Case models (Text/Diagram)

  ○ Very Low ○ Low ○ Average ○ High ○ Very high

A.2 Pre-test questions (knowledge of domain - ATM)

Please indicate your level of knowledge of the following businesses:
Using Automated Teller Machine (ATM)

  ○ Never ○ Occasionally ○ Sometimes ○ Frequently ○ Very frequently

Please indicate which of the activities listed below you have done: (circle Y/N as appropriate)

- Withdraw cash Y/N
- Deposit Funds Y/N
- Transfer money between accounts Y/N
- Pay Bills Y/N
- Print balance statement Y/N

APPENDIX B

A simulation of an Automated Teller Machine (ATM)

"Withdraw Cash" Use Case

("A customer withdraws cash from the ATM system")

Primary Actor: Customer

Goal in Context: The ATM enables authorized customer to successfully withdraw money from his/her account

Scope: ATM system
Stakeholders and Interests:
Customer – wants to withdraw cash money
Bank – maintains customers information

Precondition:
The ATM is in service
The customer have been successfully identified and authenticated
The customer has at least one active account

Success Guarantees: Customer determined amount of funds successfully withdrawn

Trigger: Customer inserts card

Main Success Scenario:

1. This use case starts when the system authenticates the user by entering his/her card through the card reader slot and then asks the user to enter his/her PIN.
2. The system prompts the customer to select one of the following transactions
   - Withdraw Cash
   - Deposit cash/check
   - Transfer Funds
   - Pay Bills
   - Print Statement
3. The customer selects the withdraw cash option
4. The system prompts the customer to select one of the following accounts
   - Checking Account
   - Savings Account
   - Credit Margin Account
5. The customer selects an account
6. The system prompts the customer to enter an amount
7. The customer enters an amount and notifies the bank
8. The system verifies that the customer has sufficient funds to satisfy the request
9. The system ensures that the request amount does not exceed the ATM daily withdrawal maximum
10. The system notifies the customer if he/she wants to perform another transaction
11. The customer selects not to perform another transaction
12. The system returns the card to the customer
13. the customer takes the card
14. The system dispenses cash to the customer
15. The customer takes cash
16. The system prints a receipt
17. The customer takes the receipt
18. The Use Case ends

Extensions:

1a. Card can not be read due to improper insertion or damaged strip: card ejected and use case terminate in failure.
1b. More than two invalid PIN entries: session is aborted, card is retained, and use case terminates in failure
8a. Insufficient funds - There is not enough money in the customer account to provide the customer with the requested amount: Customer is informed and asked to enter a different amount. Use Case continues.
   - ATM system Balance Too Low – There is not enough money in the ATM system to provide the customer with the requested amount: Use Case terminates into failure.
   - Special Requirement 1: Currency – The system shall provide cash only in US Currency.
   - Special Requirements 2: Currency Unit – The system shall provide cash amount in multiple of 20 Dollar bills.

**Post condition:** The amount withdrawn by the customer is subtracted from the customer account balance

**APPENDIX C**

Example of the multiple choice questions of the ATM case (Comprehension test)

A bank customer can make the following transactions

- Withdraw cash, deposit funds, pay bills, print balance statement, and print receipt
- Withdraw cash, deposit check, transfer money, balance inquiry, start and stop ATM service
- Withdraw and deposit cash, transfer money and print balance statement
- Withdraw cash, deposit cash/check, transfer funds, pay bills, and print balance statement

**APPENDIX D**

Post-test questions (ease of interpretation)

1. I believe that it was easy for me to understand what the Use Case model was trying to model  1-5
2. Overall, I believe that the Use Case model was easy to use  1-5
3. Learning how to read the Use Case model was easy for me  1-5
4. Using the Use Case model was often frustrating  1-5