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How Prior Knowledge Affects User's Understanding of System Requirements?

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Abstract**—**Requirements are critical to system validation as they guide all subsequent stages of systems development. Inadequately specified requirements generate systems that require major revisions or cause system failure entirely. Use Cases have become the main vehicle for requirements capture in many current Object Oriented (OO) development methodologies, and a means for developers to communicate with different stakeholders. In this paper we present the results of a laboratory experiment that explored whether different types of use case format are equally effective in facilitating high knowledge user's understanding. Results showed that the provision of diagrams along with the textual use case descriptions significantly improved user comprehension of system requirements in both familiar and unfamiliar application domains. However, when comparing groups that received models of textual description accompanied with diagrams of different level of details (simple and detailed) we found no significant difference in performance.

Keywords**—**Prior knowledge, Requirement specification, Use case format, User understanding.

I. Introduction

In early stages of software development, the quality of requirements analysis is of great importance to the later phases of software development. High quality of a requirements model can most likely reduce many potential errors occurred in later phases of software development.

The Unified Modeling Language (UML) has become a standard modeling language in software development [1]. UML is not a methodology but a set of tools that enables developers to document and describe projects in a standardized way. It offers a set of diagrams grouped in two major categories: structure diagrams and behavior diagrams. Use cases and use case diagrams are one of the key concepts in the Unified Modeling Language (UML), where they are intended to help engineers in modeling user requirements. Use cases provide an inventory of the kinds of interactions that could occur between users and a system, thus providing a forum for domain experts, end users, and developers to communicate with one another [2]. However, the use case approach has been controversial. Rosenberg and Scott [3] stressed that one of the early steps in object modeling is building a use case model. Kulak and Guiney [4] argued that use cases are the drivers for the rest of UML diagrams. Maciaszek [5] stated that use case models are the most important specification techniques in object oriented analysis. On the other hand, Krogstie [6] questioned the domain appropriateness of use cases. Furthermore, critics note that the format of Use Case Narratives is not part of the UML specifications. Issues concerning use case format and level of detail are still unclear and debatable. Dobing and Parsons [7] highlighted issues concerning the degree of variety in the level of abstraction of use cases and the ideas of use cases facilitating communication and requirements verification with users. They identified several problems with both the application and the theoretical underpinnings of use cases. Though, very few studies have empirically investigated the role of use cases in software requirements analysis, in particular with regards to its usefulness as a communication tool between stakeholders to verify system's functional requirements.

Most requirements models given by use cases consist of two parts. One is a diagram part and the other is a textual description. Use case *diagram* is an abstract, high-level view of functionality, but the diagram does not specify the interactions *within* the use cases. Fig. 1 shows an example UML use case diagram. The diagram shows use cases names, actors, relationships between actors and use cases, and relationships between use cases.

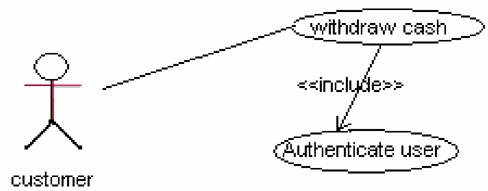

Fig. 1 A Use Case diagram

The textual description part presents the description of interactions between a system and actors in its environment. However, little attention has been paid to the role of UML diagrams in supporting user's understanding when accompanying the text. Although the literature is overflowing with work investigating the effects of pictures on facilitating text comprehension, no empirical work has investigated the cognitive processes underlying the understanding of Use Case models.

This study investigates the issue of the effect of people's prior knowledge in use case scenarios and use case diagram on

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understanding use case model; whether different use case formats are equally effective in facilitating user understanding, and whether users' prior knowledge of the modeling method affects their ability to benefit from visualization. To accomplish this, we have chosen to consider an intra-grammar comparison [8] of three informationally equivalent formats of Use Case models. In one format, a *text* description only is used. In the other two formats, *text with diagrams* of different levels of detail is used. We use theories from cognitive psychology to suggest ***why*** using the diagrams with the text might matter when users interact with actual models, and why a detailed diagram may be more useful for high knowledge users.

The remainder of this paper is organized as follows. Section 2 provides 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 the hypotheses is described in Section 3 and results are presented in Section 4. Section 5 discusses the threats to the validity of the study. Finally, conclusions from the study are presented in Section 6.

II. Cognitive Considerations and Hypotheses

A. Theories of Text and Picture Comprehension

The use case model under consideration comprises both a diagram and text. The diagram itself comprises both graphic symbols and text. Thus, the model can be considered as a *multimedia* presentation. Many researchers argued that the contribution of illustrations to the beneficial effects of multimedia is attributed to the construction of the mental model of the situation described in the text [9],[10],[11],[12]. Diagrams, then, can make important aspects of information salient and facilitate perceptual parsing and inference through directing attention to key components that are essential for different stages of learning [13]. Winn [14] contend that graphics make structures and processes in the text traceable and thus more easily understood. Each ***element*** represents an item or a value and the relationships among them are more obvious to the viewer. The roles of explanatory diagrams are to facilitate the comprehension and learning of processes where sequence is important or when learning complex sets of interrelationships among concepts. The advantages of diagrams therefore appear to stem from the way in which they make interrelationships explicit. In his *cognitive theory of multimedia learning*, Mayer [15], [16] follows the basic idea of Paivio [17], who assumes that the human cognitive system includes a verbal and pictorial (image) subsystem. Based on the working memory model of Baddeley [18], Mayer also accepts that two sensory subsystems exist in working memory: an auditory system and a visual system. His first basic assumption on multimedia learning merges these two concepts. Humans are supposed to process information in working memory through two channels: an auditory-verbal channel and a visual-pictorial channel. The second basic assumption is that humans are active sense-makers: they engage in active cognitive processing to construct coherent knowledge structures from both the available external information and their prior knowledge. According to Mayer, active learning from multimedia occurs when learners engage in active cognitive processing including paying attention to relevant incoming words and pictures, mentally organize them into coherent verbal and pictorial representations, and mentally integrate verbal and pictorial representations with each other and with prior knowledge in long term memory [15],[16],[19]. These construction processes are based on the activation of cognitive schemata in long term memory, which have both a selective and an organizing function. Sweller [20] defined schema or combinations of elements as the cognitive structures that make up an individual's knowledge base. For learners, the possibility of being able to *interact* with multimedia representations in ways not possible with single media can lead to easier learning, better understanding, and increased motivation [15] ,[21].

In summary, existing theories suggest that different forms of visualizations will lead to different understanding of the learners and also to different patterns of performance, when individuals have to solve tasks after learning on the basis of their previously gained knowledge. From the above discussion we propose the following research question:

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 format, *text only* or *text accompanied with diagram* better support user understanding of the domain requirements?

On the basis of existing theories we hypothesize that using a diagram to accompany the text descriptions in a use case model may improve viewers understanding of what the suggested software would do, specifically as it focuses their attention on the functions that the system would provide and make the relationships among model elements more obvious. Two representations of the domain may help the viewer to use one to aid his understanding of the other and integrate both sources to reach better understanding of the domain. Therefore, we hypothesize that:

High knowledge users who receive a use case model consisting of both diagrams and text will develop a higher level of understanding of the system requirements faster than will individuals who receive a use case model consisting only of text.

B. Cognitive Load Theory

The cognitive load theory (CLT) is considered a major theory of cognitive architecture and learning [19]. The CLT is based on the assumption that working memory has a limited capacity [22] which interacts with long term memory to form the basis of intellectual skills [23],[30](see Fig. 2).

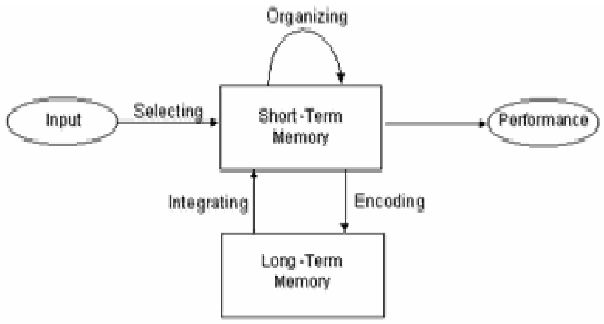


Fig. 2 An information processing model (Mayer, 1989)

It further suggests that human ability to learn is determined by our ability to reduce the burden (load) on working memory by acquiring and using schema which aids in automatic processing of information. Schema is a cognitive construct that defines how working memory organizes related elements of information as one chunk for processing with long term memory. Working memory has a capacity to process limited chunks of information at any given time [22], so schema allows more elements to be processed by combining multiple elements as one chunk. Schema acquisition is based on prior experiences and knowledge that allows individuals to create and store schema in long term memory.

Number of elements in a model increases intrinsic cognitive load since more cognitive resources are needed to process the interactive elements with schema stored in long term memory [24]. The interactivity of these elements consumes additional cognitive resources as schema is developed using the related elements. However, prior experiences and knowledge reduce intrinsic cognitive load. Experts familiar with the material may be able to group informational units into one element whereas novices not familiar with the information will need to process the informational units as several independent elements and consume more cognitive resources. Our second research question is:

Research Question(2): How does the degree of detail in a UML diagram that accompanies text in a use case model affect user understanding of the domain requirements?.

A detailed diagram of a use case model contains more interactive elements (use cases, actors, relationships) than a simple diagram. However, high knowledge users of use cases have previously developed cognitive schemata that incorporate the interacting elements. Therefore, we hypothesize that:

High knowledge users in use cases who receive a use case model consisting of text and a detailed diagram will develop a higher level of understanding of the system requirements faster than will users who receive a use case model consisting of text and a simple diagram.

III. METHOD

An experimental procedure was designed to evaluate the research hypotheses.

A. Experimental Design

The hypotheses were tested using a 3x2 factorial between-subject, randomized experiment design. The ***independent variable*** was the use case representation method and had 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) and a home security system (HSS). Two cases were used to strengthen the external validity of the comparison between the use case model formats.

The ***dependent variable*** was the level of user understanding of the use case model being presented in the treatments. In this study, we distinguish between the *process* and *product* of understanding. The process refers to the activities a user engages in to understand the domain. Following past studies [25], [26], we study one aspect of this process; the user's *ease of understanding the domain*. A post-test was conducted for measuring the perceived ease of interpretation. We used the scale adapted by Gemino and Wand [25] from the ease of use scale developed by Moore and Benbasat [27]. For the *product* of understanding, which is the main focus in this study, we distinguish between *surface understanding* and *deep understanding*. Surface understanding reflects the understanding of the domain elements, whereas deep understanding concerns the understanding of the actual relationships among elements and how to apply the understanding in solving problems [16]. A comprehension test is used to assess surface understanding and a verification test to assess deep understanding. Our comprehension test consisted of 12 multiple choice questions that tested the comprehension of explicit system functionality (see Appendix C). The verification test asked the subjects to identify any inconsistencies between a given model (that was seeded with such faults) (8 faults) and their knowledge of the system requirements gained from the comprehension task, and to explain why they think these are incorrect or inconsistent. Times taken to complete tasks are an objective measure often used to indicate the degree of difficulty or complexity in using a method [28]. Thus, in addition to correctness, time taken to complete the experimental tasks 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. 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 [29].

The study distinguishes between two *dimensions* of performance:

***Effectiveness*:** how well the model is understood, as reflected by the number of total correct answers in the comprehension and verification tasks, respectively.

***Efficiency*:** the effort required to understand the model, as reflected by the time taken to perform the comprehension and verification tasks, respectively.

Thus, there are four dependent variables in this study:
D1: comprehension effectiveness
D2: comprehension efficiency
D3: verification effectiveness
D4: verification efficiency

Hypothesis (1): Individuals who received a text with diagram Use Case model will develop higher level of understanding of the system requirements faster than individuals who received the text without diagram.

Predictions:
H1A: Participants using *text with diagram* model will perform the comprehension task more accurately than participants using *text* only.
H1B: Participants using *text with diagram* model will perform the comprehension task faster than participants using *text* only.
H1C: Participants using *text with diagram* model perform the verification task more accurately than participants using *text* only.
H1D: Participants using *text with diagram* model will perform the verification task faster than participants using *text* only.

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

Predictions:
H2A: Participants using *text with detailed diagram* model will perform the comprehension task more accurately than participants using *text with simple diagram*.
H2B: Participants using *text with detailed diagram* model will perform the comprehension task faster than participants using *text with simple diagram*.
H2C: Participants using *text with detailed* diagram model will perform the verification task more accurately than participants using *text with simple diagram*.
H2D: Participants using *text with detailed diagram* model will perform the verification task faster than participants using *text with simple diagram.*

B. Additional Dependent and Control Variables

A paper-and-pencil 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). These questions were used to create scale variables for the level of experience with modeling methods, and the level of knowledge of the modeled domains. The scale variables were used as covariates in an MANCOVA analysis. As well, a post-test was conducted for measuring a perceived ease of interpretation (Appendix E).

C. Participants

The participants were 30 members of the 'Faculty of Computer Science and Information Systems' at the University of Technology in Malaysia (17 females and 13 males). Their amount of experience with Use case modeling ranges between 2-10 years. This experience is obtained from teaching the subject for Software Engineering Department students in the Faculty, workshops, and training courses. Subjects were randomly assigned to three groups of 10 persons each corresponding to three experimental conditions (*text with simple diagram*, *text with detailed diagram*, *text only*). The experiment was monitored to assure individuals completed the tests independently.

D. Materials and Procedure

Each participant first received a closed envelope that contained the paper materials, including a pre-test questionnaire, use case models, instructions for computerized tests and a post-test questionnaire. Participant who received a model with a diagram, also received a one page of description outlining the symbols used in the diagram.

The procedure began with a pencil-and-paper pre-test (Appendix A) to rate the subjects experience with use case modeling and their knowledge of the two case domains. Each subject then completed two cases (ATM) system and Home security system (HSS) in computerized tests. For each case, the 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 (see Fig.3). (Appendix D) shows one of the detailed diagrams in this experiment, which included main use cases, include and extend relationships to finer-granularity use cases for the ATM case. A related textual description is provided in (Appendix B). The order in which subjects started the two case domains was counter-balanced to control for any learning between the two domains. The sequence of tasks was applied in a particular order to ensure internal validity of the experiment. First, subjects completed the multiple choice comprehension questions, with the correct models available. This serves to assure that the subjects scanned the whole models so they would be ready for the next test. The correct models were removed after the comprehension test of each case. This ensured that the information available to the participant is the cognitive model developed earlier by viewing the original, correct model. Then the participants received a new model that contained eight inconsistencies and completed the verification task. 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 E).

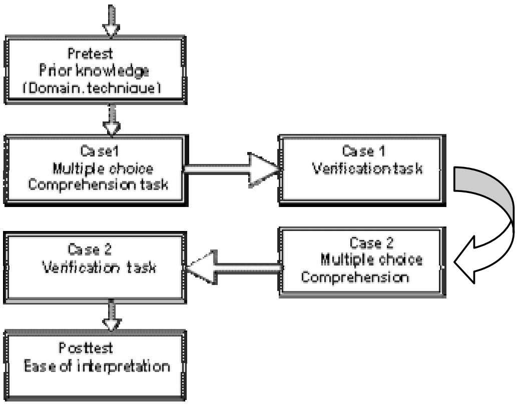


Fig. 3 An Overview of empirical procedures

IV. Results and Analyses

The hypotheses were tested using multivariate analysis of covariance (MANCOVA). A *priori* analysis was conducted to determine the effect size Eta square (η^2 >0.06), power = 0.8, alpha level (α = 0.05) according to Cohen's standards of statistical analysis [31]. Two covariates were used in the analysis: (1) Knowledge of use case model (*KMETHOD*) and (2) domain knowledge (*KDOMAIN* for the two cases ATM and HSS, respectively). These measures were collected in the pre-test. An ANOVA analysis to compare the three treatments for the two covariates is shown in Table I.

TABLE I
ANOVA Results of Control Variables and Ease of Interpretation

Scale variable		Mean	SD	ANOVA Results F	Sig.
Domain knowledge (ATM case)	Text	-.4714	2.1946	.698	.507
	Text+ simple diagram	2.788E-02	1.7349		
	Text+ detailed diagram	.4435	1.0949		
Domain knowledge (HSS case)	Text	-5.10E-02	.9685	.529	.595
	Text+ simple diagram	-.2042	1.1862		
	Text+ detailed diagram	.2552	.8693		
Use case method (method)	Text	-.2381	2.0319	.126	.882
	Text+ simple diagram	3.662E-02	1.5972		
	Text+ detailed diagram	.2015	2.2415		
Ease of use (ease)	Text	-.6559	3.0473	.387	.683
	Text+ simple diagram	.5376	1.7328		
	Text+ detailed diagram	.1183	4.0169		

Another factor may have been the layout of the model or the ease with which the model could be interpreted. For this reason, the post-test was used to collect *perceived ease of use*. Participants using the text with diagram models rated their perceived ease of use slightly higher than participants using the text only model (Table I). However, this difference was not statistically significant. In addition, no significant differences in knowledge of use case models or in knowledge of either domain were observed between the three treatment groups. The MANOVA analysis between the treatment groups (Table II) is made after considering the effect of the intervening variables. In both cases, and for all treatments, 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. Also, in Table II, the values of Eta square (η^2 >.34) indicate large treatment effect sizes according to Cohen's definition of effect size [31].

TABLE II
MANCOVA Analysis of Two Cases (ATM &HSS)

		ATM Case				HSS Case			
Effect		F	Sig.	Eta Squared	Observed Power[a]	F	Sig.	Eta Squared	Observed Power[a]
TREAT	Pillai's Trace	4.414	.001	.434	.989	2.975	.009	.341	.919
	Wilks' Lambda	5.506	.000	.500	.998	3.023	.009	.355	.921
	Hotelling's Trace	6.644	.000	.559	1.000	3.057	.008	.368	.922
	Roy's Largest Root	13.383	.000	.699	1.000	5.191	.004	.474	.927
KDOM	Pillai's Trace	.997	.430	.153	.263	1.774	.170	.244	.453
	Wilks' Lambda	.997	.430	.153	.263	1.774	.170	.244	.453
	Hotelling's Trace	.997	.430	.153	.263	1.774	.170	.244	.453
	Roy's Largest Root	.997	.430	.153	.263	1.774	.170	.244	.453
KMETHOD	Pillai's Trace	.812	.531	.129	.218	.394	.811	.067	.123
	Wilks' Lambda	.812	.531	.129	.218	.394	.811	.067	.123
	Hotelling's Trace	.812	.531	.129	.218	.394	.811	.067	.123
	Roy's Largest Root	.812	.531	.129	.218	.394	.811	.067	.123

Computed using alpha = .05

Because MANOVA does not show to which dependent variable the difference between the three treatments could be attributed, results for the hypotheses are provided in pairwise comparisons in Table III.

(Hypothesis 1):
For the comprehension task, H1A hypothesized a higher number of correct answers of multiple choice questions for the text with diagram models. For both cases (ATM and HSS), the group that received a text with simple diagram use case model scored significantly higher than the text only group, while the group that received a text with detailed diagram had marginally significant higher scores in the (HSS) case.

TABLE III
Pairwise Comparisons

			ATM Case		HSS Case	
Dependent variable	(I) number of treatment	(J) number of treatment	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.
Total correct answers in comprehension test	text	text+ simple diagram	-.827*	.047	-1.927*	.008
		text+ detailed diagram	-.139	.733	-1.356	.055
	text+ simple diagram	text+ detailed diagram	-.688	.094	.571	.409
Total time for comprehension test	text	text+ simple diagram	2.585 *	.024	4.432*	.039
		text+ detailed diagram	3.520 *	.004	3.699	.082
	text+ simple diagram	text+ detailed diagram	.935	.390	-.733	.725
Total correct answers in consistency test	text	text+ simple diagram	-.921	.238	-.310	.629
		text+ detailed diagram	-.122	.877	-1.457 *	.031
	text+ simple diagram	text+ detailed diagram	.799	.303	-1.147	.087
Total time for consistency test	text	text+ simple diagram	-4.028 *	.034	-2.817*	.039
		text+ detailed diagram	-5.693 *	.005	-7.887E-02	.952
	text+ simple diagram	text+ detailed diagram	-1.665	.361	-2.896 *	.037

* The mean difference is significant at the .05 level

For the same task, H1B hypothesized less time needed to solve the multiple choice questions for the text with diagrams groups. Results in Table III confirm that the text with diagram groups spent significantly less time than did the text only group for both cases (ATM and HSS),although the text with detailed diagram group scored marginally significant in the (HSS) case.

Overall, these results support both hypotheses H1A& H1B and suggest people viewing models created with text accompanied with diagram gain higher level of comprehension of how the system works 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.

H1C hypothesized that participants using *text with diagram* model will perform the verification task more accurately than those using a *text only* model. Table III shows insufficient support for hypotheses H1C. This result and the low level of scores obtained among the three treatment groups 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 showed the correct system functionality. Verification is probably a much more complex task than comprehension, so a possible cause might be the experiment suffers from a "floor effect", which may have biased the results. This means that the verification task was just too complex to learn from the presented material. Consequently, we were not able to find differential effects of different formats.

H1D hypothesized less time needed to solve the verification task for the *text with diagrams* groups than the *text only* group. Results in Table III did not support this prediction. A plausible reason is that the inconsistencies in the models with diagrams were distributed both in the text and the diagram, therefore, finding them may take longer time than when they are in the text only.

(Hypothesis 2)

For hypotheses H2A, H2B, H2C and H2D, we expected that subjects who received a text with detailed diagram use case model would have higher comprehension and verification task performance than individuals who received a text with simple diagram. The results in Table III show no statistically significant differences in performance between simple and detailed diagrams and there is thus insufficient support for hypotheses H2A, H2B, H2C and H2D. There might be many explanations for these results, but it is possible that we might have needed a larger sample size to detect a difference between the groups or that the manipulation of the difference between the two types of diagrams in the models was not strong enough.

V. Threats to Validity

The similar results observed across two separate cases lend further credibility to the internal validity of the results. The analysis confirms our original proposition, suggesting that a use case model consists of a text description with a diagram has advantages over models using only text description use cases with respect to understanding the functional requirements of the suggested software system. This is important as our understanding of how people ''learn'' from use case models may impact how these models are designed.

The most common threats to *statistical conclusion validity* include violations of the assumptions underlying statistical procedures, low statistical power, and low effect size. To reduce any impact of violations in the assumptions, our design of a randomized experiment with equal group size helped eliminate these impacts. Before making inferences from this test, all MANCOVA assumptions were verified. Normality for each dependent variable was tested in each group separately using graphical and non graphical tests. Several tests used for homogenous covariance matrices (Box's M), (Levene's test) and (Bartlett- sphericity) test of homogeneity of variance which are produced automatically in the MANCOVA procedure with the statistical program for Social Sciences (SPSS) that is used for the analysis of this experiment. Normality non graphical tests included: Wilks-Shapiro, Skewness & kurtosis, Kolmogorov- Simirnov test, graphical tests included Histogram, and Q-Q plot. From this analysis we concluded that the dependent variables in the study are not significantly and consistently different from normal.

With regards to *external validity*, the complexity of the cases had to be limited for practical reasons. The cases were selected to be small enough to understand in a time reasonable for the study. The results therefore, may not be extended to real world problems that are extremely complex. However, the fact that the cases are not as complex as those in the real world, does not discount the differences observed, but might limit the extension of the results to more complex situations. Our strong emphasis on existing theories that support our hypotheses partially counters this threat. Future work may seek to verify the results for larger and more complex cases.

VI. Conclusion

This study aimed to investigate the usefulness of different representations of use cases as a communication tool between software developers and users of high prior knowledge with this modeling technique. We used theories from cognitive psychology to explain *why* the characteristics of a presentation model affect the understanding of individuals viewing the model. The focus of theory may improve our ability to design and refine effective modeling techniques. It would be useful in practice if modelers could create use case models that convey accurate information and convey it in an easy to understand manner. However, research is not sufficiently advanced to inform practitioners about the most effective way to achieve both of these aims. The results provided by the experiment indicate that 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. It confirms our original proposition, suggesting that a use case model consists of a text description with a diagram aids users with respect to understanding the functional requirements of the suggested software system. However, because the sample in our experiment was small, some of our insignificant results particularly in the deep understanding test might reflect Type 2 error. A future study could be run in which a larger sample is used to detect any possible differences that result from increasing the level of detail of use case diagrams. Another possible reason for the failure to find differential effect depending on the levels of element interactivity may have been the differences between low (simple) and high (detailed) element interactivity diagrams were not substantial enough.

APPENDICES

(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 years have you been familiar with Use Cases?
( ) (please put number between brackets)

• *Competence with Use Case models (Text/Diagram)*
○ Very weak ○ Weak ○ Average ○ Good ○ Very good

• *Confidence in using 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 Y/N
18. The Use Case ends

Y/N

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)

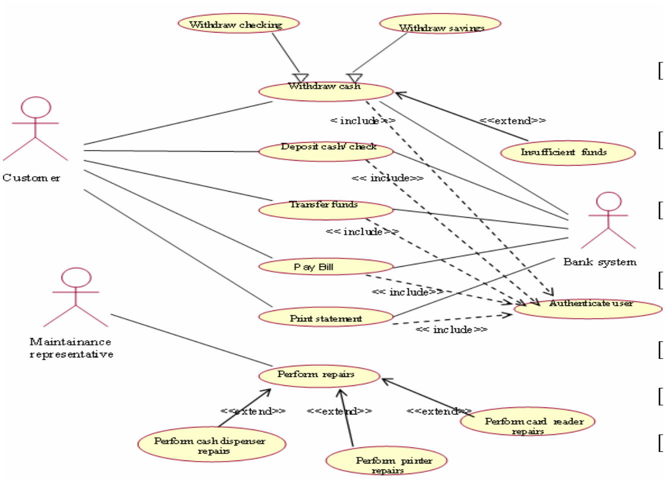
Please select the best answer for the following question:

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) ATM case detailed diagram

(APPENDIX E)



(Appendix E) 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

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REFERENCES

[1] C. Kobryn, "UML 2001: A Standardization Odyssey," Comm. of ACM, vol. 42, no.10, 1999, pp. 29-37.
[2] G. Booch G, J. Rumbaugh J, I. Jacobson, "The unified modeling language user guide," Addison-Wesley, Reading, 1999.
[3] D. Rosenberg, K. Scott "Use case driven object modeling with UML: a practical approach," Addison-Wesley, Reading, 1999.
[4] D. Kulak D, E. Guiney, "Use cases—requirements in context," Addison Wesley, Reading, 2000.
[5] L. A. Maciaszek, "Requirements analysis and system design, Developing information systems with UML,". Addison- Wesley, Reading, 2001.
[6] J. Krogstie, "Using a semiotic framework to evaluate UML for the development of models of high quality", In Siau K, Haplin T (eds) Unified modeling language: systems analysis, design, and development issues. Idea Group Puplishing, Hershey, 2000.
[7] B. Dobing, J. Parsons "Understanding the role of use cases in UML: a review and research agenda". J. Database Manag., vol. 11,no. 4, 2000, pp. 28-36.
[8] Y. Wand, R. Weber "Research Commentary: Information systems and Conceptual Modeling- a Research Agenda" Info. Sys. Res. , vol. 13, no. 4, 2002, pp. 363-376.
[9] V. Gyselinck, H. Tardieu, "The role of illustrations in text comprehension: What, when, for whom, and why?" In van Ostendorp, H., and Goldman, S. R. (eds.) Erlbaum, Mahwah,NJ. 1999
[10] W. Schnotz, , T. Rasch, T. "Enabling, Facilitating, and inhibiting effects animation in multimedia learning: why reduction of cognitive load can have negative results on learning," Educ. Tech. Res. and Devel., vol. 53, no. 3, 2005, pp. 47-58.
[11] W. Schnotz, C. Kurschner, "External and internal representations in the acquisition and use of knowledge: visualization effects on mental model construction." Instr. Scie., vol. 36, no. 3, 2008, pp. 175-190.
[12] W. Schnotz, M. Bannert " Construction and interference in learning from multiple representations" Lear. and Instr., vol. 13, 2003, pp. 141-156.
[13] M. Scaife, Y. Rogers, "External Cognition: how do graphical representations work" Int. J. Hum. Comp. Stud., vol. 45, 1996, pp. 185-213.
[14] W. Winn, W. D. Li, "Do diagrams permit more rapid and accurate problem-solving than text?" Paper presented at the annual meeting of the American Educational Research, 1989.
[15] R. Mayer "Multimedia Learning". New York: Cambridge University Press, 2001.
[16] R. Mayer "The Cambridge hand book of multimedia learning,' Cambridge: Cambridge University Press, 2005.
[17] A. Paivio, "Mental representation: A dual coding approach,". New York: Oxford Univ. Press, 1986.
[18] A.D. Baddeley "Working Memory," Oxford: Clarendon Press, 1986.
[19] R. Mayer "Multimedia aids to problem-solving transfer" Int. J. Educ. Res., vol. 31, 1999, pp. 611– 623.
[20] J. Sweller "Cognitive load during problem solving: Effects on learning," Cog. Sci., vol. 12, 1988, pp. 257–285.
[21] P. Cheng, R.K. Lowe, M. Scaife "Cognitive science approaches to understanding diagrammatic representations," Artif. Intell. Rev., vol. 15, 2001, pp. 79-94.
1-5
[22] G. A. Miller " The magical number seven, plus or minus two: Some limits on our capacity for processing information" Psych. Rev., vol. 63, 1956, pp. 81-97.
1-5
[23] J. Sweller, P. Chandler "Why some material is difficult to learn," Cog. and Inst., vol. 12, no. 3, 1994, pp. 185-233.
1-5
[24] J. Van Merrienboer, J. Sweller "Cognitive Load Theory and Complex Learning: Recent Development and Future Directions" Educ. Psych., vol. 17, no. 2, 2005, pp. 147-175.

[25] A. Gemino , Y. Wand "Complexity and clarity in conceptual modeling: Comparison of Mandatory and Optional Properties," Data& Know. Eng., vol. 55, 2005, pp. 301-326.
[26] A. Burton-Jones, P. M. Meso "Conceptualizing Systems for Understanding: An Empirical Test Decomposition Principles in Object-oriented Analysis," Inf. Sys. Res., vol.17, no. 1, 2006, pp. 38- 60.
[27] G. Moore, I. Benbasat "Development of an Instrument to Measure Perceptions of Adopting an Information Technology Innovation" Inf. Sys. Res., vol. 2. no. 3, 1991, pp. 192-222.
[28] F. Bodart, A. Patel, R. Weber "Should optional properties be used in Conceptual Modeling? A theory and three empirical tests " Inf. Sys. Res., vol. 12, no. 4, 2001.
[29] J. Parsons, L. Cole "What Do the Pictures Mean? Guidelines for Experimental Evaluation of Representation Fidelity in Diagrammatical Conceptual Modeling Techniques". Data& Know. Eng., vol. 55, 2005, pp. 327-342.
[30] R. Mayer "Models for Understanding.," Rev. Educ. Res., vol. 59, 1989, pp. 43-64.
[31] J. Cohen "Statistical Power Analysis for the Behavioral Sciences", 2nd edition. Lawrence Erlbaum Assoc Inc, 1988.