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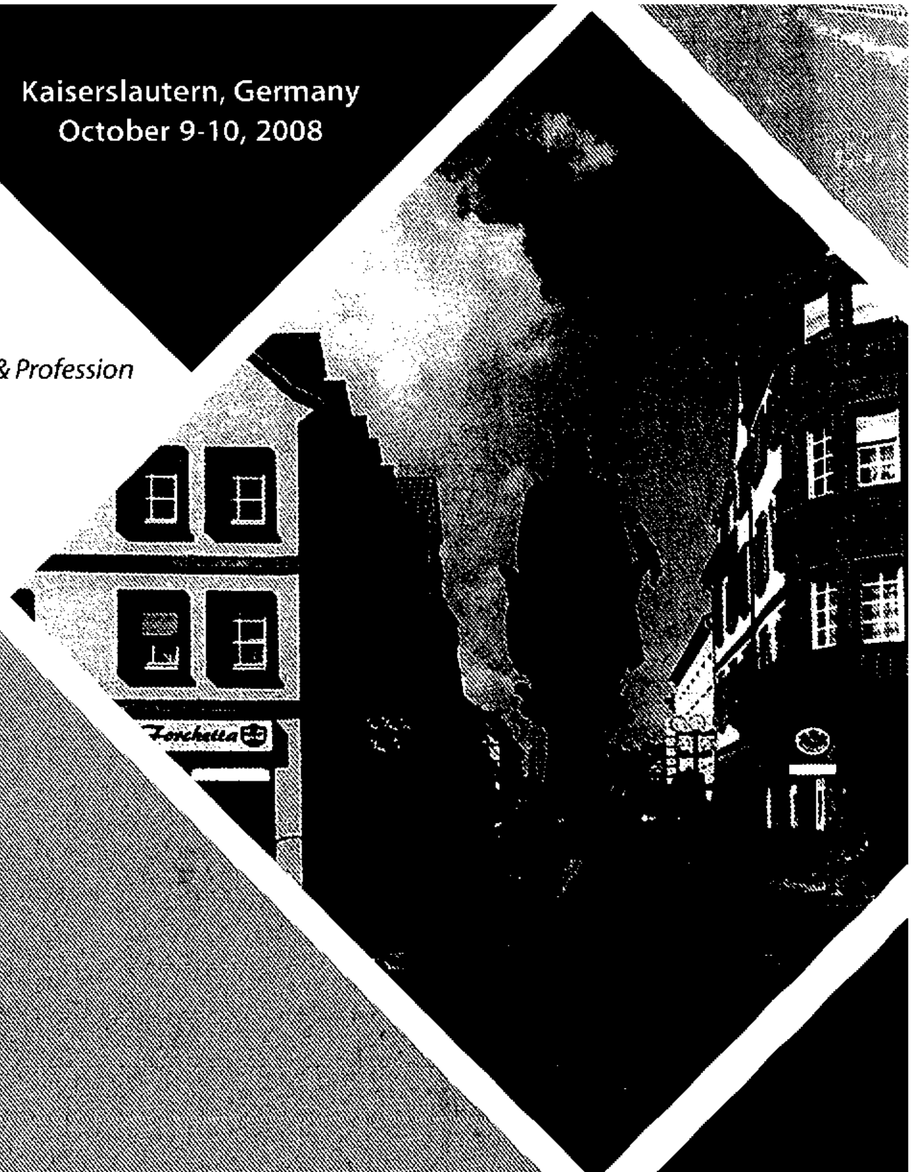

ESEM'08

Proceedings of the 2008 ACM-IEEE International Symposium on

Empirical Software Engineering and Measurement

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The Association for Computing Machinery
2 Penn Plaza, Suite 701
New York, New York 10121-0701

ISBN: 978-1-59593-971-5

Additional copies may be ordered prepaid from:

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ACM Order Number 594087

Printed in the USA

Message from the General Chair

It is my great pleasure to welcome you to the Second International Symposium on Empirical Software Engineering and Measurement (ESEM 2008) in Kaiserslautern, Germany. Empirical software engineering and measurement are important sub-disciplines aimed at advancing software engineering towards an engineering discipline. They focus on measurement in order to better understand, control, and improve software development processes, and on empirical studies to better model products and processes and understand process products.

The 1st ESEM was held in Madrid in September 2007. Although this is only the second ESEM symposium, this series continues the long tradition of two high-quality conference series. ESEM resulted from the merger of the IEEE/ACM International Symposium on Empirical Software Engineering (ISESE) and the IEEE International Software Metrics Symposium (METRICS). ISESE was held five times, first in Japan in 2002 and last in Brazil in 2006. As its name suggests, ISESE's primary goal was to disseminate knowledge on and from experimental research on software engineering. METRICS is a long-standing conference series, which was held first in the United States in 1993 and last in Italy in 2005. METRICS' foremost objective was to disseminate knowledge on and from research on software metrics.

ESEM 2008 is part of the week-long Experimental Software Engineering International Week (ESEIW) in Kaiserslautern, Germany. It is an honor to welcome this conference to Kaiserslautern. Kaiserslautern has evolved into one of the premier centers for software & systems research in Europe. About 800 scientists and engineers – spread across 3 departments of the University of Kaiserslautern and several institutes – are working on advancing the state of the art in our field. The institutes include a Max-Planck Institute on Software Systems, two Fraunhofer Institutes – for Industrial Mathematics (ITWM) and Experimental Software Engineering (IESE) – and the German Research Institute for Artificial Intelligence (DFKI). I invite you to learn more about any of these institutes during your stay.

We have a full two-day program of three parallel tracks on each day including two keynotes, technical papers, short papers, and a panel (please see the message from the Program Chairs for details).

Putting together *ESEM 2008* has been a team effort. First of all, I would like to thank the authors of all submitted papers. Furthermore, I would like to express my gratitude to the program committee and to all external reviewers, who worked very hard on reviewing papers and providing suggestions for their improvements. I would also like to thank Sebastian Elbaum and Jürgen Münch, the program co-chairs Maria Teresa Baldassarre - the short papers chair, and Haruka Nakao - the poster program chair, as well as Andreas Jedlitschka, the treasurer, and Marcus Ciolkowski, the local arrangements chair. Finally, I would like to thank our society sponsor, ACM SIGSOFT, for their continued support of these successful meetings, and our industrial supporters Robert Bosch GmbH and Siemens AG for their financial support for the social events surrounding the conference.

I hope that you will find this program interesting and thought-provoking and that the symposium will provide you with a valuable opportunity to share ideas with other researchers and practitioners from institutions around the world.

Dieter Rombach
ESEM08 General Chair
University of Kaiserslautern & Fraunhofer IESE
Kaiserslautern, Germany

Message from the Program Co-Chairs

We would like to welcome you to Kaiserlautern, Germany, for the Second International Symposium on Empirical Software Engineering and Measurement – ESEM 2008. This year's technical program continues to advance the field of empirical software engineering and metrics with thoroughly reviewed technical papers complemented by two remarkable keynotes and a vibrant panel.

The call for research papers attracted over 100 submissions. To assess these submissions, the program committee members performed over 320 reviews and carried out dozens of online discussions. This process resulted in the selection of 28 papers that form our technical program. The papers cover a variety of topics, ranging from observational studies of programmers to measurement mechanisms for assessing technologies and organizations. In addition to the technical papers, short paper sessions and a poster exhibition will help to provide further coverage of ongoing work.

The keynote speakers and the panel will broaden and enrich the program by providing insights and reflections on our community strengths, weaknesses, and promising research directions. The keynotes will be given by Professor Mary Shaw from Carnegie Mellon University, USA, and Mr. Harald Hönninger, vice-president of Bosch corporate research division. The panel consists of highly renowned experts and promises interesting insights with respect to success stories, lessons learned from failures, and the next frontiers of empirical software engineering.

We would like to thank the authors who provided the content for the program, and to express our sincere gratitude to the program committee members and the external reviewers who volunteered time and resources to make this program possible. We would also like to thank the General Chair, Dieter Rombach, for his support and guidance, and Andreas Jedlitschka and Marcus Ciolkowski for the local organization of this conference and the maintenance of the website.

We hope that you will enjoy this program and that the symposium provides you with a valuable opportunity to share ideas with other researchers and practitioners.

Sebastian Elbaum
Program Co-Chair
University of Nebraska-Lincoln (USA)

Jürgen Münch
Program Co-Chair
Fraunhofer Institute for Experimental Software Engineering (Germany)

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Does the Use of Stereotypes Improve the Comprehension of UML Sequence Diagrams?

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ABSTRACT
This paper reports on a controlled experiment that investigates the influence of stereotypes in UML sequence diagrams. The comprehension of UML sequence diagrams with and without stereotypes is analyzed from three different perspectives: semantic comprehension, retention and transfer. The experiment was carried out with 77 undergraduate students of Computer Science from the University of Bari in Italy. The results obtained show a slight tendency in favor of the use of stereotypes in facilitating the comprehension of UML sequence diagrams. Further replications are needed to obtain more conclusive results.

Categories and Subject Descriptors
D.2.2 [**Software Engineering**]: Design tools and techniques - *object-oriented design methods.*

General Terms
Design, Experimentation.

Keywords
UML sequence diagrams, stereotypes, comprehension, understandability, controlled experiment.

1. INTRODUCTION
Stereotypes are used to clarify or extend the meaning of model elements. However, the most intuitive notations are not always the best performing ones. In recent years, several studies that investigate the use of stereotypes have been conducted in the field of Software Engineering [5, 6]. These studies are focused on investigating the influence of stereotypes on the comprehension of UML class and collaboration diagrams. It is widely recognized that comprehension is one of the main factors to influence maintainability, which must be assessed from the first steps of the software lifecycle.

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In this paper, we present a controlled experiment to assess whether the use of stereotypes improves the comprehension of UML sequence diagrams. Specifically, we consider a set of stereotypes that have been proposed to enrich the semantics of interaction messages in UML sequence diagrams in the context of a Requirements Engineering approach for model-driven software development [3].

The structure of the paper is as follows. The definition of stereotypes for UML sequence diagrams is introduced in Section 2. The description and execution of the experiment is described in Section 3. The data analysis and the interpretation of the experiment results are presented in Section 4. Finally, the conclusions and future research work are presented in Section 5.

2. THE STEREOTYPES
In UML, sequence diagrams are a means to model an aspect of the dynamic behavior of a system. They can be used in the context of the whole system, of a subsystem, or they can be attached to a use case. Some authors indicate that at least one sequence diagram should be drawn per use case.

These diagrams can be used to graphically represent a pattern interaction between objects by sending and receiving messages as time advances. The following set of UML stereotypes has been proposed [3] as a means to enhance the meaning of the object interactions (messages):

- **«signal»** this is a message between an actor and the system. The objective is to describe an interaction between an external entity and the system.
- **«service»** this is a message that updates the state of an object. The properties new/destroy/update can be used if the object is to be created, destroyed or modified.
- **«query»** this is a message to query the state of a specific object or set of objects.
- **«connect»** this is a message which is used to indicate that an object from the sender object type needs to be connected (or related) to an object from the receiver object type.

The goal of these stereotypes is twofold. First, to improve the comprehension of UML sequence diagrams. Second, to give information to the transformation process of UML sequence diagrams into conceptual models following a model-driven development process.

3. EXPERIMENT DESCRIPTION

The goal of this experiment is to assess whether the use of stereotypes improves the understanding of UML sequence diagrams. Therefore, by using the GQM template for goal definition [1], the goal of our experiment is defined as follows: "*Analyze the use of stereotypes for the purpose of evaluating it with respect to the comprehension of UML sequence diagrams from the point of view of the researcher, in the context of fourth year undergraduate students in Computer Science from the University of Bari*".

To run and report this experiment we followed the recommendations provided in [7]. We selected a balanced factorial design with group-interaction confounding.

The experiment was carried out by 77 students who were taking a course in Empirical Software Engineering. The subjects had participated in two Software Engineering courses in which they had acquired training in UML diagrams. In addition, they were taught a three hour lecture about the stereotypes for UML sequence diagrams in a training session organized to take place the day before the experiment was carried out. To avoid social threats due to evaluation apprehension, the students were not graded on their performance. They were granted with 2 extra points in their final valuation at the end of the course.

The *experimental objects* consisted of four diagrams, summarized below (they complete materials can be found at http://alarcos.esi.uclm.es/ExpStereotypes):

- DA-S: stereotyped diagram A and a general description of each type of stereotype.
- DA-N: non-stereotyped diagram A.
- DB-S: stereotyped diagram B and a general description of each type of stereotype.
- DB-N: non-stereotyped diagram B.

There were two *independent variables* in the experiment, the diagram type, with values: S (stereotyped) and N (non-stereotyped), and the diagram domain (A and B). UML sequence diagram A-x describes a car rental domain whereas diagram B-x describes a hotel domain. By combining each level of the independent variables we obtain four treatments. These experimental objects were presented in Italian.

In accordance with certain suggestions concerning the measurement of comprehension [2], we have used the Cognitive Theory of Multimedia Learning (CTML) [4]. By following CTML, the comprehension of the UML sequence diagrams has been defined through three variables: semantic comprehension, retention and transfer. *Semantic comprehension* is the ability to comprehend the semantics of the models. *Retention* is related to the comprehension of material being presented, and the ability to retain knowledge from it. *Transfer* is the ability to use the knowledge gained from the material to solve related problems which are not directly answerable from it.

In order to measure these variables, we have used three separate tests based on questionnaires. Each comprehension measure is computed as:

- **Effectiveness:** the proportion of correct answers provided in each test (number of correct answers / number of questions). This measure reflects the ability to understand the presented material correctly.
- **Efficiency:** the proportion of correct answers divided by time (Effectiveness / Time).

In this work, we call these values SCEffec/SCEffic (Semantic Comprehension Effectiveness and Efficiency), TransEffec/TransEffic (Transfer Effectiveness and Efficiency), and finally, RetenEffec/RetenEffic (Retention Effectiveness and Efficiency). For Semantic Comprehension we wished to test the following *hypotheses*:

- $H_{1.1,0}$: stereotypes do not improve the subjects' SCEffec when attempting to comprehend a UML sequence diagram. $H_{1.1,1} = \neg H_{1.1,0}$
- $H_{1.2,0}$: stereotypes do not improve the subjects' SCEffic when attempting to comprehend an UML sequence diagram. $H_{1.2,1} = \neg H_{1.2,0}$

We analogously formulated a set of hypothesis H_2 for Retention measures (RetenEffec and RetenEffic), and another set H_3 related to the Transfer measures (TransfEffec and TransEffic).

The experiment consisted of two rounds. In each round, each of the groups was given a different treatment. In order to alleviate learning effect, we divided the experimental subjects into 4 groups. We randomly assigned the corresponding diagrams to each group, but in different order.

4. ANALYSIS AND INTERPRETATION

In this section, we discuss, for each variable, the descriptive statistics and the results of the ANOVA tests carried out to test the formulated hypotheses. All the statistical analyses presented in this section were performed using SPSS, with $\alpha = 0.05$.

Tables 1-3 present the descriptive statistics for the all the variables studied: Semantic comprehension, Retention and Transfer.

Table 1. Descriptive statistics for Semantic Comprehension

			SCEffec		SCEffic	
Diag.	**Dom.**	**N**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
S	A	38	0.756	0.1410	0.0020	0.00069
	B	39	0.782	0.1312	0.0027	0.00133
	Total	77	0.769	0.1360	0.0023	0.00112
N	A	39	0.761	0.1079	0.0022	0.00082
	B	38	0.741	0.1390	0.0024	0.00096
	Total	77	0.751	0.1242	0.0023	0.00089

For both the variables (SCEffec and SCEffic), the subjects obtained better results in the stereotyped diagrams. Obviously this means that the stereotyped diagrams were more comprehensible, less error prone and required less time to understand than non-stereotyped diagrams.

Table 2 shows that, related to Retention, the subjects obtained better results in effectiveness when they did not use stereotypes, while the scores were higher for efficiency when they worked with stereotyped diagrams. In addition, RetenEffec and RetenEffic values are significantly better for the diagrams of domain B. Thus, the subjects who used non-stereotyped diagrams were able to recall a greater number of correct functionalities of the models, but the subjects with non-stereotyped diagrams performed better if we relate the number of correct answers with the time spent answering the test. This is probably due to the fact that stereotyped diagrams contain more information than those which are non-stereotyped and thus prove to be more difficult to remember (but not to understand!).

Table 2. Descriptive statistics for Retention

Diag.	Dom.	N	RetenEffec Mean	RetenEffec Std. Dev.	RetenEffec Mean	RetenEffec Std. Dev.
S	A	38	0.636	0.1579	0.636	0.0036
	B	39	0.784	0.1830	0.784	0.0019
	Total	77	0.709	0.1854	0.709	0.0029
N	A	39	0.637	0.1814	0.637	0.0011
	B	38	0.807	0.1408	0.807	0.0044
	Total	77	0.723	0.1823	0.723	0.0032

Table 3. Descriptive statistics for Transfer

Diag.	Dom.	N	TransEffec Mean	TransEffec Std. Dev.	TransEffec Mean	TransEffec Std. Dev.
S	A	38	0.682	0.2501	0.682	0.0011
	B	39	0.829	0.2404	0.829	0.0058
	Total	77	0.755	0.2547	0.755	0.0053
N	A	39	0.616	0.2248	0.616	0.0013
	B	38	0.821	0.3139	0.821	0.0064
	Total	77	0.719	0.2907	0.719	0.0059

The results for Transfer (Table 3) are the opposite of those for Retention. Better results were obtained for effectiveness when the subjects used the stereotyped diagrams, but they were worse for efficiency. Moreover, these results confirm that the stereotyped diagrams are more comprehensible and less error prone but that the quantity of information they include implies that more time is needed for diagram processing: in this case, and unlike the Semantic Comprehension, the students have to reconstruct the message flow in the sequence diagram and thus have to spend more time in understanding the semantic first and the syntactic of the diagrams later. This implies more time spent, which thus leads to lower efficiency.

We carried out ANOVA tests to check the hypotheses presented in Section 3.1. From these analyses, we observed that in most cases, the domain significantly affects the comprehension of the diagrams (e.g., RetenEffec =0.000; TransEffec=0.000; TransEffic=0.000). The results indicated that the subjects performed worse with the diagrams of domain A (car rental). This could imply that the subjects found the car rental domain more difficult. With respect to the use of stereotypes, there are no significant values in the tests (SCEffec=0.388; RetenEffec=0.650; TransEffec=0.373; SCEffic=0.578; RetenEffic=0.723; TransEffic=0.693). Moreover, the powers of the tests are low (e.g., SCEffec=0.138; TransEffec = 0.144). This implies that we cannot reject the null hypotheses investigated in this work and accepting the alternative hypotheses could be risky and misleading. Furthermore, we have results that might be a consequence of the treatment or be determined by an interaction effect between treatment and domain.

5. CONCLUSIONS AND FUTURE WORK

This paper has investigated the use of stereotypes in the context of UML sequence diagrams. This took place through a controlled experiment and, unfortunately the obtained results cannot be assumed to be final. The p-values observed in the hypotheses test are non-significant and thus the null-hypotheses cannot be rejected. This implies that the stereotypes do not significantly improve comprehension in a statistical sense. Nevertheless, in 4 out of 6 cases the scores obtained by the subjects were higher when using stereotypes, which could imply that using stereotypes does, to some extent, help in the diagram comprehension.

Obviously these conflicting elements stimulate further investigation which we wish to carry out in the near future. We shall attempt to control the threats in a more effective manner and improve the experimental schema, addressing the following issues: (a) the domain effect must be eliminated before conclusions with regard to domains with a similar level of difficulty are drawn; (b) we must confront the experience factor by attempting to point out the effect that the experience of using our stereotypes had on the subjects' performance; (c) data analysis must be improved by clarifying the difference between the non unanswered questions and the wrong answers and their impact on Effectiveness and Efficiency. In this work they were dealt with in the same way; (d) to investigate the possible existence of other relevant factors [5]. The present work is the first experiment within a planned family of experiments, and it considers not only students but also practitioners.

6. ACKNOWLEDGEMENTS

This research is part of the META project (TIN2006-15175-C05-05), the IDONEO project (PAC08-0160-6141), and the Quality-driven Model Transformations project (UPV). The authors thank professors Giuseppe Visaggio and Maria Teresa Baldassarre and their students for having cooperated with this experiment.

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