A Precise Style for Business Process Modelling: Results from Two Controlled Experiments

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Abstract. We present a precise style for the modelling of business processes based on the UML activity diagrams and two controlled experiments to compare this style with a lighter variant. The comparison has been performed with respect to the comprehensibility of business processes and the effort to comprehend them. The first experiment has been conducted at the Free University of Bolzano-Bozen, while the second experiment (i.e., a differentiated replication) at the University of Genova. The participants to the first experiment were Master students and so more experienced than the participants to the replication, who were Bachelor students. The results indicate that: (a) all the participants achieved a significantly better comprehension level with the precise style; (b) the used style did not have any significant impact on the effort; and (c) more experienced participants benefited more from the precise style.

Keywords: Business Process Modelling, UML activity diagrams, Controlled experiment, Precise and Ultra-light styles.

1 Introduction

To be competitive in the global market, many organizations have been changing their business processes [11]. In this context, modelling, management, and enactment of business processes are considered relevant to support organizations in their daily activities.

The UML activity diagrams represent a natural choice for modelling business processes (see, e.g., [10]) since UML has been conceived for the communication among people and then can be easily understood and used by customers, managers, and developers. In favour of UML, there is also its flexibility that allows choosing the preferred degree of precision/abstractiveness to model business processes. For example, processes may be modelled using lighter variants/styles of the activity diagrams, where nodes and arcs are simply decorated by natural language text. Lighter styles could be simpler to use, but they could complicate the communication among stakeholders because of the possible ambiguities they introduce. More precise styles, where for example nodes are expressed in a formal language, could be more complex to use, but they may reduce ambiguities in the modelled processes.

In this paper, we present a precise style for the modelling of business processes based on the UML activity diagrams and two controlled experiments to compare it with a lighter style (*ultra-light* in the following). The participants to the original experiment were students of the Master program in Computer Science at the Free University of Bolzano-Bozen. A preliminary analysis of the experimental data [9] indicated that the participants achieved a significantly better comprehension level when business processes were represented using the precise style, with no significant impact on the effort to accomplish the tasks.

The second experiment was a differentiated replication[1] of the first experiment. It was conducted at the University of Genova with less experienced participants, namely Bachelor students in Computer Science. The data analysis confirmed the results of the original experiment. A further analysis conducted on both the experiments indicated that more experienced participants benefit more from the use of the precise style in the comprehension of business processes.

The work presented here is based on [9] and with respect to that paper, we provide the following further new contributions: (1) a deeper presentation of the visual formalism used to model business processes; (2) a new experiment with less experienced participants; (3) a further analysis to assess the effect of experience on the comprehension of business process models.

The remainder of the paper is organized as follows: Section 2 presents relevant related literature concerning business process modelling with UML and related experiments in comprehension tasks. Section 3 introduces both the precise and the ultra-light styles for business process modelling. Section 4 presents the design of the controlled experiments, while Section 5 shows and discusses the achieved results. Final remarks conclude the paper.

2 Related Work

The UML activity diagrams provide an intuitive and easy way to model business [1] and business process [8, 13, 10]. For example, Di Nitto *et al.* [10] propose an approach to model business processes by using a subset of UML diagrams, including: (1) UML activity diagrams with object flow to model the control and data flow, (2) class diagrams to model structural properties of the process, and (3) state diagrams to model the behaviour of activities. Subsequently, these models can be translated into executable process descriptions by a UML CASE tool. Several are the differences between our approach and theirs. The most remarkable one is that OCL (Object Constraint Language) is not used.

[1] This kind of replication introduces variations (e.g., different kinds of participants) in essential aspects of the experimental conditions [3].

De Lucia *et al.* [7] present a visual environment, based on an extension of UML activity diagrams, that allows to graphically design a process and to visually monitor its enactment. The main difference with our approach is that participants and objects are not explicitly considered in their proposal. Furthermore, the behavioural conditions are not formally specified.

Differently from us, all the approaches discussed above do not assess the validity of the proposed formalism by means of controlled experiments. To our knowledge, only a few studies perform comparisons among business process formalisms by using empirical evaluations. For instance, Peixoto *et al.* [16] compare UML and BPMN (Business Process Modelling Notation) [15], with respect to their readability in expressing business processes. The authors expected BPMN models to be easier to understand than UML 2.0 activity diagrams, as BPMN is a specialized language, designed for modelling business process and with the primary goal of being understandable by all business stakeholders. However, an experiment with 35 undergraduate students, unskilled in business process modelling, could not confirm their initial hypothesis. A similar result is obtained in [4], where the authors conclude that UML activity diagrams are at least usable as BPMN since neither user effectiveness, efficiency, nor satisfaction differ significantly. Instead, Gross and Doerr [12] conducted two experiments, comparing the UML activity diagrams and Event-driven Process Chains (EPCs). The authors found evidence that activity diagrams performed better than EPCs from a requirements engineer's perspective. When considering end users, no significant difference was identified between the two methods.

3 Business Process Modelling with UML

In this paper, we shall not give a rigorous definition of what a business process is, just assuming the common intuitive meaning, and we shall use the following terminology:

- basic activities in business processes are called *basic tasks* of the process;
- *business process objects* are those entities over which the activities of the process are performed, obviously these entities are passive, i.e., they are unable to do any activity by themselves;
- active entities that perform the various tasks are *business process participants*: whenever relevant, we shall distinguish autonomous participants from those corresponding to software and hardware systems.

Behavioural aspects of business processes may be modelled by using UML activity diagrams, which offer quite a large set of visual constructs to depict the flow of activities. We shall restrict ourselves to use: action nodes, initial, final, decision/merge, fork/join control nodes, control flow edges, time and accept events, and obviously also the rake construct to modularize the activity diagrams. Object nodes and swimlanes may also be optionally used. This holds also for the styles considered in the paper.

Even with such a restricted subset of constructs, a straightforward and unique modelling of a business processes with one UML activity does not exist. Indeed, it is possible to produce complex and unreadable activity diagrams, corresponding to "spaghetti" business processes, or to make mistakes, e.g., using a business object before creating it. To overcome these problems, we proposed a proper discipline for modelling business processes and some notations [17]. The notations mainly differ in the level "of the precision" in using UML to depict the basic ingredients of the activity diagrams (such as actions and guards), or in the way basic tasks are represented.

In the study presented here, we consider the ultra-light and the precise styles. These styles are described in the following through a running example, namely a business process corresponding to order processing in e-commerce systems (EC). More business process examples are available in [17].

The client sends the order. If the client is not already registered, (s)he will be asked to register to the site, if (s)he refuses the order will be cancelled. Then, the order will be sent to the warehouse, which will prepare the package, and in the meantime, to collect the payment, the handler of the credit card, or Paypal will be contacted (depending on client preferences). Then, the package will be sent, and the carrier will inform the company that the package has been delivered. Finally, the order will be archived.

3.1 Ultra-light style

In the ultra-light style a business process is modelled by a UML activity diagram, where the action nodes and the guards on the edges leaving the decision nodes are decorated by natural language text; such text does not follow any rules or patterns. Sentences defining the activities may be either in active or passive form (e.g., "Clerk fills the form" or "Form is filled by clerk"), and the entity executing the activity may be precisely determined or be left undefined (e.g., "Form is filled"); in other cases nominal sentences might be used instead of verbal phrases ("Filling the form"). Also the objects over which the business process activities are performed may be described in different ways, for example by a substantive (e.g., "Form", "The form") or by a qualificative sentence (e.g., "Client form", "Filled form", "Sent form").

Fig. 1 shows the ultra-light UML model of the EC business process. It is a simple activity diagram, where various basic tasks are denoted by natural language sentences with different structure (e.g., the first one is active and the subject is explicit, Order archived instead is passive and provides no information about who will perform the task, and Client registration is just the name of an action). Since the model is prepared in a completely unconstrained way, it is very easy to make mistakes or to introduce ambiguities. For example, the passive sentences in the UML activity diagram do not explicitly mention who will do the last three basic tasks of the process.

3.2 Precise style

Participants and objects of a business process shall always be explicitly listed and precisely modelled with UML by means of classes; and the behavioural view of business processes shall be given by activity diagrams, with basic activities and conditions written respectively in the language for the actions of UML and OCL, the textual language for boolean expressions, included in UML 2.0. Thus the *UML precise model of a business process* consists of: (1) a class diagram, introducing the classes needed to type its participants and objects, (2) the list of its participants, (3) the list of its objects, and (4) an activity diagram representing its behaviour. All these parts must satisfy the constraints listed below.

– Classes in the class diagram may be stereotyped by ≪object≫ (business process objects), ≪businessWorker≫ and ≪system≫ (business process participants distinguished between: autonomous entities, i.e., human beings or complex entities run by human beings, and hardware/software systems); for readability reasons the stereotype ≪businessWorker≫ will be omitted. Mutual relationships among participants and/or objects are expressed by associations and specializations, whereas the dependency (visually depicted by a dashed arrow) is used to represent the fact that participants from a given class will act over objects from another class.

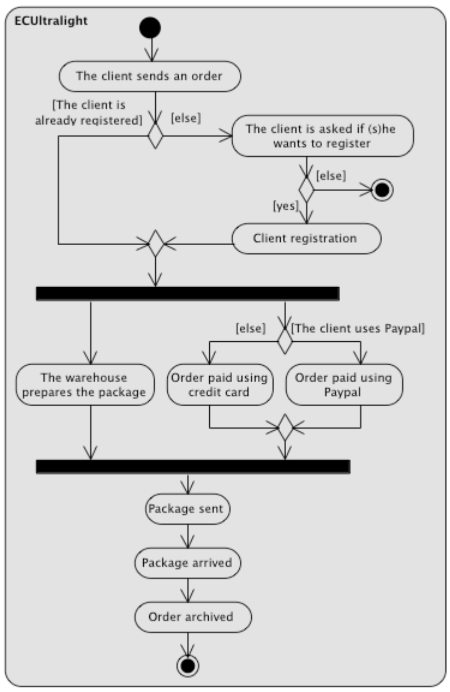

Fig. 1. EC Specified by the Ultra-light Style

- Participants are named, and they are typed by a class with stereotype either ≪businessWorker≫ or ≪system≫. Objects are named and typed by classes stereotyped by ≪object≫. Notice that participants/objects are roles for entities taking part in the business process, and not specific individuals. It is possible to impose some constraints on participants and objects of a business process.
- Basic tasks involving participants and objects are modelled by operations of the various participants/objects classes stereotyped by ≪T≫ (whenever all operations of a class have this stereotype, it shall be omitted to simplify the visual presentation). When defining ≪T≫ operations, it is important to keep in mind that: (1) an operation corresponding to a basic task, part of a class C stereotyped by ≪businessWorker≫ or ≪system≫, describes a task that a participant of type C is responsible to initiate (they should be named using the imperative verbal mode); (2) an operation corresponding to a basic task, part of a class C stereotyped by ≪object≫, describes a task that will be done over an object of type C (they should be named using the past participle).
- Action nodes of an activity diagram are decorated by calls of the the operations corresponding to basic tasks, where participants and objects freely appear as arguments, whereas conditions on edges leaving decision nodes are OCL expressions, where participants and objects shall freely appear.

Fig. 2 shows the models of the the EC business process built using the precise style. The figure shows a class diagram, an activity diagram, and the lists of participants and objects of the process. The class diagram introduces the class defining participants and objects, together with some data-type used to describe them (for example ClientInfo). EC, PAYPAL and CREDITCARD are participants of the process of kind ≪system≫ (they correspond respectively to the software system running the e-commerce site, the Paypal payment service, and the credit card handling system), whereas CLIENT is an human participant, CARRIER and WAREHOUSE are respectively an external transport company, and a department of the e-commerce company. The latter are not classified as systems since they might not be fully automated. The e-commerce system is responsible for four basic tasks, the warehouse for one and the carrier for two.

The model of the process may be made more precise, without modifying the activity diagram, by adding further details to the class diagram. For example, we could model how the class ECommerce handles the list of registered clients, and the effects on it of its operations, e.g., by means of pre-post conditions. More details on this concern can be found in [17].

4 The Controlled Experiments

In this section we present the design of the two controlled experiments following the guidelines proposed by Wohlin *et al.* in [19]. An experimental package, the raw data, and a draft of our previous paper [9] are available on the Web[2].

[2] www.scienzemfn.unisa.it/scanniello/BPM

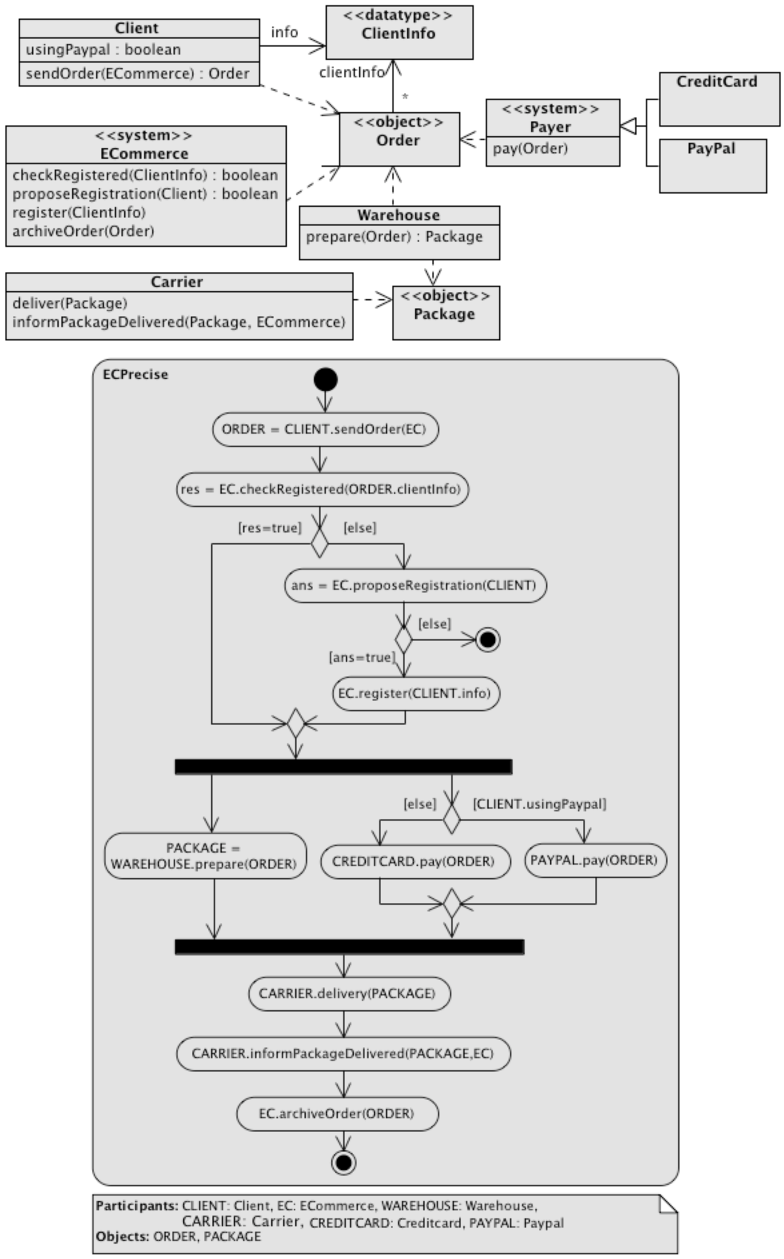

Fig. 2. EC Specified by the Precise Style

Applying the Goal Question Metric (GQM) paradigm [2], the goal of our experiments can be defined as follows: "*Analyse* the use of the precise style *for the purpose of* evaluating it *with respect to* the ultra-light style in the comprehension of business processes by two different categories of participants (i.e., High/Low experienced) *from the point of view* of researchers, *in the context of* students in Computer Science, and *from the point of view of* project managers, *in the context of* novice software engineers".

4.1 Participants

The two experiments have been conducted with:

- *Master students.* They are enrolled in a Master program in Computer Science at the Free University of Bolzano-Bozen. Some of them are, or were, industry professionals. They can be considered close to young software engineers [5], and in the following we will refer to them as UniBZ.
- *Bachelor students.* They are students of the Bachelor program in Computer Science at the University of Genova (UniGE in the following). They can be considered the next generation of young professional developers [14].

UniGE (62 participants) is a differentiated replication of UniBZ (26 participants). The participants to UniGE are less experienced than UniBZ. For ethic reasons, we informed all the participants that the data of the experiment will be treated anonymously, used only for research purposes, and revealed only in aggregated form.

4.2 Material and Experimental Objects

The prepared experimental material included: two experimental objects, the documentation for the training, and a post-experiment survey questionnaire. The experimental objects are two business processes from application domains on which the participants were familiar with. Process Order, shortly PO, is in charge of processing orders for an on-line shop. It takes as input an order, then: *(i)* the order is accepted; *(ii)* info is filled; *(iii)* payment processing and shipment are done and, finally; *(iv)* the order is closed. The second business process (i.e., Document Management Process, shortly DPM) manages the on-line review process of any kind of documents. First a document is created by the author, then it is reviewed by a reviewer, and finally it is approved (if its quality satisfies the imposed constraints). The two business processes are comparable both in complexity and in size. PO comprises 10 nodes (8 activities, 1 decisions and 1 object node) and DPM comprises 12 nodes (6 activities, 2 decisions and 4 object nodes). Furthermore, they both are small enough to fit the time constraints of the experiment and at the same time they are realistic for small/medium sized comprehension tasks. It is worth mentioning that we downloaded the models of the process PO and DPM from http://www.uml-diagrams.org/activity-diagrams-examples.html. In the experiments we used the same descriptions provided in the Website.

The documentation for the training included: *(i)* a set of instructional slides to introduce the precise and the ultra-light style; *(ii)* a training task not related with experimental objects.

Regarding the post-experiment survey questionnaire, we asked the participants to fill it out, so to gain insight and explain the results. This questionnaire contained questions about: the availability of sufficient time to complete the tasks and the clarity of the experimental material and objects. For space reasons, the analysis of the post-experiment questionnaires is not presented.

4.3 Hypotheses Formulation

The following null hypotheses have been defined and tested:
H_{lo}: The use of the precise style **does not significantly improve** the comprehension level of a business process.
H_{to}: There **is no significant difference** in terms of effort when using the precise or ultra-light styles to comprehend a business process.

According to the results of the original experiment [9], the null hypothesis H_{l0} is one-tailed, while H_{t0} is two-tailed. The objective of the statistical analysis is to reject the defined null hypotheses, thus accepting the corresponding alternative ones (i.e., H_{la} and H_{ta}) that can be easily derived from the null ones.

4.4 Design

In the first experiment, we adopted a *counterbalanced design* [19] with four groups: A, B, C, and D. Each participant within these groups worked on two comprehension *Tasks* (i.e., Task 1 and Task 2) on the two experimental *Objects*: PO and DPM. Each time, participants used the precise or ultra-light styles. For example, the participants within the group A started to work in Task 1 on PO using the precise style and then they used the ultra-light style to perform Task 2 on DPM. We randomly assigned the participants to A, B, C, and D.

In the replication a *completely randomized design* [19] was used. This design is simpler than the one used in the first experiment, since each participant used either the precise or the ultra-light styles on only one experimental object (i.e., PO or DPM). We used in the replication a different design for time constraints.

4.5 Dependent and Independent Variables

The *control group* indicates students working with the ultra-light style, while the *treatment group* indicates students working with the precise style. Thus, the only independent variable is *Method* (also named main factor), which is a nominal variable that admits two possible values: *Precise* and *Ultra-light*. To test the null hypotheses, we selected the following dependent variables: *comprehension level* and *comprehension effort*.

The *comprehension level* dependent variable measures the comprehension of the participants on each business process. Similar to previous studies (e.g., [18]), we asked the participants to answer a comprehension questionnaire (it is the same for each object) composed of multiple choice questions. Twelve questions were asked on each business process, each admitting five possible answers, with one or more correct answers. An example of question for the PO object is the following: "*Indicate the participants of the PO business process*". The goal of this question was to investigate whether the experiment participants (subjects) identified the participants to the business process.

We measured the correctness and completeness of the answers the participants provided to the questions of each comprehension questionnaire through an information retrieval based approach [18]. The correctness was measured using the *precision* measure, while we employed the *recall* for the completeness:

$$precision_{s,i} = \frac{|A_{s,i} \cap C_i|}{|A_{s,i}|} \quad recall_{s,i} = \frac{|A_{s,i} \cap C_i|}{|C_i|}$$

where $A_{s,i}$ is the set of answers provided by the participant s on the question i and C_i indicates the correct set of answers of the question i. To get a single value representing a balance between correctness and completeness of a given question, we used the harmonic mean between precision and recall:

$$F{-}Measure_{s,i} = \frac{2 \cdot precision_{s,i} \cdot recall_{s,i}}{precision_{s,i} + recall_{s,i}}$$

The overall comprehension level achieved by each participant was computed using the overall average of the F-Measure values on all the questions. This average assumes a value ranging from 0 to 1. Values close to 1 and 0 indicate a very good and very bad understanding, respectively.

The *comprehension effort* dependent variable measures the time, expressed in minutes, that each participant spent to accomplish a task. We got this value using the start and stop times the participants were asked to record.

5 Results

Because of the sample size and mostly non-normality of the data, we adopted non-parametric tests to test the null hypotheses. We used the Mann-Whitney (MW) test for unpaired analysis since it is very robust and sensitive [19]. Further, it has been widely used in the past in studies similar to the one presented in the paper. In all the performed statistical tests, we decided (as it is customary) to accept a probability of 5% of committing Type-I-error [19], i.e., rejecting the null hypothesis when it is actually true.

While the statistical tests check the presence of significant differences, they do not provide any information about the magnitude of such a difference. Therefore, we used the Cohen's "d" standardized difference between two groups [6]. Typically, it is considered negligible for $|d| < 0.2$, small for $0.2 \leq |d| < 0.5$, medium for $0.5 \leq |d| < 0.8$, and large for $|d| \geq 0.8$.

5.1 Comparison between the experiments

To compare the results of the two experiments, we considered the overall values of comprehension level and effort, without partitioning the observations by Method. For comprehension level we obtained: UniBZ=0.70 and UniGE=0.60. From this preliminary analysis, we observe that the mean value of comprehension level in the first experiment (UniBZ) is 10 points (i.e., 16.6%) higher than in the second experiment (UniGE). This means that the UniBZ participants comprehended better the business process (both represented with the precise and ultra-light styles) than the UniGE participants. The difference is confirmed by the MW test ($p - value = 0.0004$). As far as Comprehension Effort is concerned, the mean effort in the first experiment is about 2 minutes (11.2%) higher than in the first experiment. For the effort, such a difference is not statistically significant as the results of the MW test show ($p - value = 0.48$). Given the observed differences in the results, we cannot simply merge the data from the two experiments. As a consequence, the two data sets ought to be analysed separately and then we can draw joint conclusions from the results.

5.2 Comprehension level and effort

Table 1 reports some descriptive statistics (i.e., mean, median, and standard deviation) of comprehension level, and the results of statistical analyses conducted on the data from both experiments with respect to this dependent variable. The comparison for the two experiments, without partitioning the observations by Object, is visually presented in Fig. 3 by means of boxplots. From them, it appears that students with the precise style outperformed in comprehension the students provided with the ultra-light one in both the experiments.

		Precise			Ultralight			Mann-Whitney	Cohen's "d"
Experiment	Object	Mean	Median	SD	Mean	Median	SD	p-value	
UniBZ	PO + DPM	0.79	0.84	0.11	0.62	0.66	0.14	**<0.001**	1.35 (large)
	PO	0.80	0.84	0.11	0.58	0.69	0.19	**0.003**	0.56 (medium)
	DPM	0.76	0.74	0.10	0.64	0.64	0.10	**0.005**	1.14 (large)
UniGE	PO + DPM	0.64	0.63	0.14	0.57	0.54	0.13	**0.02**	0.19 (negligible)
	PO	0.66	0.66	0.15	0.52	0.49	0.13	**0.005**	0.24 (small)
	DPM	0.63	0.61	0.14	0.61	0.60	0.11	0.31	0.05 (small)

Table 1. Descriptive statistics of comprehension level and the MW p-values

The MW test provides evidence that the difference in terms of comprehension level between the two styles, and for both experiments ($p - value < 0.001$ for UniBZ and $p - value = 0.02$ for UniGE), is significant. Therefore, we can reject the null hypothesis H_{l0} both for UniBZ and UniGE. As shown in Table 1, the difference is significant for both the objects (PO and DPM) in the first experiment, while only for PO in the replication. The mean comprehension level improvement, achieved with the precise style, is 17 points for UniBZ (see means

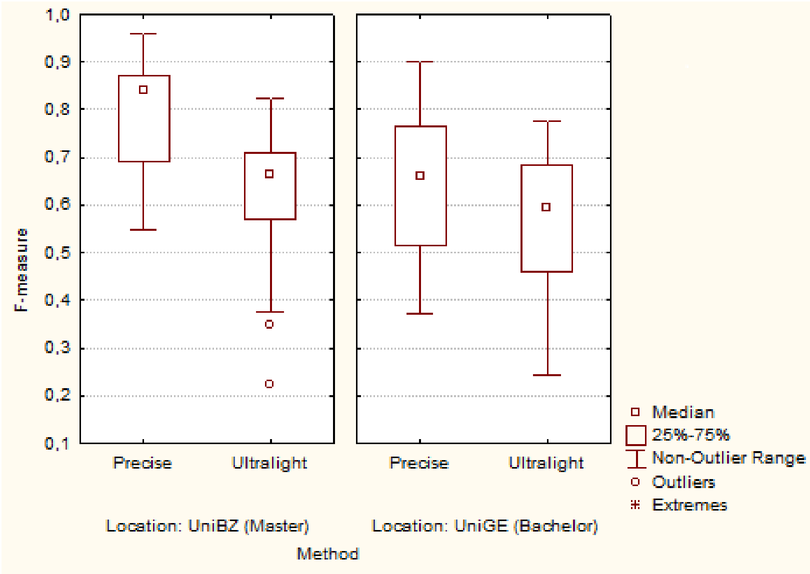

Fig. 3. Boxplots of Comprehension level grouped by Method and Experiment.

of the "UniBZ PO + DPM" row in Table 1), i.e., 27.41%[3] and 7 points for UniGE (see means of the "UniGE PO + DPM" row in Table 1), i.e., 12.28%.

Participants with the precise style employed slightly more time than participants with the ultra-light style. Means per experiment are respectively: 22'16" and 22'11 minutes for UniBZ; 20'41" and 19'46" minutes for UniGE. The MW test returned 0.89 for UniBZ and 0.21 for UniGE as $p - values$, respectively. Therefore, we rejected the null hypothesis H_{t0} neither for UniBZ nor for UniGE.

5.3 Effect of Experience

Fig. 4 shows the interaction plot of method and experience vs. comprehension level. Potential benefits gained with the precise style are represented by the slope of the segments: the slope – and thus the benefit gained with the precise style – is higher for master students from UniBZ than for bachelor students from UniGE. The plot shows a possible trend (to be verified by further experiments): more experienced participants received greater benefits from the precise style than less experienced participants. This could be due to the expertise and level of maturity needed to understand the language for the actions of UML and OCL, used in the precise style.

The effect of experience on the dependent variable has also been analysed using a two-way Analysis of Variance (ANOVA). The results of this further

[3] The value is computed using the equation: 0.62+0.62*x%=0.79

analysis confirm the results shown by the interaction plot. On the overall data set, we found a significant effect of the experience on the comprehension level ($p - value = 0.0002$), already shown by the MW test, and a marginal interaction with the main factor ($p - value = 0.06$).

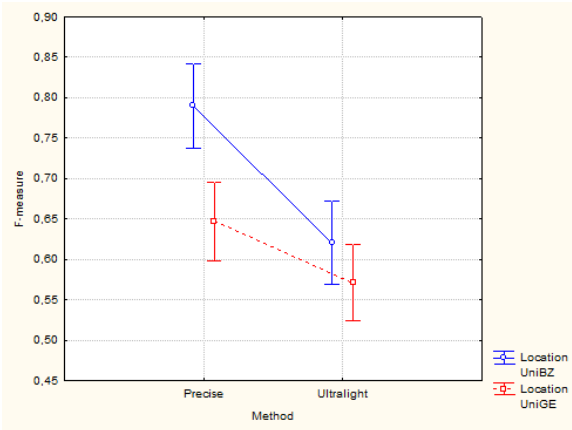

Fig. 4. Interaction of Experience and Method.

5.4 Threats to Validity

The threats that could affect the validity of the results for both the experiments belong to the following four categories [19]: *internal*, *external*, *construct*, and *conclusion*.

The experimental designs adopted in these experiments enabled us to mitigate as much as possible *internal validity* threats. The adopted designs mitigated possible learning and fatigue effects as well as the effect of the order of the method. Another threat could be the exchange of information among the participants. This was prevented by monitoring the students while performing the tasks. In addition, students were evaluated neither on the time to accomplish the tasks nor on the their comprehension on the business processes. This reduced possible threats related to the participants' apprehension.

External validity may be threatened when experiments are performed with students and not with software professionals. However, tasks considered in our experiments do not require a high level of industrial experience. Replications with professionals are however needed. To confirm or contradict the achieved results, we also plan to conduct empirical investigations in terms of case studies on larger and more complex tasks.

Construct validity threats are related to the metrics used to quantitatively evaluate the participants' comprehension and effort. We used questionnaires to assess the comprehension of the business processes and the participants' answers to these questionnaires were evaluated using an information retrieval based approach. This design choice avoided as much as possible any subjective evaluation. Furthermore, the comprehension questionnaires were defined to be complex enough without being too obvious. The comprehension effort was measured by means of proper time sheets, and it was validated by researchers. This approach is widely used in the literature.

Conclusion validity concerns data collection, reliability of measurements, and validity of statistical tests. We used a conservative statistical non-parametric test (i.e., Mann-Whitney) to reject the null hypotheses and two-way ANOVA to detect possible effects and interactions between the main factor and the participants' experience. Even if all the assumptions/conditions to use ANOVA were not checked, this test is quite robust and has been extensively used in the past to conduct analyses similar to ours.

6 Conclusion

We have presented a precise style for the modelling of business processes based on the UML activity diagrams. An experiment and a differentiated replication have been conducted to compare it with a lighter variant. The results of these experiments indicate a clear improvement in the comprehension of business models when the precise style is used (UniBZ +27.41% and UniGE +12.26%) with no impact on the effort to accomplish a comprehension task. The analysis of the experiments together showed that more experienced subjects benefited more from the precise style. This result could be due to the needed expertise and level of maturity to understand business processes represented with this style.

Future replications have been planned to investigate: *(i)* the effects of changing the domain of the business processes used in the controlled experiments; *(ii)* whether the observed benefits of the precise style are preserved or improved for subjects with different levels of experience; and *(iii)* whether the additional effort and cost to create models with the precise style is adequately paid back by an improved comprehension of business process models.

Acknowledgements: We would like to thank the participants to the experiments.

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