The effect of modularity representation and presentation medium on the understandability of business process models in BPMN

The effect of modularity representation and presentation medium on the understandability of business process models in BPMN

Oktay Turetken[1], Tessa Rompen[2], Irene Vanderfeesten[1],
Ahmet Dikici[3], Jan van Moll[2]

[1] Eindhoven University of Technology, Eindhoven, The Netherlands
{o.turetken, i.t.p.vanderfeesten}@tue.nl
[2] Philips Health Tech, Best, The Netherlands
{tessa.rompen, jan.van.moll}@philips.com
[3] TÜBİTAK BİLGEM Software Technologies Research Institute, Ankara, Turkey
ahmet.dikici@tubitak.gov.tr

Abstract. Many factors influence the creation of understandable business process models for an appropriate audience. Understandability of process models becomes critical particularly when a process is complex and its model is large in structure. Using modularization to represent such models hierarchically (e.g. using sub-processes) is considered to contribute to the understandability of these models. To investigate this assumption, we conducted an experiment that involved 2 large-scale real-life business process models that were modeled using BPMN v2.0 (Business Process Model and Notation). Each process was modeled in 3 modularity forms: fully-flattened, flattened where activities are clustered using BPMN groups, and modularized using separately viewed BPMN sub-processes. The objective is to investigate if and how different forms of modularity representation in BPMN collaboration diagrams influence the understandability of process models. In addition to the forms of modularity representation, we also looked into the presentation medium (paper vs. computer) as a factor that potentially influences model comprehension. Sixty business practitioners from a large organization participated in the experiment. The results of our experiment indicate that for business practitioners, to optimally understand a BPMN model in the form of a collaboration diagram, it is best to present the model in a 'fully-flattened' fashion (without using collapsed sub-processes in BPMN) in the 'paper' format.

Keywords: business process model, understandability, comprehension, modularity, BPMN, sub-process, group.

1 Introduction

Business process modeling is an essential component of successful business process management (BPM). It is a fundamental activity to understand and communicate process information, and often a prerequisite for conducting process analysis, redesign and automation [1]. However, in order for process models to successfully serve for their potential uses, they should be perceived as understandable by their audience.

Process model understandability (or comprehension) can be defined as the degree to which information contained in a process model can be easily understood by a reader of that model [2]. It is typically associated with the ease of use and the effort required for reading and correctly interpreting a process model [3].

The increasing complexity of real-life processes leads to an increase also in size and complexity of the models that represent them. These two factors are known to impair understandability [4], [5]. Hierarchy through the use of sub-processes has widely been considered as a practical means to deal with the size and complexity of models [6], [7]. Many modeling languages allow for the design of hierarchical structures (e.g. sub-processes in BPMN and EPCs). Hiding less relevant information in sub-models is expected to decrease the mental effort (cognitive load) needed to understand the model [8], whereas fragmentation due to modularization increases the mental effort by forcing the reader to switch attention between different fragments (so called the split attention effect [6]). In consequence, the discussions about the proper way of using modularity and its implications on the understandability of models are not conclusive [6], [9], [10]. This also leads to a lack of theoretically grounded guidelines for modularizing process models into sub-processes. In particular, the influence of using different forms of modularization in BPMN v2.0 (e.g. sub-processes, groups) on the understandability of process models has not been investigated.

Another factor that has not been addressed in the literature is the medium used to present the models to their audience. Although the paper is usually the preferred means for interacting with model readers in practice [7], the models are typically designed using software applications (particularly when the objective is process automation), and communicated through an online environment (e.g. web portal, company intranet) across the organization and beyond. Therefore, it is important to explore if using paper or a computer environment has any effect on model understandability.

Accordingly, the objective of this study is *to investigate the influence of using different forms of modularity and presentation medium on the understandability of processes modeled in BPMN*. To this end, we conducted an experiment with the participation of 60 practitioners working in a large organization. For the experiment, we used models of two business processes of the organization, which are of similar size and structure, and can be considered large in scale.

The remainder of the paper is structured as follows. Section 2 discusses briefly the related work on the effect of modularity on process model understandability. Section 3 presents the research design including the research model that we tested, and the setup of the experiment. In section 4, we report and discuss the results of our analyses. Finally, section 5 presents our conclusions and future research directions.

2 Related Work

Although modularity in business process models is considered to have benefits in various dimensions, such as increased reuse, maintainability and scalability [11], [12], its influence on the understandability is not well understood [9], [13], [14]. The findings of empirical studies that investigate the effect of modularization (decomposition, or structuring in a hierarchy) on the understandability hardly converge into a validated set of practical guidelines for applying modularization in process modeling.

The works by Reijers et al. [7], [9] test the influence of using sub-processes on the understandability of two real-life processes that are modeled using Workflow Nets in two forms: modular and flattened. The participants (28 consultants) were asked to answer a set of (control-flow related) understandability questions regarding these models (to measure effectiveness). For the first process model, the experiment did not result in a significant difference between the modular and flattened versions, but a positive influence of modularity on understandability was found for the second model. The authors attribute this to the difference in the degree of modularization applied in these models. As the second model had more sub-processes, they sparingly conclude that 'modularity appears to have a positive connection with process understanding'.

Zugal et al. [6] tests the effect of modularization on the understandability of *declarative* process models. Four processes were modeled in two forms (modular and flattened) using a declarative language ConDec. The understandability is measured using the number of correct answers given for the questions (all related to process activities and their ordering/control flow), and the (perceived) mental effort. The results suggest that modularization decreases perceived mental effort but has no influence with respect to the number of correct answers. The limited number of participants (9 respondents) is reported as a threat to the validity of the findings.

The technique used for modularizing process models also plays a role in the effect of modularity on understandability [9]. Applying different modularization methods could yield different structures, in turn different levels of influence on comprehension. The study by Johannsen et al. [15] uses eEPC process models and tests the use of Wand and Weber's five decomposition conditions [16], which are considered to yield well-decomposed models. The models are modularized in three forms with respect to their level of adherence to these conditions. The results indicate that models that are structured in full adherence to these conditions are more understandable than those that violate them. However, the study does not compare the performance of modularized models against their flattened counterparts.

The study by Figl et al. [10] uses expert evaluation approach (with 15 process modeling experts) to determine whether some visualization strategies provide a better fit for representing process model hierarchies than others. Accordingly, the experts prefer to navigate in the hierarchy with the help of an *overview+detail* strategy (where sub-processes are shown as separate models detached from the context of the higher level model) instead of a *focus+context* strategy (where sub-processes are expanded in the higher-level model directly within their context). The 'overview+detail' view was considered to simplify the design and provide undistorted views on focus and context.

In a closely relevant domain of software modeling, Cruz-Lemus et al. [17] presents a family of experiments investigating the effect of hierarchy on the understandability of UML statechart diagrams (which are used not only to model software but also business processes). The results indicate insignificant or varied effects of hierarchy on understandability. Moreover, the understandability worsens with the increase of the nesting level (depth of hierarchy).

This diversity in the results can be attributed to the outcome of two opposing effects of modularization: *abstraction* (information hiding) and *split-attention effect* (browsing costs) [9], [18]. Using sub-processes might increase reader's understanding of a complex model by abstracting away less relevant information (and thereby reducing

complexity). However, additional cost (increased cognitive load) incurred in browsing through and integrating fragmented pieces of models can counter-balance this gain [10].

The existing research as discussed above calls for further empirical studies to contribute to a better understanding of the impact of modularization. In particular, there is a lack of studies on the effect of modularity that involve BPMN - de-facto process modeling notation in practice [19]. BPMN v2.0 has specific elements and techniques for representing modularity (e.g. collapsed/expanded sub-processes, groups) which have not been addressed in the research concerning process model understandability. In addition, to the best of our knowledge, no empirical work has studied the effect of the presentation medium on the understandability of process models.

3 Research Design

We used a *between-groups* design for our experiment where separate groups of participants for each of the different conditions in the experiment were tested once only [20]. Aligned with our research question, there are two main *independent* variables: *modularity representation* (in 3 forms) and *presentation medium* (paper vs. computer). We describe these variables in detail later in this section. In addition, we asked participants about their experience in process modeling (following [21]), knowledge on process modeling and BPMN, and familiarity with the domain to investigate the potential effects of these *personal factors*.

We used *two process models* as the objects of our experiment. These processes are taking place in a large corporation headquartered in The Netherlands (which employs more than 115,000 employees and operates in over 100 countries worldwide). The experiment took place in a division in the headquarters in June 2015.

Fig. 1 presents the research model that we tested in our experiment. The model proposes that the understandability of process models (in terms of understandability task effectiveness and efficiency, and perceived usefulness and ease of understanding) is influenced by the modularity technique applied in modeling the process and the medium used for its presentation. Accordingly, we can draw two groups of hypotheses:

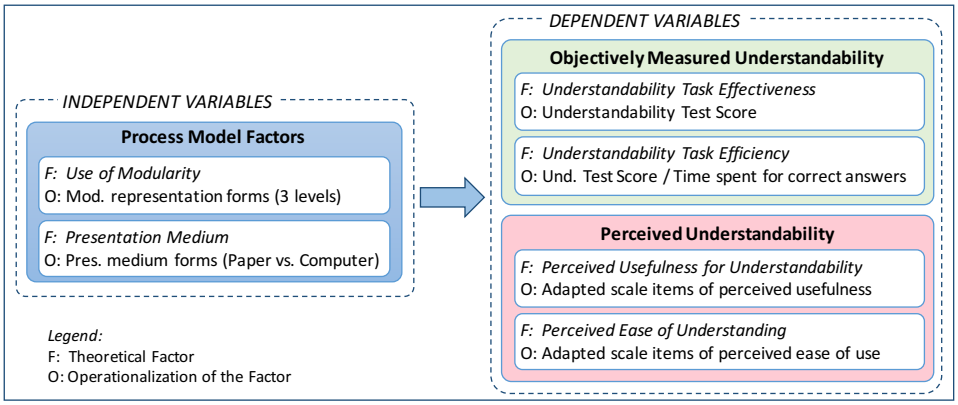

Fig. 1. Research model.

- *H1*. The form of modularity representation has a significant influence on the understandability factors, i.e.: *(a)* understandability task effectiveness, *(b)* understandability task efficiency, *(c)* perceived usefulness for understandability, and *(d)* perceived ease of understanding.
- *H2*. The medium used for presenting process models has a significant influence on the understandability factors (as listed above).

In the sections that follow, we explain the details regarding the process models and forms of modularity representations used, dependent and independent variables as well as their operationalization, and the design of the experiment.

3.1 Process models used for the experiment

Among several processes in the quality management system of the company, two processes of similar size and nature were selected by the company representatives taking into account their criticality in the business domain in which the company operates. The processes can be considered as large and rich in terms of the interaction taking place between different departments and divisions of the company. The selected processes were initially modelled in BPMN v2.0 using sub-processes where applicable (based on existing process documentation, and interviews with process owners and participants). The resulting models were BPMN collaboration diagrams, where the interaction between process participants (roles, organizational units) was explicitly modeled using message flows. (Signavio.com was used for modeling processes, however only resulting static images were used for the experiment, as explained in section 3.3.)

The models were subsequently reviewed by process modeling experts for syntactical correctness, and validated for their correctness (including the choice of modularization) by the domain experts in the company, who were also knowledgeable about process modeling. The basic metrics used to measure the structural properties of process models show that these models are comparable in terms of size and complexity (see Table 1).

Table 1. Comparing the structural properties of process model A and B.

Metric	Process Model A	Process Model B
#Nodes	133	122
#Activity nodes	47	46
#Sub-processes	15	14
#Pools	5	5
#Gateways	34 *(8 AND split/join; 22 XOR splits/joins; 4 Event-based)*	38 *(8 AND split/join; 27 XOR splits/joins; 3 Event-based)*

3.2 Forms of modularity representation

The verified and validated models were subsequently re-structured into two other forms using different modularity representations in BPMN v2.0, leading to three forms of representation to be tested. Fig. 2 illustrates these forms. The first form (Repr1) is the *fully-flattened* representation of the process models. This type acts as the reference model which offers the possibility to draw conclusions about whether the use of any modularity technique has an influence on the understandability. (Note that, re-structuring models does not affect the business logic in a semantic sense, but may influence the extent of information provided in the models. For instance, the sub-process information disappears in the fully-flattened models.)

The second form of representation (Repr2) combines the fully-flattened form with *groups* that informally cluster a logically related set of activities. We used groups in a way similar to the use of 'expanded sub-processes' in BPMN (but without the use of additional start/end events for each sub-process). This form shows some characteristics of a 'focus+context' view (as in Figl et al. [10]), which is considered to require less cognitive load of the user, who usually has to integrate model parts again when sub-processes are extracted from the main model as separate models (i.e. in 'overview+detail' view). However, in this form, the complexity of the full-flattened model is inherited and amplified by the additional information on process groupings.

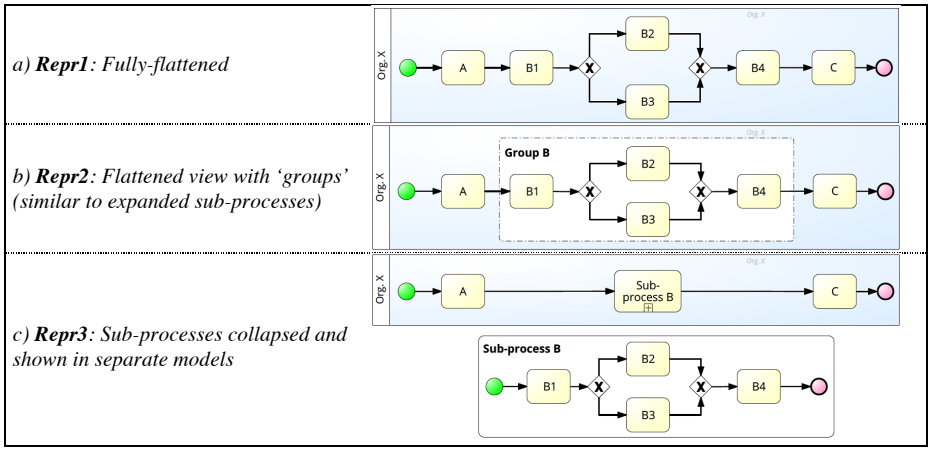

Fig. 2. Three modularity representations: *a)* Fully-flattened [Repr1], *b)* Flattened view with groups [Repr2], and *c)* Sub-processes collapsed and shown in separate models [Repr3].

The third form (Repr3) is the initial representation, which addresses the size and complexity with the use of collapsed sub-processes in BPMN. The sub-processes are hidden in the higher level (main) process model, but can be accessed as a separate model whenever the user is interested in the information it contains.

Fig. 3 shows example models of the processes A and B in two representation forms (Repr2 and Repr3), respectively. (Note that the figure is provided to give an indication of the size and structure of the models, and labels of all process elements that existed in the experiment are removed here for confidentiality reasons.)

3.3 Presentation medium for the process models

We experimented with two alternative presentation mediums: paper and computer. Half of the participants were provided with the models on A3 size papers, which allowed for adequate readability. The sub-processes in Repr3 were also printed on separate A3 size papers with 6 sub-processes on each.

The other half of the participants received the models on the computer environment through an online website developed for the experiment (see also sec. 3.7). The models with Repr1 and Repr2 (fully-flattened, and flattened with groups) were displayed as images, which can be zoomed and navigated in all directions. For the models with Repr3 (with separate sub-process models), the sub-processes pop-up when the mouse pointer hoovers on the collapsed sub-process element in the main model.

The possible effect of using computer environment with different size and resolutions was reduced, as the participants performed the experiment in their business settings where they were provided with standard computer facilities.

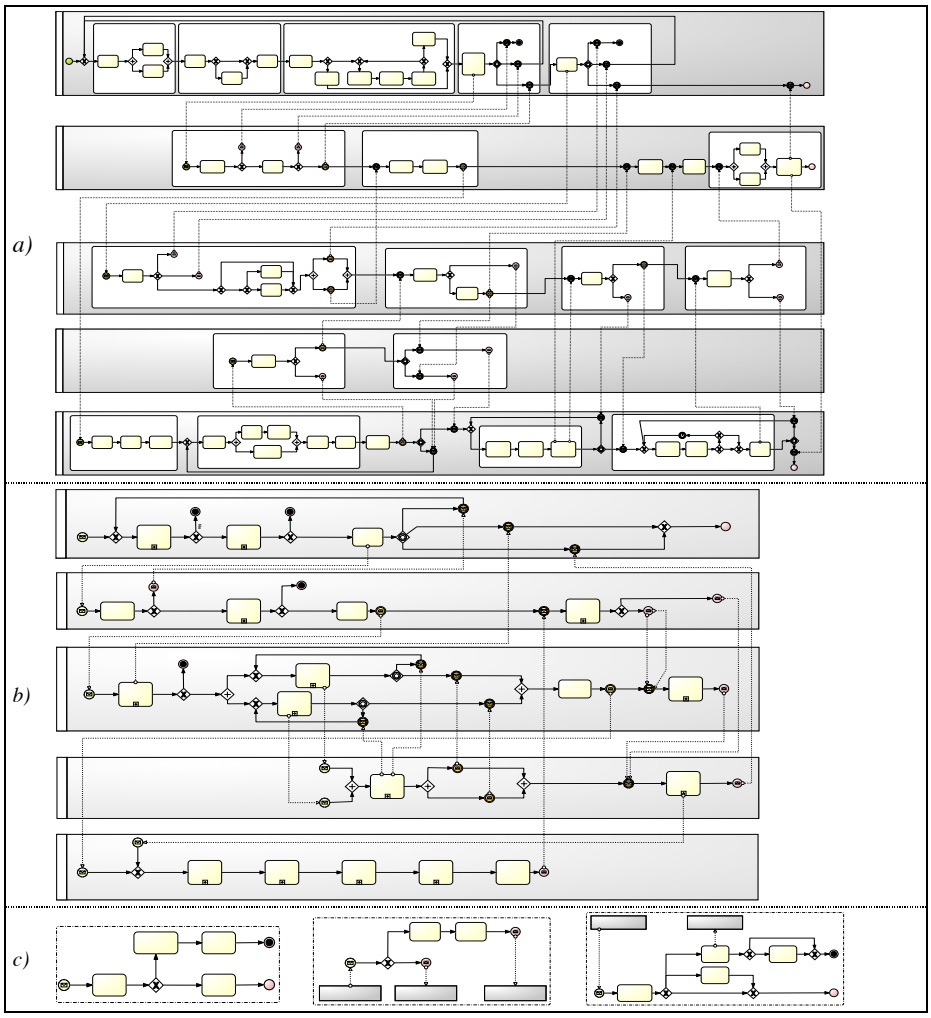

Fig. 3. The process models in two forms of modularity representation: *a) Process A* in *Repr2* (flattened with groups of activities), *b) Process B* in *Repr3* (with collapsed sub-processes), c) Few of the *sub-process models* of Process *B* in *Repr3*.

3.4 Understandability questions

In order to evaluate participants' level of understanding of the processes, we developed 9 questions for each process by following an iterative approach with the domain experts employed in the company. This was to make sure that each question can be used as a representative and valid way to assess someone's understanding of the processes.

Since the quality of these questions has significant influence on the validity of the findings [22], we paid particular attention on developing a set of questions that is

balanced in relation to different *process perspectives* (i.e. control flow, resource, and information/data), and *scope* (i.e. global and local). Accordingly, a *local* question can be answered within the scope of a single sub-process, while information available in the modularized (high-level) model is sufficient to answer a *global* question. The third type is the *global-local* questions which require information available not only in the modularized model but also in one or more sub-processes. Availability of these three types of questions is important particularly for the investigation of the potential influence of modularity [9]. Out of 9 questions (for each process), there were 3 global, 3 local, and 3 global-local questions.

The distribution of questions with regard to process perspectives is as follows: For Process A, out of 9 questions, 3 relates to all process perspectives, 2 only to the control flow, 1 both to the control flow and resource, and 3 both to the resource and information perspectives. A very similar configuration is maintained also for Process B.

Each question has a multiple-choice design, where respondents are provided with 5 choices – the last one always being 'I don't know' (i.e. unable to tell). An example question for Process A is given below. For instance, this question is a *local* question that relates to all three perspectives: control-flow (cnt), resource (res), information (inf).

Q: Who will know that the AB Request is accepted after a positive opinion of the Review Board?

a) Only AB Manager *b) Only AB Owner* *c) Only Requester*
d) Both AB Manager and Requester *e) I don't know* (unable to tell)

3.5 Dependent variables

As illustrated in our research model (in Fig. 1), we identified four dependent variables concerning process model understandability. The first two relate to the (objectively measurable) level of understanding that the participants can demonstrate with respect to each model [14], [9]. These are as follows:

- *Understandability Task Effectiveness* is operationalized by the understandability test *score*, i.e. the number of correctly answered understandability questions.
- *Understandability Task Efficiency* indicates the degree of cognitive resources spent by the reader in understanding the model [21]. It is operationalized by dividing the test score to the total time spent by a participant for the questions that he/she correctly answered.

The remaining two variables are based on the two constructs of the Technology Acceptance Model (TAM) [23] (i.e. perceived usefulness and perceived ease of use) and concern users' perception of the models in terms of their usefulness for understandability and ease of understanding:

- *Perceived Usefulness for Understandability (PUU)* indicates users' perception on the utility of a process model structured in a particular form in providing gains to the user in terms of understandability.
- *Perceived Ease of Understanding (PEU)* indicates the degree to which a person believes that understanding a model is free from mental effort (as also in [14]).

TAM and its derivatives (e.g. [24]) are the commonly referred theories that predict and explain the acceptance and use of design artefacts, such as IS methods and models [25], [26]. In TAM, the two constructs (perceived usefulness and ease of use) are believed to be strong determinants of users' intentions to use a design artefact. For the

experiment, the variables that are adopted are operationalized using multiple indicators (scale items), which have been evaluated for reliability and validity in previous research [23], [25]. Following [24], we used 4 items for each construct, where the wording of the items was modified to accommodate this research. Below are two example items:

- *PUU-1: Using this type of process models would make it more easy to communicate business processes to end-users.*
- *PUE-1: I found the way the process is represented as clear and easy to understand.*

The participants expressed their level of agreement with each statement on a 7-point Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree).

3.6 Experiment Blocks

The experiment was designed to have six blocks (as shown in Table 2). Each participant went through a single block, where he/she was given two process models (A and B) in sequence. In each block, the models were shown using different forms of modularity representation but either on paper or in a computer environment.

Table 2. Experimental block-design

Exp. Block	Representation *Process A*	*Process B*	Presentation Medium
1	Repr1	Repr2	Paper
2	Repr1	Repr3	Computer
3	Repr2	Repr1	Computer
4	Repr2	Repr3	Paper
5	Repr3	Repr1	Paper
6	Repr3	Repr2	Computer

3.7 Questionnaire

The questionnaire for the experiment was provided through an online web environment, which was developed using a software application available for creating online surveys (Sawtooth Software SSI WEB 8.4.6). The questionnaire consisted of 5 parts. The *first* part involved questions related to the personal factors, where participants were asked to give their opinion about their experience and knowledge on process modeling and BPMN, and familiarity with the process and its domain. In the *second* part, the participants were given Process A in a particular form and on a medium depending on the experiment block that they were assigned to. They were expected to answer 9 understandability questions (each placed on a separate online webpage in sequence). In the blocks where computers were used, the process models were embedded in the questionnaire environment in such a way that the question and model were presented on the same page. The *third* part gathers users' perceptions on the particular representation form and medium used to represent the model for Process A. The *fourth* and the *fifth* parts of the questionnaire had the same structure as the second and third parts, but this time for Process B.

All participants (whether they received the models on paper or on computer) received the questions through the *online* environment. This was particularly necessary for accurately tracking the time it took for participants to answer each understandability question, and for computing metrics regarding the *understandability task efficiency*. The participants were informed upfront that they were time-tracked.

Before the actual experiment took place, the questionnaire was pre-tested as a final step by 6 people (4 graduate students, and 2 PhD students). This also gave an indication about the required time-frame for the experiment. As a result of the pre-test, several ambiguities and minor mistakes were corrected in the final version.

3.8 Participants

The company representatives initially selected 74 employees working in 13 departments of the division (where the experiment took place), who had already taken or might potentially take part in the execution of one of these processes. Ultimately, 60 employees participated in the experiment, leading to a response rate of around 81%. All participants have at least a university degree - majority with an engineering background. Out of 60, 26 employees had previously taken part in the execution of one of these processes or were moderately familiar with their execution.

The participants were randomly assigned to each experiment block with the exception of the 26 employees that had certain degree of familiarity with the domain and process models. These were evenly assigned to the blocks (4 or 5 participants per experiment block). Each participant was sent an invitation with practical guidelines on accessing the online experiment site, including a username which also determined the experimental block that the participant was assigned to.

4 Results and Discussions

Fig. 4 presents the distribution of participants based on their opinion about how frequently they encounter process models in practice, and what their level of knowledge on process modeling and BPMN is. Accordingly, around half of the participants encountered process models less than once a month, while the majority of the rest (33% in total) encountered process models more than once a month. About 72% of the participants stated that they are knowledgeable or somewhat knowledgeable about process modeling. However, they had no or limited knowledge about BPMN. In the overall, we can consider majority of the participants to be fairly novice in terms of general BPM skills and capabilities.

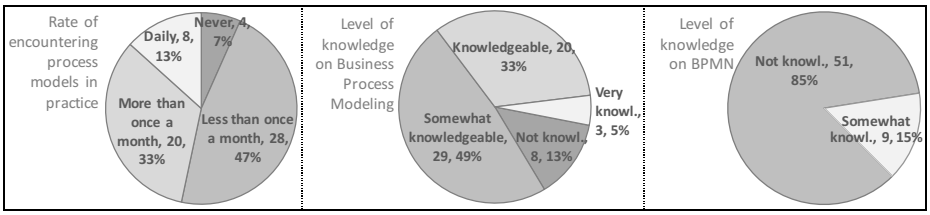

Fig. 4. Participants' background information about process modeling.

As each participant tested two process models in different forms, the experiment led to 120 observations distributed largely in a uniform way over different modularity representations and presentation mediums. Table 3 presents the descriptive statistics for the variables tested in the experiment. The boxplot diagrams for the dependent variables over the modularity representation and presentation medium are shown in Fig. 5.

Table 3. Descriptive statistics.

Independent Variable / Levels	N	Unders. Task Effectiveness *(Scale: 0 - 9)*[1]		Unders. Task Efficiency *(in Score/Hour)*		Perceived Usefulness *(Scale: 4 - 28)*[2]		Perceived Ease of Und.ing *(Scale: 4 - 28)*[2]	
		Mean	S.Dev.	Mean	S.Dev.	Mean	S.Dev.	Mean	S.Dev.
Repr1 (fully-flattened)	39	6.2	1.5	33.2	21.0	20.7	5.6	23.2	5.1
Repr2 (flat with groups)	41	5.9	1.5	33.1	12.9	18.3	6.0	20.1	5.6
Repr3 (with sub-processes)	40	5.3	1.6	40.5	24.9	15.8	6.2	18.6	6.3
Paper	62	6.0	1.5	38.4	24.2	20.0	5.4	21.6	5.8
Computer	58	5.6	1.6	32.6	14.9	16.3	6.5	19.6	5.9

[1] *Each correctly answered question counts for 1 point for the Score, totaling to 9 points max for 9 questions.*
[2] *Four items to be answered in a 7-point Likert scale, totaling to a min value of 4, max value of 28 (4 x 7).*

To test our hypotheses, we first analyzed the data for conformance with the assumptions of the statistical tests that can be used. The results of our initial analysis showed that there are clear deviations from *normality* for the measures of all dependent variables over independent variables (Kolmogorov–Smirnov test of normality, all with $p < 0.02$). Therefore, we forewent the predictive power of parametric tests and applied their non-parametric counterparts, in particular the Kruskal-Wallis test (with stepwise step-down multiple comparison) [27] to evaluate our hypotheses (using SPSS v.23).

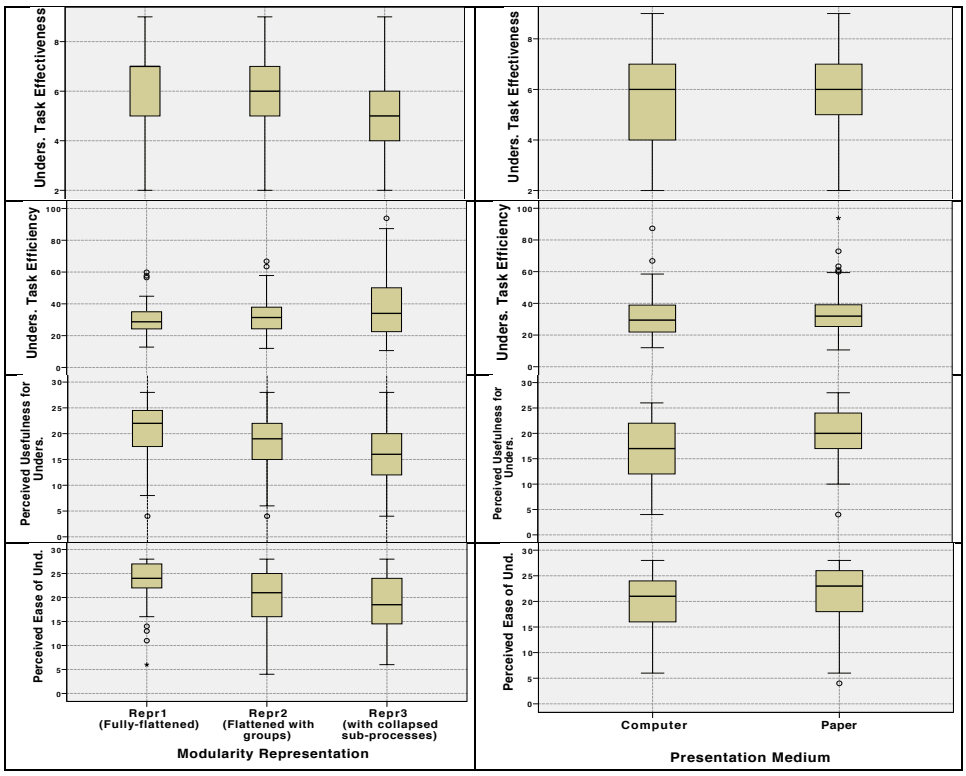

Fig. 5. Boxplot diagrams for dependent variables over independent variables.

4.1 Testing the hypotheses on the forms of modularity representation

We argued in our first group of hypotheses that different forms of modularity representation in BPMN significantly influences process understandability. Table 4 shows the results of our tests regarding this set of hypotheses. Accordingly, modularity representation has significant impact on three of the four understandability factors.

Table 4. Results of the Kruskal-Wallis statistical tests.

Independent Variables	Unders. Task Effectiveness		Unders. Task Efficiency		Perceived Usefulness		Perceived Ease of Und.ing	
	H	p	H	p	H	p	H	p
Modularity Representation	8.49	*0.014**	9.67	0.208	13.12	*0.001**	13.59	*0.001**
Presentation Medium	1.89	0.169	2.24	0.134	9.54	*0.002**	4.32	*0.038**

Understandability Task Effectiveness. The results of the Kruskal-Wallis tests indicate that the understandability task effectiveness measured by the *score* achieved from the understandability questions, is influenced by the modularity form [H(2): 8.49, p = 0.014]. According to stepwise multiple comparison, the scores attained with fully-flattened models (Repr1) and with models where BPMN groups are used (Repr2) are *significantly higher* than the score with models where sub-processes (Repr3) are used. The scores with Repr1 and Repr2 do not differ significantly. Hence, the flattened models (with or without the use of groups) lead to a higher effectiveness than the models where sub-processes are used.

We performed further tests to investigate if the scores obtained from questions regarding different *process perspectives* (cnt/res/inf) and *scope* (global/local) show any major difference. The results indicate that, the scores concerning different *process perspectives* do not differ significantly. However, in line with the results obtained with the overall score values, the scores from *local* questions (which involve information only about sub-processes) are significantly higher in Repr1 and Repr2 than in Repr3 [H(2): 10.32, p = 0.006]. For the *global* questions (where answering requires information only about the main/modularized model) and *global-local* questions (where answering requires information about both modularized model and one or more sub-processes), the differences in the scores for each form of modularity representation are not significant (p=0.757 and p=0.459, respectively).

Based on these results, we can infer that for *local* questions, modularization degrades effectiveness when *overview+detail* strategy is used (as in Repr3, where sub-processes are shown separately, detached from their context). This is likely due to the increased browsing costs (split-attention effect) in Repr3 and *insignificant* cost of complexity in flattened models (Repr1) even with the group information (Repr2). This may further indicate that the context -where a sub-process takes place, plays an important role in understanding (sub-)process information. On the other hand, the use of modularization in which the sub-processes are displayed directly within the context of the higher level model (as in Repr2) doesn't offer any advantage for effectiveness.

For *global* and *global-local* questions, the modularization does not have significant effect on effectiveness. This implies that the understandability gain acquired in abstracting away less relevant information through modularization is insignificant in these types of process models.

Understandability Task Efficiency. Although the average understandability task efficiency (i.e. the number of correctly answered questions divided by the time spent for answering them) is higher for Repr3, our statistical analysis does not indicate a *significant* difference for the three forms of modularity representations [H(2): 9.67, p = 0.208]. A relatively high dispersion of the efficiency values for Repr3 is also worth mentioning. The results are in line also with respect to the efficiency obtained for questions concerning different process perspectives and scope (i.e. there is no significant difference with respect to the forms of modularity representation).

Perceived Usefulness for Understandability. Participant's view on the usefulness of three modularity representation forms differs significantly [H(2): 13.12, p = 0.001]. Although the stepwise multiple comparisons indicate no statistically significant difference between Repr1 and Repr2, and Rep2 and Repr3, the difference between Repr1 and Repr3 is significant. Accordingly, participants found Repr1 significantly more useful in fostering understandability than Repr3. Hence, fully flattened models in BPMN (collaboration) diagrams are considered more useful in providing gains to the user in terms of understandability in comparison with the models with sub-processes.

Perceived Ease of Understanding. Similar to usefulness, the attitude on the ease of understanding also differs significantly with respect to the forms of modularity representation [H(2): 13.59, p = 0.001]. However, in this case, Repr1 is considered easier to understand than *both* modular forms, i.e. Repr2 and Repr3. This indicates that, fully flattened models are regarded as easier to understand than any of their modularized form. Given that the only difference between Repr1 and Repr2 is the grouping information, we can deduce that any additional information on the process model can be perceived to increase the difficulty of understanding.

4.2 Testing the hypotheses on the presentation medium

The second group of hypotheses argued for the influence of the medium used to present process models on the understandability. The results of the tests regarding this set of hypotheses are shown in Table 4 (second row). The results indicate that the presentation medium does not have significant influence on the understandability task effectiveness or efficiency, but is regarded as critical from users' point of view.

Understandability Task Effectiveness and Efficiency. The statistical tests indicate that the use of paper or computer for presenting process models does not lead to a significant difference on the understandability task effectiveness or efficiency [H(1): 1.89, p = 0.169] and [H(1): 2.24, p = 0.134], respectively. Similarly, the results of the analyses on the scores gained from questions concerning different process perspectives and scope (local/global) do not show any significant difference.

Perceived Usefulness for Understandability and Ease of Understanding. The participants consider models presented on paper easier to understand and more useful (from understandability's point of view) than the ones presented on the computer [H(1): 4.32, p = 0.038] and [H(1): 9.54, p = 0.002], respectively.

The analysis on the effect of presentation medium indicates that using paper or computer influences only the perceived understandability when it comes to the models of this type, structure and complexity. We observed that the participants that received models on paper studied them using their fingers, which can be more difficult on the screen. However, very few of the participants took notes directly on the printed models.

4.3 Testing the influence of personal factors and using different process models

As mentioned, we gathered information about participants' experience and level of knowledge in process modeling and BPMN, as well as their familiarity with the processes. We used this information to test the direct or moderating effects of these factors on the understandability. Our statistical analyses did not yield any significant effect of these factors. Additional research is required to better operationalize these factors and investigate their influence.

As we used *different* sets of understandability questions for the two process models we used in our experiment, it would not be plausible to compare the average score and efficiency values regarding these models. However, we checked the perceived understandability variables (PUU, PEU) and were not able to find a significant difference between the results obtained for these two models. Separate results for these two models are in line with the general findings discussed above.

5 Conclusions

Business process models are important elements at various phases of the BPM lifecycle. As such, their understandability for their intended audience is crucial. In this paper, we have described the design and conduct of an experimental study to investigate two factors that potentially influence process model understandability. We have examined if and how different forms of modularity representation and the medium used for the presentation influence the understandability of process models that are in the form of BPMN collaboration diagrams. To contribute to the generalizability of our findings, we used two real-life processes as the objects of our experiment and 60 practitioners as our participants. The participants were employees of a large organization and potential audience of the models tested. The majority had some degree of BPM knowledge but relatively limited familiarity with the BPMN.

Table 5 summarizes our hypotheses and findings. Overall, we found that using sub-processes in BPMN (where sub-processes are shown as separate models) negatively influences understandability effectiveness without any contribution to efficiency (when compared with models that are flattened or modularized using groups). Fully-flattened models are considered to better facilitate understanding and to be easier to comprehend than models with sub-processes. These models are regarded as easier to understand even than models that show additional modularization information in flat models using BPMN groups. If modularization is necessary (due to practical reasons), displaying sub-processes within their context rather than as separate models should be preferred, if the understandability of the process model is of a key concern.

As for the presentation medium, although using paper or computer does not influence the objectively measured understandability (effectiveness and efficiency), *paper* is practitioners' preferred choice of medium in terms of the degree it facilitates understandability and ease of understanding.

Our work has a number of limitations from which several possible directions for future research emerge. Experimenting with real-life processes and business practitioners has a positive effect on the external validity of our study. This allows us to better generalize the results towards practical implications. However, having participants from a single enterprise (despite being from 13 different departments)

reduces this effect. Future research should consider involving practitioners with different backgrounds and working in diverse business environments.

Table 5. Summary of hypotheses tests.

Hypothesis	Result	Description
H1- Forms of modularity representation has a significant influence on:		
a) Understandability task effectiveness	*Supported*	Effectiveness is higher with *flattened* BPMN models (with or without groups) than with modularized models with sub-processes.
b) Understandability task efficiency	*Not supported*	Efficiency is not different with models in any form (flattened or modularized using groups/sub-processes).
c) Perceived usefulness for understandability	*Supported*	Fully-flattened models are considered more useful (in terms of facilitating understanding) than models with sub-processes.
d) Perceived ease of understanding	*Supported*	Fully-flattened models are perceived easier to understand than models that are modularized (using groups or sub-processes).
H2- Presentation medium has a significant influence on:		
a) Understandability task effectiveness	*Not supported*	Presenting models on paper or on computer does not influence effectiveness.
b) Understandability task efficiency	*Not supported*	Medium (paper, computer) does not effect efficiency significantly.
c) Perceived usefulness for understandability	*Supported*	Paper is considered more useful (in terms of facilitating understanding) as a presentation medium.
d) Perceived ease of understanding	*Supported*	The models on paper are considered easier to understand than models on computer.

The specific choice for the modularization of two processes can also be regarded as a further threat to the validity of our findings. It is difficult to verify that the choices for the parts that are structured as sub-processes are optimal (but not arbitrary, which may lead to a flawed modularization [9]). We addressed this risk by requesting domain experts (who also act as process modelers/owners in the case organization) to validate the models including their modularity structures. Yet, future research should experiment the effect of modularity when other (theoretical) modularization approaches (such as Wand & Weber's [16] as in [15]) are employed.

Our experiment was not able to identify any influence of process modeling experience or level of knowledge on understandability (based on the self-reported levels by the participants). Future research should consider using other methods to more objectively operationalize such factors (e.g. in the form of tests to quantify the level of theoretical knowledge on process modeling and notation).

Following a rigorous method in developing, verifying and validating the understandability questions contributes to the accuracy by which the understandability factors are operationalized. This reinforces the construct validity of our work. However, our findings are valid only for BPMN collaboration diagrams, where a number of *pools* are used (each with a single control-flow). To understand the potential effect of using this type of BPMN models, future work should consider experimenting also with BPMN models where a single main control-flow is present (i.e. a single pool potentially with multiple lanes). Future works should also use processes of different size, complexity, and applied level of modularity to better understand the interplay between these factors and contribute to the development of guidelines for applying modularization in business process modeling.

References

1. Dumas, M., La Rosa, M., Mendling, J., Reijers, H.A.: Fundamentals of business process management. Springer Verlag (2013).
2. Reijers, H. a., Mendling, J.: A Study Into the Factors That Influence the Understandability of Business Process Models. IEEE Trans. Syst. Man, Cybern. - Part A Syst. Humans. 41, (2011).
3. Houy, C., Fettke, P., Loos, P.: On the Theoretical Foundations of Research Into the Understandability of Business Process Models. ECIS 2014. pp. 1–38 (2014).
4. Recker, J.: Empirical investigation of the usefulness of Gateway constructs in process models. Eur. J. Inf. Syst. 22, 673–689 (2012).
5. Sanchez-Gonzalez, L., Garcia, F., Ruiz, F., Mendling, J.: Quality indicators for business process models from a gateway complexity perspective. Inf. Softw. Technol. 54, (2012).
6. Zugal, S., et al.: Investigating expressiveness and understandability of hierarchy in declarative business process models. Softw. Syst. Model. 14, 1081–1103 (2013).
7. Reijers, H.A., Mendling, J.: Modularity in Process Models: Review and Effects. BPM 2008. pp. 20–35. Springer, Milan, Italy (2008).
8. Moody, D.L.: Cognitive Load Effects on End User Understanding of Conceptual Models: An Experimental Analysis. ADBIS 2004. pp. 129–143. Springer (2004).
9. Reijers, H.A., Mendling, J., Dijkman, R.M.: Human and automatic modularizations of process models to enhance their comprehension. Inf. Syst. 36, 881–897 (2011).
10. Figl, K., Koschmider, A., Kriglstein, S.: Visualising Process Model Hierarchies. ECIS 2013. p. 180 (2013).
11. Leymann, F., Roller, D.: Workflow-based applications. IBM Syst. J. 36, 102–123 (1997).
12. van der Aalst, W., van Hee, K.: Workflow Management: Models, Methods, and Systems. MA: MIT Press (2002).
13. Zugal, S., Pinggera, J., Weber, B., Mendling, J., Reijers, H. a.: Assessing the impact of hierarchy on model understandability. Ws. MODELS 2011, LNCS 7167. pp. 123–133 (2012).
14. Houy, C., Fettke, P., Loos, P.: Understanding Understandability of Conceptual Models - What Are We Actually Talking about? ER 2009. pp. 64–77. Springer (2012).
15. Johannsen, F., Leist, S., Braunnagel, D.: Testing the Impact of Wand and Weber's Decomposition Model on Process Model Understandability. ICIS 2014. pp. 1–13 (2014).
16. Wand, Y., Weber, R.: A Model of Systems Decomposition. ICIS 1989 (1989).
17. Cruz-Lemus, J.A., Genero, M., Manso, M.E., Morasca, S., Piattini, M.: Assessing the understandability of UML statechart diagrams with composite states—A family of empirical studies. Empir. Softw. Eng. 14, 685–719 (2009).
18. Zugal, S., Soffer, P., Pinggera, J., Weber, B.: Expressiveness and understandability considerations of hierarchy in declarative business process models. BPMDS 2012, (2012).
19. Wolf, C., Harmon, P.: The State of Business Process Management, BP Trends. (2014).
20. Field, A., Hole, G.: How to Design and Report Experiments. SAGE Publications Ltd., (2003).
21. Mendling, J., Strembeck, M., Recker, J.: Factors of process model comprehension—Findings from a series of experiments. Decis. Support Syst. 53, 195–206 (2012).
22. Laue, R., Gadatsch, A.: Measuring the Understandability of Business Process Models - Are We Asking the Right Questions? BPM 2010 Workshops. pp. 37–48. Springer (2010).
23. Davis, F.D.: Perceived Usefulness, Perceived Ease Of Use, and User Acceptance of Information Technology. MIS Q. 13, 319–340 (1989).
24. Venkatesh, V., Morris, M.G., Davis, G.B., Davis, F.D.: User Acceptance of Information Technology: Toward a Unified View. MIS Q. 27, 425–478 (2003).
25. Moody, D.L.: The Method Evaluation Model: A Theoretical Model for Validating Information Systems Design Methods. Inf. Syst. J. 1327–1336 (2003).
26. Recker, J., Rosemann, M., Green, P., Indulska, M.: Do Ontological Deficiencies in Modeling Grammars Matter? MIS Q. 35, (2011).
27. Field, A.: Discovering statistics using IBM SPSS Statistics. SAGE Publications Ltd. (2013).