

Investigations on User Preferences of the Alignment of Process Activities, Objects and Roles

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Abstract. Numerous attempts have been made to research the variety of different influences on the understandability of process models. Common to all of these attempts is the limitation to the process model itself. Little empirical effort is spent on investigating the understandability of the alignment of process activities, objects, and roles. This paper tackles this issue and empirically studies preferences of how to visually align process activities with objects and roles. In particular, three visualization techniques are evaluated in order to support the combination of the object and organization units with their corresponding process model elements. The empirical study provides a strong support for the visualization of a process model that is disburdened from context information such as objects used and roles involved and thus is reduced to the sole visualization of process activities and its control-flow.

Keywords: process modeling, understandability, model visualization.

1 Introduction

In the context of Business Process Modeling, models have several intentions. For instance, they act as discussion foundation or are used as basis for the implementation of an information system. Thus, process models are usually not designed for personal use but rather need to be understood by a variety of peers. Consequently, apart from particular intentions, process models should be designed in a way that they are (easily) understandable by a heterogeneous set of users.

Effects on understandability of process models are subject of a plethora of academic discussions. In particular, it has been diagnosed that some syntax elements such as the number of routing symbols or the design of routing symbols [3,4,12] have implications on process model understandability. Thus, the design of process models has a significant effect on user's comprehension. To date, the debate on understandability mainly focuses on the process model itself. To allow for a more comprehensive

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insight into impacts on understandability of process models, additional information about the process model context (beyond activities and control-flow) is required. A process model is jointly linked with further model types. In addition to process activities, a process model aligns e.g., data used and/or the roles involved. The latter are specified in separate models and are connected through assigning this information to process activities. To complement debates on process model understandability, an advanced view on the visual alignment between process models and its related model types is essential.

Such an investigation requires considering practical implementation of aligning process activities and its related information. One option is displayed in Fig. 1, which exemplarily shows the visual assignment of objects (data) and organization units (roles) to process activities in one window. The user views all corresponding information of each process activity within one window (“Process Window”). This kind of integrated visualization technique (further in this paper called *single view*) is used by several modeling languages (see section 2.) To view relationships between the objects and organization units themselves, the user has to open separate windows (“Object Window” and “Organization Window” respectively).

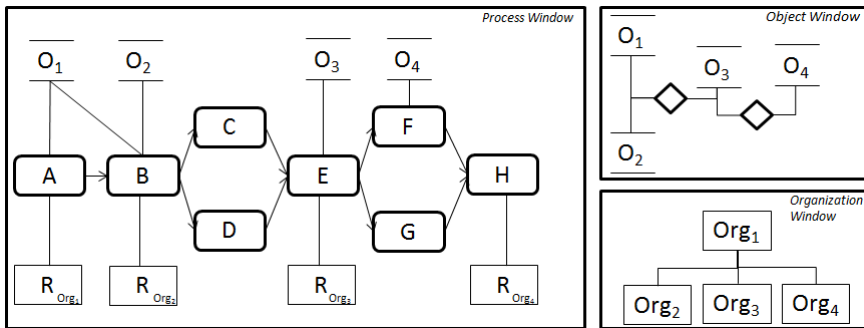


Fig. 1. Alignment of process activities, object and organizational units

The objective of this paper is to understand *visualization preferences* of the alignment of a process model and its corresponding objects and roles (what kind of visual alignment does the user prefer?). Exemplarily, we investigate preferences for the visualization of an alignment between process activities, objects and organization units (roles). The latter can be replaced by any other model type (e.g., risk model).

To achieve this objective, we proceed as follows. Next section summarizes visual alignment techniques implemented for common process modeling languages in practice. Section 3 discusses three visualization techniques, which mainly base upon these practical implementations. To provide evidence about the three visualization techniques, an empirical study has been conducted. The results of the study are presented and discussed in section 4. The topic addressed in this paper is highly related to discussions on process model understandability and visualization techniques for process models. These related approaches are tackled in section 5. The paper concludes with an outlook in section 6.

2 Alignment Visualization in Practice

To investigate visualization preferences, we studied the alignment visualization of common process modeling languages, here Business Process Modeling Notation (BPMN), Event-driven Process Chain (EPC), Unified Modeling Language (UML) and Petri nets.

In EPC (respectively eEPC) process objects and organizational units are linked to the process activities through arcs. Undirected arcs are used to link an organizational unit to a process activity for the definition of roles, whereas information objects are linked to activities with directed arcs to display the type of operation (read/write). Table 1 shows an example of an eEPC model created with ARIS Express. It displays a process activity A executed by a member of the role O1, which reads a document D1 and writes a document D2.

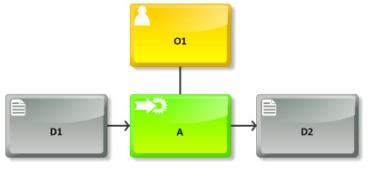
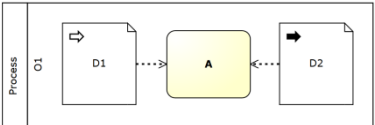
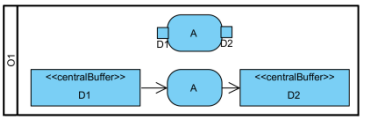
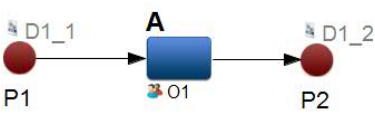
The BPMN 2.0 specification defined by the Object Management Group (OMG) provides several graphical elements to display process objects (data objects or data store). These objects can also be assigned in the control-flow model and linked to process activities, processes or global tasks using a data association arc. Organizational units however are embedded with the use of lanes, which is a fundamentally different solution than in eEPC. For each role in the process, a lane is created and process activities are distributed across the lanes according to the underlying role model for the task execution. Table 1 shows an example BPMN model for the visual alignment of a process activity A, which is executed by a member of role O1 and uses data object D1 as input and data object D2 as output. The model has been created with the Signavio Process Editor.

The current UML 2.4.1 specification provided by the OMG offers 14 different diagram types, which are designed mainly for modeling purposes from the field of system and software engineering. Most suitable for the modeling of business processes are UML activity diagrams. With UML 2.0 four different types of object nodes have been introduced for the representation of objects. So-called Pins can be used to represent the object flow between process activities (called actions in UML). They are visualized as small squares directly attached to action elements. It is also possible to use a `CentralBufferNode` (or the respective persistent equivalent `DataStoreNode`), which represents an object node storing objects independent from actions. Also, `ActivityParameterNodes` can be used to represent input or output objects to an activity (which in UML corresponds to a subprocess consisting of atomic actions). It is therefore necessary to understand the different semantics of the various object types in order to choose an appropriate element for the visual representation. Like BPMN, UML uses lanes (called partitions) to describe role distribution across the process activities. Table 1 contains two example UML models created with Visual Paradigm for UML. It demonstrates the two fundamental visualization styles UML offers. The examples show a process activity A, which is executed by role O1 and reads an object D1 and writes an object D2 as in the previous examples.

Finally, Petri nets are bipartite directed graphs consisting of places and transitions. In so-called high-level Petri nets places contain tokens, which are interpreted as distinguishable process objects travelling dynamically through the process model.

The token itself can be represented by different types of information. In Petri nets, the alignment between process activities, objects and roles is not represented with arcs or additional routing constructs (as it is done in the previously described notations). Instead, related context information can be accessed interactively by clicking through each process activity if supported by the modeling tool. The Petri net based modeling tool Horus Business Modeler allows visualizing the aligned information of process activities without browsing through the activities. The example Petri net model in Table 1 shows a process activity A being executed by role O1. Places P1 and P2 are containers for objects of type D1_1 and D1_2, which indicates that activity A reads object D1_1 and writes object D1_2.

Table 1. Visualization examples for the alignment of activities, objects and roles in different process modeling languages

Modeling Language	Visualization example	Short description
eEPC		<p>Activities (A) are connected to objects (O) through directed arcs representing the access type (read/write), roles (D) are assigned through undirected arcs.</p>
BPMN		<p>Activities are connected to objects through directed arcs, the access type is represented by the icon style (white arrow: read; black arrow: write). Roles are displayed via lanes.</p>
UML		<p>Objects are either directly attached to activities or connected with directed arcs. The above example shows pins, the example below shows buffer nodes (CentralBuffer-Node). Roles are displayed via lanes.</p>
Petri net		<p>Objects can be stored in places, which are connected to activities through directed arcs. There is no explicit support for roles, however some tools realize the integrated display with an extended annotation of the model.</p>

However, the sole inspection of a process model itself is not sufficient to give the user a complete picture about the business process. Independent from the modeling language used to design the process control-flow, additional but separate models must be studied (object or organizational perspective) in order to fully understand the internal structure. Fig. 2. shows such additional models for the Petri net from Table 1.

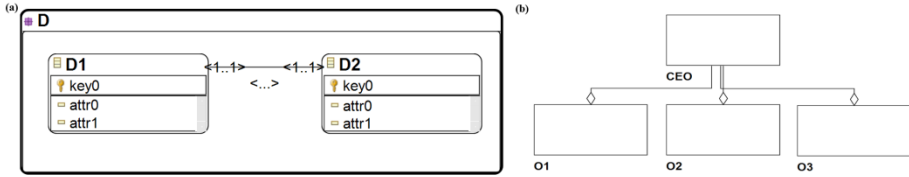


Fig. 2. Object model (a) and organization model (b) corresponding to the Petri net model from Table 1, both created with Horus Business Modeler

The object model (cf. Fig. 2a) visualizes the internal 1:1 relationship between objects D1_1 and D1_2 on the object/database level, whereas the organization model (cf. Fig. 2b) displays the organization structure and reveals the existence of further process roles.

The implementation of common process modeling tools requires that separated windows must be opened for a simultaneous view on all process model related information. To date there is no tool support for an integrated or parallel visualization of the different model types. Therefore, relationships of e.g., process activities and roles must be accessed by browsing different models and different windows.

In summary, the eEPC, BPMN and UML formalisms support the alignment of information from the object and role perspective with the control-flow model by inserting additional elements (as nodes) and linking them to the corresponding activities. Similarly, annotations can be used to tag the basic Petri net elements (places and transitions) with related information. Based on these findings, we aim to investigate both the efficiency of the present integrated visual implementation (single view) and the simultaneous display of different model types (multiple views) for the alignment of process activities with objects and roles.

3 Visualization Techniques

Visualizing the alignment between a process model, its assigned objects and organizational units at the same time with sufficient legibility and level of detail on the available screen space is often a big challenge and therefore effective visualization strategies are necessary. In this section we present three visualization techniques, which are a general representation of the visual implementations reported in section 2. Each of these three techniques – single view, multiple views, and multiple views in combination with linking and brushing – are discussed in this section. They build the foundation for the empirical validation of visualization preferences for process model alignment discussed in the subsequent section.

3.1 Single View Technique

The first visualization technique represents the alignment between a process model and its assigned information as node-link representation in a single view (see Fig. 3 for an example). Process activities, objects and roles are visualized as nodes. Different shapes for the nodes are used to differentiate between nodes that represent process activities (rectangle shape), roles (ellipse shape) or objects (trapezium shape).

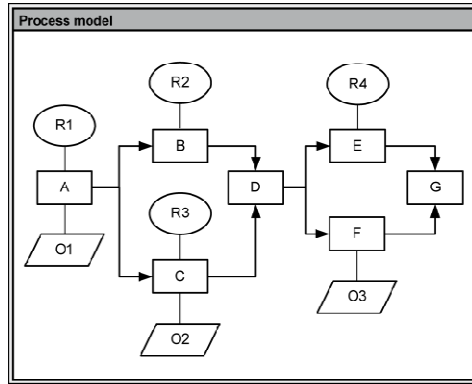


Fig. 3. Example for the single view visualization

The objects and roles are directly connected with the corresponding process activity in the process model with an arc. This kind of visualization allows users to get an overview about the structure of the process model and to see the connections between objects and roles for each process activity at the same time. If users want to view the structure of the organization model or of the object model, they can click on a role or object node in the process model to open the corresponding model in a separate window.

The single view technique provides an integrated overview about the structure of the process. However, users have to switch between three models to get a complete view. Especially for process models with plenty of objects and roles, the visualization of the process model at the same time in a single view/window is inefficient with regard to legibility. Clarity and consequently understandability of the single view decrease with the number of objects, roles and connection arcs used. Such a visualization technique is used in eEPCs, UML and also to some degree in BPMN.

3.2 Multiple Views Technique

Another technique is to use multiple views to present the alignment points between a process model and its organization model, and object model as node-link representation (see Fig. 4 for an example). Multiple views support different viewpoints that allow users to see process activities in combination with their objects and roles. The advantage of this technique is that the corresponding object and organization model are simultaneously displayed in the same window with the process model (they share one window). This allows for an immediate understanding of the connections between corresponding process elements. Scrolling and panning techniques are necessary for large process models, objects models and/or organizational models. In contrast to the single view approach (cf. example in Fig. 3), the connections between process activities to the corresponding objects and roles are not visualized as arcs respectively links in the process model view. This reduces the complexity and number of links that can have a negative effect on the general overview (understandability). The reduction of arcs also gives room to represent the object and organizational model together with the process model in one space. Especially for large process models it can happen that

the links between the nodes are very long. Hence, following these links is very difficult and users can get lost in the node-link representation. The annotation of objects and roles directly below their process activity might be beneficial for large process models. Such a visualization technique is used for Petri net-based process modeling tools.

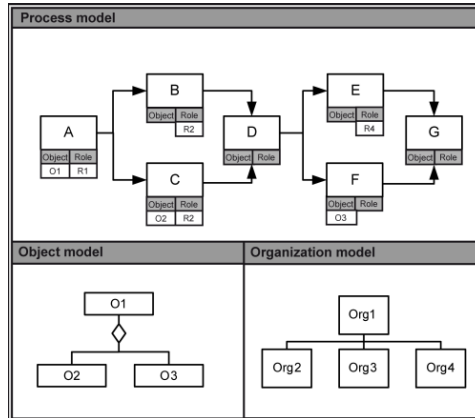


Fig. 4. Example for the multiple views visualization

3.3 Multiple Views Technique in Connection with Linking and Brushing

With the single and multiple views techniques, it is possible that the process model view is overloaded with too much information. A possible solution is to combine the visualization with interaction strategies, such as the linking and brushing technique [10], to simplify the representation of relationships between the process model, the object model, and the organization model in order to reduce overlaps between nodes and links. Linking and brushing technique is the most common interaction strategy for the representation of relationships between different views. If items are selected or highlighted in one view (called *brushing*), the corresponding connected items in the other views are also selected and highlighted (called *linking*). In our case, it supports users to trace the connections between the different models. For example, Fig. 5 shows four possibilities to present the connections between the process model view, the object model view, and the organization model view:

- No nodes are selected (cf. Fig. 5 (A)).
- One process activity is selected in the process model view. The corresponding objects in the object model view and the corresponding role in the organization model are highlighted (cf. Fig. 5 (B)).
- One object is selected in the object model view. The corresponding process activities in the process model view and the corresponding roles in the organization model are selected (cf. Fig. 5 (C)).
- One role is selected in the organization model view. The corresponding process activity in the process model view and the corresponding object in the organization model are highlighted (cf. Fig. 5 (D)).

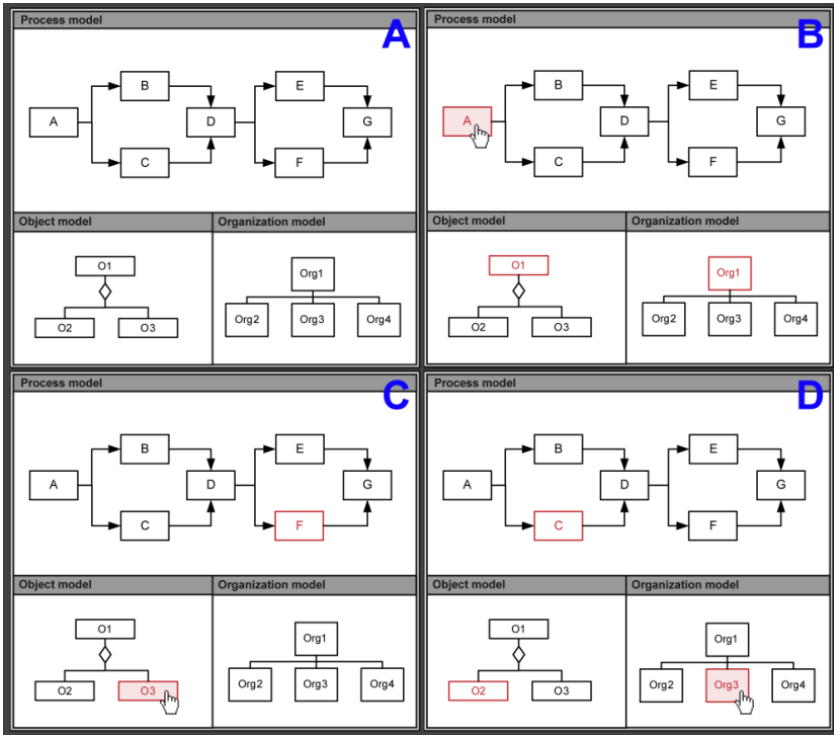


Fig. 5. Examples for multiple views approach in combination with linking and brushing technique: (A) no selection, (B) a process activity is selected, (C) an object is selected, and (D) a role is selected

3.4 Design Setting

To explore whether preferences for a particular visualization exist, we investigated the understandability of the alignment of process activities, objects and roles. This is validated with a web-based questionnaire that was set up. Participants were free to answer the questions and could withdraw the completion of the questionnaire at any time. The collection of data was anonymous. The questionnaire was designed in the following way.

Objects. The objects evaluated by each participant were five process models from the order management domain. One process model each was shown for the multiple views (see Fig. 7) and single view visualization (cf. Fig. 6) and three process models for the multiple views in combination with linking and brushing visualization (see, e.g., Fig. 8 and Fig. 9). The process models were not designed with a particular modeling language in order to avoid dogmatic discussions. To keep the process model itself simple, only sequence, split and join routing constructs were used. Additionally, we used a small process model (10 process activities). It has been identified that the number of process elements has implications on understandability if the preferred visualization is not used [7]. Therefore, we used a process model of moderate size in order to reduce cognitive load of the process model itself and direct the focus of the

respondent to the alignment of process activities, objects and roles. While displaying a particular visualization technique, we asked some comprehension questions, which had to be answered with yes or no:

- The process activity *Process backorders* requires the objects *Order* and *Payment*.
- The object *Order* is used by six process activities.
- The process activity *Process order* is performed by the role *Buyer*.
- Two process activities require two different types of objects (data).

The last question was not asked for the visualization technique multiple views in combination with linking and brushing. This visualization technique is an interaction-based visualization. To answer the last question would require showing too many screenshots, which is beyond the scope of the questionnaire.

Factors and Factor Level. In our study, the alignment of process activities, objects and roles is the factor and the factor level is the visualization of the alignment.

Response Variable. The response variable in our study is the level of understanding that the respondents displayed with respect to the alignment. Understandability is measured as follows:

- the number of correct questions answered about the alignment visualization,
- the perceived ease of understanding (PEOU),
- the perceived usefulness (PU), and
- preferences between the three visualization techniques.

PEOU and PU are well-established measures that are widely used to investigate the understandability of models. They have been studied in [8]. PEOU, PU and visualization preferences had to be rated on a 5 point Likert scale (between 1=strongly disagree and 5=strongly agree).

Subjects. The survey was run from February to April 2013. To attract participants, we spread the link of the online questionnaire to modeling experts of different European universities and to research-driven institutes. In particular, we mainly personally asked post-graduate and assistant professors of institutes that work on business process management to complete the questionnaire¹. The level of education of all participants was at least a completed master degree.

Instrumentation. We showed the participants a set of process activities, objects and roles visualized as multiple views, single view and multiple views in combination with linking and brushing. As the latter might not be intuitively understandable, we provided a short description of this technique (“*This visualization technique is an interaction technique (i.e., a click on an element shows its relationships to different units).*”).

Data Collection. Along with the questionnaire, we asked the participants about their gender, their professional situation, the years of modeling experience, their modeling

¹ After half time of the survey period we noticed an unbalance between responses concerning the principal modeling language. Therefore, we asked experts of European institutes that principally use a particular modeling language to also answer the questionnaire.

environment, number of created process models, number of analyzed process models, and their principal modeling language. Also, we received the answers for the comprehension questions, the PU and PEOU measures for each visualization technique and the preferences between the visualization techniques.

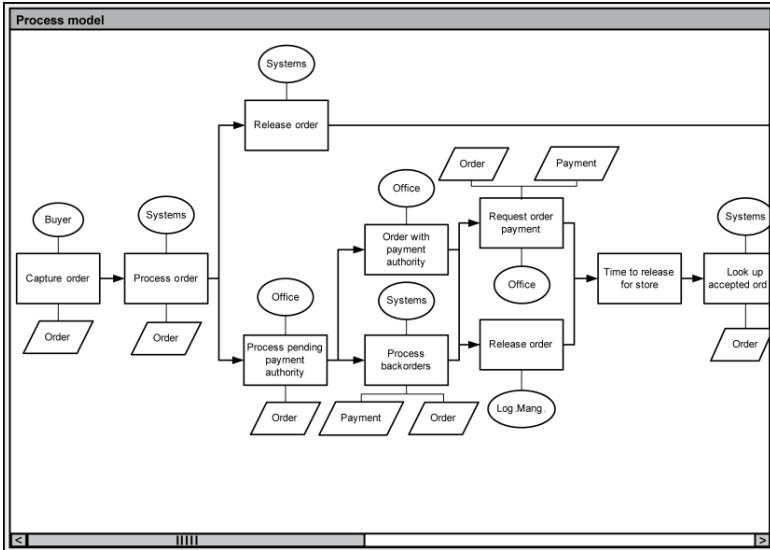


Fig. 6. Single View visualization from the evaluation (applied on the Order Management process)

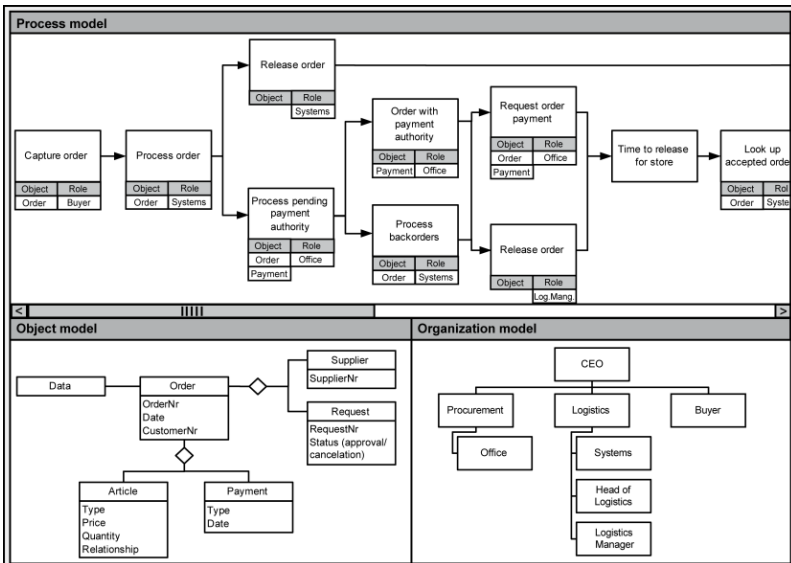


Fig. 7. Multiple views visualization from the evaluation (applied on the Order Management process)

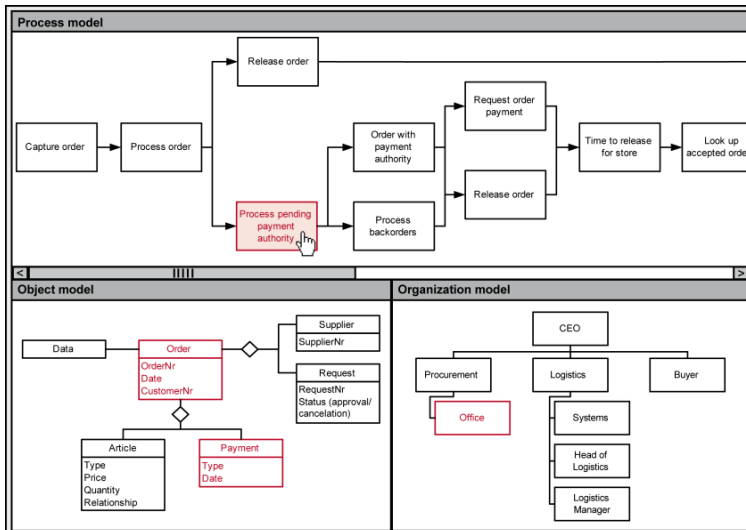


Fig. 8. Multiple views visualization in combination with linking and brushing from the evaluation (applied on the Order Management process)

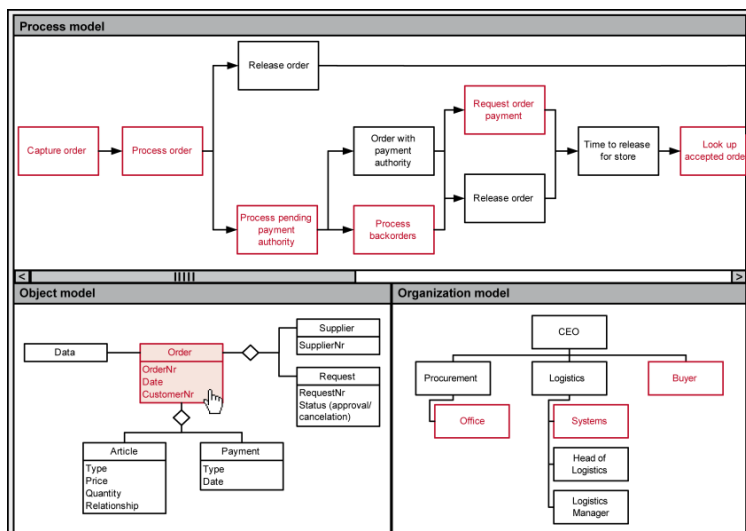


Fig. 9. Multiple views visualization in combination with linking and brushing from the evaluation (applied on the Order Management process)

3.5 Results

The questionnaire has been sent out to 81 persons. Overall, the questionnaire was answered by 52 persons, but only 33 completed questionnaires were obtained. The participants were 21.21% female (7 persons) and 78.78% male (26 persons).

Table 2. Statistical results for visualization preferences²

Preference	Options	Freq.	Freq. (%)	Cum.Freq(%)
Usefulness of <i>multiple views over single views</i>	s.agree	9	27.27	39.39
	agree	4	12.12	
	undecided	4	12.12	48.48
	disagree	10	30.30	
	s.disagree	6	18.18	
Improvement of performance between <i>multiple views over single views</i>	s.agree	6	18.18	39.39
	agree	7	21.21	
	undecided	7	21.21	39.39
	disagree	7	21.21	
	s.disagree	6	18.18	
Usefulness of <i>multiple views over multiple views in combination with linking and brushing</i>	agree	4	12.12	12.12
	undecided	6	18.18	72.72
	disagree	8	24.24	
	s.disagree	16	48.48	
Improvement of performance between <i>multiple views over multiple views in combination with linking and brushing</i>	agree	1	3.03	3.03
	undecided	9	27.27	69.69
	disagree	8	24.24	
	s.disagree	15	45.45	
Usefulness of <i>single views over multiple views</i>	s.agree	5	15.15	51.51
	agree	12	36.36	
	undecided	4	12.12	36.36
	disagree	8	24.24	
	s.disagree	4	12.12	
Improvement of performance between <i>single views over multiple views</i>	s.agree	6	18.18	42.42
	agree	8	24.24	
	undecided	6	18.18	39.39
	disagree	9	27.27	
	s.disagree	4	12.12	
Usefulness of <i>single views over multiple views in combination with linking and brushing</i>	s.agree	1	3.03	12.12
	agree	3	9.09	
	undecided	7	21.21	66.66
	disagree	12	36.36	
	s.disagree	10	30.30	
Improvement of performance between <i>single views over multiple views in combination with linking and brushing</i>	s.agree	1	3.03	12.12
	agree	3	9.09	
	undecided	7	21.21	66.66
	disagree	12	36.36	
	s.disagree	10	30.30	
Usefulness of <i>multiple views in combination with linking and brushing over multiple views</i>	s.agree	17	51.51	78.78
	agree	9	27.27	
	undecided	4	12.12	9.09
	disagree	3	9.09	
Improvement of performance between <i>multiple views in combination with linking and brushing over multiple views</i>	s.agree	15	45.45	78.78
	agree	11	33.33	
	undecided	4	12.12	9.09
	disagree	3	9.09	

² Please note that options, which were not selected are not considered in this table.

Most participants had only a modeling background in research, but 33% of the respondents additionally gained modeling experiences in industry projects. In average they had 4.81 years of modeling experience (St.Dev=3.8), modeled 59.5 and analyzed 59.68 business processes. The principal modeling language used by the participants was BPMN (13 persons, 39.39%), Petri nets (10 persons, 30.30%), EPC (5 persons, 15.15%), UML (3 persons, 9.09%), BPEL (1 person, 3.03%) and one person selected others (1 person, 3.03%). The results for visualization preferences were analyzed with respect to frequency distribution. Table 2 shows the statistical results for each preference, its answer options, the frequency in numbers per option, the frequency (%), and the cumulative frequency (%) for each question. Cumulative frequency is determined by aggregating agreement (strong agree, agree) and disagreement (disagree, strongly disagree) with the preference.

The multiple views in combination with linking and brushing is clearly preferred over multiple views and single view. The usefulness and the improvement of performance are significantly higher for multiple views in combination with linking and brushing visualization as for the other two visualization techniques. Comparing the frequency distribution between multiple views and single view, then a general indifference is observed. The single view visualization marginally wins with respect to usefulness. However, the agreement and disagreement for usefulness between both visualization techniques does not differ significantly.

We further investigated the PEOU and PU measures for each visualization technique in order to confirm the preference for the multiple views in combination with linking and brushing visualization. Table 3 summarizes the statistical results. The highest ease of use (PU) (agreement) is assigned to multiple views in combination with linking and brushing visualization (78.78) followed by single view (66.66) and multiple views (51.51). The same order is given for PEOU (agreement for ease of understanding and disagreement for frustration). Table 3 indicates an order between the three visualization techniques with respect to understandability, also multiple views in combination with linking and brushing visualization dominates marginally.

To detect any significant difference in the performance of participants, we checked the number of correct questions answered, which are showed in Table 4. Additionally, we determined the correlation between wrongly answered questions and each visualization approaches. The resulting values are shown in Table 4. The p-values exceed the threshold of 0.05 (using a confidence level of 95%) except for task 2 single view vs. multiple views in combination with linking and brushing (0.0066) and task 3 for multiple views vs. single view (0.0004). These results mean that mistakes for task 1 do not depend on a visualization technique studied in a previous question. Although a significance exists between mistakes for a particular task and visualization approaches, the correlation has no high validity. For instance, for task 3 the 0.0 mistake rate for the single view visualization is not given for the subsequent multiple views in combination with linking and brushing approach. This means that no differences can be observed (otherwise a significant p-value would be given for SingleView vs. MultipleViewsLB for task 3).

To investigate whether the understandability of a particular visual alignment depends on a principal modeling language, we run a correlation analysis. Table 5 shows the correlation coefficients calculated between the principal modeling language and PEOU, PU.

Table 3. Statistical results for PEOU and PU measures²

Statement	Options	Freq.	Freq. (%)	Cum.Freq (%)
Multiple Views				
It was easy for me to understand what the visualization was trying to model. (PEOU)	s.agree	11	33.33	66.66
	agree	11	33.33	
	undecided	6	18.18	
	disagree	3	9.09	15.15
	s.disagree	2	6.06	
Understanding the visualization was frustrating. (PEOU)	s.agree	1	3.03	12.12
	agree	3	9.09	
	undecided	5	15.15	
	disagree	12	36.36	72.72
	s.disagree	12	36.36	
Overall, the visualization was easy to use. (PU)	s.agree	6	18.18	51.51
	agree	11	33.33	
	undecided	10	30.30	
	disagree	3	9.09	18.18
	s.disagree	3	9.09	
Single View				
It was easy for me to understand what the visualization was trying to model. (PEOU)	s.agree	15	45.45	87.87
	agree	14	42.42	
	undecided	3	9.09	
	s.disagree	1	3.03	3.03
Understanding the visualization was frustrating. (PEOU)	s.agree	3	9.09	18.18
	agree	3	9.09	
	undecided	3	9.09	
	disagree	12	36.36	69.69
	s.disagree	11	33.33	
Overall, the visualization was easy to use. (PU)	s.agree	10	30.30	66.66
	agree	12	36.36	
	undecided	6	18.18	
	disagree	3	9.09	12.12
	s.disagree	1	3.03	
Multiple Views in Combination with Linking and Brushing				
It was easy for me to understand what the visualization was trying to model. (PEOU)	s.agree	15	45.45	81.81
	agree	12	36.36	
	undecided	3	9.09	
	disagree	2	6.06	9.09
	s.disagree	1	3.03	
Understanding the visualization was frustrating. (PEOU)	agree	2	6.06	6.06
	undecided	3	9.09	84.84
	disagree	11	33.33	
	s.disagree	17	51.51	
Overall, the visualization was easy to use. (PU)	s.agree	12	36.36	78.78
	agree	14	42.42	
	undecided	3	9.09	
	disagree	4	12.12	12.12

Table 4. Average Number of Mistakes and p-value for tasks

<i>Avg.Mistake</i>			
	Multiple Views	Single View	Multiple ViewsLB
task 1	0.2	0.000	0.029
task 2	0.114	0.571	0.000
task 3	0.086	0.000	0.143
task 4	0.314	0.227	
			<i>p-value</i>
task 1	MultipleViews vs. SingleView		0.1442
	SingleView vs. MultipleViewsLB		0.4049
	MultipleViews vs. MultipleViewsLB		0.3121
task 2	MultipleViews vs. SingleView		0.2905
	SingleView vs. MultipleViewsLB		0.0066
	MultipleViews vs. MultipleViewsLB		0.2609
task 3	Multiple Views vs. Single View		0.0004
	SingleView vs. MultipleViewsLB		0.1694
	MultipleViews vs. MultipleViewsLB		0.1729

Table 5. Correlation coefficients for principal modeling language and PEOU and PU measures

	<i>Corr.Coefficient(r)</i>	<i>p-value</i>
Multiple Views	mod.lang,PEOU ₁ =0.284	0.0544
	mod.lang,PEOU ₂ =0.34	0.0264
	mod.lang,PU=0.347	0.0239
Single Views	mod.lang,PEOU ₁ =0.36	0.0198
	mod.lang,PEOU ₂ =0.34	0.0264
	mod.lang,PU=0.26	0.0719
Multiple Views in Combination with Linking and Brushing	mod.lang,PEOU ₁ =0.36	0.0198
	mod.lang,PEOU ₂ =0.417	0.0078
	mod.lang,PU= 0.32	0.0347

A significant indication for r is given for values from -0.6 or 0.6 respectively, which is not the case for any value in Table 5. However, significant p -values (<0.05) are given for several measures. It seems that understandability of visual alignments depends on the principal modeling language. Results in Table 5 reinforce the multiple views approach in combination with linking and brushing (since all corresponding p -values are <0.05). This visualization technique is easily understandable for all modeling language.

3.6 Discussion

Interpretation: The empirical study provides strong support for a process model visualization that is disburdened from context information such as objects used and roles involved. Instead an interactive alignment of process elements should be supported. The visualization of the process model should be reduced to the level of process activities and its control-flow when the model is shown for the first time.

This finding does not directly correspond to common practical implementations (see section 2) where plenty of graphical symbols and constructs are assigned to

process activities. BPMN is an example for a “fussy layout”; i.e., the process model is overburdened with a variety of constructs.

Our statistical results also show that the visualization technique multiple views in combination with linking and brushing is easily understandable for users. Therefore, this visualization approach is a suitable alternative to current implementations.

Implications: The strong preference for a visual alignment in combination with linking and brushing is also in line with the postulation to decrease *symbol excess*, which increases diagrammatic and graphical complexity [10]. Therefore, the following implications are given for researchers and practitioners. Firstly, when proposing a new extension for a modeling language (e.g., consideration of security issues in BPMN) it is essential to empirically compare a visualization approach that add new symbols to process activities versus an interactive visualization technique (e.g., linking and brushing). Secondly, BPMS vendors should mainly implement tools that allow an interactive alignment between models.

Limitations: One might criticize the limited “complexity” of the used process models (e.g., the objects are abstracted from access controls, process model size). The intention of this study was to investigate the initial preferences for visualizing the alignment and therefore we decided to strip further disturbing factors from the process models. However, the visualization preference might change in case of large process models and in case that additional scrolling and panning techniques are necessary. This is one interesting issue, which provides room for further investigation.

Another open issue stems from the context of collaborative process models. In such a context, several organizations are involved in the modeling/management of the business process. Thus, inter-divisional questions must be addressed, which requires the consultation of several object and organization models. It remains open to investigate whether the multiple views in combination with linking and brushing visualization is still appropriate in such a context. Thirdly, it remains to investigate if process modelers in practice have same preferences as the academic respondents of this study. Lastly, the participants in our empirical study answered the questionnaire independent of a modeling purpose. However, [11] identified a correlation between the preferred visualization and the modeling purpose. For instance, the preference for a simplified BPMN (reduced to core constructs) depends on the modeling purpose. For persons with a managerial background, the core BPMN constructs are sufficient to finish the modeling task, while persons with an IT background argued for an extended set of BPMN constructs, which are more appropriate to model requirements in software implementation projects. Therefore, our findings might be suitable for users with no technical purpose.

4 Related Work

Various studies have investigated the factors which influence the understandability of business process models. Typically, two essential groups of factors are taken into account. Firstly, *model characteristics* such as control-flow complexity [2], the

number of routing symbols [4] or activity labeling [12] give examples for metrics used to assess a process model itself. Secondly, *reader characteristics* describe e.g., the personal expertise of the person reading and interpreting a process model [13]. While previous work focuses solely on process model characteristics, this study addresses the integrated visualization of additional models: the object (data) model and organizational (role) model. We also assess reader characteristics to analyze possible correlations (see section 4).

Furthermore, several visualization concepts for information in and about business processes have been proposed. For example, the *proView* project aims at creating solutions for the flexible and personalized visualization of (large) business processes, e.g., with the help of parameterizable process views [5,6]. [13] developed an approach to cope with complexity of visual representations using a decomposition mechanism to split software system models “into manageable and understandable parts”. In [1], a concept for the 3D representation of Petri nets is introduced, thus allowing the integration of additional information into a process model while still maintaining a compact and understandable visualization. Though, none of the mentioned examples investigates the simultaneous display of different models types (and provides an empirical evidence), which has been tackled in this paper.

5 Outlook

Cognitive load has an impact on understandability of process models. A heavy cognitive load is generated if novel material has to be understood [14]. A process model, which is viewed, e.g. for the first time ever, should be visualized in an easy and understandable way. Investigations of global and local understandability of models have been conducted in [3,4]. In this paper we present the first study that investigates the understandability of aligning process activity related information (in particular roles and objects). Three different types of visualization based on alignment techniques and practical implementations were proposed to participants.

The reported empirical study provides strong support for a visual alignment of models on demand, which is fully in line with the postulation to decrease *symbol excess* [10]. This means that users initially view the “pure” process model (with its activities and control-flow) and process element related alignments are displayed when users show interest for a particular context. This result requests researchers decreasing the number of symbols when suggesting a new extension for a process modeling languages. Instead alternative visualization techniques (e.g., in combination with linking and brushing) must be evaluated. Combining our results with findings of [11], we suggest fostering a purpose-oriented visualization starting with a process model that is reduced to the sole visualization of process activities and its control-flow and is continuously adjusted.

Aside from these implications, the results of our study provide extended insights into process model visualization and complement the body of experimental research on process model understandability.

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